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Pedro M. Arezes · J. Santos Baptista · Mónica P. Barroso · Paula Carneiro · Patrício Cordeiro · Nélson Costa · Rui B. Melo · A. Sérgio Miguel · Gonçalo Perestrelo *Editors*

Occupational and Environmental Safety and Health II

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Occupational and Environmental Safety and Health II

Springer

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Preface

Occupational and Environmental Safety and Health II is a compilation of the most recent work of some selected authors from 13 countries within the domain of occupational safety and health (OSH). The included works are focused on selected topics, including occupational safety, risk assessment, safety management, ergonomics, management systems, environmental ergonomics, physical environments, construction safety and human factors, among others.

This book represents the state of the art, and it is mainly based on research carried out at universities and other research institutions, as well as some on-field interventions and case studies. Due to the broad scope, relevance and originality of the contributions, it is expected that this book contains useful and up-to-date information, and it presents fundamental scientific research that is being carried out in the subject, as well as it contributes to the outreach of practical tools and approaches currently used by OSH practitioners in a global context. All the included contributions were selected based on their potential to show the newest research and approaches, giving visibility to emerging issues and presenting new solutions in the field of occupational safety and health.

This book is based on selected contributions presented at the 16th edition of the International Symposium on Occupational Safety and Hygiene (SHO 2020), which was held on 6–7 April, in Porto, Portugal.

All the contributions included in this book were previously peer-reviewed by, at least, two of the 131 members from 17 different countries of the International Scientific Committee of the 2020 edition. The event is organised annually by the Portuguese Society of Occupational Safety and Hygiene (SPOSHO).

Editors would like to take this opportunity to thank their academic partners, namely the School of Engineering of the University of Minho, the Faculty of Engineering of the University of Porto, the Faculty of Human Kinetics of the University of Lisbon, the Polytechnic University of Catalonia and the Technical University of Delft. The editors also would like to thank the scientific sponsorship of several academic and professional institutions, the official support of the Portuguese Authority for Working Conditions (ACT), as well as the valuable

support of several companies and institutions. Finally, the editors wish also to thank all the reviewers, listed below, who gave a critical contribution, without which it would not be possible to develop and publish the current book.

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Safety Score Permit (SSP) to Enhance Safety Performance

A. Fundo, M. Carrasqueira, B. Dias, J. Santos, D. Antunes, J. Dias and C. Jacinto

Abstract This paper addresses the need for efficient management control tools and it focuses on behavioural performance. This work aimed to develop a system to monitor and improve behaviours in Occupational Health and Safety (OHS). The new system is called Safety Score Permit (SSP) and its development was based on three main concepts, namely, the behavioural-based philosophy, the score cards system, and the reasoning underlying the "point system" in use for road safety. Behaviors are assessed by direct observation, either by OHS specialists, or by trained "observers" elected by their peers. There are bonus and penalty points, depending on the safe/unsafe behaviors observed. The SSP tool is intended to promote effective management control through the implementation of a strategy focused on collective and individual performance. This approach to reinforce OHS management could play an important role in improving workers' risk perception and encourage safe behaviours. The SSP tool will allow everyone—workers and managers—to know, at any time, their individual and collective performance, as

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well as to disseminate positively the best practices and commitment to safety, which clearly will influence the whole organization. It has the potential to become a useful and transparent tool for monitoring OHS performance of employees in all hierarchical levels.

Keywords Safety score permit · OHS performance · Behavior-based safety

1 Introduction and Background

A large part of workers' life is spent at the workplace; therefore, the relevant safety precautions should be taken in their sometimes quite hazardous workplaces to safeguard their lives and well-being [1]. Many organisations around the world support their safety management on international standards, of which the ISO 45001:2018 is the most recent and is quickly replacing the well-known OHSAS 18001:2007 widely used for certification purposes. Within the novelties brought by the ISO 45001, is the way it reinforces the importance of effective Leadership commitment and Workers participation.

Among the many strategies available to improve workplace safety is the Behaviour Based Safety (BBS) approach, which is recognized for its ability to influence attitudes, both individual and collective. BBS is becoming increasingly popular across industry sectors, and it has the "great advantage of needing the involvement of the individual employee, in addition of course, to employer commitment" [2]. Thus, this approach has great potential to assist in the implementation of ISO 45001.

Adhesion to BBS in the industry is considered beneficial, as it will increase safety culture and human welfare [3]. This topic has been well covered in the literature for decades, namely after the 1980s, giving evidence of its maturity and suitability to enhance safety. According to DePasquale and Geller [4], "behaviour-based safety starts by defining one or more critical behaviours to target. Then these behaviours are observed and recorded in particular work settings". Despite the need to ensure employers' commitment and leadership, BBS is considered an outstanding technique to improve safety among "front-line workers", and to achieve an accident-free work culture [5, 6].

In contrast with traditional safety programs, which allocate responsibility for accident prevention to top management, the BBS philosophy aims at educating employees and employers to examine the root causes of their accident-prone behaviours [7].

A more recent study [8], reports a BBS initiative based on a card-issuing system. The purpose of the study was to evaluate the effectiveness of the BBS card system as a tool for reducing accident frequencies, and the findings suggest that the card system brought a significant decrease in accident rates. These authors [8] highlight that the card system had a significant influence in the mind-set of workers towards safer working practices.

On the other hand, performance evaluation (e.g.: quality, safety, etc.) can be attained through scored-based systems. There is evidence that scorecards have been applied in different ways, and across a range of activities, and have proven to be promising tools to help organizations address challenges and support strategic decisions [9]. Among such tools, a recognized referential is the “point system” (scored system) used internationally on drivers’ licenses [10, 11].

This paper describes a joint project aimed at developing a score system/tool especially designed to monitor and enhance safety performance. The system is called Safety Score Permit (SSP) and it combines the new requirements of ISO 45001, the BBS philosophy and transposes the road safety “point system” to the management of occupational health and safety.

2 Development Methodology

The development of *Safety Score Permit* (SSP) was based on both theoretical and empirical foundations. Figure 1 illustrates the general approach followed by this project for developing the proposed tool. The current paper gives account of the first stage, up to draft version “1” of the tool. This represents the conceptual stage aimed at monitoring safety performance of individuals; this version already went through a pilot testing using past records of real accidents/incidents (named here a laboratory testing).

The second and final stage will be carried out during 2020 and it includes more work, such as the inclusion of tailored safety performance indicators (at company level), field testing (i.e., with participation of companies), refinement, and validation, after which the SSP will be released for use (final version). In parallel, the corresponding SSP electronic platform is already being developed by a specialised consortium.

3 Results. Description of SSP®

3.1 Characteristics and Overview

From a management point of view, the SSP tool can provide an assessment of overall organisational performance and also reveal trends to ascertain whether the strategies/efforts are being well addressed. It can provide information at micro level by the analysis of individual performance and assess to what extent the actions adopted (when necessary) promote safe behaviours on workers. It is clearly a complementary tool for supporting continuous improvement to achieve and sustain a good level on safety culture (Fig. 2).

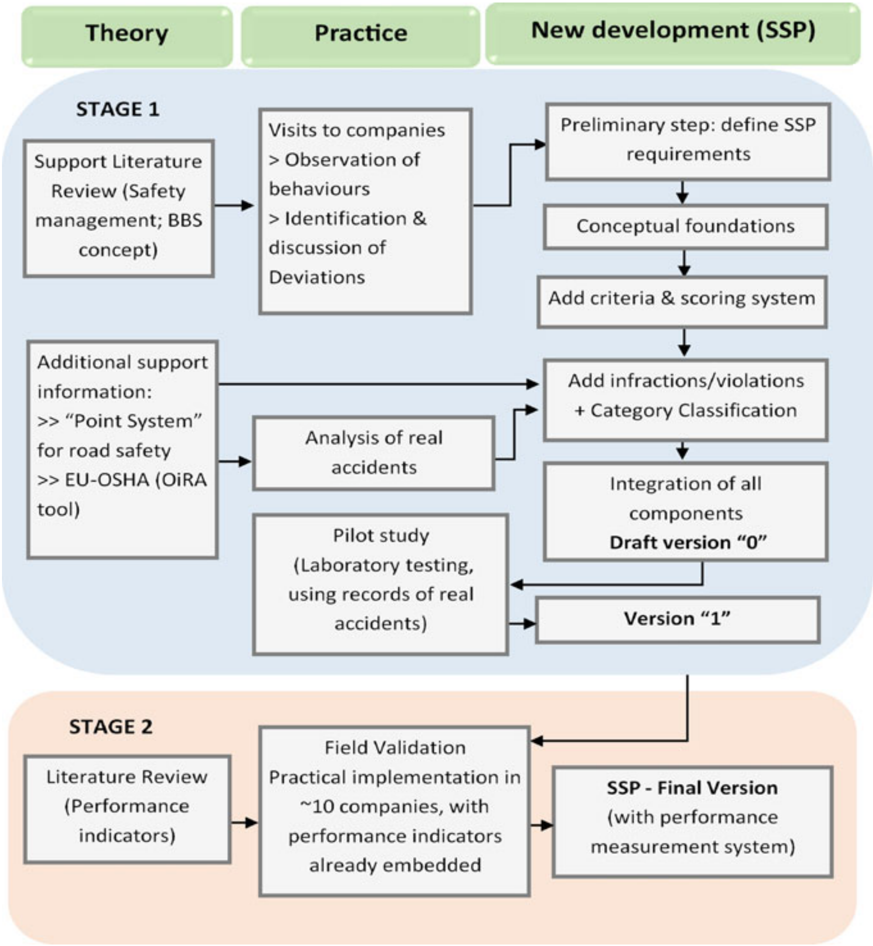

Fig. 1 Development of SSP—methodological steps

3.2 *Specification of Performance Levels. Criteria*

The scale of performance levels. SSP scale is designed with six performance levels (Fig. 3). The neutral level, by default, is worth 12 points. This is called the "initial level". The positive behaviours will entitle the person to climb three levels (on the right-hand side), worth 16-18-20 points respectively. Excellence is attained at 20 points. It was considered important to define a maximum limit, since there are historical data on the Demerit Point System (DPS) applied to road safety, in a study made by Castillo-Manzano [12], which proved that one of the factors that led to poor effectiveness of some long-term solutions was that the initial fear of reprisals

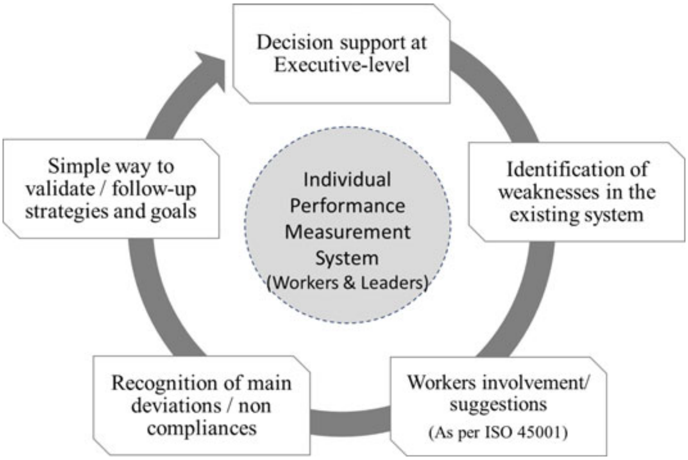

Fig. 2 Potential of SSP system as a complementary management tool

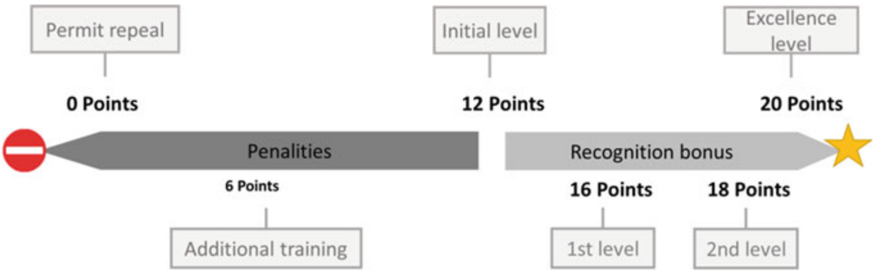

Fig. 3 Point system—recognition bonus (positive) and penalties (negative) levels

had relaxed over time. So, by setting a maximum upper limit, the SSP system prevents the employee from being over self-confident and becoming complacent.

By contrast, infractions are negative safety behaviours and, therefore, will lead to a decrease of points down to 6 and 0, respectively. The person can recover from this situation and is encouraged to do so. At the 6 point level, for instance, the employee is subjected to a compulsory training session followed by specific evaluation.

Bonus criteria. Similar to what is suggested for the implementation of a BBS in a safety management system, it is necessary to give positive feedback to reinforce exemplary behaviours and influence the other employees follow them [2].

As the objective is providing a comprehensive solution and support companies to progress to a safety excellence level, workers (at all levels) will be subsidized with points. It is suggested that organizations reward good behaviours on a regular basis to encourage discipline and recognise good examples, thus allowing every person to reach the level of excellence.

SSP is a transparent system based on direct observations; it intends to be a tool that values safe behaviours and pro-activity, giving bonus points to individuals who, during a period of time (annually), do not have any penalties and/or make efforts to propose suggestions for improving or solving problems. To earn points, such suggestions need to be evaluated by management and be considered a "viable solution that worth being implemented". However, the individuals cannot, by this way, exceed 18 points.

To achieve the top—excellence level—the employee needs to attain 20 points. If an employee has 18 points registered in his/her Safety Score Permit and, additionally, he/she is recognized as an example to follow in terms of OHS (through criteria defined in each company), the employee will receive the distinction of excellence, i.e., the person reaches the excellence level by receiving the two additional points. Thus, the transition from 18 to 20 points requires a peer recognition.

Penalties criteria. The practice of a safety infraction/violation determines the subtraction of points to the employee's permit. It was decided to relate the number of lost points to both the frequency and severity/seriousness of the infraction/violation resulting in accidents, or that could have caused an accident. This will help increase the credibility and fairness of the system. To evaluate and apply the penalties, the analysis of deviations is based on three levels, namely, Human, Technical and Organizational (Fig. 4). Moreover, the system distinguishes between an error/mistake and a violation based on Reason's classification [13]. To facilitate the evaluation and promote transparency of the whole process, a decision-tree was built and is embedded in the tool, but it can be customized by each organisation. If it is proven to be a violation, the decision-tree will help to analyse whether the situation was generated solely by the worker, or if the respective manager(s) knew or have influenced the occurrence. The SSP system covers the entire hierarchy.

The number of points to be subtracted will depend on (1) the seriousness of the occurrence, (2) whether it is a recurrence or (3) whether there are multiple

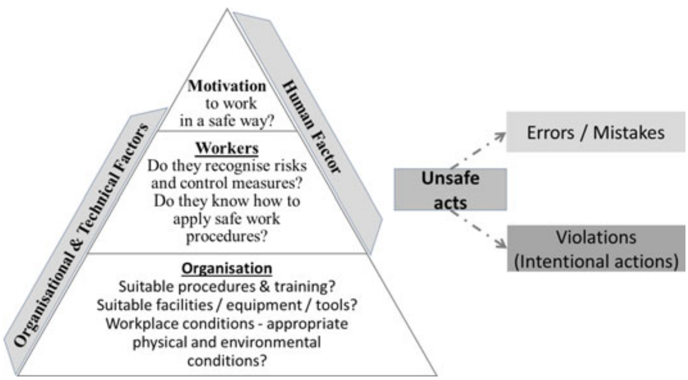

Fig. 4 Factors in which to look for deviations

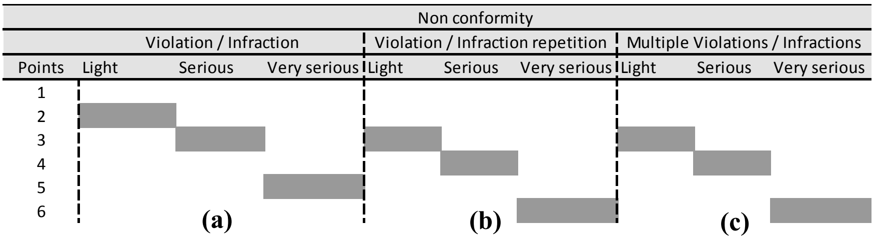

Fig. 5 Points lost depending on **a** the seriousness of occurrence, **b** recurrence, or **c** multiple violations/infractions

infractions/violations (Fig. 5). To avoid complexity in the system, and in the case of multiple infractions (Fig. 5c), 1 penalty point will be added to the most serious one. Similarly, in case of recurrence, 1 extra point is added to the respective infraction level.

Whenever an employee completes one year without committing any infraction/violation, he/she will receive a bonus point. Therefore, it will take 3 years to recover from a serious infraction, and 5 from a very serious one. In any case, as previously mentioned, the person can only accumulate 16 points due to absence of infractions. In addition to the safety training sessions that are given to all workers on a regular basis, there will be a special training scheme for those who first get down to a score of 6 points, or less. At the end of this training there will be an evaluation; if the employee achieves a grade of 95%, he/she will recover 1 point, if not additional training (on-job training) will be necessary. The permit will be cancelled when the employee reaches the lower limit of 0 points, and disciplinary measures must be applied.

3.3 Infractions. Types and Categories

The SSP considers 85 types of infractions. These 85 infractions are classified into 9 categories or classes (Fig. 6). The referred 9 categories will allow identifying where the main problems, deviations and deficiencies are located and, therefore, the system can assist in the design of prevention, and be a complementary management tool.

3.4 Preliminary Testing (Laboratory Testing)

The preliminary testing of the system’s applicability and consistency was made through the analysis and categorisation of real accident records (archive records). These accidents occurred in 4 companies collaborating in the project. By analysing

Fig. 6 Categories classification for infractions

(a)

STRATEGIC	2
ETHICAL AND MORAL	4
COMMUNICATION	0
ACCESSES	0
ALCOHOL/SUBSTANCES	0
CIRCULATION	3
ORGANIZATION / HOUSEKEEPING	1
OPERATION / MAINTENANCE	30
PROTECTION MEASURES	6
TOTAL	**46**

(b)

Fig. 7 Extract of human safety violations/infractions from the accidents of 4 companies' database, **a** number and **b** relative distribution by categories using the classification of SSP system

all investigation reports, the first step was to set aside all cases where any kind of "human (mis)action" had occurred and had been explicitly identified.

From this first step, a total of 211 cases were selected for testing the infraction's classification (and criteria) proposed in SSP. The results are summarized in Fig. 7. From the 211 accidents analyzed, 46 were violations/infractions and not just human errors/mistakes. In addition, from the categories' classification it was observed that the higher number of situations occurred within the category operation/ maintenance. Going deeper into the system will allow identifying which are, specifically, the prevalent types of violations/infractions. This ability of the system will help to spot and understand the main problems, and consequently will help to develop strategies to continuously monitor and improve the OHS management system already in place.

The length restrictions of the paper do not allow a more in-depth description. However, the next stage is an industrial "piloting implementation", which will be carried out in 10 companies of different activity sectors and it will allow a further and more realistic validation of the system.

4 Concluding Remarks

This paper described the design and construction of a new safety tool called *Safety Score Permit* (SSP) intended to encourage positive safety behaviours of individuals (both workers and managers) that will last over time within an organisation. The prototype already developed and explained here (stage 1; Fig. 1) will proceed to stage 2, which involves further development of new functions based on key indicators to asses overall performance.

The SSP proposed herein has real potential to become a valuable new generation tool for executive decision-support, with watch-lists, configurable visualisations and customisable alerts and notifications. It is a system that perceives, and gives alert on what the weaknesses are, namely the seriousness of errors/violations that have occurred, at both individual and collective levels. It allows classifying the deviations in specific categories, and thus, facilitates taking effective preventive measures; moreover, it allows to measure and sustain results improvement, which is a top priority for industry managers. SSP tool is a transparent system, provides a means for rapid and continuing feedback, it is flexible and allows setting up individual strategies for improving safety behaviours.

Its adequate implementation is expected to decrease unsafe behaviours and incidents and, consequently, to reduce direct and indirect associated costs, namely, insurance costs, absenteeism, or shutdowns due to accidents; all such factors will contribute to an increased productivity and better health and safety at work.

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References

1. Moyo, D., Zungu, M., Kgalamono, S., Mwila, C.D.: Review of occupational health and safety organization in expanding economies: the case of Southern Africa. Ann. Glob. Health **81**(4), 495–502 (2015)
2. HSA: Behaviour based safety guide. Guidance HAS0392. Health and Safety Authority, Dublin, Ireland (2013)
3. Geller, E.S., Perdue, S.R., French, A.: Behavior-based safety coaching: 10 guidelines for successful application. Prof. Safety **49**(7), 42–49 (2004)
4. DePasquale, J.P., Geller, E.S.: Critical success factors for behavior-based safety: a study of twenty industry-wide applications. J. Safety Res. **30**(4), 237–249 (1999)
5. Choudhry, R.M.: Behavior-based safety on construction sites: a case study. Accid. Anal. Prev. **70**, 14–23 (2014)
6. Lal, K.H.: Emerging issues and outcomes of behavior based safety (BBS) implementation. Adv Manage **7**(8), 7–11 (2014)
7. Jasiulewicz-Kaczmarek, M., Szwedzka, K., Szczuka, M.: Behaviour based intervention for occupational safety: case study. Proc. Manuf. **3**, 4876–4883 (2015)

8. Nunu, W.N., Kativhu, T., Moyo, P.: An evaluation of the effectiveness of the behaviour based safety initiative card system at a cement manufacturing company in Zimbabwe. Saf. Health at Work **9**(3), 308–313 (2018)
9. Journeaut, M.: The integrated scorecard in support of corporate sustainability strategies. J. Environ. Manage. **182**, 214–229 (2016)
10. Lee, J., Park, B.-J., Lee, C.: Deterrent effects of demerit points and license sanctions on drivers' traffic law violations using a proportional hazard model. Accid. Anal. Prev. **113**, 279–286 (2018)
11. Sagberg, F., Ingebrigtsen, R.: Effects of a penalty point system on traffic violations. Accid. Anal. Prev. **110**, 71–77 (2018)
12. Castillo-Manzano, J., Castro-Nuño, M.: Driving licenses based on points systems: efficient road safety strategy or latest fashion in global transport policy? A worldwide meta-analysis. Transp. Policy **21**, 191–201 (2012)
13. Reason, J.: Human Error. Cambridge University Press (1990)

Minimization of Electrical Risks in Activities in Very High Voltage Transmission Lines

A. Sofia Azevedo, J. Duarte and António Machado e Moura

Abstract Live working (LW) is a complex and of high organizational requirement process. It requires the interaction of all actors in the process, from the beginning to the end, and therefore there is a great need to determine the security rules that are fundamental to minimize the occurrence of accidents related to electric risks. The main objective of this study was to make a risk assessment and compare the results obtained between the different methods used. In order to accomplish this study, it was necessary to monitor on the spot some works in LW, to be able to carry out a risk assessment as close to reality as possible. This risk assessment was performed based on three different methods: William T. Fine, NTP 330 and the method developed and used by the company, and 119 risks were evaluated. Although different types of risks have been considered, those that pose a greater risk to the health and hygiene of the workers are: "Live Working" and "Work at Height". In all methods, these tasks represented the highest level of danger and therefore require more attention. Considering the risks that presented a higher level of risk, they should be monitored systematically and require urgent intervention to minimize the consequences.

Keywords Live working · Risk assessment · William T. fine · NTP 330

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1 Introduction

The technological advancements that are widely spread and rooted in today's society have shaped every known field which means the occupational health and safety situation in the European Union has also been shifted. On one hand, the facilities automation allowed the mitigation or even elimination of some of the traditional risks, but, on the other hand, new risks associated with the use of new technologies were raised [1, 2].

In 2015, and considering only the universe composed by the European Union (EU) countries, Portugal ranked 4th in terms of accidents number, which involved 100,000 of the total employed people: of the 134,378 accidents taking place during that year in national territory, 161 were fatal. Work-related accidents accounted for about 3.4% of all accidents (fatal and non-fatal) that occurred in 2015 in all EU countries. In Portugal, and according to the available statistics, just in 2014, 45,238 occupational accidents were registered. Of these, 4 were fatal occupational accidents. Considering the sectors of electricity, gas, steam, hot and cold water and cold air (that account for sector D), it is possible to notice that of the 45,238 accidents that occurred in that year, 238 corresponds to that sector [3]. Currently, the most common form of energy in industrial society is electricity, essentially because of its ease of transportation and transformation into other forms of energy [4]. However, in specific situations, electricity can pose a risk to the safety of people, since, due to its characteristics, electricity is something that does not have a particular scent and cannot be seen [5, 6]. In this way, it is necessary to understand what rules should be implemented in order to minimize the electrical risks present in the occupations involving electricity. The execution of live working is a complex process and of great organizational requirements [7, 8]. It entails the interaction of all role-players in the process, from its beginning to its conclusion and, for this very reason, there is a great need to determine the safety rules that are crucial to minimize the occurrence of accidents related to this hazard [9]. Nonetheless, there is a difficulty in drawing the workers' attention to this issue and making them realize what the risks are and how serious is the occurrence of an accident during the work on very high voltage lines. Therefore, this study addresses the minimization of the electric risk of the activities in very high voltage lines. Its main objective was to carry out a risk assessment in order to identify the hazards and risks associated with the tasks performed during the different works executed in tension in these lines. The secondary outcomes were the following:

- To identify the risks associated with each task in the different activities observed;
- To conduct a critical analysis of the results obtained;
- To understand the advantages of each method and its limitations.

2 Materials and Methods

In order to develop a risk assessment that could simultaneously be useful to the company and to answer more theoretical and statistical questions, it was decided to use three methods of risk assessment [10, 11]:

- William T. Fine Method
- NTP 330 Method
- The method developed and currently used by the company.

The William T. Fine method is based on the characterization of the level of risk in three variables [12]: consequence, which is the most probable result of a potential accident; exposure, which represents the frequency with the risk situation occurs; and the probability, that represents the probability associated with the occurrence of the accident. Based on these variables, the hazard or risk level is defined as the product of the extent of the consequences, exposure and probability. The NTP 330 method allows quantifying the magnitude of the existing risks and, consequently, ranking its correction priority [10]. The risk assessment method developed and used by the company is based on the history of incidents, analysis of nonconformities, processes and workplaces audits results, workers' communications as well as other interested parties, information on facilities and activities of the company, technological options, technical data, inventory of hazardous materials, toxicological and other data on occupational safety and health, and context of the protection measures implemented in the company. The risk assessment that is associated with the different processes, activities and locations of the company is based on the following main criteria: severity (S), reflecting the result of integrating the severity of the incident into exposure to the effects of the occurrence; and probability (P), which represents the number of times that a dangerous situation can materialize in a pre-established time frame. The chosen activity to test this methodology was the method to the potential, which consisted of two distinct tasks:

Fig. 1 Replacement of an insulator in an LW suspension

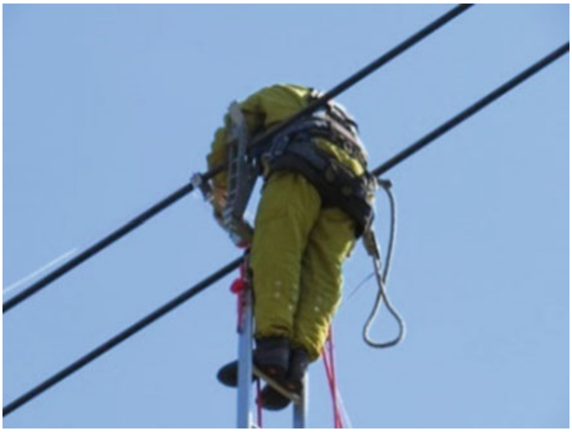

Fig. 2 Work in bundle combactors

- Replacement of an insulator in an LW suspension and substitution of a half-span insulator in LW (Fig. 1)
- Replacement of an insulator in an LW mooring (Fig. 2).

3 Results and Discussion

By applying the risk assessment, it was possible to perceive which risks presented the greatest magnitude, and which risks required greater attention in terms of preventive or corrective measures. Table 1 summarizes the hazards and risks encountered during the activity. Regarding the "work in the support", 77 risks were identified and 42 were identified for the "half-way work". In total, 119 occupational risks were assessed between the two types of work.

In the case of the obtained results with William T. Fine method, both in the "work in the support" and in the "half-way work", it was possible to perceive that most risks are classified as "Low", as can be seen in Fig. 3. However, there are risks that in both cases are classified as "Extreme", as it is the case of "Use of vehicles" and "Live Working". Risks classified at this level require an immediate system shutdown as well as continuous assessment.

In the case of the obtained results with the application of the NTP 330 method and according to Fig. 4, it is possible to perceive that most of the risks are classified with the intervention level II. According to this methodology, risks assessed at an intervention level III, require measures that better address the risk, which means measures that allow the risk to be mitigated or reduced so as not to pose a danger to the health and safety of workers. In the case of risks assessed at the intervention level II, it is necessary to adopt control measures. For risks classified as intervention level I, which is considered a critical situation, they require an urgent correction. Examples of these risks are the "Use of vehicles" and "Live Working".

Table 1 Major hazards and risks

Hazard	Risk
Use of vehicles	Collision/rollover
	Fatigue
Work in the presence of animals/interaction with animals	Stings
	Bites
Machines	Falling objects
	Crush
Irregular floor	Fall to the same level
Disorganization of material	Shock against objects
	Fall to the same level
Handling of materials in height	Falling objects
Live working	Electrification
	Electrocution
Work at height	Fall in height

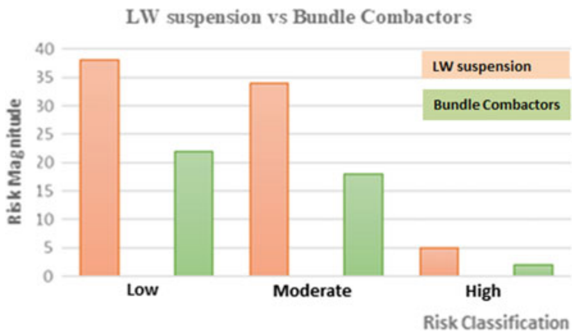

Fig. 3 Results with William T. Fine method

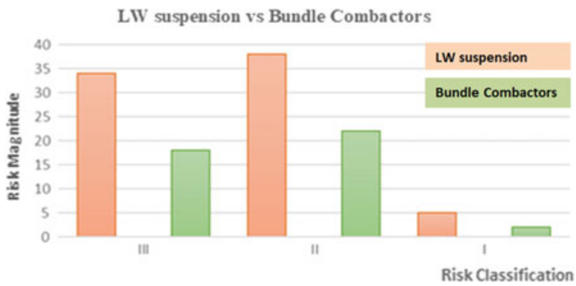

Fig. 4 Results with NTP 330 method

In the case of the method developed and currently used by the company, through the results obtained and by the analysis of Fig. 5 it is possible to perceive that most risks are classified as “Low” in both cases. Risks classified as “Low” are not considered a priority for intervention. In this way, they can be managed by routine

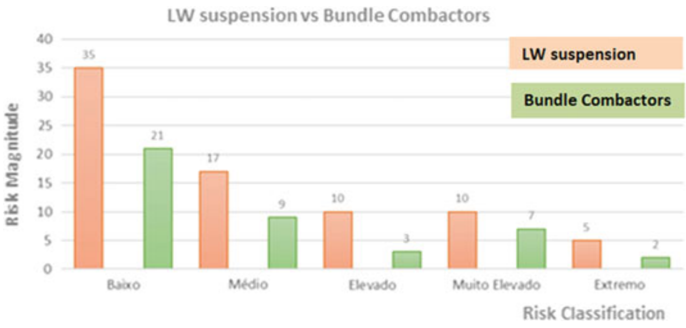

Fig. 5 Results with the method developed and currently used by the company

procedures and do not require the creation of additional risk control and prevention measures. In the case of risks classified as "Moderate", such as "Over-efforts" and "Fall in height", appropriate measures should be identified for the treatment of the risk and their implementation should be planned within a set deadline, with the aim of reducing the risk. The risks assessed as "High", as is the case of "Live Working", are considered to be a priority and urgent. In this way, and due to their severity, these risks should be reported immediately. In addition, they require urgent action to be taken to minimize the consequences.

Although the results are not totally coincident, what is expected given the subjectivity of a risk assessment, it is possible to perceive that the operations where the use of equipment in tension is verified and where it is necessary that the worker comes into contact with the electric chain in high-intensity values are those that require more attention. These operations require extensive knowledge and experience of the operators, as well as a preliminary analysis by the technicians and managers of the whole environment and the way in which the operations will be carried out, in order to minimize to the maximum a risk that will always be present.

4 Conclusions

Risk assessment is not the answer to all questions, but it allows determining possible situations with harmful consequences for both workers and materials and should be carried out whenever possible and well in advance. In this study, 119 risks were evaluated where the danger is the presence of an electric chain, in which contact with it results in electrocution/electrocution that can result in death. The operations were evaluated according to three different risk assessment methodologies: William T. Fine, NTP 330 and the method developed by the company. Although risk assessment is a very subjective working tool, it is very important in the prevention of workers' safety and health. Evaluation should be structured effectively so that no hazards and their respective risks are overlooked. The success of any risk management program depends on the importance that is given to risk assessment and how it is carried out, and should always focus on prevention rather than correction [13]. In general, it was possible to perceive that of the three methods the one that presents major limitations is the method developed and used by the company. This is because this method takes into account the accident history to calculate the probability of occurrence of a certain event. However, LW do not occur very frequently and so there is no accident history that allows one to realize the probability of a dangerous situation materializing as an incident. In this way, the need arises to choose to carry out the risk assessment for live working through another method. This method can be William T. Fine or even the NTP 330- since these methods do not contemplate the history of accidents, but rather the probability of the worker being exposed to a certain risk factor. With this study, and based on the methodologies used as well as the bibliography analyzed, it is possible to conclude that it is essential to carry out the risk assessment by utilities, organizations and entities that work with risk activities [14, 15].

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References

1. Sá, T.: A evolução do conceito de gestão do risco e a sua ligação com o governo das sociedades A evolução do conceito de gestão do risco e a sua ligação com o governo das sociedades (2012)
2. Bureau Internacional do Trabalho: A segurança e saúde no trabalho: Ergonomia (2015)
3. ACT: Promoção da Segurança e Saúde no Trabalho em 2016 Relatório de atividades apresentado à Assembleia da República (2016)
4. Morais, S., Waplington, F.: Elementos de Eletricidade. Lisboa (2011)
5. Muniz, A.R., Silva, R.D.O.: Segurança em eletricidade. 1–22 (2004)
6. Brenner, B., Cawley, J.: At-Risk Occupations in Power Line Fatalities: How Do Occupational Safety and Health Administration and U.S. Bureau of Labour Statistics Data Compare? (2016)
7. Nogueira, H., Monteiro, N.: Manual de Trabalhos em Tensão na Alta Tensão (2017)
8. Cigré: Live Work—A Management Perspective Joint Working Group (2013)
9. Sargaço, S.: Trabalhos Em Tensão. 5235 (2006)
10. INSHT: NTP 330: Sistema simplificado de evaluación de riesgos de accidente
11. Pereira, R.: Aplicação de metodologia integrada de avaliação de riscos de SHO e impactes ambientais (2010)
12. de Mendonça, A.L.P.V.: Métodos de avaliação de riscos: contributo para a sua aplicabilidade da construção civil. 226 (2013)
13. EU-OSHA: Avaliação de riscos : funções e responsabilidades. Facts 1–2 (2008)

14. Fîță, D., Băncilă-Afrim, N.: Identifying Vulnerabilities/Risk Factors of the Critical Infrastructure in the Power Installations of Ultra-high and High Voltage from the National Power System with International Connections (2017)
15. Fordyce, T., Leonhard, M., Watson, H., Mezei, G., Vergara, P., Krishen, L.: An Analysis of Fatal and Non-fatal Injuries and Injury Severity Factors Among Electric Power Industry Workers (2016)

Evaluation and Control of Professional Risks in Intensive Care Units

Ana Ferreira, João Paulo Figueiredo, Mariana Girão and Ana Lança

Abstract We know that certain areas of work pose a greater risk to the health and safety of the worker, and for this reason the present study focused on the intensive care units (ICU), where risks are a constant, allowing a more individualized intervention professional risk assessment and control. It was proposed, as objective of this study, to evaluate the occupational risks to which the workers of the intensive care units are exposed. This was a descriptive-analytical, cross-sectional, observational, where the working conditions of workers in the intensive care units of the Coimbra county hospitals were evaluated. The risk assessments identified multiple risk factors in the intensive care units under study and showed the most incidental risks are those of biological and ergonomic origin. The analytical studies showed unsatisfactory results in some parameters when compared with the legislated values. It is concluded that the work in intensive care units presents multiple and constant risk factors, in which it is evident that the most prevalent are biological and ergonomic risks, however, in order to explain the probability of the damage it is necessary to point out that the exposure is related to the time spent on the tasks.

Keywords Professional risks · Hospital environment · Risk assessment

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1 Introduction

The study of the occupational hazards to which ICU workers are exposed is related to the fact that they provide direct and continuous assistance to the users, besides constituting a greater representation of personnel within the hospital, acting in diverse contexts like the promotion, prevention and recovery of health [1].

The work performed in the hospital area is considered extremely unhealthy because, in addition to grouping patients with several infectious diseases, it is the scene of numerous invasive and non-invasive procedures that offer risks of accidents and illness to their workers [2]. The relationship between work and health must be seen as decisive when considering the injuries that can occur to the worker. In this perspective, there is a need to ensure appropriate conditions for the development of workers' activities, protecting and promoting their health [3].

The ICU differentiates itself as a sector dedicated to providing complex care to patients with serious health problems. These patients end up needing diverse technological resources, as well as a specialized multiprofessional team [4]. Treatment usually involves continuous monitoring and ongoing care, as the possibility of instability of these patients is a constant [5]. The characteristics of the intensity of care performed in this type of unit, such as more frequent performance of procedures with the patient, consequently gives these workers greater exposure to occupational risks [6]. These units are characterized by being a multidisciplinary and differentiated area that are directed towards the diagnosis and treatment of acute, potentially reversible disease in patients who present with failure of one or more vital, imminent or already installed functions [7].

Professionals perform their functions in a context where the characteristics described above coexist, such as working directly with vulnerable people; the high level of responsibility for their tasks and the consequences of possible mistakes; the need to face unpredictable events, suffering, pain and death; the development of critical judgment in relation to the actions derived from a medical diagnosis; interaction with the families of the caregivers; and maintaining the balance between work and personal life [8, 9].

Currently, some standardizations are established for the operation of intensive care units, which aim to reduce the risks to patients cared for, to professionals and to the environment. These standardizations refer to the ICU as a critical area in which there are increased risks for the occurrence of healthcare related infections. Such risks may be present in activities involving critical materials or biological material, in performing invasive procedures and in the presence of patients more subject to pathogens [10].

Health professionals are exposed to working conditions that include high stress and shift workload environments, and both can have an impact on the physical and mental health of these professionals [11, 12]. Workers' health may, in turn, affect patient safety both by the potential for increased error and by increased risk of transmission of hospital infections [13, 14].

Occupational health and safety require that a wide range of occupational factors be taken into account, from the individual workload to the time of movement. Given the occupational exposure to which ICU workers are exposed, it can be said that their health, not only physical but also psychological, is compromised. In this sense, it is important that the risk is always estimated with the aim of eliminating it and, if this is not possible, its control or reduction. Studying the work from the worker's point of view reduces evaluation mistakes and, therefore, the rationality of researchers and technicians is not enough, it is necessary to involve the one who lives the work situation so that, from the singularities, there is actually construction collective [15].

The main objective of the study was to evaluate how health and safety conditions influence the quality of life and health of ICU workers in hospital settings.

2 Materials and Methods

2.1 Research Design, Population and Sample

This study was an observational, descriptive-analytical and cross-sectional study where the working conditions of the workers of the intensive care units of three hospitals in the county of Coimbra were evaluated. The target population was the workers of intensive care units, the sample being represented by them. The type of sampling was non-probabilistic and for the sampling technique, this was for convenience. The inclusion criteria were: the workers of the intensive care units.

2.2 Instruments and Data Collection

In the first phase, the theoretical data were collected through a bibliographical research, to analyze the subject in question. In the second phase, a checklist designed on the basis of the legislation in force to support the assisted observation study was carried out and applied in order to assess the conditions of the service in question. Subsequently, the measurements of the analytical studies were carried out. In the third and last phase, the application of methodologies for the evaluation of professional risks and the treatment of data occurred.

The risk assessment was carried out using the Simplified Method of Assessment of Professional Risks, evaluating the degree of hazard (GP) according to the probability of an accident (P), the frequency of exposure to risk (E) and the consequences (C) normally expected in the case of the accident occurring translating by the expression [16, 17]:

$$GP = P \times E \times C \tag{1}$$

The methodology of risk assessment is proactive and direct [17]. It is based on an assisted observation study based on checklists drawn up for this purpose. It identifies hazards, quantifies the magnitude of existing risks and, consequently, rationally prioritizes its intervention. This methodology is qualitative, given that the hazard identification, the estimation of the magnitude (gravity) and the probability of occurrence are made on a qualitative basis, also complying with the legislation in force, which is based on the general principles of prevention, present in the legislation in force. The present methodology takes into account the classification of professional risk factors [18, 19].

In relation to the analytical studies, with regard to indoor air quality, the equipment used was a MultiFunctions Marca TSI, Model 9565-X. Parameters such as CO_2, T (°C) and % Hr were evaluated and later compared and analyzed through DL nº 118/2013, of August 20 and Port. No. 353-A/2013, of December 4, (Threshold of protection, comfort), DL nº 243/86 of August 20 (Regulation of hygiene and safety at work in commercial establishments, offices and services) and through the ACSS (Technical recommendations for heating, ventilation and air conditioning (HVAC), and the method applied was to evaluate the existing infrastructural and functional conditions and also through a previous diagnosis. In order to carry out the measurements, the following aspects were considered: Conditions in which the measurements were taken (season, morning or afternoon), ventilation (natural or artificial), measurement site, number of workers and measurement time.

As for the analytical studies of illuminance, the equipment used was a Center 337 Mini Light Meter and the method applied was by direct observation through the characterization of the work environment. The Luximeter was placed on top of the equipment present in the workplace, in front of the worker and, where possible, with the worker at the workplace. The values of the illuminance were recorded after the stabilization of the Luximeter, and were later compared and analyzed with DIN 5035 (1990) and ISO 8995: 2002.

2.3 Statistical Analysis

Data were processed using the IBM SPSS 25 software. At the level of statistical inference, we used Student's t-test, Chi-square test of Independence. Finally, the inference was based on a confidence level of 95% for a random error up to 5%.

3 Results

In this study, the workers of the intensive care units of each hospital under study were integrated. With regard to workers, these can be divided into three groups: Operational Assistants, Nurses and Doctors. For Hospital A we have: 8 operational assistants, 33 nurses, 11 doctors and 1 technical assistant; for Hospital B we have: 4 operational assistants, 23 nurses, 15 doctors and 1 technical assistant; finally, for Hospital C we have: 10 operational assistants, 30 nurses, 8 doctors and 1 technical assistant.

The service distribution of the workers of these units is done through three shifts throughout the 24 h daily: morning shift, afternoon shift and night shift. With this study, we sought to understand and evaluate the working conditions to which intensive care workers are exposed in view of the nature of the risk factors to which they are exposed in relation to the tasks performed. When analyzing the results which shows the nonconformities observed during the risk assessments, we found that the three hospitals had a high number of nonconformities, ranging from 40 (32%) in Hospital C and 43 (33.6%) in Hospital B. In Hospital A, 42 (33.6%) nonconformities were found, of which 11 (26.2%) were related to the general conditions of the unit, 9 (21.4%) related to biological risks, 6 (14.3%) with chemical risk and 5 (11.9%) related to ergonomic risks. At hospital B, the most commonly found risk was chemical risk with 11 (25.5%) nonconformities, followed by 9 (20.9%) related to biological risk and 9 (20.9%) related to general conditions of the unit and we also highlighted 4 (9.3%) nonconformities found related to ergonomic risks. As for Hospital C, once again, we found a greater number of chemical nonconformities, 9 (22.5%), followed by 7 (17.5%) of a biological nature, 7 (17.5%) related to the general conditions of the unit and still 6 (15%) of an ergonomic nature.

As for the tasks performed by the workers of the intensive care units we can discriminate them: “Resting bathing suits”; “Organize and tidy up unit”; “Preparing bath water”; “Provide support during bathing”; “Remove all types of waste from the unit”; “Disinfection of showers”; “Replacing consumables in the unit; Provision of general hygiene care”; “Providing oral and ocular hygiene care”; “Patient positioning”; “Monitoring of vital parameters”; “Arterial and venous puncture”; “Referral of users for exams”; “Nasoenteral, nasogastric, bladder of relief and delay”; “Colostomy bag installation”; “Patient and family information on treatment progression”; “Exchange of information with a multidisciplinary team”; “Handling biological waste and short-perforating objects”; “Hospital discharge” and “Liberation of the body in case of death”.

After identifying the tasks performed in the three hospitals, we sought to analyze and identify the occupational risks inherent in the tasks. According to the results, it was verified that the risks that presented higher values are, respectively, the exposure to biological agents (45%), the adoption of incorrect postures and the efforts of the upper and lower limbs (35%) and shock and blows against objects and equipment (25%).

Next, we verified the risk factors associated with occupational risks that most affected in the course of the tasks performed. We found that the risk factors most involved in the tasks are biological risks (40%), ergonomic risks (35%) and mechanical risks (30%). Despite fewer incidents, it is important to emphasize chemical risks and physical risks (20%).

One of the objectives of this research was to carry out analytical studies and, thus, the level of illumination and indoor air quality in the intensive care units of the three hospitals under study were evaluated. For the assessment of indoor air quality the parameters to be taken into account were carbon dioxide (CO_2), carbon monoxide (CO), air temperature (°C) and relative humidity (% Hr). Note the following tables.

Observing the Table 1, we could verify that the average value of illuminance in the three hospitals was much lower than the recommended value (500 lx). Comparing the values obtained in the three hospitals, it can be stated that, although all three patients had values that were much lower than expected and recommended, Hospital B (174.33 lx) presented lower values.

According to the Table 2, we found that the CO_2 values obtained in the three study units were well below the value established in the legislation for the Protection/Comfort Threshold that is 1250 ppm.

Regarding the values of carbon monoxide in the intensive care units, we found that in all of them they are much lower than the limit established by the law (9 ppmv), since the mean values vary between 0.33 ± 0.21 ppmv in Hospital A and 0.79 ± 0.43 ppmv in Hospital B ($p < 0.0001$).

When observing the results obtained regarding the temperature, we verified that, in the majority (84.6%), they were inadequate, according to the technical recommendations for HVAC installations. Regarding Hospital A and C, the temperature should be between 24 and 25 °C, depending on the measurement site, and only two places in Hospital A and one in Hospital C had adequate values. Regarding Hospital B, the values should vary between 24 and 27 °C depending on the measurement sites, and only one place was of adequate value. Of the 26 temperature measurements performed in the three hospitals, 22 (84.6%) were inadequate and only 4 (15.4%) were in accordance with the recommendations.

Table 1 Hospital illuminance parameter

Canteen	Lux			
	n	Mean	Standard deviation	p
Hospital A	11	268.04	183.39	0.002
Hospital B	8	174.33	88.95	<0.0001
Hospital C	9	274.83	158.73	0.003

Test: Student t test for population mean

Table 2 CO_2 parameter versus hospital

Canteen	Lux			
	n	Mean	Standard deviation	p
Hospital A	11	531.46	205.16	<0.0001
Hospital B	8	570.56	233.87	<0.0001
Hospital C	9	505.67	311.59	<0.0001

Test: Student t test for population mean

At Hr level, we could observe that, as with temperature, the values were not adequate according to the technical recommendations for HVAC installations. In Hospitals A and C the % Hr should be between 40 and 50% and, of the 17 measurements performed in both hospitals, only one was adequate. It should be noted that all values obtained for Hospital C were inadequate, according to the recommendations. For Hospital B, the% Hr should vary between 40 and 60%, depending on the sites, and of the 7 measurements performed only 2 (28.6%) were adequate.

4 Discussion and Conclusion

The results showed that, in the three hospitals under study, the number of nonconformities found in each of them was shown to be high. These nonconformities were verified in the risk assessments carried out and are based on situations of risk witnessed, related to various types of risks. In this sense, it is emphasized that these risks are understood as the possibility of situations that affect in some way the health of the worker in his place of work [20].

As regards biological risks, they have been found to pose a serious problem to the health of workers, in view of their high incidence, as workers, in particular doctors and nurses, provide care that includes invasive and non-invasive technical procedures, which put them in direct contact with body fluids and secretions [21]. Other studies are in agreement with these facts and also say that they are one of the main causes of work accidents in hospital environment [22]. Among the most common biological risks in the hospital environment, contact with body fluids is the most important, since contamination by secretions and eliminations is considered to be serious for the health of the worker, exposing him to the infections transmitted by microorganisms present in the blood or other organic fluids [23]. As for ergonomic hazards, physical wear and tear on workers can often lead to fatigue and even exhaustion. This is mainly due to the existence of a constant need for movement and motor actions during the care given to the patient physically and may also be related to a high work letter [24]. In addition to physical wear and tear, workers may have the need to adopt incorrect postures due to poor lighting, which can create reflections and shadows, inducing neck flexion and back pain. It should be noted that the manual movement of loads is a constant in an intensive care unit and the posture adopted by workers is always influenced by the size of the furniture, the work organization, as well as the age and anthropometric characteristics of each professional. Studies have shown that many of the accidents that occur are caused by excessive weight lifting or transfer, in relation to obese and/or dependent patients during the bath, as well as transport of equipment and stretchers [26].

The ICU needs to have institutional regulations related to biosafety measures. The measures shall include occupational and environmental safety relating to biological, chemical and physical aspects. For this, guidelines for the use of individual and collective protection equipment, as well as handling, transportation and proper disposal of biological material are essential [26].

It is concluded that the work in intensive care units presents multiple and constant risk factors, in which it is evident that the most prevalent are the biological and ergonomic risks. However, in order to explain the probability of the damage it is necessary to point out that the exposure is related to the time dedicated to the tasks. As to the tasks, it was possible to conclude that the most likely to be at risk due to the biological risk factor are those in which the presence of biological agents is a constant, such as arterial or venous puncture, nasoenteral probing and placement of a colostomy bag, among others. Faced with the ergonomic risk factor, two of the tasks where this risk is most incident is the provision of support in the baths and the positioning of patients. In addition to these two risk factors, it is important to pay attention to the mechanical and chemical risks that were also evident throughout the study.

Taking into account the preventive measures already existing in the intensive care units and based on the risk assessments carried out, we also concluded that the implementation of Basic Precautions for Infection Control (BPIC) is a great ally for the protection of the health and safety of workers. One of the most important measures to reduce the transmission of infectious agents is hand hygiene which, together with the use of personal protective equipment, provides adequate protection to workers [27].

In addition to this, it is extremely important to promote training, information and awareness among workers on hazards and risks in the workplace, to request improvements in lighting and HVAC systems and to provide ergonomic solutions as well as to change the organization of work so as to risk exposure is as small as possible.

References

1. Rapparini, C.: Riscos biológicos e profissionais de saúde: procedimentos clínicos (2001)
2. National Institute for Occupational Safety and Health: Guidelines for protecting the safety and health care workers, Atlanta (1988)
3. Forte, E., Trombetta, A., Pires, D., Gelbcke, F., Lino, M.: Abordagens teóricas sobre a saúde do trabalhador de enfermagem: revisão integrativa. Cogitare Enferm. **19**(3), 604–611 (2014)
4. Chaves, L., Laus, A., Camelo, S.: Ações gerenciais e assistenciais do enfermeiro em unidade de terapia intensiva. Rev Eletrônica Enferm. **14**(3), 671–678 (2012)
5. Santos, A., Vargas, M., Schneider, N.: Encaminhamento do paciente crítico para unidade de terapia intensiva por decisão judicial: situações vivenciadas pelos enfermeiros. Enferm. Foco **1**(3), 94–97 (2010)
6. Marinho, M., Almeida, C., Andrade, E.: Risco ergonômico nas práticas da equipe de enfermagem de uma UTI. Rev Ciênc Desenvolv Fainor **8**(1), 192–205 (2015)
7. Silva, A.: Reformas no sector da saúde: a equidade em cuidados intensivos. Universidade Católica Editora, Lisboa (2010)

8. Lakanmaaa, R., Suominenb, T., Perttilä, J., Puukkae, P., Leino-Kilpi, H.: Competence requirements in intensive and critical care nursing—still in need of definition? A Delphi study. Intensive Crit. Care Nurs. **28**, 329–336 (2010)
9. Moreno, E., Villegas, J., Prieto, F., Nieto, J.: Efectosadversos, intercomunicación, gestión del conocimiento y estrategias de cuidados en enfermería intensiva. Medicina Intensiva **35**(1), 3–5 (2011)
10. Agência Nacional de Vigilância Sanitária (Brasil). Resolução Anvisa/DC nº 7, de 24 de fevereiro de 2010. Dispõe sobre os requisitos mínimos para funcionamento de Unidades de Terapia Intensiva e dá outras providências. Diário Oficial da União fev 2010;Seção **1**, 48–51 (2010)
11. Hugonnet, S., Harbarth, S., Sax, H., Duncan, R.A., Pittet, D.: Nursing resources: a major determinant of nosocomial infection? Curr. Opin. Infect. Dis. **17**(4), 329–333 (2004)
12. Hugonnet, S., Villaveces, A., Pittet, D.: Nurse staffing level and nosocomial infections: empirical evaluation of the case-crossover and case-time-control designs. Am. J. Epidemiol. **165**(11), 1321–1327 (2007)
13. Rogers, A.E., Hwang, W.T., Scott, L.D., Aiken, L.H., Dinges, D.F.: The working hours of hospital staff nurses and patient safety. Health Aff. (Millwood) **23**(4), 202–212 (2004)
14. Virtanen, M., Kurvinen, T., Terho, K., Oksanen, T., Peltonen, R., Vahtera, J., Routamaa, M., Elovainio, M., Kivimaki, M.: Work hours, work stress, and collaboration among ward staff in relation to risk of hospital-associated infection among patients. Med. Care **47**(3), 310–318 (2009)
15. Cabral, F., Veiga, R.: Higiene, Segurança, Saúde e Prevenção de Acidentes de Trabalho - Um Guia Prático imprescindível para a sua atividade diária. Verlag Dashöfer, Lisboa (2007)
16. Roxo, M.: Segurança e Saúde do Trabalho: Avaliação e Controlo de Riscos. Almedina, Coimbra (2009)
17. Ribeiro, A.: Avaliação de Riscos: Estimação Qualitativa da Probabilidade e da Gravidade em Contexto de Risco Elevado (2013)
18. Miguel, D., Loro, M., Rosanelli, C., Kolankiewicz, A., Stumm, E., Zeitoune, R.: Percepção de trabalhadores de uma unidade oncológica acerca dos riscos ocupacionais. Ciênc Cuid Saúde **13**(3), 527–534 (2014)
19. Benatti, M., Nishide, V.: Elaboração e implantação do mapa de riscos ambientais para prevenção de acidentes do trabalho em uma unidade de terapia intensiva de um hospital universitário. Rev. Latino-Am. de Enfermagem. **8**(5), 13–20 (2000)
20. Souza, M., Vianna, L.: Incidência de acidentes de trabalho relacionada com a não utilização das precauções universais. Rev. Bras. Enferm. Brasília **46**(4), 234–244 (1993)
21. Balsamo, A., Felli, V.: Estudo sobre os acidentes de trabalho com exposição aos líquidos corporais humanos em trabalhadores da saúde de um hospital universitário. Rev. Latino-am Enfermagem **14**(3), 346–353 (2006)
22. Cruz, E., Souza, N., Correa. R., Pires, A.: Dialética de sentimentos do enfermeiro intensivista sobre o trabalho na terapia intensiva. Esc. Anna Nery **18**(3), 479–485 (2014)
23. Silva, D., Marziale, M.: O adoecimento da equipe de enfermagem e o absenteísmo doença. CiêncCuid Saúde **1**(1), 35–39 (2016)
24. Agência Nacional de Vigilância Sanitária (Brasil). Resolução Anvisa/DC nº 7, de 24 de fevereiro de 2010. Dispõe sobre os requisitos mínimos para funcionamento de Unidades de Terapia Intensiva e dá outras providências. Diário Oficial da União;Seção **1**, 48–51 (2010)
25. Ferreira, A., Lança, A., Mendes, C., Sousa, M., Paixão, S.: Occupational Safety and Hygiene VI, p. 620. CRC Press, Guimarães (2018)

Guidelines for the Use of Quality Engineering Tools to Improve Occupational Safety. The Case of Polish Construction Companies

Adam Górny

Abstract The successful assurance of safe working conditions is predicated on successfully identifying the root causes of non-conformities and the extent of their impact. This is helpful in defining the aims of improvement measures. Measures should be targeted particularly at areas where accident rates soar. One such area in Poland is the construction business. For added efficiency of improvement efforts, the use of quality engineering tools is highly recommended. A broad range of such instruments are available. The article emphasizes that the prime consideration in this context is for companies to secure the ability to process the information at hand and deploy adequate improvement measures and solutions with a view to achieving effective outcomes and continuous adjustment to changing environments. Quality engineering tools help recognize the complexities of the challenges faced, develop an improvement strategy and select the most appropriate measures. To make certain that the right tools for the job are selected, it is crucial to rely on accident reports and statistics and examine risks and hazards. Proper account should also be taken of any features of the concerned industry. The use of quality engineering tools is a recommended way for gain benefits including assurance of working environment improvements. Getting of benefits depends on use of proper tools to collect information and identify improvement area.

Keywords Quality engineering tools · Safety · Polish construction companies

1 Introduction

In order to effectively improve safety by mitigating hazards and non-conformities, it is imperative that improvement processes be structured and worker awareness raised [1–3]. An essential means to this end is the early identification of issues and

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causes of non-conformities and an assessment of both their impacts and of the capacity to make improvements [2]. The actions taken must be based on data and information describing the actual state of safety in the companies.

Such measures will reduce the number of breaches of safety standards and, by the same token, help lower occupational accident rates, the incidence of occupational diseases and the number of workers exposed to hazards. The above outcomes can be viewed as effectiveness yardsticks in occupational safety management [2, 4].

Owing to the sheer complexity of the issue, it is crucial that improvements be deployed in a systemic and orderly fashion [2, 5]. Improvements can be made more effective with the use of proper support instruments that include quality engineering tools. Efforts to ensure the safe operation of workers in the working environment are particularly vital in industries plagued by high rates of accidents and hazards. In Poland, such industries include the construction business and construction-related fields.

2 Use of Quality Engineering Tools in Improving the Working Environment

To conduct safety assessments covering accident statistics and a company's operating conditions, it is essential to identify the causes of non-conformities and their effects [2]. The assessment process can be improved by means of quality engineering tools which, as an additional benefit, support the choice, planning and optimization of improvement measures [6, 7].

Figure 1 shows an proceedings process for obtaining improving both working conditions and the working environment. To assess safety undertakings need to make use of adequate improvement tools that will enable them to evaluate safety, identify the causes and nature of non-conformities and specify the key alterations they seek to achieve using measures that are adequate for the issues they face. The assessment of safety as well as the identification of sources and the nature of non-compliance are unrelated actions that use information appropriate carry out. In the first case, it may be statistical data, e.g. on accidents at work and their causes. In the second case, these is characteristic of the work performed.

One tangible measure of corporate safety are accident statistics. Improvement efforts also require that proper account be taken of the industry and the specific features of the company's operations that affect the nature of any non-conformities. Once such considerations are duly accounted for, one can select and apply solutions that will ensure effective improvements. Examples of data, on the basis the safety can be assessed are provided in Sect. 3 of this article.

To ensure effective improvements, companies need first to identify hazards as well as their causes and impacts [5, 8]. By putting the information they gather to good use and recognizing the specific nature of an organization's business, they can

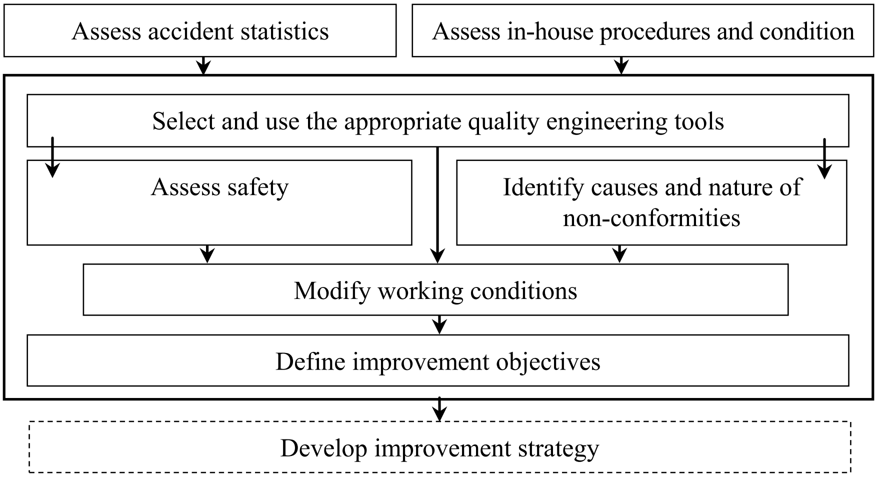

Fig. 1 Flowchart of measures taken to improve occupational safety

chart out future actions. The application of quality engineering tools requires reliable input data that is put to proper use [7, 9, 10]. Such tools can be seen as instruments for supervising and diagnosing measures and observing the end result.

3 Poland's Construction Industry

3.1 How the Characteristics of the Construction Industry Affect Safety

The construction business is a sector covering the building, maintenance, renovation and reconstruction of buildings and other structures. Due to the significant role of investment in the social and economic development of countries, the sector is considered to be a mainstay of national economies. The industry has the potential to stimulate economic growth, mobilize societies and activate businesses in many segments.

In Poland, construction is a major driver of economic growth. Its current share in GDP stands at ca. 10% [11]. The construction industry is closely linked with and dependent upon many other sectors of the economy. The uniqueness of construction companies lies in the nature of their business. Roughly 97% of the country's construction companies are privately owned, most of them falling into the category of SMEs [11].

Due to its specific features, the Polish construction sector is plagued by numerous non-conformities that result from the way work is performed. The key factors that adversely affect safety at work include:

- Unavailability of highly competent workers with proper work experience forcing companies to High Representative persons whose knowledge of occupational health and safety is insufficient and whose experience in this field is limited,
- Seasonal intermittent nature of employment in construction companies coupled with the absence of properly trained workers leading to the employment of poorly-skilled employees, many of whom have a limited command of the Polish language,
- High worker turnover leading to the employment of young unassertive workers who view high-risk jobs as a challenge and a way to gain the approval of senior workers,
- Focus on meeting deadlines ahead of occupational safety concerns placing high time pressure on the workers,
- The complexity of construction projects resulting in heavy vehicle traffic that raises accident risk on construction sites,
- Budget restrictions leading to hiring workers who accept lower pay but whose professional skills are also more limited,
- Much of the work being performed by small and financially strapped companies that are unable to invest in safety improvements,
- In an effort to meet shorter deadlines, companies are forced to work multiple shifts, which leads to fewer supervisors per shift; in addition, work during the night shift leads to greater fatigue, tends to be more monotonous and erodes worker concentration, creating a more hazardous environment,
- Poorly arranged and managed construction sites and large waste volumes trigger accidents and injuries suffered by workers and visitors alike.

The above factors were indicated on the basis of research carried out in Polish construction enterprises.

The majority of construction projects involves multiple subcontractors, which are small businesses that fail to adhere to systemic occupational safety management guidelines, do not have safety policies in place, fail to identify safety objectives, fail to assess risks and neglect to prevent on-the-job accidents in an orderly fashion.

3.2 Assessment of Safety in the Construction Industry

In Poland, safety assessments are performed by the Central Statistical Authority based on worker-reported accident rates and causes. The aggregate rates can then be associated with specific industries by accident severity. A detailed account of accident trends in the construction sector between 2016 and 2018 is provided in Table 1.

Table 1 Accident rates in the construction industry

Year		Number of occupational accidents (total)		Number of serious accidents		Number of fatal accidents	
		–	Per 1000 workers	–	Per 1000 workers	–	Per 1000 workers
2016	Industry total	87,886	7.00	467	0.04	243	0.02
	Construction	5468	6.36	70	0.08	52	0.06
2017	Industry total	88,330	6.80	671	0.05	270	0.02
	Construction	5390	6.01	102	0.11	58	0.06
2018	Industry total	84,304	6.37	517	0.04	209	0.02
	Construction	5247	6.02	84	0.06	48	0.06

Source [10, 11]

The available data reveal a trend in construction companies in recent years. A comparison of accident rates in the construction sector and in the economy overall puts the construction industry among the most accident plagued segments. In particular, construction sector is a negative leader in the category of fatal accidents.

A detailed analysis of safety levels and accident causes shows that the majority of accidents are caused by inappropriate human behavior. For instance, ca. 32% of accidents result from falls from heights causing grave injuries [11, 12]. The primary causes of accident in the construction industry in Poland are shown in Table 2.

Table 2 Primary causes of construction accidents in Poland

Cause category	Cause category
Poor work procedures Category: procedural requirements	• Work in inclement weather including ice-covered, snow-covered and wet surfaces, gusty winds, etc. • Work at heights despite the lack of physical examinations that verify worker fitness for such work • Lacking or insufficient signage at sites posing particular hazards of falling
No supervision over workers Category: procedural requirements	• Lacking supervision over proper use of technical means resulting in workers violating laws, e.g. by failing to properly anchor scaffolds • Workers allowed to perform work despite lacking or insufficient personal protection items, including protections against the consequences of falling from heights

(continued)

Table 2 (continued)

Cause category	Cause category
Insufficient technical equipment Category: technical requirements	• Use of makeshift solutions (platforms) that fail to ensure safety while working at heights • Failure to use protections to guard hazard zones such as railings as protection against falling from heights • Failure to use (lack) of additional protections such as safety nets • Unavailability of personal protection items necessary to secure against and minimize the consequences of hazards
Inadequate training for work and work performance in breach of requirements Category: human factor	• Workers failing to comply with safety rules • Lacking or inadequate worker training on safe work at heights leading to breaches of occupational safety laws and principles • Inability to move around the work area and loss of balance by workers resulting in slipping and tripping that ultimately lead to injuries

Source Own work based on accident records and accident statistics from the Central Statistical Office

4 Tasks Tools of Quality Engineering in the Development of Safety

Other than helping to assess safety, accident statistics should be a reviewed to motivate companies to strive to prevent non-conformities. Such assessments can also improve occupational safety. For any follow-up measures to be effective, it is vital to identify the root causes of any non-conformities. A critical factor for the successful implementation of measure is also their nature. Companies should make sure not to limit their safety in particular efforts to technical and workflow modifications. Their endeavors should encompass all aspects of safety, including human-factor related [4, 13, 14], which incorporate people's perceptions of hazards and their understanding of the need for safe performance. All these conditions influence the selection of the appropriate tools to identify the problem.

For safety improvements to be successful, it is best to use instruments that promote effectiveness. The choice of such instruments should follow from the specific nature of the circumstances at hand and the stage at which measures are taken. The scope and nature of improvements should be tailored to the nature of non-conformities. One should also bear in mind that a limited knowledge of quality engineering tools and of the ways to use them will inevitably force companies to rely on only the simplest quality management tools.

In order to apply such tools to manage the working environment, companies need to improve the way they perform their tasks [4, 5, 15] by means of quality engineering tools. This applies to the four fundamental abilities [14]:

- The ability to identifiability of the nature of non-conformities,
- The ability to discern hazards and the related risks,
- The ability to specify how the workers should comply with safety requirements,
- The ability to objectively identify proper improvement measures.

To learn to manage and effectively improve the working environment, businesses need to identify the factors that bear on the conditions in which work is performed [13]. The tools they use to that end must ensure accurate issue identification and properly accounting for the knowledge and training of the concerned workers. This will ultimately allow the companies to design a proper response and compose a sequence of measures that will improve the company's overall performance and set it on a path of growth [1, 3].

In the modern approach to the working environment that incorporates safety culture management, employers are expected to set an example by behaving properly and assume responsibility for the health and lives of their workers. This is highly important in those fields of business in which the consequences of irregularities are particularly grave [14, 16] and is related to the operating conditions of the enterprise [17]. In such fields, quality engineering tools that foster proper worker behaviors and help garner benefits should be employed.

The necessary minimum requirement in this context is to recognize the non-conformities that affect the effectiveness of rectification measures. In choosing quality engineering tools, companies should seek to acquire the capacity to [7]:

- Collect information on factors affecting the final outcomes of their actions,
- Specify the timeline and logic of the measures they envision,
- Select the best way to achieve their objectives,
- Identify mutual links between the individual measures they envision,
- Structure a large number of ideas and information regarding specific issues,
- Account for any and all factors affecting the final outcomes of their actions,
- Identify relationships among all requirements,
- Structure the causes of specific problems,
- Find new aspects of issues and new ways to address them.

These factors should be considered as guidelines for choosing the appropriate quality engineering tools.

Table 3 brings together the quality engineering tools whose application helps ensure the effective implementation of improvement measures. Their descriptions and features do not limit their applicability to any single area.

The tools can be used to analyze issues and select best improvement measures. In order for such measures to be effective, due note needs to be taken of [14, 18]:

Table 3 The possibility of using a quality engineering tool

Task	Available quality engineering tools	
Accident analysis	– Control chart – Relationship diagram	– Ishikawa diagram – Brainstorming
Identification of non-conformity causes	– Ishikawa diagram – Pareto diagram – Relationship diagram	– Tree diagram – Matrix data analysis – Control chart
Choice of improvement measures	– Tree diagram – Matrix diagram – Matrix data analysis	– Affinity diagram – Brainstorming
Planning and conduct of improvement measures	– Block diagram – Action plan	– Arrow diagram

Source Own study based on [2, 7, 13, 15]

- The physical working environment covering machinery and equipment and workstation workflows and procedures,
- Worker behaviors that result from the way workers perform their duties, perceive safety rules, share information, engage in cooperation and care for safety,
- Workers' internal characteristics such as worker knowledge, skills and motivations.

In performing improvement measures, companies may not lose sight of the harmonizing aspects of working environment management.

5 Summary

Accident-triggering non-conformities require improvement measures that adequately reflect the nature of such non-conformities. Therefore, the characteristics of all issues faced by a company need to be thoroughly identified followed by the selection of improvement measures, whose deployment should reflect the results of such identification. The improvement tools used for that purpose must reflect the nature of the non-conformities [18] as a necessary condition for the effective rectification of problems [13]. The study indicates that the possibilities in this area are great.

Despite growing safety awareness among managers and rank-and-file workers, accident rates persist at a high level. This drives companies to take action and utilize proper improvement tools. Some tangible outcomes of the use of such tools include better compliance with safety and health requirements demonstrated by reductions in accident rates and efficiency improvements. The use of quality engineering tools helps view and examine problems comprehensively and select the best improvement measures tailored precisely to the nature of relevant issues.

This requires identifying the most appropriate tools for specific applications to achieve the intended effects.

References

1. Boer, J., Blaga, P.: A more efficient production using quality tools and human recourses management. Proc. Econ. Finance **3**, 681–689 (2012)
2. Górny, A.: Improvements in the production environment made using quality management tools. In: Hamrol, A., et al. (eds.) Advances in Manufacturing II, LNME, vol. 3, pp. 267–276 (2019)
3. Salguero-Caparrós, F., Pardo-Ferreira, M.C., Martínez-Rojas, M., Rubio-Romero, J.C.: Management of legal compliance in occupational health and safety. A literature review. Saf. Sci. **121**, 111–118 (2020)
4. Wilson, J.R.: Fundamentals of systems ergonomics/human factors. Appl. Ergon. **45**(1), 5–13 (2014)
5. Fox, M.A., Spicer, K., Chosewood, L.C., Susi, P., Johns, D.O., Dotson, G.S.: Implications of applying cumulative risk assessment to the workplace. Environ. Int. **115**, 230–238 (2018)
6. Susa, S., Rodrigues, N., Nunes, E.: Application of SCC and quality tools for process improvement. Proc. Manuf. **11**, 1215–1222 (2017)
7. Hamrol, A.: Zarządzanie i inżynieria jakości. PWN, Warszawa (2017)
8. Holcroft, ChA, Punnett, L.: Work environment risk factors for injuries in wood processing. J. Saf. Res. **40**(4), 247–255 (2009)
9. McCormik, K.: Quality. Butterworth-Heinemann, Elsevier, Amsterdam (2017)
10. Kiran, D.R.: Total Quality management. Key Concepts and Case Studies. Butterworth-Heinemann, Elsevier, Amsterdam (2017)
11. Accident at Work in 2017. Statistical Office in Gdansk, Centre for working Conditions Statistics, Warszawa, Gdańsk (2018)
12. Accident at Work in 2016. Statistical Office in Gdansk, Centre for working Conditions Statistics, Warszawa, Gdańsk (2017)
13. Górny, A.: Use of quality management tools to identify ergonomic non-conformities in human activities. In: Trzcielinski, S., et al. (eds.) AHFE 2019: Advances in Manufacturing, Production Management and Process Control, Advances in Intelligent Systems and Computing, vol. 971, pp. 319–329 (2019)
14. Lis, K.: Kultura i klimat bezpieczeństwa pracy. Studia Oeconomica Possnaniesia **7**(1), 7–16 (2013)
15. Górny, A.: Occupational risk in improving the quality of working conditions. In: Vink, P. (ed.) AHFE 2014: Advances in Social and Organizational Factors, pp. 267–276 (2014)
16. Coyle, I.R., Sleeman, S.D., Adams, N.: Safety climate. J. Saf. Res. **26**(4), 247–254 (1995)
17. Gopang, M.A., Nebhwani, M., Khatri, A., Marri, H.B.: An assessment of occupational health and safety measures and performance of SMEs: an empirical investigation. Saf. Sci. **93**, 127–133 (2017)
18. Dul, J., Neuman, W.P.: Ergonomics contribution to company strategies. Appl. Ergon. **40**(4), 745–752 (2009)

Safety Performance Measurement Maturity in Finnish Industrial Companies

Aki Jääskeläinen, Sari Tappura and Julius Pirhonen

Abstract Organizations typically have a lot of indicators for their safety performance. Nevertheless, the information is not always used efficiently, and the relationship between the indicators and safety outcomes is not clear. Maturity analysis can provide information on how safety performance measurement can be developed. The aim of this study was to analyse the level of safety performance measurement maturity in Finnish industrial companies. A maturity model for safety performance measurement was used to analyse the current level. Analysis was carried out with a survey (n = 172) addressed to four companies. A maturity matrix was drawn up based on the results. The results showed that the current measurement practices were rather advanced while the use of performance information and commitment to performance measurement were inefficient. Several more detailed development needs were identified. Managerial support and employee commitment related to performance measurement and utilization of performance information (e.g. in planning safety procedures) were found to link positively to safety performance while performance measurement practices (e.g. scope of measures and supportive information systems) did not have this link. In the future, the links between performance measurement and management practices and safety performance should be studied in more detail. Also a further qualitative study can extend the explanations related to the results of this study.

Keywords Safety performance measurement · Safety management · Maturity analysis · Maturity model

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1 Maturity in Safety Performance Measurement

Nowadays, safety is a priority and business value in many companies. Measuring and controlling performance is the foundation of any business management process, and there is no exception for safety performance management [1]. Organizations typically have a lot of performance information related to safety [2]. Nevertheless, the information is not always used efficiently [3], and the relationship between the indicators and safety outcomes is not clear [4]. Maturity analysis can provide information on how safety performance measurement can be developed. Maturity in safety can be defined as a certain level of effectiveness and performance with regard to the management of safety and occupational health and safety (OHS) risks [5]. Maturity in performance measurement can be defined as a combination of three aspects: scope, sophistication and satisfaction of employees [6]. Scope means the various areas where performance measurement can be used and the scope of measures in use. Scope can be linked to the comprehensiveness of performance measurement [7]. Sophistication relates to the possibility to provide and use information at a more detailed way which means both in-depth measurement information and more specific organizational area. It is also important to acknowledge the context where performance measurement is used. The ultimate test for performance measurement is the decision of managers to utilize the provided information. Hence, employee satisfaction completes the understanding of performance measurement maturity [6].

Maturity models have been widely used in different fields such as information, strategy and performance management [6, 8, 9]. Maturity models typically define maturity levels which assess the completeness and sophistication of analysed objects. These objects are measured by multi-dimensional criteria with attributes describing the different stages or levels of maturity [10, 11]. Maturity models can be used both as an assessment tool and as an improvement tool [12].

Current maturity models with regard to safety typically focus on safety culture and climate [12–14] or Occupational Health and Safety (OHS) management system [15]. It is known that good safety culture links to high safety performance [16, 17]. Recently, Jääskeläinen et al. [18] suggested a new maturity model for safety performance measurement. The model has three main themes, namely (A) Safety measurement practices, (B) Commitment and culture related to safety performance measurement, and (C) Use of safety performance information. The model provides information on why safety performance measurement might be flawed and how the information could be used better. However, more research is needed in order to understand the maturity level of safety performance measurement and management and its implications on safety performance. The aim of this study is to analyse the status of safety performance measurement maturity in Finnish industrial companies and to identify the link between performance measurement and management practices, and safety performance.

2 Materials and Methods

A self-evaluation survey was carried out in four companies participating the study (see Table 1). Industrial companies representing both manufacturing and service sector were selected as a target group. The survey tool was tested by two fellow researchers and four representatives of the target population. The testing resulted in minor changes improving the understandability and clarity of evaluation statements. The online survey was sent to 488 respondents, and 172 answers were received (response rate of 38%). The respondents included top management (9%), middle management (34%), supervisors (26%), safety experts (19%) and other expert duties (12%).

The survey was based on Jääskeläinen et al. [18] model and consisted of 20 evaluation items in three main themes: (1) Safety performance measurement practices, (2) Commitment and culture related to safety performance measurement, and (3) Use of safety performance measurement. Written evaluation criteria (see example in Table 2) for four maturity levels was chosen to differentiate the model from some earlier maturity surveys using Likert scales and to clarify the alternatives to the respondents.

The answers were scaled from 1 to 4 points where 1 presented the lowest and 4 the highest level of maturity. Satisfaction related to each of the 3 main themes were also enquired and scaled with a 5-point Likert scale (from 1 very dissatisfied to 5 very satisfied). The final responses were further classified into four profiles by the average of performance points and the average of satisfaction points received (Fig. 1). The profiles can be interpreted as follows: 1. "Novice" (Low employee satisfaction and basic practices), 2. "Experimenter" (Low employee satisfaction and advanced practices), 3. "Facilitator" (High employee satisfaction and basic practices) and 4. "Advanced exploiter" (High employee satisfaction and advanced practices).

In addition, the level of safety performance in an organization (10 questions) was evaluated with 4-point Likert scale (from 1 totally disagree to 5 totally agree). Information about the current level of safety performance was gathered to measure

Table 1 The background information of the participating companies

Company	Number of employees in Finland (approx)	Respondents	Response rate (%)
Company 1	1400	59	27
Company 2	1500	53	54
Company 3	6000	41	41
Company 4	450	20	45

Table 2 Example of item-level evaluation with written criteria

Level	Item: links between safety performance measurement objects
Level 1	Linkages between measurement objects have not been considered
Level 2	Linkages between measurement objects are discussed
Level 3	Factors explaining the main measurement results are partially identified
Level 4	Linkages between measurement objects are analysed and modeled (e.g. with a strategy map). There is a common understanding in the organization regarding the factors that should be improved in order to affect the main measurement results

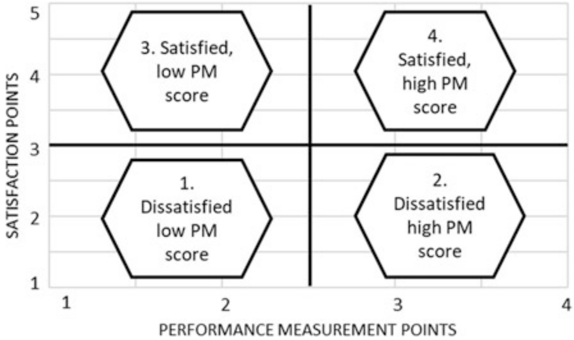

Fig. 1 Maturity matrix based on the results of performance measurement points and satisfaction points

if safety performance measurement is linked with safety performance. Linear regression analysis with bootstrapping of 1000 was used to investigate how performance measurement practices, commitment and culture and use practices of performance information drive the level of safety.

3 Results

Based on the results of the survey in four companies, a safety performance measurement maturity matrix was drawn up (Fig. 2). The averages of all companies' responses were similar. All the companies ended up in the category with high performance measurement (PM) scores and high satisfaction with the current practices. However, there is still room for improvement within maturity profile 4.

When maturity scores were analyzed by different respondent groups, the results showed that the top management had more positive picture of safety performance measurement than other respondents (Fig. 3) while supervisors especially had less positive perception.

When maturity scores were analysed in the three main categories evaluated, the results showed that the performance points decrease when moving from category A (Safety performance measurement practices) to category B (Culture and commitment related to safety performance measurement) and category C (Use of safety

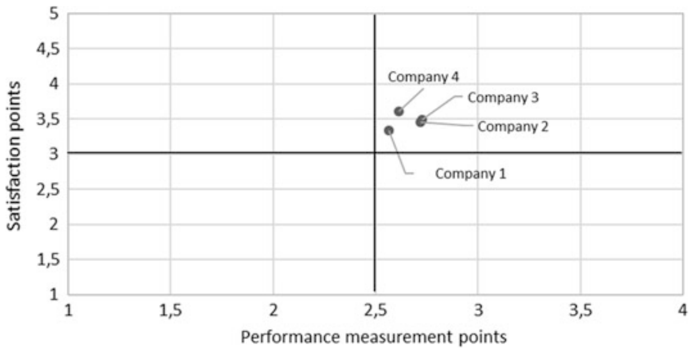

Fig. 2 Overall safety performance measurement maturity scores in four companies

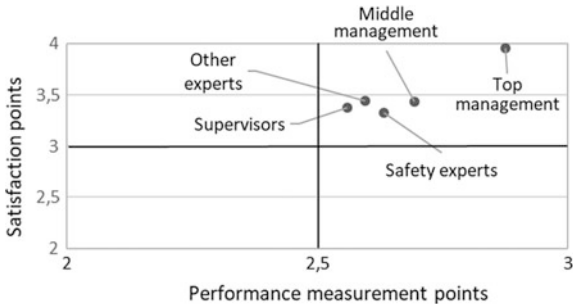

Fig. 3 Safety performance measurement maturity scores by respondent groups

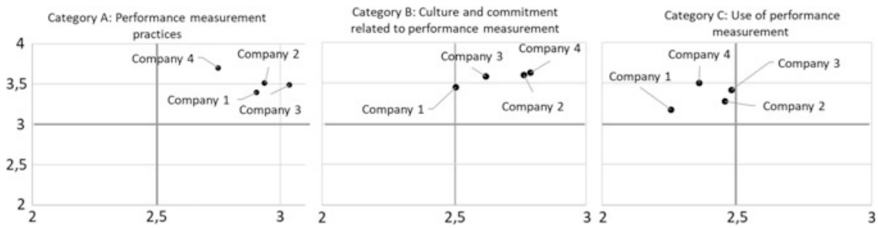

Fig. 4 Company-specific maturity scores in three different evaluation themes

performance measurement) (Fig. 4). The respondents were also less satisfied with the use of performance information than with performance measurement practices or related culture and commitment. However, in all categories the respondents were rather satisfied with the current situation.

In Category A, most practices were at a satisfying level but measuring safety-related costs was an issue for all companies. In addition, companies take notes of factors predicting occupational safety, but the focus is still on lagging indicators and the links between safety performance measurement objects are not fully identified. In Category B, major development needs are related to employees' commitment and engagement in developing measurement practices as well as resources for systematic analysis of the current indicators. In Category C, major development needs were related to systematically utilizing safety performance information in planning, development, rewarding, benchmarking and supplier evaluating.

The level of safety performance was on average pretty high, 3.86 (1–5 Likert scale). It appears that the safety climate is good in the studied organizations, since employees can talk freely about safety. However, employees might take risks when the schedule is tight. It is the only statement where any of the participated organizations received results below 3. Interestingly, high score was received in relation to supervisors' encouragement for employees to work by safety rules—even when the schedule is tight. It seems that encouraging is not enough to ensure that rules are followed.

Regression analysis shows that the level of safety performance is most essentially driven by the culture and commitment towards performance measurement in an organization (Table 3). Also the practices of using performance information have a role in improving safety performance. Surprisingly, it appears that performance measurement practices as such are not significantly linked to the level of safety performance. Overall the examined variables explain around 25% of the variance in safety performance which is a decent amount. However, it is clear that several other aspects than performance measurement and its supportive practices and structures explain the level of safety performance.

Table 3 Links between performance measurement and management practices, and safety performance

Factor explaining safety performance	Performance measurement practices	Culture and commitment	Use of performance measurement
Regression coefficient	0.024	0.353	0.241
p-value	N.S.	<0.001	<0.05
R2		0.249	
Adjusted R2		0.237	
F statistics		20.308***	
F change		20.308***	

$^{*}p$-value <0.05; $^{**}p$-value <0.01; $^{***}p$ -value <0.001

4 Discussion

This study answered to the need to analyse the maturity of safety performance measurement and the performance implications of safety performance measurement practices. It gave an overview of the current level of safety performance measurement maturity in four Finnish industrial companies. A recently developed safety performance measurement maturity model [18] was used to analyse the current situation.

The results showed that the level of safety performance measurement is in a rather good state and the organizations are quite satisfied with their current practices. Even though the measurement practices were satisfying, the use of performance information was inefficient and commitment to performance measurement was insufficient. Resources for using performance information are limited and systematic approach for using the information was lacking. Safety performance measurement is not always being regarded useful in the community and the views of employees are not taken into account when developing measurement practices. These observations explain the argument by Sinelnikov et al. [3] stating that turning data into action is a real struggle for many organizations and their indicators are often data-collecting machines rather than means for continuous improvement efforts. However, the results also show that only the use of performance information (e.g. in planning safety procedures) as well as supportive employee commitment and managerial support relate positively to the level of safety performance. It is therefore clear that the next development efforts should highlight these supportive practices and structures of performance measurement [16, 17]. In addition to ensuring sufficient resources and commitment of employees, performance information usage needs to be improved by paying attention especially to the use of performance information in developing OHS competencies, in incorporating different examination levels to safety management (e.g. whole company, business lines, units) and in managing safety of suppliers.

The results gave new understanding of the factors affecting safety performance, its measurement and related development needs. In practice, the companies can clarify their weaknesses and strengths and use the information to develop these further. Moreover, the companies can utilize the analysis to follow the suggested evaluation criteria to give direction to the advanced maturation levels, i.e. the evaluation instrument would give insights on the next level of practices. In the companies participating in this study, the results will be utilized through discussions with employees and identification of targets for improvement by evaluating the individual items of the survey. According to Chen [15], organizations often fail in following a sequential maturation that models suggest. Hence, after the analysis, organizations will need resources and support in order to reach the higher levels of maturity.

A further qualitative study could identify more detailed explanations for the results observed in this study. Also the quantitative data set could be extended in order to enable comparisons of different regions and industries. Further, the links between measurement practices and safety performance should be studied in more detail. This could include mediation analysis and use of more detailed variables for safety performance measurement, its use practices and the level of safety performance.

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References

1. Janicak, C.A.: Safety Metrics: Tools and Techniques for Measuring Safety Performance. Government Institutes (2009)
2. Jallon, R., Imbeau, D., de Marcellis-Warin, N.: A process mapping model for calculating indirect costs of workplace accidents. J. Saf. Res. **42**(5), 333–344 (2011)
3. Sinelnikov, S., Inouye, J., Kerper, S.: Using leading indicators to measure occupational health and safety performance. Saf. Sci. **72**, 240–248 (2015)
4. Robson, L.S., Bigelow, P.L.: Measurement properties of occupational health and safety management audits: a systematic literature search and traditional literature synthesis. Can. J. Public Health **101**(2), 34–40 (2010)
5. Kaassis, B., Badri, A.: Development of a preliminary model for evaluating occupational health and safety risk management maturity in small and medium-sized enterprises. Safety **4** (5) (2018)
6. Jääskeläinen, A., Roitto, J.M.: Designing a model for profiling organizational management. Int. J. Prod. Perform. Manage. **64**(1), 5–27 (2015)
7. Homburg, C., Artz, M., Wieseke, J.: Marketing performance measurement systems: does comprehensiveness really improve performance? J. Mark. **76**(3), 56–77 (2012)
8. Van Aken, E.M., Letens, G., Coleman, G.D., Farris, J., Van Goubergen, D.: Assessing maturity and effectiveness of enterprise performance measurement systems. Int. J. Prod. Perform. Manage. **54**(5/6), 400–418 (2005)
9. Wettstein, T., Kueng, P.A.: A maturity model for performance measure systems. In: Brebbia, C., Pascola, P. (eds.) Management Information Systems: GIS and Remote Sensing, pp. 113–122. WIT Press, Southampton (2002)
10. Becker, J., Knackstedt, R., Pöppelbuß, J.: Developing maturity models for IT management—a procedure model and its application. Bus. Inf. Syst. Eng. **1**(3), 213–222 (2009)
11. Wendler, R.: The maturity of maturity model research: a systematic mapping study. Inf. Softw. Technol. **54**(12), 1317–1339 (2012)
12. Goncalves Filho, A.P., Waterson, P.: Maturity models and safety culture: a critical review. Saf. Sci. **105**, 192–211 (2018)
13. Hudson, P.T.W.: Safety management and safety culture: the long, hard and winding road. Occup. Health Saf. Manage. Syst. 3–32 (2001)
14. Westrum, R.: Cultures with requisite imagination. In: Wise, J.A., Hopkin, V.D., Stager, P. (eds.) Verification and Validation of Complex Systems: Human Factors Issues. NATO ASI Series, vol. 110, pp. 401–416. Springer, Heidelberg (1993)
15. Chen, S.: Towards the Definition of an OHS Management Maturity Model and Assessment Tool. M.Sc. Thesis, Politecnico di Milano (2016)
16. Stemn, E., Bofinger, C., Cliff, D., Hassall, M.E.: Examining the relationship between safety culture maturity and safety performance of the mining industry. Saf. Sci. **113**, 345–355 (2019)

17. Vinodkumar, M.N., Bhasi, M.: Safety climate factors and its relationship with accidents and personal attributes in the chemical industry. Saf. Sci. **47**(5), 659–667 (2009)
18. Jääskeläinen, A., Tappura, S., Pirhonen, J.: Maturity analysis of safety performance measurement. In: Ahram, T., Karwowski, W., Pickl, S., Taiar, R. (eds.) Human Systems Engineering and Design II. IHSED2019. Advances in Intelligent Systems and Computing, vol. 1026, pp. 529–535. Springer, Cham (2019)

CSETIR—Construction Safety with Education and Training Using Immersive Reality

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Abstract Construction sites are dynamic and complex environments, making them difficult to control and monitor. Construction safety prevents people from dying or becoming incapacitated. It is a socially relevant issue that persists despite several initiatives. To cope with the pressure of avoiding accidents development, safety can no longer rely on traditional accident preventions measures. The project (CSETIR—Construction Safety with Education and Training using Immersive Reality, co-funded by the Erasmus + Programme of the European Union—http://csetir.civil.auth.gr/) arises from the synergy between higher education institutions and construction company provider to implement the use of smart technologies in proper training. The digital tools allow the creation of instruments that simulate construction scenarios allowing the identification and prevention of risks for teachers, technicians, and engineers. This approved project aims at enhancing knowledge exchange between representatives of three sectors to innovate the accident prevention approaches through effective collaboration between researchers in the virtual reality filed and construction companies. The project will develop innovative and interactive VR/AR (Virtual and Augmented Reality) solutions based on BIM

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modelling capacities to prevent accidents and train workers. The project intends to create usable tools for teachers, technicians, and engineers that will be used in any construction project. Project also aims at offering training sessions online on an online platform (project website, wiki) to grant learners and trainees access to interactive material and resources. These tools will range from applications to be used on smartphones to virtual reality contexts depending on the needs of training.

Keywords Construction accidents · Prevention · Augmented reality · BIM · Virtual reality

1 Preamble

Most of the accidents that happen on-site are due to human failure. Manual monitoring and supervision are prone to error due to blind spots, workers loss of focus, awareness, and fatigue. As a result, serious injuries and fatalities are occurring. The human error theories discuss that human error is the factor to be blamed for the accidents, with specific work, and under the environmental circumstances.

According to the Occupational Safety and Health Administration (OSHA) in 2015, 937 (21.4%) workers out of 4379 workers had fatal accidents were from the construction industry. U.K. construction industry is responsible for 31% of the overall work fatalities. In Portugal, there are about 0.5 million employees in the construction sector and has 41 fatal injuries per year. New worker's first months on the job have more than 3 times the risk for injury than workers who have been at their job for more than a year. Since new workers are unfamiliar with the site conditions, they are generating danger for themselves and other workers, by unrealizing or underestimating risks.

This will affect the ongoing work-flow, other workers, lower performance and schedule delay. In addition to the non-accounted cost, which is direct costs (equipment damage, workers compensation, insurance, medical expenses, rehabilitation, etc.) and indirect costs (well-being, productivity and the morale of the workers etc.). This is a major setback in terms of the financial status and the growth of the project and the enterprise.

Although all workers receive training and orientation meetings, they are not receiving on-the-job, hard-knocks-type training that simulates the site conditions. Nowadays, students finish their education and travel abroad to work, and every construction site is unique with different activities, schedules, approaches etc. In that sense, the construction sites are full of international people speaking different languages and from different backgrounds, many training programs are being made and they are showing to be effective and elevating the safety statues, but they lack the flexibility and the ability to adapt to the current site environments, and to be malleable according to the students, workers needs and capabilities. Yet, these traditional methods will leave out people with disabilities or have limitations or special educational needs, as well as foreigners or immigrants.

HEIs educational programs especially civil engineers and occupational H&S (masters and Ph.D. programs), lack the IPD methodology, and even with the research being done everything is just theoretical far from practical. This is because of the detached link between the industry and the HEIs and VET schools. The educational programs need to be upgraded based on the needs of the industry, to give students more experience and preparation before going to professional life. The need to bridge the gap between the industrial sector and the educational sector is crucial for both entities.

2 Needs Analysis

Based on several systematic and literature reviews done by researchers, involvement in several international conferences, H&S meeting, having effective members inside H&S organizations, having several members involved in the construction sector, several aspects were becoming clear. First, the research on integrating technologies such as VR/AR, machine learning is considered relatively new, but not getting enough attention. After holding a meeting with safety professionals, contractors and consultants from several countries it seemed that enterprises were isolated from academia. Lacking the advancements of technologies and tools that might assist workers. Although some enterprises demonstrated some digital education and training techniques, these methods were not reaching their full potential, including a lot of limitations. These issues were an indication to start involving new technologies in the industry. After BIM/VR/AR showed a lot of potential in the research field and is a promising tool for education and training, CSETIR was created [1]. This project will offer innovative and different education and training techniques. VR/AR had been in the market for a while and a lot of research is being done involving them, it is time these tools are put into the test and especially in terms of H&S [2].

Taking "hands-on" experiences and the digital platforms like BIM and VR/AR simulations will be an innovative way of transmitting the diverse group roles of the construction site in a familiar language to the youths, supporting schools in their efforts to teach and attracting students to continue their education with a creative and interactive mindset [3].

CSETIR will be based on a network of innovative cooperation activities, through the creation of active links with institutions. As a complement to these initiatives, the digital tools look for a more practical approach of teaching H&S in various environments based on integrated design "Project Based Learning" as a knowledge acquisition tool. CSETIR aims to apply a methodology for collaborative and hands-on work, integrating a broad vision concerning a project where all disciplines establish a very close and interconnected communication - an Integrated Project. The tools to support enhanced communication are defined as well as the training sessions to convey the skills to work with them. Students (VET/HE) will experience a more practical and innovative learning approach in an environment, mimicking their actual future professional careers.

The transnational nature of the project will portrait the work reality of international teams, a practice that is becoming more common. Additionally, an Integrated and Innovative Project methodology allows the development of an autonomous learning attitude (learning by doing) and the exchange of knowledge between all participants. Additionally, the activities will enable the interaction between students from different countries and from complementary fields. Therefore, the project's activities must encompass different types of innovative experiences that will happen in the partner countries to fulfil this vision [4].

3 Methods and Results

The relation with the reality of the professional world and the active involvement in solving problems that affect local communities present aspects that require further engagement by HE courses and research. Given that, HEIs play a decisive role in training new professionals, efforts should also be formulated to raise the students' awareness about their future professional and human roles in building a society. Nevertheless, employability, attractiveness, and visibility of EU HEI and its curricula are becoming important subjects on the European agenda and its emphasis is moving from a national to an international perspective. Few types of research is being done in terms of H&S in construction, and how to prepare students to go into the working environment, emphasising the need for adopting proactive strategies and tools.

In this context, CSETIR's design was based on joint analysis and on partners' know-how and experience, to propose viable solutions. The specific aims for the projected are:

- Developing, implementing, validating and tuning of interactive VR/AR approaches to promote multidiscipline creativity, innovative thinking, and practical skills in the digital era.
- Ensuring education and research are mutually reinforcing, and strengthening the role of institutions in their local and regional environments:
- Explore synergies and stimulate greater dialogue between HE, enterprises and VET schools, in the scope of community and outreach activities;
- Supporting the civic and social responsibility of students and institutions
- involving people with special needs in terms of mental or physical limitation.

To elaborate on the previously mentioned aims and objectives CSETIR includes:

- Contribute indirectly by encourage (VET) school students and its staff to interact with HEIs.

- CSETIR intends to promote best practice exchanges, supporting the development of more varied teaching methods and personalized learning, in accordance with the 2012 "Bucharest Communication" (Ministerial Conference-EHEA) recommendation of promoting 'student-centred learning' characterised by innovative methods of teaching.
- CSETIR pedagogic development together with its activities is expected to mobilise institutions, teachers, and students. CSETIR interactive learning tools development and maintenance of an open, collaborative repository, including general construction information, tutorials and operational guides that support the performance of specific tasks.
- Contribute towards the development and application of rules of thumb and practical guides for Architects and Engineers.

By taking into consideration the listed aims CSETIR will be achieving and focusing on the collaboration and knowledge exchange between the HEI and enterprises the objectives of the Knowledge Alliances action will be met. In addition, the advancement and innovation in an HR/VET education, business and in the broader socio-economic environment, developing an entrepreneurial mindset and skills. Nevertheless, allowing the collaboration between HE and enterprises. CSETIR will be developed using a multidiscipline team having different educational backgrounds, involved to create an educational and training strategy which will boost the H&S in the construction industries. Involvement of company staff into teaching and research aiming at strengthening employability, creativity, and new professional paths. Furthermore, help in opening new learning and research fields. It will set-ups to trial and test innovative measures.

4 Discussion

The CSETIR project is following a collaborative and hands-on strategy to learning, integrating a broad vision concerning a project where all disciplines establish a very close and interconnected communication (an Integrated Project), where the exchange of co-creation of knowledge between HEIs and enterprises is a key factor. This methodology defines the responsibilities of the stakeholders during the project and within all its phases. Furthermore, the tools to support an enhanced communication are defined as well as the training sessions to convey the skills to work with them.

Additionally, an Integrated Project methodology allows the development of an autonomous learning attitude (learning by doing) and the exchange of knowledge between all participants. Providing students with multidisciplinary and collaborative activities including training session. Therefore, the project's activities will encompass different types of international experiences that will happen in the partner countries. The fulfilment of this vision requires the development of physical and software resources (innovative integrated VR/AR tools), online content and platforms (supporting the dissemination of knowledge and implementation of the results), and collaborative processes (to strengthen the transnational nature of the project) [5]. This intends to portrait the work reality of collaborative teams, a practice that is becoming common and useful. For the project, the development and communication are essential to achieve the project goals of raising civic and social awareness and contributing to innovation. students will also be experiencing a more practical learning approach in an environment like the one they may find in their future professional careers [6].

The tasks were developed according to the expertise of each partners. Besides Project Management, and Quality assurance tasks, the project activities were divided into 4 main groups:

1. Preparation
   (a) Identification of the state of art in the field strategies, solution, trainings, studies, technologies etc.
   (b) Selection of an online platform for interaction with users and content developers.

This WP is crucial in setting the grounds for the Development and Implementation WP.

2. Development and Implementation
   (a) Physical content: the interactive VR/AR tools.
   (b) Learning content: Development of interactive movies, VR/AR models and simulations, written materials/manuals, and other forms of pedagogical publications.

Both "Physical" and "Learning" content must be adequate for different kinds of interaction. These different types of contents are project outcomes, as described in the appropriate section of the proposal.

3. Validation and Tuning
   (a) Development of activities in laboratories, construction sites, workshops; and other facilities, including local and international events to implement validate and tune the solutions.
   (b) Testing of the learning tools amongst other HEIs so they can be improved, gauged and validated for Engineering Education and Training.

4. Exploitation and Dissemination events
   (a) Considering user participation and location, activities can be divided in three main groups: Lab centred events, site centred activities, Online activities.
   (b) Content developed in this project will be designed to allow use in different environments, when possible. For each type of activities, videos and manuals will be developed and made available online. That allows these activities to be adapted or simply replicated elsewhere. This section is where the data is interpreted. The author should include explanation of how the

results are similar/differ from those which were hypothesized, or are similar/differ to those related with experiments performed by other researchers. Relating the results with theoretical context is recommended.

5 Final Comments

Having the project on an international level it is important for these types of multidisciplinary projects for several aspects. On the industrial level, enterprises and local governments have their own H&S regulations and guidelines, different construction and natural environment, culture and educational backgrounds of the working groups, types of projects, costs and legislations etc. International HEIs and enterprises will be able to implement interactive strategies regardless of regional policies and guidelines.

On an educational level, the transnational nature of the project will portrait the work reality of international teams, a practice that is becoming more common. Additionally, an Integrated Project methodology allows the development of an autonomous learning attitude (learning by doing) and the exchange of knowledge between all participants. Providing HE students with multidisciplinary and collaborative activities including advanced tools. Extended collaborations and communications are essential for this project to achieve the project goals of raising civic and social awareness and contributing to innovation. Enabling students to work safely while knowing the international H&S standards and regulations, since nowadays student's mobility and traveling to work abroad for different reasons is common. So raising the student's awareness in an international point of view will prepare them to face and work in any construction site, under any circumstance. Additionally, the activities will enable the interaction between students from different countries and from complementary fields (architecture, engineering, computer sciences etc.). Therefore, the project's activities must encompass different types of international experiences that will happen in the partner countries to fulfill this vision.

As for having European cooperation not only will it strengthen the collaboration and cooperation between students and workers, it will be helpful to raise more awareness, and reach a wider audience. The added value of these learning/teaching/training activities will be the possibility of different students in different countries with different cultures and learning methodologies to be in touch with each other and to experience a transnational "Project Based Learning" activity.

Different configurations for learning materials and approaches will be tested, leading to a virtual information repository that can be accessed by any student regardless of his/her location, allowing results to be compared, different scenarios to be tested and even different local prototypes to be visited and understood, underlining the requirement to adapt engineering solutions to local needs. If this type of project is done as a national, regional or local level it would not have the same strength and effectiveness as it being international. Students and workers would have a narrow vision of risks and access to limited solutions. It is expected that this project will provide efficient and effective tools to be used by the different stakeholders to reduce accidents in construction sites and to progress towards a Zero Vision transformed in reality.

References

1. Antwi-Afari, M.F., Li, H., Pärn, E.A., Edwards, D.J.: Critical success factors for implementing building information modelling (BIM): a longitudinal review. Autom. Constr. **91**, 100–110 (2018)
2. Bae, H., Golparvar-Fard, M., White, J.: High-precision vision-based mobile augmented reality system for context-aware architectural, engineering, construction and facility management (AEC/FM) applications. Vis. Eng. **1**, 3 (2013). https://doi.org/10.1186/2213-7459-1-3
3. Sidani, A., Dinis, F., Sanhudo, L., Duarte, J., Calvetti, D., Poças Martins, J., Soeiro, A.: Impact of BIM-based augmented reality interfaces on construction projects: protocol for a systematic review. Int. J. Occup. Environ. Saf. **3**, 38–45 (2019). https://doi.org/10.24840/2184-0954_003.002_0006
4. Park, C.-S., Kim, H.-J.: A framework for construction safety management and visualization system. Autom. Constr. **33**, 95–103 (2013). https://doi.org/10.1016/J.AUTCON.2012.09.012
5. Gheisari, M., Foroughi Sabzevar, M., Chen, P., Irizzary, J.: Integrating BIM and panorama to create a semi-augmented-reality experience of a construction site. Int. J. Constr. Educ. Res. **12**, 303–316 (2016). https://doi.org/10.1080/15578771.2016.1240117
6. Zaher, M., Greenwood, D., Marzouk, M.: Mobile augmented reality applications for construction projects. Constr. Innov. **18**, 152–166 (2018)

Communication of Environmental Risks to Potentially Exposed Workers: An Experience in the Oil Industry, Bahia, Brazil

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Abstract Conflicts between workers and health experts and their multiple rationalities must always be considered in the risk communication process. Disagreements are frequent in understanding occupational exposure to environmental agents among stakeholders. The present study aimed to describe the evolution of differences between experts and oil industry workers in Bahia, Brazil. The Tool of Instructions to the Double was applied and the results followed over three annual assessment cycles (2017–2019). In the observed period, a reduction in the share of disagreements between workers and experts was identified: 25.2% (n = 183) to 3.1% (n = 22), representing a percent variation of 98.9% relating the understanding of occupational noise exposure based on normative classification. The relations of conflict between workers and experts and the multiple social and cultural dimensions must always be considered as an important challenge in workers' health. Thus, the use of models encouraging dialogue and value knowledge from the experience of workers seem to be more appropriate in conflicting contexts, enhancing risk control, protection and health promotion.

Keywords Occupational health · Environmental risks · Occupational hygiene

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1 Introduction

Risk communication is an area of intervention in the field of public health and the environment, through the use of multiple methodologies, with the objective of mitigating risks, answering doubts of groups involved and resolving communication barriers, aiming at its greater effectiveness [1]. Such communication, seen as a technology for risk control and health and safety promotion, aims to understand the sociocultural context of the worker, in order to add information to their knowledge and experience, and should be done in a clear and understandable way [2]. This communication may imply a formal or informal estimate if an event poses a high or low threat to personal worker safety and, based on that perceived threat, indicate how to respond [3]. Findings from empiricist research in the context of liberal democracies, among other aspects, consider that people's risk and values are different, probabilities can be difficult to interpret, and risk debates are conditioned by their social/political text [4]. Thus, this practice is more likely to succeed when the audience, rather than manipulated, is empowered [5]. In dealing with risk communication, it is often perceived that while scientists determine risks, potentially exposed populations perceive it. According to Beck [6], there are multiple rationalities around risk, sometimes generating conflicts, particularly in the relationship between scientists/experts and lay people, and a distancing of views on the subject, constituting a point of divergence in a supposed dialogue between the interested parties. Monetization of risks, i.e., when risk reduction in the workplace is not possible and the employer compensates the worker with additional consideration compensation due to work in more severe typified circumstances [7], can also be a situation that generates disagreements in risk classification between lay people and experts.

According to Sato [8], the clarification of a proposal for risk communication in the workplace from the knowledge of workers is not a new practice, having the Italian Labour Movement (ILM) [9] inspired in Brazil, the obligation to prepare the Environmental Risk Map by the Internal Accident Prevention Commissions (CIPA) [10] Thus, the mapping of risks in the workplace, or simply risk mapping is recognized as the first configured contribution of ILM. Although this model has as its premises the formation of homogeneous groups, workers' experience or subjectivity, consensual validation and non-delegation, thus enabling the participation of workers, it has been questioning how referrals and discussions take place between employees and employers, on the findings of the risk map limited to the floor plan design to be displayed somewhere in the company [11]. Other more technically strengthened methods adapted from Occupational Health and Safety Assessment Standard (OHSAS) OHSAS 18001:2007 [12] and known in Brazil as Preliminary Risk Analysis for Occupational Hygiene (APR-HO) have been used. APR-HO is a formative document that aims to characterize and recognize the exposure to occupational hazards of workers in a company, through field research and information collected after observing the activities performed in the occupational environment. As it can be verified from observation and interview, it does not the highlight workers' perceptions about potential risks to which workers may be exposed, and further validation by the group of workers belonging to the homogeneous exposure group is consequently recommended.

This study aims to describe the evolution of divergences about environmental risks between workers and experts in an oil company in Bahia, Brazil, based on risk communication premises, considering the elaboration of APR-HO as a complex integrator of experiences.

2 Materials and Methods

This is a descriptive study, developed over 3 cycles of annual periodic occupational assessments, from January 2017 to September 2019, where 2116 workers in various positions of an oil industry in Bahia, Brazil were individually evaluated. The evaluation was performed by occupational hygiene experts and, at the same time, the worker was assisted by a working physician, dealing with exposure to risks in an interdisciplinary manner, considering the environment and the individual, respecting the specific aspects of each subject involved (interdisciplinary). The professionals had on average ten years of experience in the area. The occupational evaluation range 15–40 min.

The evaluations followed the following procedures: (i) presentation of APR-HO, produced in advance in the field through direct observation of the workers' activities, (ii) discussion and validation of APR-HO, (iii) guidance on the use of equipment personal protective equipment (PPE), respiratory protection equipment (RPE) and chemical handling, (vi) performing mask screening test, (for workers eligible for the respiratory protection program), (v) delivery of PPE and (vi) updating records in computerized systems. By internal procedure, an APR-HO is considered valid when the simple majority of the population that makes up the homogeneous group (50% + 1), is in accordance with the description of environmental risks and exposure times for each of the agents.

Workers who expressed disagreement with the risk description were selected and visited at their workplace by a field team. In this practice, and individually, the workers were submitted to the Tool of Instructions to the Double [9, 13], a methodological approach based on the assumption that the worker has a degree of knowledge (experience) that the expert (in their field as workers) does not have. As Clot explains [14], this methodology implies group work in the course of which a volunteer subject receives the following task: "Suppose I am your look-alike and that tomorrow I must replace you in your job. What instructions should you give me so that no one notices the replacement?" With this, the worker is invited to think about what is performed automatically and usual, which seems simple, but which, when detailed, allows to glimpse how much of unprecedent, creative and specific there is in every work activity. During this period, the percentages of "disagreements" with the risk mapping performed by occupational hygiene experts in the field were followed up.

The study was approved by the Research Ethics Committee of the Bahiana School of Medicine and Public Health and CAAE no. 84318218.2.0000.5544. Before participating in the study, all subjects gave their informed consent for inclusion.

3 Results e Discussion

From January 2017 to September 2019, the percentages of workers who disagreed with the experts regarding the exposure to environmental risks described in the APR-HO showed significant variation, maintaining a downward trend, as shown in Table 1.

A reduction in the number of workers in disagreement during the period from 2017 to 2019 was observed from 25.2 to 3.1% (from 183 to 22 workers). In this period, a smaller movement of workers in this unit (inputs and outputs) can also be observed, suggesting that the same population was subjected to the methodology for consecutive years, consolidating the knowledge about risks in the workplace and, at the same time, their experience contributing to improve field expert assessment methods. In general terms, the disagreements were based on the understanding on the part of the worker that the mere existence of noise in the working areas was enough to cause some injury. Therefore, the layperson did not consider for this judgment the limits imposed by the health and safety rules in force.

Table 2 presents the categorization of workers' disagreement regarding exposure to environmental risks.

The analysis of Table 2 shows a significant reduction in all categories of disagreement, with the most significant variation being between 2017 and 2019 (−20 to 100%). In none of the categories is identified an aggravation, except for the "All previous options" category, which presents a considerable aggravation between 2018 and 2019 (300%). However, with the best results (2017–2019), the categories of disagreement between workers and specialists, namely "Other" (−100%), "Risk category" (−94.1%) and "Described activities" (−93.0%), are highlighted. Overall, total disagreements had an effective reduction of 98.9%

The categorization of disagreements enabled an approach directed to the specific needs of each worker, resulting in a significant improvement of workers' understanding of risk exposure. Considering a better workers acceptance in understanding the risk to which they are potentially exposed, it is necessary to understand

Table 1 Disagreement between workers and experts regarding exposure to environmental risks

Year	2017		2018		2019	
	n	(%)	*n*	(%)	*n*	(%)
Disagreement	183	25.2	36	4.9	22	3.1
Total	726	100	737	100	716	100

Table 2 Categorization of workers' disagreements regarding exposure to environmental risks (2017–2019)

Disagreement Categories	2017 n (%)	% Δ (2017–2018)	2018 n (%)	% Δ (2018–2019)	2019 n (%)	% Δ (2017–2019)
Identified risk agents	35 (19.1)	**−62.9**	13 (36.1)	**−23.1**	10 (45.5)	**−71.4**
Described activities	43 (23.5)	**−90.7**	4 (11.1)	**−25.0**	3 (13.6)	**−93.0**
Frequency/duration of risk exposure	36 (19.7)	**−86.1**	5 (13.9)	**−20.0**	4 (18.2)	**−88.9**
Risk category	17 (9.3)	**−23.5**	13 (36.1)	**−92.3**	1 (4.5)	**−94.1**
All previous options	5 (2.7)	**−80.0**	1 (2.8)	300.0	4 (18.2)	**−20.0**
Other	47 (25.7)	**−100.0**	0 (0.0)	0.0	0 (0.0)	**−100.0**
Total disagreements	183 (100)	**−80.3**	36 (100)	**−38.9**	22 (100)	**−98.9**

Notes to the table: disagreements reduction in bold

that the work activity is not an object given to a researcher who would collect it, but an object to be built and rebuilt, in partnership with the protagonists of the work under review. This is because the activity is not limited to what can be directly observed, recorded and quantified, and confrontation and verbalization of the operator is essential [15].

In this sense, theoretical contributions provided by ergonomics are appropriated, as a discipline that also explores the environment and its interaction with operators. The method developed by Oddone et al. [16] was also able to unravel the lines between work, based on four assumptions, in the form of concepts: the homogeneous group, the experience, or subjectivity, of the worker, the consensus validation and non-delegation. It is necessary to understand that all living beings have normative capacity and that the curiosity and the search to learn from others is a driving force [17]. Considering a better acceptance in understanding the risk to which they are potentially exposed, it is understood that the work can be built and rebuilt, in partnership with workers and specialists. This is because the activity is not limited to what can be directly observed, recorded and quantified, being essential to confront and verbalize the worker [18].

4 Conclusions

It should be noted here that risk communication prescribing risk prevention and protection norms and conducts must be aware of the fact that these may be unreliable and acceptable to the population. Thus, conflicting relations between workers and experts and the multiple social and cultural dimensions must always be considered as an important challenge. Thus, the use of Technique of Instructions to the Double encouraging dialogue and value knowledge from the workers' experience seem to be more appropriate in conflicting contexts. In order to minimize conflicts, enhancing risk control, protection and health promotion using communication strategies, it is necessary to analyse the sociocultural mediations involved.

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References

1. European Agency for Safety and Health: Risk Perception and Risk Communication with Regard to Nanomaterials in the Workplace, Luxembourg (2012)
2. Santos, M.: Communication on health and safety risk control in contemporary society: an interdisciplinary approach. Ciência & Saúde Coletiva saúde coletiva **12**(5), 1375–1378 (2007)
3. Haas, E.J., Yorio, P.L.: Using sensemaking theory to improve risk management and risk communication: what can WeLearn? In: Selected Issues in Global Health Communications, pp. 11–26 (2018)
4. Castiel, L.D., Vasconcelos-Silba, P.R., Moraes, D.R.: Micromortevida Severina? A comunicação preemptiva dos riscos. Cad. Saúde Pública **33**(8), 1–14 (2017)
5. Rowan, F.: The high stakes of risk communication. Prev. Med. (Baltim) **25**(1), 26–29 (1996)
6. Beck, U.: Risk Society. Towards a New Modernity (Internet), London (1986)
7. Delgado, M.G.: Curso de direito do trabalho [Work Law Course], 17th edn, p. 50. Editora LTDA, São Paulo (2017)
8. Sato, L.: The common-sense knowledge and its implication for the occupational health surveillance. Cad Saude Publica **12**(4), 489–495 (1996)
9. Vogel, L.: La actualidad del modelo obrero italiano para la lucha a favor de la salud en el trabajo (The current Italian worker model for the fight for health at work). Laboreal **12**(2), 10–17 (2016)
10. Brazilian National Standards Organization. NR5—Internal Commission on Accident Prevention (CIPA) (2011)
11. Mattos, U.A., Freitas, N.B.: Brazilian risk map: limited applicability of a worker model. Cad Saude Publica **10**(2), 251–258 (1994)
12. British Standards Institute: BS OHSAS 18001:2007: Occupational Health and Safety Management Systems—Requirements. BSI Global, London (2007)
13. Oddone, I.: Reflexiones sobre el modelo obrero italiano: entrevista por Estela Ospina S [Reflections on the Italian worker model: interview by Estela Ospina S]. Rev. Sind. Salud Trab. y Medio Ambient. **5**(2), 4–8 (2007)
14. Clot, Y.: A função psicológica do trabalho (The psychological function of the work), p. 222. Vozes, Petrópolis (2006)
15. Filho, J.M.J.: Engajamento no trabalho, impedimentos organizacionais e adoecer: a contribuição da Ergonomia da Atividade no setor público brasileiro (Engagement at work, organizational impediments and illness: the contribution of activity ergonomics in the Brazilian public sector). Rev. Bras. Saúde Ocup. **7657**(131), 98–108 (2015)
16. Oddone, I.: Ambiente de trabalho: a luta dos trabalhadores pela saúde (Work Environment: Workers' Struggle for Health). Hucitec, Sao Paulo (1986)
17. Schwartz, Y.: A comunidade científica ampliada e o regime de produção de saberes (The enlarged scientific community and the system of knowledge production). Trab. Educ. **7**, 38–46 (2000)
18. Teiger, C.: O trabalho, esse obscuro objeto da Ergonomia (The work, this obscure object of ergonomics). In: Castillo, J.J., Villena, J. (eds.) Ergonomia: conceitos e métodos, pp. 47–60. Dinalivros, Lisboa (2005)

Worker Location-Based Safety Performance Indicator

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Abstract The Civil Construction Industry is considered dangerous due to its dynamic nature. Occupational safety and health management systems establish, implement and maintain processes for monitoring, measuring, analyzing and evaluating safety performance. Most of the current proactive monitoring practices rely on manual efforts that, not only require a lot of work, but are also prone to errors. The main objective of this research is to propose a Worker Location-Based Safety Performance Indicator (PI), based in a technology for collecting data in a real-time procedure via sensors. The developed PI has potential to assist in measuring one key issue in construction site safety, i.e. determining the number of proximity events to hazardous areas. Using the proposed key PI as a leading safety indicator, safety performance of each worker can be taken into evaluation. It is feasible for a construction site safety manager to identify frequently occurring proximity hazards before incidents happen. The importance of this study is linked to the possibility of providing, using the proposed key PI, safety level scores that may improve safety in construction sites.

Keywords Key performance indicator · Leading indicator · Safety · Civil construction industry

1 Introduction

The Civil Construction Industry (CCI) is considered one of the most dangerous industries due to its dynamic nature, which leads to high rates of work accidents. For occupational safety and health management, construction companies must establish, implement and maintain processes for monitoring, measuring, analyzing

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and evaluating safety performance. Based on the information on how a system is working, it is possible to act on it to improve the situation if needed. Key Performance Indicators (PIs) enable the assessment task to measure how good the system is, allowing benchmarking different systems and prioritizing the actions, and they might even show a reason for the inappropriate operation and give indications of what should be done [1].

A PI can be classified according to its focus of measurement. If the focus is on past results it is considered a lagging indicator. If the focus is on events that have the potential to influence results it can be considered a leading indicator. Thus, lagging PIs provide information of past events and support reactive actions to improve results, while leading PIs provide information of events that support proactive actions to improve results [2].

Current proactive monitoring practices depend on manual efforts which are laborious and prone to errors, so construction companies have been looking for new technologies to aid in safety management. An example of a solution and object of study of this work is Smartsafety, a technological platform with pro-active real-time safety technology, by which it is possible to warn and alert personnel immediately. The goal of this paper is to design a PI as a post processing effort to convert the data into information in order to add value to SmartSafety technology supporting decision making.

The importance of this study for industry is related to the possibility of providing, using the proposed indicator, safety level scores for construction sites that may result in improvements in the workers' health and safety.

This paper is structured as follows: second section introduces theoretical background related to safety indicators, the technology used in the platform, the platform itself and some technical issues related to the PI. The third section presents the method used to create this PI, and in the fourth, its attributes. The last two sections present discussion of the developed performance indicator and overall conclusions.

2 Theoretical Background

2.1 Safety Performance Indicators

A safety PI is a way of measuring changes in the level of safety over time as a result of the actions taken. The main objectives of safety PIs are: (1) to monitor the level of safety in a system; (2) decide, where and how to act; and (3) motivate those who can take the necessary steps to do so.

Safety PI such as accidents, its frequency, severity and days of absence are traditionally used by organizations to comply with legislation. Such PI are relatively easy to collect, understand or benchmarking; and are useful in identifying trends over time [3]. However, these PI have been criticized for several reasons. They can be classified as lagging indicators that support reactive actions when the safety levels deteriorate. Regarding the CCI, registrable injuries are generally not valid nor stable when measured in a single construction project due to the fact that, even in very large construction projects, the frequency of accidents and injuries is insufficient to calculate a significant rate, and the absence of accidents in one place does not necessarily mean that it is safer than another in which an accident occurred in the same period [4].

In this way, the use of accident numbers as the only safety indicator for construction sites is, in most cases, inappropriate, also they measure the absence of safety [5], therefore cannot be considered as a direct measure of the level of safety in a work system. Thus, even if a construction site does not present accidents, there is no guarantee that safety risks are being controlled and that accidents will not occur in the future [6]. It can also be concluded that number of accidents is a lagging indicator, as the accident is a consequence of hazard situations. Thus, the development of safety performance indicators should adopt leading indicators related with preventive safety measures.

For these reasons, new methods are being proposed, based on measures considered proactive, that represent how well the company is in terms of activities that prevent accidents and promote quality of life in the workplace, reflecting a more effective level of safety. For example, research on proactive safety indicators has studied the relationship between the quality of the work environment and occupational safety to calculate a safety index. Finally, the same study found a correlation between a higher safety index and a lower accident rate [7]. Another example found in the literature is a project that resulted in the safety monitoring method known as TR (Finnish word acronym meaning "civil construction"). It is a method of observation to determine the percentage of correct items in terms of work habits, scaffolding and ladders, machinery and equipment, lighting and electricity, fall protection and organization. From the feedback on the weekly audit system based on TR observation method, the participation of workers and performance management principles, the safety level of a construction site that served as a pilot study increased, suggesting that proactive PIs are more trustable to implement on a company [6].

Most of these proactive monitoring practices rely on manual efforts that, not only require a lot of work, but are also prone to errors. To overcome it, data collection technologies have been developed.

2.2 Technology for Data Collection

The CCI presents a dynamic work environment, the evolution and constant changes in workflows and people make it difficult to control safety by conventional methods. Safety performance is generally observed, evaluated, and measured manually, so there is not a frequent collection and share of information [8]. These limitations of current practices can become a bottleneck for rapid and accurate decision making at construction sites [9]. The use of technologies becomes an important ally to promote security since it allows the continuous collection and analysis of data, as pointed out by several studies [8–11]. The automated monitoring is an innovative approach that promises to address these problems [11]. Among the benefits generated using this type of technology in the CCI, it is possible to highlight the visual management. Availability of information generated in real time, automatically, continuously and easy to interpret is a good support for decision making [6, 8, 9].

Safety monitoring at construction sites is one of the areas of application that has benefited the most from real-time tracking and visualization [9]. For example [9] and [10], have developed systems for transmitting safety-related information from various construction projects to a centralized database where real-time safety indicators are generated. Both were tested in pilot studies with positive safety results. Another technology that can also be converted to real-time indicators is related to the tracking and location of workers, which can be automatically compared to previously identified areas of risk or to the location of moving objects. In [8] it is presented a system that detects static and dynamic risk areas in a construction site from sensors that automatically collect spacetime conflicts between workers and identified risks. Using a similar technology, the research [12] analyzed the behavior of the workers in these conflicts, and with safety training and feedback of the data collected, it was observed an increase of awareness and consequent decrease of unsafe behaviors.

Information regarding workers behavior in relation to hazardous areas usually involves location and movement of workers which can be analyzed to assist safety improvement in construction sites [13]. Concerning safety in construction, workers engage in unsafe behavior by a lack of safety awareness, a macho culture, work pressure, coworkers' attitudes and other organizational, economic and psychological factors [14]. It is hard to predict how and when such things may impact in the workplace. Looking more specifically at some of the underlying organizational factors linked with the construction site environment, it is apparent that the following are common and yet hard to control in terms of impact on safety behavior [15]: (i) the differing nature of each project and the subsequent need for customized safety training and induction; (ii) The transient and sub-contract nature of the workforce on projects; (iii) the variable worker population over the life of the project—the people on site change regularly; (iv) the way the work environment and the object under production are the same thing, therefore the physical work environment changes daily—as does the safety environment—until the product is finally reached.

These issues are not easily controlled by pre-construction planning alone but must instead be managed as dynamic variables during construction. Existing efforts have tended to focus on enhancing safety management procedures, protective measures, signage, and providing safety training [15].

One of the potential benefits of the real-time tracking and alerting technology is that it can provide individually based feedback that has the potential to be quickly and simply understood by a wide variety of users—thus dealing with quite a few of the bullet point items mentioned above. What this article proposes, however, is a PI regarding safety level scores obtained through a technologic platform. It may improve safety in construction sites by a post processing effort to convert the data gathered by this real-time tracking technology into information.

3 Method

The SmartSafety technology platform developed by the company was studied in relation to its functionalities [16]. This step was fundamental to understand the database that the platform produces, and which PI can be constructed from such data. For this, a document analysis was made of the materials available for consultation: the platform user manual and project work plan. The literature was revised to gather information on the methodologies that have been commonly used to monitor the safety performance of the CCI and the functionalities of the Management System were considered to guarantee the adjustment of the methodology to the reality of the platform.

In order to design the PI, the following attributes were defined: title, purpose, relates to, target, formula, frequency, who measures, source of data, who acts on the data, what do they do, notes and comments [17].

4 Design of Worker Location-Based Safety Indicator

4.1 Context, Platform for Data Collection and Control

The key PI proposed in this paper is applicable on any construction site that uses a platform called SmartSafety. By using this technology, it is possible collecting data in a real-time base, and further post-processing and analyze it in order to create some decision-making procedures to improve this specific PI. Hence, the Worker Location-based Safety indicator is proposed to enable monitoring behaviors of workers based on their location, not to measure their performance, but to improve their safety conditions. The SmartSafety platform can provide to the managers information about the location of the workforce, an interactive view of ongoing risk activities and the proximity of workers to high risk areas, a versatile way for workers to receive alerts, allowing the reinforcement of safe behaviors at the construction site.

Dangerous zones can be identified and tracked by detection technology, so it is possible to manage the risks associated by assigning permission to workers to have access to such areas according to their assigned permission [16]. A "cone" can be placed on the hazardous areas in the construction site, such as work areas with hazard of falling from height (Fig. 1a). Although the construction schedule is dynamic, hazardous areas as the one exemplified in Fig. 1a have temporary locations.

(a) Cone with visual alert. (b) Beacon on the helmet.

Fig. 1 Smartsafety technologies

A wearable and interactive technology solution was adopted for the workforce, incorporated into the safety helmet. In each helmet there is a beacon (Fig. 1b) that transmits the identification of the worker who is in the area of risk. If the worker is not allowed to access such area, the cone generates a beep and light signal (Fig. 1a), alerting the worker about the prohibition.

Once the detected distances between workers and the surrounding controlled areas are less than a permitted safety value, the warning signals are triggered and sent to the real time locating mechanism, which retransmits the signal to activate the warning devices, then the manager receives real time notifications as an alert, identifying the worker(s) in unsafe locations. Workers who choose to ignore warning signals and head toward hazardous areas are regarded as exhibiting unsafe behaviors while those who take actions such as turning around or leaving the area to avoid possible dangers are regarded as exhibiting safe behaviors.

4.2 *Formula and Target*

Based on smart safety functionalities regarding hazardous area monitoring, it is suggested that the records of each location-based behavior be converted into percentage indexes, according to formula of Eq. 1 [13].

$$SI(\%) = N_{SB}/(N_{SB} + N_{UB}) * 100\% \quad (1)$$

where, N_{SB} is the number of observed instances of safe behavior, N_{UB} is the number of observed instances of unsafe behavior, and $N_{SB} + N_{UB}$ is the sum of all instances of the previously specified safety-related behavior. Workers who choose to ignore warning signs and access danger zones exhibit unsafe behavior, while those who avoid potential hazards are viewed as exhibiting safe behaviors. As the number of unsafe behaviors increases, action is needed to control the occurrence of accidents. Therefore, this indicator can also be called the proactive index or leading PI.

A similar PI was used in a pilot study at a construction site in Hong Kong in which an experiment was conducted with 198 workers. During this period, training was conducted for workers and subsequently the safe behavior index was increased from 60% at the beginning of the experiment to 90% after nine weeks [18]. The application of this similar real-time alerting technology used for daily construction operations has suggested the effectiveness of the proposed approach for improving the safety in construction sites. It is expected to see a significant increase in the safety of construction sites, since it helps workers to recognize areas of risk, increases communication and transparency in the process and enhances employee autonomy and engagement. The target for this PI is to achieve 100%.

4.3 Attributes of the Performance Measure

Based on the above, Table 1 summarizes the attributes of the key PI proposed in this paper. As the system works based on real-time measurement system, streams of data will be created over continuous time. The data analysis mainly depends on the goals. Since the historic of workers safe and unsafe behaviors are recorded over

Table 1 Attributes of the performance measure

Title	Worker location-based safety indicator
Purpose	Enable to monitor the safe behavior of workers based on their location
Relates to	Continuous monitoring and improvement
Target	100%
Formula	Equation 1
Frequency	Real time
Who measures	Software—Smartsafety
Source of data	Location-based sensors
Who acts on the data	Safety staff (safety supervisors and project managers)
What do they do	Safety supervisors and project managers can: (1) encourage and reward workers who behaved safely; (2) interview workers who did not behave safely and discuss their behaviors; (3) provide retraining to workers who did not demonstrate the necessary safety skills and safety awareness; (4) Set up a continuous improvement group to identify reasons for poor safety performance and to make recommendations as to how safety behavior can be improved; (5) Publish all safety performance data as a means of demonstrating commitment to empowerment
Notes and comments	Location-based safety indicator scores can be generated according to a variety of parameters: (1) individual; (2) by category; (3) by project team-level; (4) daily or weekly; (5) scores for different subcontractors

time, managers have access to analyze and evaluate data in different time intervals i.e. hourly, daily or monthly. In order to calculate Eq. 1, it is required to define update time for this formula to be able to reset the calculation, what generally dependent on managers decision; changing this update time, in general, has no influence on the formula.

The PI may not give the expected result until the technology do not reach the stage of “human factor” testing, meaning testing how well the technology interfaces with and influences human safety behavior on site. According to the culture of each company, it might be easier or more difficult to adapt to some rules on how to interact and react to technology. If people feel that they are being controlled with a punishing purpose, its most likely that they will not cooperate with the safety system. Also, on construction projects, hazard identification is often far from ideal, so it is essential to review and update potentially dangerous zones.

5 Conclusion

This research developed a safety worker location indicator based on a platform named SmartSafety, which provides real-time pro-active warning and alert technology. This is done by defining hazardous areas in the construction site and then implementing real-time location-based technology, to monitor and quantitatively visualize the safety level based on workers location and subsequently producing timely reports for both workers and construction stakeholders.

The developed approach has potential to assist in measuring construction site safety, determining the number of proximity events to hazardous areas. Using Worker Location-Based Safety Indicator as a leading safety indicator, safety performance of each worker can be taken into evaluation. Once such ratings are available, it is feasible for a construction site safety manager to identify frequently occurring proximity hazards before incidents happen. Actions that prevent incidents can be taken ahead of time. This system has an effortless data collection mechanism which gives the stakeholders situational awareness and helps decision-makers to find better solution for improving safety level. The use of this system may reduce construction costs related with injuries, fatalities and insurance costs. As a result, this system is capable of measuring safety and improve safety management efficacy.

For future work, it is proposed to consider the severity level of each dangerous zone by applying different weights to refine equation and the worker location-based indicator data can be analyzed to understand workers behaviors.

References

1. Dománski, P.D.: Control performance assessment: theoretical analyses and industrial practice **245**, 119–124 (2020)
2. Hale, A.: Why safety performance indicators? Saf. Sci. **47**, 479–480 (2009)
3. Lingard, H., Hallowell, M., Salas, R., Pirzadeh, P.: Leading or lagging? Temporal analysis of safety indicators on a large infrastructure construction project. Saf. Sci. **91**, 206–220 (2017)
4. Elster, J.: Reply to comments. Theory Soc. **12**(1), 111–120 (1983)
5. Arezes, P.M., Miguel, S.: The role of safety culture in safety performance measurement. Meas. Bus. Excel. **7**(4), 20–28 (2003)
6. Laitinen, H., Ruohomäki, I.: The effects of feedback and goal setting on safety performance at two construction sites. Saf. Sci. **24**(1), 61–73 (1996)
7. Mattila, M., Rantanen, E., Hyttinen, M.: The quality of work environment, supervision and safety in building construction. Saf. Sci. **17**(4), 257–268 (1994)
8. Teizer, J., Cheng, T.: Proximity hazard indicator for workers-on-foot near miss interactions with construction equipment and geo-referenced hazard areas. Autom. Constr. **60**, 58–73 (2015)
9. Cheng, T., Teizer, J.: Real-time resource location data collection and visualization technology for construction safety and activity monitoring applications. Autom. Constr. **34**, 3–15 (2013)
10. Aguilar, G.E., Hewage, K.N.: IT based system for construction safety management and monitoring: C-RTICS2. Autom. Constr. **35**, 217–228 (2013)
11. Awolusi, I.G., Marks, E.D.: Safety activity analysis framework to evaluate safety performance in construction. J. Constr. Eng. Manag. **143**(3), 05016022 (2016)
12. Li, H., Lu, M., Hsu, S.C., Gray, M., Huang, T.: Proactive behavior-based safety management for construction safety improvement. Saf. Sci. **75**, 107–117 (2015)
13. Guo, H., Yu, Y., Skitmore, M.: Visualization technology-based construction safety management: a review. Autom. Constr. **73**, 135–144 (2017)
14. Forsythe, P.: Proactive construction safety systems and the human factor. Proc. Inst. Civ. Eng.-Manag. Procure. Law **167**(5), 242–252 (2014)
15. Choudhry, R.M., Fang, D.: Why operatives engage in unsafe work behavior: investigating factors on construction sites. Safety Sci. (2008)
16. Reis, A.M.: Proposta de framework para medição e monitoramento proativo de segurança em canteiros de obra. Master Dissertation, Universidade Federal de Santa Catarina (2018)
17. Neely, A., Richards, H., Mills, J., Platts, K., Bourne, M.: Designing performance measures: a structured approach. Int. J. Oper. Prod. Manag. **17**(11), 1131–1152 (1997)
18. Chen, D., Tian, H.: Behavior based safety for accidents prevention and positive study in China construction project. Procedia Eng. **43**, 528–534 (2012)

Safety of Containment of Facades in Urban Rehabilitation Works

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Abstract This research purpose concerns a major challenge facing civil construction today: to promote, safely, the rehabilitation of historic centers. This problem occurs due to several factors, either due to the difficulty of removing debris from a work in historic centers, or because one does not know what the balance of some constructive elements is. Also often in buildings of historical areas is mandatory to maintain the facades. Therefore, this procedure must be carried out very carefully, in order to avoid instability in the structure, which can lead to serious or fatal accidents, since these are high-risk tasks and preventive measures must be effective. A very effective alternative is the use of wooden beams to act as shoring of facades, exerting an opposition to the operant compressive forces.

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1 Introduction

1.1 Population Flow

Nowadays, around the big cities there is typically a housing complex where many people live, usually called dormitories. There was a movement of people from urban centers to the periphery [1]. It is therefore necessary, for the municipalities, to make a good management of the urban infrastructures and of the peripheries of the cities. It is essential to find out where there will be concentration of people and manage the issue of location and conditions of real estate, overcrowding, traffic and mobility of residents. It is the responsibility of the urban infrastructure planning of the municipalities and the outskirts of the populous cities to carry out previous studies in the region to organize and limit the supply of real estate in order to avoid that the region bear more people than it usually does [1].

In addition, an alternative that has proven to be effective enough to support the large population in urban areas is the rehabilitation of historical centers, enabling dwellings, previously uninhabitable (especially for safety reasons), to house people with the purpose of restoring the constructive systems and promoting good housing.

Rehabilitation, according to Rocha and Calejo [2], should be considered as an evaluation opportunity where the need is considered to perform a series of operations to make a building operational again according to current standards. It is, therefore, an act that encompasses all actions designed to ensure knowledge of the characteristics of the building and the study of the operational and constructive anomalies that affect it, including all decisions resulting from the objectives behind the act of rehabilitation. The rehabilitation of historic areas is of the utmost importance, either by giving a new life to a vacant building, or by reusing a space that was unused or uninhabited, or according to Rocha et al. [3], for the use of all resources available on a need to build more efficient and sustainable buildings, much to the scarcity of some of the resources, in an understanding of how the project author has today to design, build and maintain the work of architecture.

1.2 Difficulties and Risks

Urban environments have been expanding constantly. However in the last three years there has been a demand for housing in historic centers, which had been uninhabited for years and without any type of restoration. According to Salgueiro [4], the historical centers, besides being “the oldest parts of the city”, constitute a “succession of testimonies from various eras, a monument that brings us alive the past, gives us the temporal dimension with the sequence of facts that structure identities". The need for restoration is observed to meet the needs of a growing population. In most cases, very old cities expose irregular plants that lead to a disorderly flow of goods and people in these areas, in addition to presenting eroded buildings with no protection. After a certain interval of time without dwelling, the constructions deteriorate. At the moment they are unsafe or unfit for use, it is necessary to restore them.

The process of the demolition for the subsequent restoration is not limited to throwing down walls in a disorderly way, throw everything down and transform the property into a field full of rubble. In this act, carried out by an engineer (planning the work), it is possible to check the structural elements of the building and some danger zones. In the possibility of fragile parcels, allowing the risk of collapse, the responsible professional must identify and determine the correct sequence for the demolition to take place, eliminating or minimizing the risks [5].

It is fundamental to carry out a survey of the work with special risks in order to program safety in construction. Rehabilitation works must be carried out by experienced laborers, specialized companies, and practiced by a qualified technician. The most common risks include: the uncontrolled demolition of all parts of the building, the fall in height of people and materials, noise pollution, the projection of dust and particles, damage to neighboring structures and arising from them.

It should be noted that it is recommended to carry out the Neighborhood Report, to avoid problems with the neighbors. Such a study ensures the state of conservation of the real estate around the worksite for damages during the demolition of the elements of the building that is intended to restore, determine responsibilities if it is necessary to make repairs or ask for compensation.

A building permit is required, both for construction and for demolition, where the building in question is located. The hiring of a demolition company is another relevant issue that must be taken into account. The company must provide the contractor with a complete and detailed description of the demolition process that will be carried out.

The clauses concerning the safety of workers must be present in the demolition plan. It should be borne in mind that, in a demolition work, the risk of accidents is greater than in a construction site, since the act of building is more common than the act of demolishing. According to Bowie et al. [6], research has shown increased levels of lead in environmental dust during the demolition of lead paint houses in Baltimore, Maryland, and increased dust on streets, alleys and sidewalks. During this study, community residents and organizations provided reports of other concerns about current demolition practices, including lack of prior notification and health education, and minimal efforts to control dust, rats, wastewater, and public access to sites.

Bowie et al. [6], in an investigation study, it was verified an increase of the levels of lead in the environmental dust during the demolition of houses containing lead-based paint, in Baltimore, Maryland, and an increase of the dust in the streets, alleys and sidewalks. During that study, community residents and organizations provided reports of other concerns about current demolition practices, including lack of prior notification and sanitation education and minimal efforts to control dust, rats, wastewater and public access to sites.

Thus, before the demolition processes, a detailed study of the structure to be dismantled and those in the vicinity should be carried out. In this sense, a Specific Safety Plan becomes an element of paramount importance, since it highlights each task to be carried out, ordering and the form of execution. Also, the aerial lines, cables and pipelines existing in the vicinity must be signaled and protected and, with fences, be bounded by the whole area surrounding the building to be demolished. Likewise, the appropriate location for the removal of the debris should be selected and ensure that all entrances to the public service such as water, electricity and gas have been properly closed and insulated. Otherwise, accidental damage to these conduits can compromise the supply of the entire neighborhood and generate an expense to the owner.

With regard to public protection, the standard is to isolate the zones conditioned to the movement of machines and equipment with sidings, nets. It is mandatory to place warning signs in the surrounding area of the building.

A Demolition Plan is essential to carry out this work, a complement to the Health and Safety Plan (PSS), whose main objective is to establish the procedures to be observed in demolition, assisting the actors and guiding the means involved, with a view to the application of prevention and safety measures, seeking to minimize and eliminate the observed risks.

The demolition process follows some essential steps, which are identified below. After removal of the roof and the slab of the treadmill, it is continued to demolish the last floor. When recovering massive bricks and some partitions, it is necessary to carry out the work manually. Then the walls are demolished, with the help of water in the presence of gypsum plaster, thus reducing the formation of dust, then the removal of balconies or other existing consoles short with the help of levers and picks. Then the removal and transport of the wood floor for reuse is started, with the removal of the wooden beams supporting the floor. This whole process is repeated on the remaining floors, from top to bottom until arriving at the ground floor, in the case of total demolition of the building, with the proper accompaniment and disassembly of part of the scaffold, the height of the floors already removed and always taking into account that the access stairs to the upper floors and the respective handrails should be the last elements to be demolished. After the work is completed, excavators are used to remove debris still in place for transport trucks to treatment or storage areas.

2 Study Case

2.1 Methodology

A study case was chosen to confront the safety problems associated with the demolition and rehabilitation of historic centres. It is a single-family dwelling located in the historical centre of Vila Real, more precisely at Rua da Misericórdia, nº 59, 5000–653 Vila Real. This housing was built on two floors and has been rehabilitated, since it was in an advanced state of degradation and with little safety, hygiene and comfort. Works have been programmed to remove the partitions and to implant traditional masonry and dry wall inside the wet environments. Safety conditions surrounding the walls and neighbouring buildings, and the way wooden beams are anchored to these walls were implemented to ensure greater safety for the work to be done. According to Cristina et al. [7], during the shoring of the facades, there must be a special attention to the current state of the walls and, if necessary, carry out some repairs to prevent the collapse of the structure, when it's preceding the shoring of the facades, with disastrous consequences that may even be fatal. A shoring poorly built, has the potential to collapse part of the structure, making it vital that this kind of intervention have to be designed by structural engineers or other competent professionals.

Figure 1 shows the general appearance of the building, after demolishing the interior, by the manual demolition method.

In a preliminary phase and to allow the containment of the facade in a safe way, since the beams were in good condition and nailed to the facade, they remained until the end of the construction of the work, as it can be seen in Fig. 2.

Only after the containment of the building facade (Fig. 3) it is possible to work safely, so as to offer no additional risk to the workers. Then the concrete slabs were made using reinforced concrete. As the slabs were being executed, they increased the stability of the building, allowing the work to be carried out safely and without any kind of accident.

Fig. 1 General appearance of the interior of the building after demolition of its interior

Fig. 2 Containment of facades with two existing beams

Fig. 3 Metal beam and facade containment

3 Conclusion

According to Apolpia et al. [8] the term, urban regeneration, is synonymous of rehabilitation or urban renewal. Whatever the mode of expression, this term is based, therefore, on a set of action principles, aiming at the sustainable development of cities. The problem of urban growth can be tackled effectively through the rehabilitation of historic centers. The rehabilitation of historic centers allows new life to be given to the cities that are already dead, but in turn it is an added value for traffic control, as it will avoid the movement of vehicles from the surroundings to the urban center.

Based on the acquired knowledge obtained during the monitoring of the work, and with some practical examples observed in daily life and other research studies in this area, it can be concluded that the safety of workers should be assumed as a factor of great importance, since many accidents occur due to poor planning. The urban rehabilitation represents an added value for the control of traffic and welfare of societies, allowing a new life to cities already lifeless.

It should be noted, that in the buildings rehabilitation, one of the main concerns is the efficient shoring of the neighboring walls of the work and the facades. Previous studies and calculations [4] should be carried out in order to ensure the safety of the workers, the competitors and all those who are, directly or not, affected by the work.

References

1. Repositório Institucional da Universidade de Lisboa. Instituto de Geografia e Ordenamento do território. http://repositorio.ul.pt/bitstream/10451/3862/8/igotul000916_tm_3.pdf. Last accessed 21 Nov 2018
2. Rodrigues, C., Rocha, P.F.: A manutenção como fator de gestão de edifícios reabilitados. 5ª Conferência sobre patologia e reabilitação de edifícios PATORREB 2015, 26 a 28 de Março de 2015, proceedings, pp. 1–6. FEUP, Porto (2015)
3. Rocha, P.F., Rodrigues, R.C.: Maintenance as a guarantee for roofing performance in buildings with heritage value. J. Build. **6**(15), 1–10. (2016). https://doi.org/10.3390/buildings6020015
4. Salgueiro, T.B.: A Cidade em Portugal. Uma geografia urbana. Edição: Edições Afrontamento, abril de 1992, (1992). ISBN: 9789723602029
5. Reis, C.M., Silva, P.L., Ferreira, J., Oliveira, C.: Risks and preventive measures in building demolitions. In: Occupational Safety and Hygiene V—Selected Extended and Revised Contributions, from the International Symposium on Safety and Hygiene, pp. 603–606. Taylor & Francis Group, London (2017). ISBN 978-1-13805761-6
6. Bowie, J., Farfel, M., Moran, H.: Community experiences and perceptions related to demolition and gut rehabilitation of houses for Urban redevelopment. J. Urban Health: Bull. N. Y. Acad. Med. **82**(4), (2005). https://doi.org/10.1093/jurban/jti075. The Author 2005. Published by Oxford University Press on behalf of the New York Academy of Medicine. June 15

7. Reis, C., Oliveira, C., Mieiro, M., Pereira, V.: Preventive measures in rehabilitation of buildings—facades shoring. In: Arezes, P., Baptista, J.S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R., Miguel, A.S., Perestrelo, G.P. (eds.) Occupational Safety and Hygiene II. Taylor & Francis, London. ISBN: 978-1-138-00144-2 (2014)
8. Alpopia, C., Manolea, C.: Importance of urban rehabilitation. Procedia Econ. Financ. **6**, 178–185 (2013). https://doi.org/10.1016/s2212-5671(13)00130-5

Building Information Modeling Normative Analysis Applied to Occupational Risk Prevention

Daniel Bragança, Manuel Tender and João Pedro Couto

Abstract While some countries are in the process of disseminating Building Information Modeling (BIM) applied to occupational risk prevention, others already have normative documents in application, such as Finland, the United States, Singapore and the United Kingdom. These frameworks assist and encourage the use of BIM for safety information sharing, early risk detection and collaboration among all stakeholders in all specialties. In view of the rapid growth in the use of BIM in the construction industry, the use of this methodology in the area of safety should be standardized, as is the case with other specialties, to keep up with current trends and to achieve a correct and wide implementation of this new methodology applied to construction projects. Based on the existing normative documents, this study intends to create a proposal for a standard on the use and transmission of preventive information for Portugal. Given the gradual implementation of BIM in the construction sector in Portugal, this type of document is shown to be very important for the future of BIM applied to safety.

Keywords Occupational risk prevention · BIM · Construction site management · Standardization

1 Introduction

Standardization is interesting for the construction sector, and BIM as an innovative technology, needs standardization to have a uniform and efficient application. Thus, BIM is an asset for society, by increasing safety and quality in the executed jobs. Another factor is the dissemination of information in a consistent manor for project-relevant principles, additionally information for clients, who can be layman

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on construction information, and may want to know how the process will be executed [1].

The need for BIM standardization stems from the rapid growth of its use. Thus, construction projects will have a standardization and minimum levels of acceptable quality. If BIM becomes standardized, stakeholders will have to define in more detail what will happen on site. It is therefore interesting that efforts should be made to create national standards for the sharing of occupational risk prevention information using BIM.

In the Portuguese context, the use of BIM to promote safety began with the dissertation of an integrated Master's degree at the University of Minho [2] who used Revit modeling for safety analysis of the '*Marão*' tunnel construction site. The next step was the integration of occupational risk prevention in BIM. In 2017, a partnership was established between the School of Engineering of the University of Minho (SEUM) and Xispoli Engineering, establishing itself for strategic purposes related to the dissemination of a concept called *BIMSafety*—which later became a R&D research project. Consequently, an article was published in the journal Safety "The integration of BIM in the prevention management in construction" (n. 237, pp. 7–8) [3] and an oral communication was held at the 5th International Conference on Construction Safety and Health, Nicosia, Cyprus—"*BIMSafety*—at the service of production" [4].

The next step was to apply BIM in a practical case with the established *BIMSafety* concept. Two master's dissertations were carried out at the School of Engineering of the University of Minho in collaboration with Xispoli Engineering, using a rehabilitation work of a building in the center of Porto, as a practical case. The results were presented at the 21st Congress of the Order of Engineers—Engineering and Digital Transformation: Lisbon in 2017—"BIM as a prevention instrument in the design and construction phase" and in Ingenium Magazine in 2017—"O BIM as a prevention tool in building maintenance management" [5]. The most recent advance of BIM applied to prevention on the national scale has been to analyze a simulation of *BIMSafety* implementation in 3D, 4D and 5D. The results of this study were presented at the 2nd Portuguese Building Information Modeling Congress—"BIM as a 3D, 4D and 5D prevention tool in construction site management", which pointed out the following main conclusions: "*Efforts should be joined by institutions, for the creation of a normative document at national level, in the context of the transmission and use of preventive information using the BIM* [6]".

2 Short Review of Standardization of BIM Applied to Safety

BIM standardization is in a premature state, however, the current efforts made are of great relevance and content, starting in 2012 with the launch of the Common BIM Requirements (COBIM) in Finland, followed by the release of the BIM submission standard by the New York City Department of Buildings (NYCDOB) in 2013, “Building Information Modeling Site Safety Submission Guidelines and Standard”, in parallel with the current version of “The BIM Guide” of the Building and Construction Authority of Singapore and which preceded the UK standard named “PAS 1192-6—Specification for collaborative sharing and use of structured Health and Safety information using BIM” released in 2018 which currently corresponds to the most up-to-date framework. Following is a brief analysis of studies using BIM for construction site risk prevention.

Hu and Zhang [7] published one of the most influential articles of this subject, where BIM is integrated with construction site planning (BIM 4D) for safety analysis. Using the geometric information contained in the model, the authors combined this information with the work schedule, easily identifying certain sequences and activity collisions that could create risks for workers. They concluded that BIM was essential in identifying various risks and brought advantages over traditional methodology, which was later confirmed by Kim et al. [8] and Tixier et al. [9]. Zhang and Teizer are among the most productive and influential authors in the field, investigating automated safety rule-based verification [10], risks by utilizing scaffolding [11], real-time tracking systems [12, 13] and the risks caused by working near large machinery and equipment [14, 15].

The main conclusions found in the studies of BIM applied to safety management were: that BIM optimizes planning and productivity, allowing efficient problem analysis [16]; identifying preventive measures becomes more automatic and intuitive [17]; has the ability to overcome the language barrier [18] increases the capacity for information sharing and task planning [19]; creates a new way of delivering and approving city safety plans [20]. In conclusion, BIM is in a special stage of development, with attention increasing, but the research limit of the subject is still far from being exhausted [17].

With the analysis of those important studies that have applied BIM to promote safety, the next step of this study will be to analyze the normative documents already in place in the context of the pre-referred countries, namely: Finland, New York City, Singapore, UK and finalize with suggestions for a possible document for Portugal.

2.1 Finland

The first normative document released of BIM applied to prevention was the Finnish document in 2012, known as “Common BIM Requirements” or COBIM, which was divided into 13 parts, one for each stakeholder. In this section, we will analyze part 13 on construction and risk prevention. The beginning of the document refers to contractual and accessibility elements, specifying that the contractor should assist the security professional by defining the construction method so that prevention analyzes are performed according to the specified construction method. The standard also stipulates that security BIM model upgrade periods should be defined at the beginning of the construction life cycle, in addition it should be recorded which stakeholder made the specific modifications to the safety model, thus generating the history of the model. Should any intervener identify any safety errors or omissions in the model, the coordinator should be advised to make appropriate adjustments. The standard further states that 3D and 4D models can be used to share safety information to the client in a more didactic manner, such as building modifications and chronogram definitions.

The COBIM standard provides suggestions for modeling the construction site, such as: buildings, constructions and temporary equipment (enclosure or storage facilities, fences, walkways and excavated areas or storage of materials and machines), cranes (with areas of range), sidewalks and space reserves, with a level of detail sufficient to expose the problems. The objects exemplified above will be more easily understood if accompanied by text with detailed information. Pedestrian paths and evacuation of construction workers are part of the safety planning of the building and the modeling of these elements makes it easier for the developer to understand if the project is modified.

The document lists some contributions and advantages of BIM to safety, such as:

1. The ability to plan and model construction work in advance, as well as determine safety strategies;
2. Ensure that the structure can be safely built by modeling the necessary details;
3. View the appropriate solutions in documents.

The document exemplifies that for the assembly of prefabricated structural elements the delimitation of safety equipment through the BIM model reduces the work that must be performed in the later stages, i.e., in the execution stage. Thus, the standard presents examples such as guard rails, safety nets and anchor points, which can be modeled and made available for use by safety professionals, as illustrated in Fig. 1. As for the contractor, the document indicates that: The professional uses the terrain modeling to define the starting point of the construction and thus certain safety elements can be determined in the design stage. The standard calls for special attention to non-visible MEP (Mechanical, Electrical and Plumbing) installations, suggesting the insertion of risk prevention and maintenance information [21].

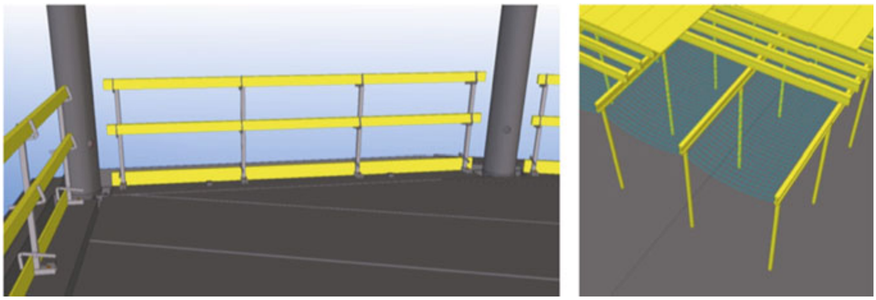

Fig. 1 Examples of fall protection measures in BIM. Adapted from [21]

2.2 New York

The New York City document was developed to establish how the submission of a BIM safety project should be carried out. The New York City Department of Buildings (NYCDOB) "Site Safety Building Information Modeling Guidelines and Standards" document primarily describes the requirements, processes, and procedures for preparing and submitting BIM safety project models, beyond the production and communication of data in universal formats.

The intent of the standard to be very practice-oriented is demonstrated early on, with the literal indication of software such as Autodesk Revit and AutoCAD for designing, and Autodesk Navisworks for model review. The authors of the normative document indicate how the files should be nominated for submission, work phasing and reviews. The expectations and requirements for digital submission are presented in detail and of great interest to the quality of the model, such as proper modeling of streets and sidewalks, temporary structures, machines and staff. Objects of which are properly detailed according to categories such as construction, yard, excavation and streets. This section of the standard refers to the library of

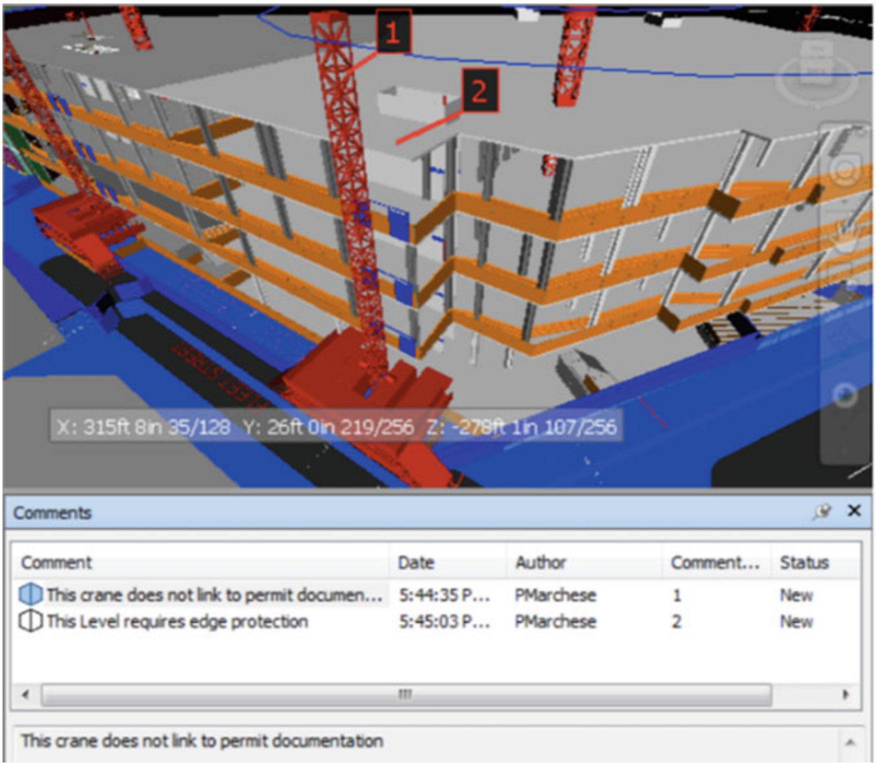

Fig. 2 Example of safety information BIM model. Adapted from [20]

objects available on the NYCDOB website with already parameterized elements and a template to facilitate modeling.

The normative document defines how the project should be carried out, if the professional does not use the template file provided. The Level of Detail (LOD) of objects is also specified, with the benefits of having a very detailed element shown, however it is also explained in the document that little detail can be accepted as well so that professionals do not waste time unnecessarily detailing. After describing the parameterization of the objects, the submission procedures for the New York City department begin, with step by step design review by Navisworks, Design Review (illustrated in Fig. 2) and finally submission for evaluation by the department. The standard sets out the evaluation process after submission until the model is approved. Finally, Annex A describes the application of parameterization, Annex B refers to the best practices in Revit and Annex C consists of the definition, definitions and definitions [20].

2.3 Singapore

"The BIM Guide," volume 2, was published by the Building and Construction Authority of Singapore to regulate the use of BIM in construction. For the use of BIM applied for prevention there are sections on site modeling, temporary structures and fire protection (fire hydrants, sprinklers, extinguishers, smoke detectors). The document does not yet have a section specifically intended for safety, however the fire protection part is the most detailed of all the standards studied [22].

2.4 United Kingdom

The most recent normative document was released in the UK in 2018 by The British Standards Institution (BSI), and is named "PAS 1192-6—Specification for collaborative sharing and use of structured Health and Safety information using BIM" (illustrated in Fig. 3). Probably the most important of the standard is that it deals with the implementation of strategies for construction stakeholders. The standard regulates the specifications of roles and duties of each intervener, starting with the "Owner" and their initial obligations, requirements determination and what is acceptable. It reiterates the extreme importance of the involvement of the developer in determining the characteristics of the construction site, the objectives of the final design and the characterization of critical and unacceptable OHS risks.

With the responsibilities of the "Owner" exposed, the next stakeholder that the standard addresses are the "Designers", the document directs projection determinations for risk mitigation, construction feasibility, maintenance and final use. The standard states that the initial design detail should be enough to determine safety risks such as design conflicts, significant temporary constructions, lifting

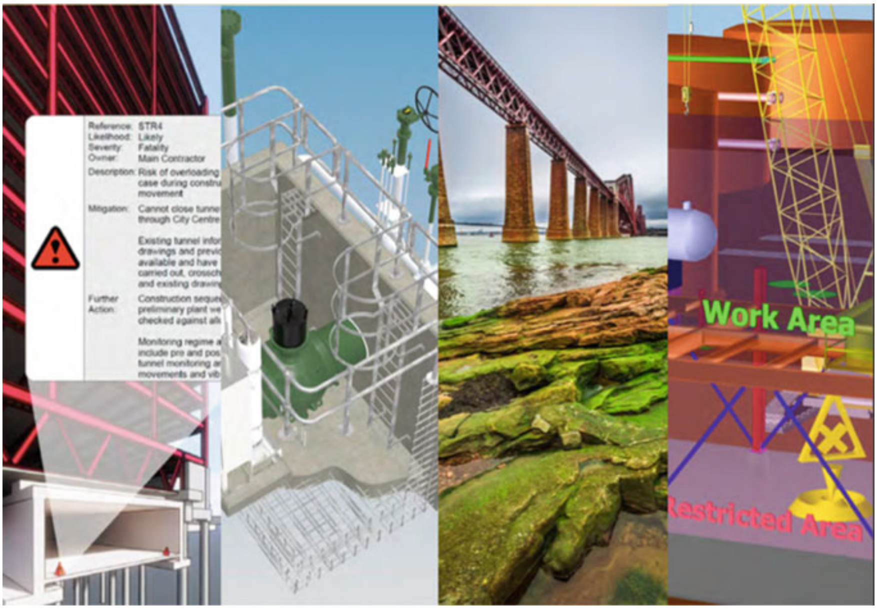

Fig. 3 Examples of BIM applied to prevention. Adapted from [23]

operations, excavations, risk zones and hazardous areas, work at heights and access or evacuation routes.

Following the definitions of the "Designer", the standard specifies the "Contractors", making it clear that in addition to contractual obligations, occupational safety and health should always be kept in mind. The paper addresses items such as construction and site planning and points out that if risk prevention identification and management is pre-made in the model, preventing risks becomes more efficient. The chapter of the "Contractor" concludes with strategies for the construction focused on the use and maintenance of the building.

In order to finalize the stakeholders, the last mentioned in the standard is the maintenance and end use manager, whose objective is to perform tests to mitigate risks to the maximum. The utilization of COBie can be of added value to the end user, with detailed supplier information, user guide, purchase note and maintenance dates. Commissioning of a large-scale building can be done in a simpler and more organized manner.

The normative document is finalized with ways to share safety information and definitions, hazard importance matrix, and appropriate and standardized formatting for sharing safety information is determined [23].

3 Suggestions for a National Document

After analyzing the documents already in use at the international level, it is clearly identified contents can be applied in a Portuguese document. Starting mainly from the index of the English document, Chapters 5 (PAS application), 6 (Risk information cycle), 9 (Document representation), 10 (COBie representation), 11 (Model representation) and 12 (annexes) were excluded; Item 5 has also been removed as it is specific to the English document, while the rest of the items have been removed as they can be summarized and seeded in other chapters and subchapters, additionally Chapter 3 can be moved to the end, for the references.

Given that the English document is divided into stakeholder subsections, it contains the principles common to all stakeholders, owners, designers, contractors, building user and supply chain. The criteria utilized to structure the document proposal where mainly based off the PAS 1192-6, but specific differences between British and Portuguese construction reality were taken into consideration, specifically the fact that only in Portugal do the coordinator of health and safety in the project and work phase. Following this section, will be exposed the proposed index, in contrast more investigation and consolidation will still have to be made until a finalized standard can be published.

The proposed index for the Portuguese standard is:

(1) Introduction;
(2) Purpose;
(3) Terms and definitions;
(4) Stakeholder implementation strategy;

  (4.1) Owners;
  (4.2) Designers;
  (4.3) Health and safety coordinator in the project phase;
  (4.4) Health and safety coordinator in the construction phase;
  (4.5) Contractors;
  (4.6) User of the building;
  (4.7) Supply chain;

(5) Implementation of information requirements;
(6) References.

4 Conclusions

BIM applied to occupational risk prevention is still far from being widely implemented worldwide. For this implementation to become reality, a work processes need to be systemized among professionals in the area. The standardization of the subject aims at such systemization of work and consequently will bring greater relevance to the studied area, possibly encouraging non-practitioners to apply this methodology.

A normative document is indispensable for the implementation of BIM for safety, as demonstrated in other countries. In this study, the first step was taken, with the objective of initializing the process of standardization of BIM utilized to transmit and use safety information. After the analyses of the current knowledge in applying BIM for safety, a proposed index was developed for a future standard. To keep up with current and future trends, institutional efforts should be made to create and implement a Portuguese standard for the transmission and use of safety information using BIM.

References

1. Poljanšek, M.: Building Information Modelling (BIM) Standardization. European Commission (2017)
2. Fernandes, J., Tender, M., Couto, J.: Utilização do BIM na gestão de segurança do estaleiro da construção do Túnel do Marão. In: 1º Congresso Português de Building Information Modelling: Universidade do Minho, Guimarães, Portugal (2016)
3. Tender, M., Couto, J., Reis, R., Lopes, C., Cunha, T.: A integração do BIM na gestão da prevenção na construção. Revista Segurança, **237**(7–8) (2017)
4. Tender, M., Couto, J.P., Reis, R., Lopes, C., Cunha, T.: BIMSafety—at the service of production. In: 5th International Conference on Construction Safety and Health, Nicosia, Chipre (2017)
5. Tender, M., Couto, J., Reis, R., Lopes, C., Cunha, T.: O BIM (Building Information Modelling) como instrumento de prevenção em fases de projeto, de obra e da manutenção do edificado. Ingenium **161**, 106–107 (2017)
6. Tender, M., Couto, J.P., Reis, R., Monteiro, P., Rocha, T., Delgado, T., Pinto, J., Vicente, G.: O BIM como ferramenta de gestão 3D, 4D e 5D de um estaleiro de construção. In: 2º Congresso Português de Building Information Modelling: Instituto Superior Técnico, Lisboa, Portugal (2018)
7. Hu, Z., Zhang, J.: BIM-and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 2. Development and site trials. Constr. Innov. **20**(2), 167–180 (2011)
8. Kim, H., Lee, H.-S., Park, M., Chung, B., Hwang, S.: Information retrieval framework for hazard identification in construction. J. Comput. Civ. Eng. **29**(3) (2013)
9. Tixier, A., Hallowell, M.R., Rajagopalan, B., Bowman, D.: Construction safety clash detection: identifying safety incompatibilities among fundamental attributes using data mining. Autom. Constr. **74**, 39–54 (2017)
10. Wang, J., Zhang, S., Teizer, J.: Geotechnical and safety protective equipment planning using range point cloud data and rule checking in building information modeling. Autom. Constr. **49**, 250–261 (2015)
11. Kim, K., Cho, Y., Zhang, S.: Integrating work sequences and temporary structures into safety planning: automated scaffolding-related safety hazard identification and prevention in BIM. Autom. Constr. **70**, 128–142 (2016)
12. Fang, Y., Cho, Y.K., Zhang, S., Perez, E.: Case study of BIM and cloud–enabled real-time RFID indoor localization for construction management applications. J. Constr. Eng. Manag. **142**(7) (2016)

13. Zhang, S., Teizer, J., Pradhananga, N., Eastman, C.M.: Workforce location tracking to model, visualize and analyze workspace requirements in building information models for construction safety planning. Autom. Constr. **60**, 74–86 (2015)
14. Golovina, O., Teizer, J., Pradhananga, N.: Heat map generation for predictive safety planning: Preventing struck-by and near miss interactions between workers-on-foot and construction equipment. Autom. Constr. **71**, 99–115 (2016)
15. Teizer, J.: Right-time vs real-time pro-active construction safety and health system architecture. Constr. Innov. **16**(3), 253–280 (2016)
16. Godfaurd, J., Abdulkadir, G.: Integrating BIM and planning software for health and safety site induction. In: The Royal Institution of Chartered Surveyors International Research Conference: RICS, University of Salford, Inglaterra (2011)
17. Martínez-Aires, M., López-Alonso, M., Martínez-Rojas, M.: Building information modeling and safety management: a systematic review. Saf. Sci. **101**, 11–18 (2018)
18. Azhar, S., Behringer, A.: A BIM-based approach for communicating and implementing a construction site safety plan. In: 49th ASC Annual International Conference Proceedings: Associated Schools of Construction, Califórnia, EUA (2013)
19. Tender, M., Couto, J., Fernandes, J.: Using BIM for risk management on a construction site. In: Arezes, et al. (eds.) Occupational Safety and Hygiene V, pp. 269–272. CRC Press/Balkema, Londres, Inglaterra (2017)
20. NYCDOB: Building Information Modeling Site Safety Submission Guidelines and Standards (BIM MANUAL) New York (2013)
21. Karppinen, A., Törrönen, A., Lennox, M., Peltomäki, M., Lehto, M., Maalahti, J.: Common BIM Requirements 2012: Series 13: Use of models in construction, Retrieved from Building Smart Finland: http://www.en.buildingsmart.kotisivukone.com/3 (2012)
22. BCA: Singapore BIM Guide. Singapore (2013)
23. BSI. PAS 1192–6:2018 Specification for Collaborative Sharing and Use of Structured Health and Safety Information using BIM, London (2018)

Worker Visual Concentration as Risk Factor of Work on Scaffolding

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Abstract Problems concerning occupational safety and health are commonly found in the construction industry, including falling of materials, tools or people from height, stepping on objects and injuries by hand tools handling. Important factor in the occupational safety in construction industry is the use of scaffold. All scaffolds used in construction, renovation, repair (including isolating, modernization, painting and decorating), and demolition shall be erected, dismantled and maintained in accordance with safety procedures. Therefore, it is crucial to deal with scaffolds safety and risk assessment in construction industry; thus, way on doing assessment and liability of assessment seems to be essential for professionals. However, it is found that those professionals are prone to heavily rely on their own experiences and knowledge on decision-making on risk assessment. Materials and methods. Scaffold Use Risk Assessment Model (SURAM) accompanied by several submodules has been developed for assessing risk levels as various construction process stages with various work trades. The SURAM is the result of research project realized at the above 60 construction sites, both in Poland and Portugal where 728 observations have been completed including both harmful physical and chemical factors, stress level, worker habits, as well as a hundreds ex-post reconstruction of construction accidents scenarios. Results. We have found Worker Visual Concentration (WVCM) seems to be more direct predictor for developing of the unsafe chain leading to the accident than the workload, and concentration of

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harmful factors at the workplace. Conclusions. The developed Worker Visual Concentration Module (WVCM) of SURAM seems to be benefit for predicting high-risk construction activities and thus preventing accidents to occur, based on a set of historical accident data.

Keywords Construction safety · Visual concentration · Scaffold · Eye-tracking

1 Introduction

1.1 Safety in Construction

The construction industry is a booming sector of Polish economy, however, according to Eurostat, this branch of industry is classified among the sectors of the economy presenting high occupational risks and an unsatisfactory level of occupational safety. Although some safety programs have been developed in the country but the observed accident reduction rate seems to be rather weak. Employees in the construction sector are exposed to biological, chemical factors, as well as the effects of noise, vibrations, insufficient illumination and temperature. Also, the peak of workload and especially frequent changes of workload level have been observed in many investigations. More than 45% of workers in the construction sector say that their work has a negative impact on their health [1]. Construction activity is still characterized by a high level of threat to the employees' health, as well as a high accident rate. The results of occupational accidents analysis in 28 countries of the European Union completed in 2014 indicate that the construction industry was in 3rd place among all sections of the economy regarding the total number of occupational accidents; in 2nd place regarding the frequency of accidents causing longer (more than three days) absence from work; and in 2nd place regarding the rate of fatal occupational accidents. Similarly, looking at the issue from a global perspective organizations costs spend on injured people in 2009, was an amount of 73.9 billion USD [1]. In 2006, OSHAs' reports show that lost productivity in 2006 due to injuries during work and illness cost companies $60 billion. Production accounted for 20% of all injuries to the musculoskeletal system [2]. The costs of accidents at work, as well as work-related illnesses and injuries are significant. The vast majority of accidents took place at the scaffolds or at the construction sites with scaffolds. Taking into consideration the frequency of accidents and high occupational risk in the construction industry with scaffold use, it is important to take the necessary steps to reduce this exposure.

1.2 Scaffold Use Risk Assessment Model—Research Project

In these conditions the research project Scaffold Use Risk Assessment Model for Construction Process Safety "ORKWIZ" have been developed in Poland from early 2016. The project focused on the introduction of a system of new/additional procedures and tools for monitoring safety on construction sites [2–5]. This system built as model could impose strict rules regulating the conduct of contractors in a comprehensive manner to ensure an elimination of hazards from the construction site or an effective reduction of associated risks. During the implementation of the research project, the authors' attention was drawn to the fact that the general model module analyzing the aspect of the employee's visual concentration in the work area gains a much more important prognostic significance in terms of risk of accidents than the resulting factor of the complete model.

The construction of SURAM and its submodule of the Worker Visual Concentration (WVCM) are the core parts of the ORKWIZ project. The research also shows that many accidents can be avoided by developing a proper concept of safety assurance at the preparation stage [5–8].

2 Methods

Population The study was conducted in Poland. Five different regions of the country have been selected for the project research. The regions have been selected by virtue of economic development level, unemployment rate, technical culture of employees, construction processes intensity, and infrastructure level, among other factors. Accordingly, the study was conducted in the different construction sites, representing typical (more frequent) scaffold size, scaffold system types and technical equipment. Such a diversity of regions, sites and employee praxis habits and customs is required to achieve universal safety climate for the proposed safety model. At least 128 construction sites with scaffold use have be examined during the research project period. Subsequently, a random sampling procedure was conducted to select individual workers at each construction site; 728 individual workers of those sites potentially exposed to occupational hazards were selected in the first two years of the project. A dedicated questionnaire for risk perception and safety climate assessment at the construction site has been developed. At the beginning of our investigation, we have verified several existing questionnaires including NOSACQ-50, Life Quality Questionaire Module (NIOSH), Contractor OH&S Evaluation, as well as some polish ones especially IZZ questionnaire and we prepared original tool that better fit to the construction site occupational environment and construction workers perception [9–11]. Before using the original questionnaire among the selected population, we ran a pilot study among 60 workers. The trial and first run exploratory factor analysis confirmed that the original 45-item questionnaire, could be used as a risk perception and safety climate scale in polish construction industry [12]. A 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree) was used to collect the workers' responses. Yes/no responses lists of options, check-the-box responses, quantity choice etc., were used to self-report incident involvement and demographic data.

Instrumental methods were also involved to assess work conditions:

- Technical scaffoldings' conditions (static and dynamic calculations).
- The level of considering the ergonomics'– safety engineering conditions.
- Workload, procedures during assembly, usage and dismantling of scaffolds.
- Psychophysical condition of workforce working in the scaffold environment—stress, physiological parameters, staff experience, etc.
- External factors influence—noise, lighting, dustiness, external vibration, as well as climate conditions.
- Social-economic factors indirect influence.

2.1 Visual Concentration While Performing Work Tasks at Scaffold

As can be determined based on the subject matter analysis (research rapport and literature studies) the first head mounted eye tracking tool have been developed in late 40's. However, its' still mainly used to carry out researches related to work on the visual information environment, websites analysis and computer applications, is rarely used elsewhere [13–22]. Eye tracking tool produced by SMI company contains protected glasses with built-in camera, which have and phone with built in software. This modern tool gives us opportunity to record, track and analyze visual concentration path, personalization of collected data is a result of calibrating tool to every single tasted separately [23]. In SURAM project we had only one eye-tracking mobile tool so we couldn't use it on each scaffolding to every worker so research of visual concentration were provided on randomly selected workers in scaffoldings surrounding, mainly in Lublin's area, but there were also control samples in Lodz, Warsaw and Gdansk. Total of measurements collected is 36 shifts. Time of single lot measurement was at least 30 min. On the beginning we tried to provide one measurement at least 1.5 h long, which is a time of long lasting one standard battery during measurement. Quickly we had reverse information that this seems to become uncomfortable after working with it more than 60 min, so we had to shorten period of single research lot to avoid research errors that could occur in consequence of subjective sense of comfort in the work process while using eye tracker mobile device. There were unique implementation of eye-tracking analysis in the real time at the construction sites and particularly at the workplaces with scaffold use [24–27]. The saccade movements analyses and the visual concentration maps have been performed. Areas that should be recognized by workers, to increase safety are often overlooked, or the concentration on those points is negligible. We may conclude that behavior of scaffoldings' workers is more like following an amount of mini habits, which leads focus of visual concentration out of work and often out of scaffolding area.

3 Results

3.1 *Workload and Visual Concentration Resulting Risk Perception*

To present full view of worker, while analyzing his visual concentration, it is crucial to look wider and present those data in correlation of risk perception, workload level and finally visual concentration, as it have been shown in Table 1. There are presented partly results of three regions research: Lublin Voivodeship, Lodz Voivodeship and Lower Silesia. As we can see workload of workers on scaffoldings are very high, placing from 88% up to almost 97% with Lower Silesia presenting comparatively lowest workload with minimum of 0.8869 allowed top workload (8000 kJ per 8 h shift). With that high parameter of work load we can see that visual concentration is under 50%. What seems to be important that visual concentration decreases significantly, while workload increase, while we compare Lublin Voivodeship to Lower Silesia, but in Lodz Voivodeship decreases of workload is over 0.06, while difference between eye concentration is only a decrease of 0.0062. Risk perception felt by scaffolding workers is rated below average, which we can see from medians 0.375, 0.45, 0.4333. The differences presented in Table 1 were significant at CI = 95%. In the data presented below it is hard to find correlation of visual concentration and risk perception.

3.2 *Eye-Tracker Results*

Measurement of eye movement and points of its concentrations shows how worker see his work area. That what we don't notice is that only those point of visual concentration are seen clearly, rest of surrounding we only see blurry. To determine safety of human factors, we find it very important to find out where are points of visual concentration. On example of one chosen worker we can see on Fig. 1 as well as on Fig. 3 that area of main visual concentration is out of scaffolding, next point of concentration is on work area. Scaffolding itself is not a point of a visual concentration, what exactly show scan path of visual concentration on Figs. 2 and 4.

In the analyzed period of working shift—60 min; visual concentration in the working area on the scaffolding, in relation to the monitored worker was 24.19%—14.5 min, while visual concentration on objects located outside the construction site 25.59%—15.4 min. The remaining 40.1 min of visual concentration of the employee referred to the structural elements of the scaffolding as well as materials of devices and people at the construction site (Fig. 1).

Figure 2 illustrates the distribution of short-term visual observations (fixations and saccades) in the distribution to individual objects on the construction site.

Figure 3 illustrates the observation path of the eyes of the employee performing scaffolding work plotted on the actual image of the construction site space on one of

Table 1 Analysed work parameters in selected regions of Poland

Analyzed region and variable	Valid N	Median	Min	Max	Lower (Quartile)	Upper (Quartile)	Percentile (10)	Percentile (90)	Quartile (Range)
LUBLIN Voivodship									
Risk perception (0,1)	146	0.4333	0.05	0.7167	0.3667	0.5167	0.2667	0.5667	0.15
Visual concentration (0,1)	146	0.362	0.286	0.672	0.294	0.372	0.286	0.372	0.078
Workload level (0,1)	146	0.9661	0.8733	0.9987	0.9009	0.9946	0.8733	0.9987	0.0938
LODZ Voivodship									
Risk perception (0,1)	98	0.375	0.25	0.6333	0.3333	0.4333	0.2833	0.4833	0.1
Visual concentration (0,1)	98	0.3558	0.281	0.661	0.289	0.3657	0.2811	0.3657	0.0767
Workload level (0,1)	98	0.9021	0.8379	0.9899	0.867	0.9774	0.8379	0.9899	0.1104
Lower Silesia									
Risk perception (0,1)	89	0.45	0.2167	0.6333	0.3833	0.5	0.3	0.5667	0.1167
Visual concentration (0,1)	89	0.4366	0.345	0.811	0.3546	0.4487	0.345	0.4487	0.0941
Workload level (0,1)	89	0.8869	0.8429	0.9536	0.8429	0.9536	0.8429	0.9536	0.1107

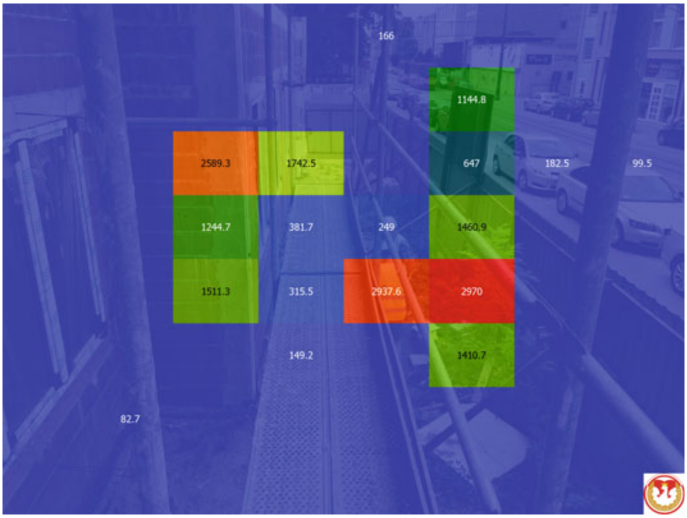

Fig. 1 Gridded AOIS measured by eye-tracker on E23 scaffolding in Lodz

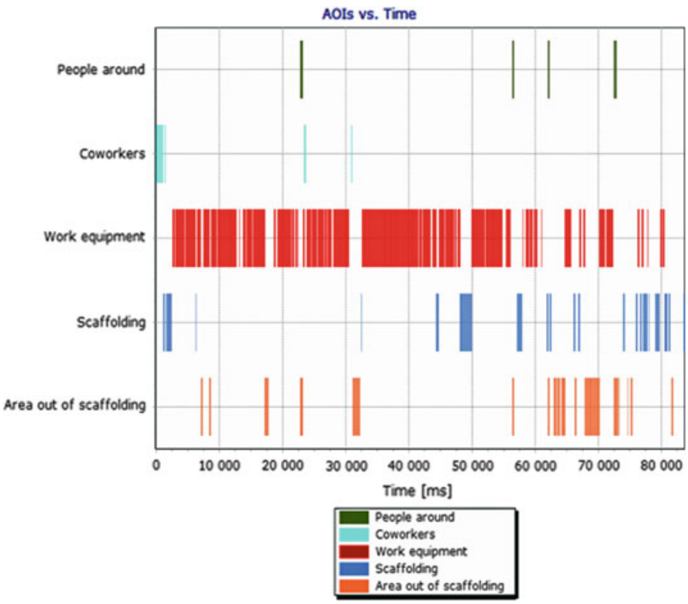

Fig. 2 Gridded the results of the analysis of the distribution of visual activity of a construction worker (carried out with the use of the eye-tracker SMI device) directed at co-workers and elements of the work environment and the workplace environment

Fig. 3 Scan Path measured by eye-tracker on E23 scaffolding in Lodz

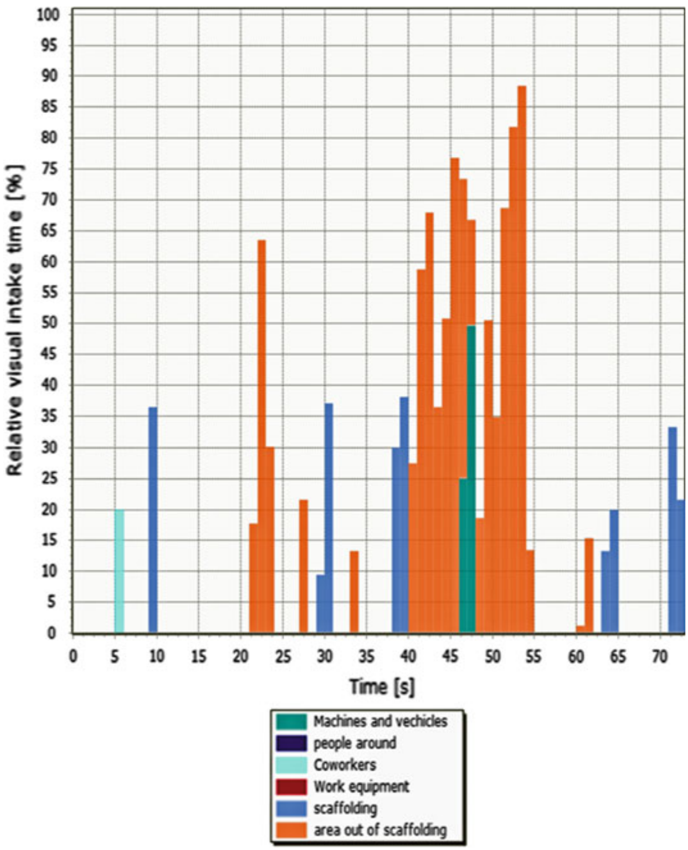

Fig. 4 Estimate time of eye concentration on scaffolding measured according the WVCM

the monitored buildings in Lodz. As it results from the analysis of this situation, also in this case the observation area is dispersed and not focused on the direct field of work.

Figure 4 illustrates the total estimated concentration time of a construction worker performing scaffolding work on individual elements of the work environment—generated using the WVCM model.

4 Conclusion

While creating a visual concentration maps in usage of data collected by eye tracker, it seems that pattern appears, which shows area of workers visual concentration, which is out of scaffolding area and what is alerting, that even during movement on scaffolding visual concentration on scaffolding itself is negligible.

Another alerting factor is that part of the job on scaffolding is work on one small area of the work surface, which with the passage of time increases the number of visual focus points outside the work area. Results of our study shows that during assembly as well as disassembly of scaffoldings visual concentration (median value) on work area is reduced to less 46% of total observation time.

It seems that Worker Visual Concentration and the lack of concentration on the work area affect directly on the increase of risk during work. The only factor, that seems, that correlate with increase of visual concentration on scaffold area is workload. Simultaneously the risk perception level decreases in those workers in which the percentage of attention concentrated on off-site facilities is higher than 40% during the shift. According to this further research should be carried in the direction of founding solutions to increase visual concentration on scaffolding and decreasing a workload.

Constructed as a result of research in the area of visual concentration of employees in the working field—the results matrix supported by appropriate software can be used both as a predictive space for the level of accident risk as well as an effective measure of the effectiveness of preventive actions in the examined enterprise.

References

1. Bureau of Labor Statistics: U.S. Department of Labor (2016)
2. Eurostat: Europe in Figures: Eurostat yearbook 2010 (2010)
3. Eurostat (2014) Eurostat regional yearbook 2014
4. Salguero-Caparros, F., Suarez-Cebador, M., Rubio-Romero, J.C.: Analysis of investigation reports on occupational accidents. Saf. Sci. **72**, 329–336 (2015)
5. Eurostat: EU Labour Force Survey Database User Guide (2015)
6. Tomei, M., Belser, P.: New ILO standards on decent work for domestic workers: a summary of the issues and discussions. Int. Labour Rev. **150**(3–4), 431–438 (2011)

7. Gao, R., Chan, A.P.C., Utama, W.P., Zahoor, H.: Multilevel safety climate and safety performance in the construction industry: development and validation of a top-down mechanism. Int. J. Environ. Res. Public. Health. **13**(11) Art. no. 1100 (2016)
8. Behm, M.: Linking construction fatalities to the design for construction safety concept. Saf. Sci. **43**(8), 589–611 (2005)
9. Namian, M., Albert, A., Zuluaga, C.M., Behm, M.: Role of safety training: impact on hazard recognition and safety risk perception. J. Constr. Eng. Manag. **142**(12) (2016)
10. Pingani, L., Evansacko, S., Luciano, M., Del Vecchio, V., Ferrari, S., Sampogna, G., et al.: Psychometric validation of the Italian version of the reported and intended behaviour scale (RIBS). Epidemiol Psychiatr Sci. **25**(5), 485–492 (2016)
11. Allen, K., Reed-Rhoads, T., Terry, R.A., Murphy, T.J., Stone, A.D.: Coefficient alpha: an engineer's interpretation of test reliability. J. Eng. Educ. **97**(1), 87–94 (2008)
12. Czarnocki, K., Hoła, B., Nowobilski, T., Rudy, J.: An analysis of the influence of selected factors on the accident rate in the construction industry. Czas. Tech. **6**, 95–101 (2018)
13. Saga, R., Fujita, T., Kitami, K., Matsumoto, K.: Improvement of factor model with text information based on factor model construction process. Front. Artif. Intell. Appl. **2013**(254), 222–230 (2013)
14. Seo, H.-C., Lee, Y.-S., Kim, J.-J., Jee, N.-Y.: Analyzing safety behaviors of temporary construction workers using structural equation modeling. Safety Sci. **77** (2015). https://doi.org/10.1016/j.ssci.2015.03.010
15. Kim, H., Kim, K., Kim, H.: Vision-based object-centric safety assessment using fuzzy inference: monitoring struck-by accidents with moving objects. J. Comp. Civ. Eng. **30**(4), 4015075 (2016). https://doi.org/10.1061/(ASCE)CP.1943–5487.0000562
16. Buica, G., Antonov, A.E., Beiu, C., Pasculescu, D., Remus, D.: Occupational health and safety management in construction sector-the cost of work accidents. Quality—Access to Success **18**, 35–40 (2017)
17. Lin, S.-H., Wang, Z.-M., Tang, W.-J., Liang, L.-H., Wang, M.-Z., Lan, Y.-J.: Development of safety climate measurement at workplace: validity and reliability assessment. J. Sichuan Univ. (Med. Sci. Ed.) **38**(4), 720–724 (2007)
18. Mohammadfa, I., Ghasemi, F., Kalatpour, O., Moghimbeigi, A.: Constructing a Bayesian network model for improving safety behavior of employees at workplaces. Appl. Ergon. **58**, 35–47 (2017)
19. Mitropoulos, P.T., Cupido, G.: The role of production and teamwork practices in construction safety: a cognitive model and an empirical case study. J. Safety. Res. **40**(4), 265–275 (2009)
20. Ho, D.C.K., Duffy, V.G., Shih, H.M.: An empirical analysis of effective TQM implementation in the Hong Kong electronics manufacturing industry. Hum. Factors & Ergon. Manuf. **9** (1), 1–25 (1999)
21. Amiri, M., Ardeshir, A., Fazel Zarandi, M.H.: Fuzzy probabilistic expert system for occupational hazard assessment in construction. Safety Sci. **93**, 16–28 (2017)
22. Liao, P.-C., Lei, G., Xue, J., Fang, D.: Influence of person-organizational fit on construction safety climate. J. Manag. Eng. **31**(4) (2015). https://doi.org/10.1061/(asce)me.1943-5479.0000257
23. Molina, M.L., Lloréns-Montes, J., Ruiz-Moreno, A.: Relationship between quality management practices and knowledge transfer. J. Oper. Manag. **25**(3), 682–701 (2007)
24. Rubio-Romero, J.C., Carrillo-Castrillo, J.A., Gibb, A.: Prevention of falls to a lower level: evaluation of an occupational health and safety intervention via subsidies for the replacement of scaffolding. Int. J. Inj. Contr. Saf. Promot. **22**(1), 16–23 (2015)
25. Carrillo-Castrillo, J.A., Rubio-Romero, J.C., Onieva, L., López-Arquillos, A.: The causes of severe accidents in the andalusian manufacturing sector: the Role of human factors in official accident investigations. Hum. Factors Ergon. Manuf. & Serv. Ind. **26**(1), 68–83. https://doi.org/10.1002/hfm.20614 (2016)

26. Choudhry, R.M.: Behavior-based safety on construction sites: a case study. Accid. Anal. Prev. **70**, 14–23 (2014)
27. Fruchter, R., Cavallin, H.: Attention and engagement of remote team members in collaborative multimedia environments congress on computing in civil engineering. Proceedings 875–882 (2011)

Safety at Rehabilitation Works of the Cavez Bridge Over Tâmega River

Felipe Schroeder Meretti, Cristina Reis, João Jorge Ferreira Baptista, L. F. Sanches Fernandes and Carlos Oliveira

Abstract The construction has many important parts which are many often studied at the academical environment. This work focuses at two general areas, which are the rehabilitation and the security at a construction work. Rehabilitation is an intervention at an old building which has a need of repair, in order to maintain the major attribute and ensure the structural health. This type of effort has a lot of risks for the workers, and for that, protective measures must be implemented with the purpose of avoiding accidents. The methodology that was used in this work is a study of case at an intervention on Cavez Bridge over Tâmega River. It focusses on safety and health required by the Decree-Law no. 273/2003 of October 29, which provides the correct approach, according to the repairing plan for each issue found at the bridge. It was concluded that it is fundamental to plan the correct tactic by knowing the actions, measuring them by the law, applying the right protection and supervising, to make sure that every person is following the regulations to avoid from the smallest injuries to the major ones.

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Keywords Rehabilitation · Safety · Risks · Prevention

1 Introduction

Construction has many areas whose studies are very important. The rehabilitation of old buildings is a very common activity, which includes ancient towers, houses, bridges and monuments. However, without the proper security, it is very hard to achieve the desired results, without accidents or risks. The security and prevention must be a fundamental concern at this area. Therefore, this article shows the importance of the security and safety of the workers and how they are executed at the rehabilitation of the Cavez Bridge.

1.1 Rehabilitation

An intervention in a building is the impact produced by the changes that are proposed in manner to preserve the construction. Some may change in a way to keep the main aspect and some change to a whole different type or use. Rehabilitation, according to Appleton, is a way to protect and guarantee the usability and the historical matter by adapting to contemporaneous requirements of security [1].

1.1.1 Rehabilitation Works at Cavez Bridge

The Cavez Bridge, located at Braga district, is a bridge over the Tâmega river—important limit between Braga district and Vila Real district [2]. It was built during the 13th century for the transportation of important supplies and people at this time [3]. Knowing the importance of the preservation of its originality, the intervention must be very cautious. Besides a plan of rehabilitation in order to guarantee the security and performance, there was a big concern to maintain the architecture and main characteristics as the five arches and the big structural stones, for an example [4].

1.1.2 Structural Issues

Through the years, the bridge suffered time damages which led the government to act in behalf of this historical and cultural monument [5]. It was listed these issues at the bridge:

- Fissures all over the structure;
- Infestation of mold and fungus;
- Lack of impermeabilization at joints and holes;

- Lack of structural reinforcement;
- Damaged sidewalks;
- Lack of a drainage system at the walls;
- Damaged guardrails;
- Damaged pavement;
- Lack of expansion joints at the transition zone;
- Lack of cleanness at the embankments (Fig. 1).

1.1.3 Proposed Measures

These measures where proposed by Infraestruturas de Portugal, which is the company responsible of the intervention at Cavez Bridge:

- Vegetation removal in order to create enough space for the working machines and the construction site;
- Reallocation of the natural course of the river through concrete pipes in order to work on the columns;
- Insertion of reinforced concrete belts around pillars P2 and P3;
- Insertion of 52 tie rods to raise resistance of the bridge section;
- Sealing of joints and holes;
- Replacement of rusting guardrails;
- Cleaning the mold and fungus;
- Replacement of the guardrail walls with a new drainage system;
- Replacement of the pavement and insertion of expansion joints;
- Rehabilitation of a water flow coming from the soil under the bridge (Fig. 2).

Fig. 1 Bridge of Cavez before the rehabilitation (March 2018)

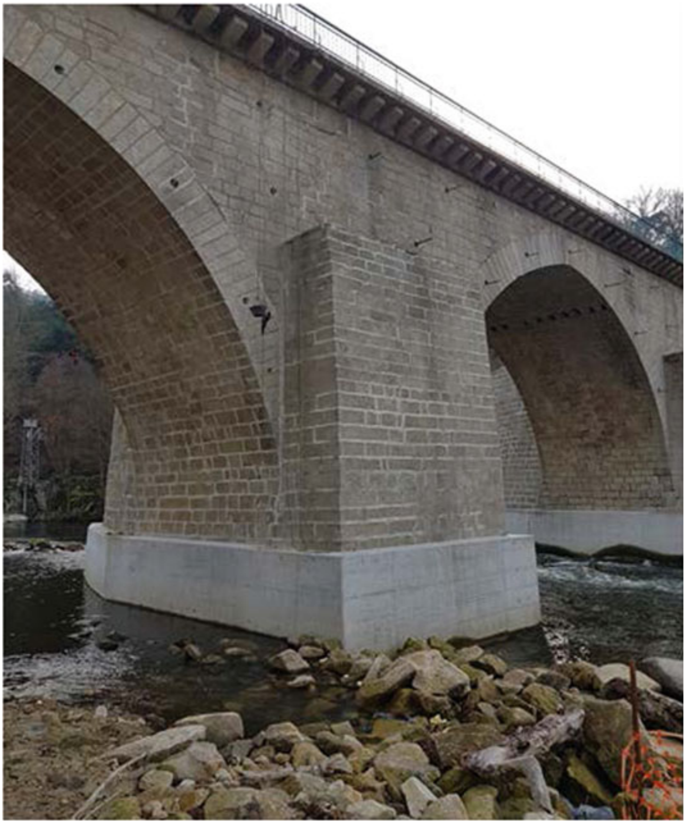

Fig. 2 Concrete belts at pillars P2 and P3

2 Case Study

2.1 Methodology

A rehabilitation task requires previous planning to achieve and guarantee the safety of workers and the job itself [6]. This article has the purpose of analyzing the rehabilitation on both preventive and security perspective. The methodology that was used for it, includes the evaluation of risks and the preventive measures according to the parameter of the Portuguese legislation. The Decree-Law no. 273/2003 of October 29 is the specific law which deals with the safety and health in order to avoid and prevent any possible accidents at the construction site.

2.2 Risks

The risks found at a construction site depends, mainly, of the adopted systems for fixing the problems at the rehabilitation. The first step is to define the most efficient intervention method, considering both structural and financial performance, and quantify all the possible accidents that may occur. For that, the *Non-Exhaustive List of Works with Special Risks* contains the risks of potential accidents according to its severity. The categories are labeled as Low (L), Mid (M) and High (H) potential danger. Here is an exhaustive survey of all the risks encountered in Cavez's Work. However, it is noteworthy that not all were the subject of careful analysis using the risk assessment methods described in Sect. 2.3.2, because they were quickly resolved throughout the execution of the work, as they are low risk and promptly resolved. In addition, the workers quickly acknowledge them and did not repeat them.

The risks found at the intervention of Cavez Bridge are as follows:

- Dermatosis (M);
- Drowning (M);
- Electric shock (M);
- Entrapment (M);
- Inhalation of dust particles (M);
- Irritation and corrosion (M);
- Perforations (M);
- Risk of crushing (M);
- Skin cutting (M);
- Spilling of cleaning products (M);
- Fall hazard (H);
- Falling objects (H);
- Inhalation of toxic gases (H);
- Running over and collisions (H).

2.3 Prevention Measures

2.3.1 Implementation of the Worksite

The worksite is the place where the construction will occur. It contains all the facilities which are essential to the workmen, such as the storage of materials and tool, and the utilization of this space for personal needs, as the lunchroom and the meeting room, for an example. These facilities are either permanent or temporary, and must accomplish all safety and health rules, in a way to organize the working space [7].

Working area specified, the next step is to delimitate the territory and its proper sealing, for allowing only authorized people. After that, the facilities must be built according to the working plan, which are called infrastructures. Sanitary rooms, electrical arrangements like power generators, industrial shelter or storage room for the equipment, materials and tools, and administrative rooms for the proper meetings and members of the supervision team are the main structures used at this intervention. The last step is to set up a firefighting system using fire extinguishers, for example [7].

2.3.2 Preventive actions

Prevention actions are safety methods which present many positive results related to work injuries. These procedures are planned and tested to avoid any accident that may happen at the worksite. The big challenge is to find all the risks and to correct them with the right procedure [8]. The risk assessment method used in this article is presented in Tables 1, 2, 3 and 4, and is the one used by Infraestruturas de Portugal. Although it is a very expeditious and simple method, it was the one that was applied because it is very easy for anyone to use. Furthermore, as this research work was prepared with the cooperation of Infraestruturas de Portugal in the meetings with security technicians and security coordination, it was decided to use the method used by them in the specific monitoring and prevention plan, in order to assess the applicability of it by other people. Although there are many similar risk assessment methods, such as the one used by Eliana Carpinteiro [8], it was chosen to maintain the one used by Infraestruturas de Portugal. The applied methodology at the intervention at Cavez Bridge uses a determination and quantification of different levels of Probability (P) and Severity (S) according to the Specific Plan of Monitorization and Prevention (SPMP):

As:

$$RL = P \times S$$

RL being Risk Level

Table 1 Characterization of degrees of probability and severity

Level	Probability	Severity
1	Rarely happens	Almost no damage
2	Happens sporadically	The damage is light
3	Happens many times	The damage is significant
4	Happens almost every time	The damage is very significant

Table 2 Quantification of degrees of probability and severity

Severity \ Probability	1	2	3	4
1	1	2	3	4
2	2	4	6	8
3	3	6	9	12
4	4	8	12	16

The Table 3 defines, according to the risk level resulted of the classification on Table 2, if the risk found at the quantification will be fixed urgently—at the highest levels, in red color—or less urgently—as the level decreases, in green color.

It is noteworthy that the risks presented in Sect. 2.2 do not all appear in the risk assessment made and presented in this chapter in Table 4, because here only those of the highest risk in the Cavez bridge construction are considered.

According to the data obtained by the tables, it is possible to understand which are the main items that need the most attention of the systems of protection. The next step is to define the best elements to prevent and guarantee safety for the workers and the intervention. Although all the risks and preventive measures listed in Table 4 and Sect. 2.2 are detailed in each procedure sheet, they are not presented in this research work as it would make it too lengthy.

- Appropriate clothing—The utilization of the Personal Protection Equipment (PPE) are mandatory, like helmets, steel-toe boots and reflective jacket;
- Informative rules for the workers—Inform about breaks, logistics and safety measures;

Table 3 Risk level assessment criteria

Risk Level	Meaning	Intervention
12-16	Unacceptable	Urgent correction
6-9	Important	Fix and add control actions
3-4	Moderate	Stablish control actions
1-2	Acceptable	No need of a short-term intervention

Table 4 Risk level

Assemblage of the worksite				
Classification	Potential risks	P	S	PL
Physical/ mechanics	Falling objects	1	2	2
	Manipulation of objects, crushing risks and skin cuts	3	4	12
	Perforation (non-protected sharp elements)	1	2	2
	Exposure to extreme environmental conditions	3	1	1
	Exposition to enhanced noise levels	2	1	1
	Rollover of vehicles	1	3	3
Order and cleanness	Short falling, stumbles and slips	2	1	2
Electrics	Contact with the electrical supply (exposed or damaged electrical parts)	1	3	3
Ergonomics	Excessive stresses (wrong body postures for a long period of time)	3	2	6

- Signaling devices—Preventive system for protection of the worksite to avoid unallowed people;
- Electrical insulation—Protective actions for the cables and signalize the damaged ones until it gets repaired;
- Fire preventions—Informative and practical actions to prevent or easier way to escape in case of fire;
- Correct storage—Good sized shelfs, safe height storage of tools and materials and avoiding high density of the area;
- Cleaning—Keep the circulation area clean and ordered;
- Correct storage of hazardous products—Keep separated from regular materials and from each other and with signalization to indicate danger;
- Vehicles and people circulation—Rules of logistics to avoid any accidents by ordering the area and keep it signalized;
- Precautions with equipment and heavy machines—Manage to steady and smooth the equipment, in a proper location and refuel it with the engine turned off (Fig. 3).

After several visits at the construction site, attending meetings with the safety coordinator and the contractor, it was noticed that all the risks found at the rehabilitation of Cavez' bridge—the ones which were firstly found and resolved instantly by Infraestruturas de Portugal, together with the ones found with the risk assessment method and posteriorly solved by the solutions listed above—follow the Decree-Law no. 273/2003 of October 29 to the letter. To follow this Decree, is to prevent accidents at the work site.

Fig. 3 Utilization of the PPE's

3 Conclusion

Based on the studies made about the characterization and the analysis of the issues and the rehabilitation process at the Cavez Bridge, focusing on the prevention of accidents during the intervention, it was concluded that the rehabilitation work is very important to preserve the historical monument to its originality along with the security, solid structure and beauty. And to do that, the safety and health of the workers at the construction site must be a big priority, in order to keep the best performance of the work. Besides that, based on the Decree-Law no. 273/2003 of October 29, it is possible to know what are the consequences of a non-preventive work, avoiding them by planning the whole operation and taking all the required measures, in order to have a safe construction site, by investigating all the risks that may appear at the intervention.

After several months of monitoring the work on the bridge of Cavez, it is concluded that a good risk assessment accompanied by the implementation of preventive measures contributes to no accidents on site. Despite a very simple and subjective methodology, it provided excellent results in matters of safety.

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References

1. Appleton, J.: Reabilitação de Edifícios: princípios e práticas. http://www.ordemengenheiros.pt/fotos/dossier_artigo/jappleton_1452865970545a07405d43c.pdf. Last accessed 23 Feb 2019
2. Municipio de Cabeceiras de Basto Homepage: Freguesia de Cavez. https://cabeceirasdebasto.pt/concelho-freguesias-cavez. Last accessed 26 Feb 2019
3. Museu das Terras de Basto Homepage: Lenda da Ponte de Cavez. https://museuterrasbasto.wordpress.com/2014/09/11/lenda-da-ponte-de-cavez/. Last accessed 26 Feb 2019
4. Coias, V.: Reabilitação Estrutural de Edifícios Antigos - Alvenaria, Madeira - Técnicas pouco intrusivas. Ed. Argumentum & Gecorpa, Lisbon, Portugal (2007)
5. do Governo, D.: Decreto de 16-06-1910, DG, n. o 136. de 23-06-1910 (1910)
6. Roque, J.C.A.: Reabilitação estrutural de paredes antigas de alvenaria, Doctoral dissertation, Universidade do Minho (2002)
7. Cardoso, P.S.R.: Modelo de prevenção de acidentes na construção. Dissertação de Mestrado em Engenharia Civil – Especialização em construções. FEUP. Junho (2009)
8. Carpinteiro, L., Reis, C.M., Paula, S., Correia, J., Ferreira, J., Oliveira, C.: Risk Analysis in the Execution of the Águas Santas Tunnel. Occupational Safety and Hygiene VI—Selected, Extended and Revised Contributions from the International Symposium Occupational Safety and Hygiene, 2018. CR Press Taylor & Francis Group. ISBN: 978-1-138-54203-7 (Hardback) ISBN: 978-1-351-00888-4 (eBook), pp. 595–600 (2018)

Risk Assessment Associated with the Use of Manual Commands in an Industry

Isa Espinheira, J. Duarte and J. Santos Baptista

Abstract Introduction In the early twentieth century, maintenance tasks were on the list of the top 10 processes responsible for the highest number of fatal accidents. To reduce the likelihood of these accidents, operators use manual controls for the machines. Objectives The main purpose of this analysis is, through risk assessment procedures, to evaluate the relevance of replacement of enabling switch by a two-hand control device. Methodology To this end, all control devices in the industrial area were surveyed, as well as all risks associated with their use. These risks were assessed by three distinct risk assessment methods: William T. Fine WTF), *Notas Técnicas de Prevención* 330 (NTP 330) and Integrated Risk Management Method (IRMM). Results In the end, 503 occupational risks were assessed, mostly associated with contact with moving parts, entrainment and entrapment that can cause bruising, pinching, crushing, amputation and, in the extreme case, death of the worker. The results of the risk assessment did not show agreement between all methodologies. The different risks were assessed similarly by WTF and IRMM. However, using NTP-330, the same risks were assessed as more severe. Conclusion The highest risks are related to the possible tampering with the activation of the hand controls, deactivation of safety devices on the machine, no emergency button on some controls and damaged manual controls.

Keywords Safety · Risk assessment · Control device

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1 Introduction

The industrial revolution, namely the discovery of steam, was essential for the development of the industry. Advances in the robotics led to a highly automated production process and the emergence of new risks [1, 2]. Maintenance tasks, including repairs, tuning, among others, rank fourth in the list of the top 10 processes responsible for the highest number of fatal accidents between 2003 and 2005 [3]. Adoption of additional protective safety devices is essential to minimise the risks that operators are exposed to during machine interventions [4–6]. Manual controls are operator driven devices that confirm the machine can operate. Depending on design, ergonomics, features and characteristics, hand-held control devices can be classified into three typologies, according to its activation procedure [7, 8]:

- Footswitch—foot operated;
- Validation devices—triggered by one hand;
- Two-hand controls—triggered by both hands simultaneously.

In a company with multiple production lines and different types of hand control devices, the present study aimed to assess the relevance of replacing each of these devices by new ones with two-hands control, by risk assessment, using three different methods [9, 10].

2 Methodology

The present study follows the methodology presented in Fig. 1.

2.1 Identification of Manual Controls

Considering the large number of machines (33 machines—automatised cells with robots, filling, labelling and modular machine) available in the industry, an initial survey was carried out to identify all the ones with manual controls. Subsequently, "in loco" each particular manual command (67) was observed and analyzed.

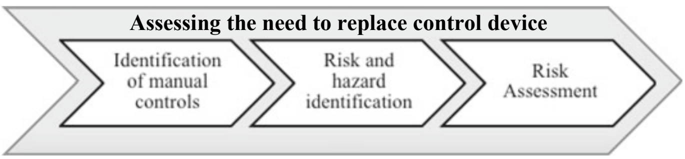

Fig. 1 Study methodology

2.2 Risk and Hazard Identification

Depending on the typology of hand controls and the respective normative documents in force, a grid has been constructed to facilitate the identification and record the associated risks and hazards. To identify performed tasks with manual controls, as well as the main risks, different technicians related to the operational, electrical and mechanical components gave their insights.

2.3 Risk Assessment

Risk assessment aims to effectively implement the necessary measures to ensure the safety and health of the workers. Some of these measures may be prevention, information and appropriate training [11].

Several methodologies can be applied for risk assessment development. This study applies three methods: William T. Fine (WTF), *Notas Técnicas de Prevención* 330 (NTP 330) and the Integrated Risk Management Method (IRMM) [12–14].

The WTF method assesses risk according to three variables. In the end, the risk is categorized according to five risk levels [6].

In the NTP 330 method, the risk level is obtained by the product between the level of consequences and the level of probability, the latter being calculated as a function of the level of disability and exposure. In the end, the risk is categorized according to four levels (being level I the highest and level IV the lowest) [13].

The IRMM method assesses the risk using the product between severity, the extent of impact and frequency of occurrence. In the end, the risk is assessed according to five risk levels [14].

3 Results and Discussion

3.1 Risk and Hazard Identification

After analysing and surveying all the risks and hazards associated with the use of manual controls on the different machines, were obtained 503 occupational risks.

The main risks are due to contact with moving parts, dragging and entrapment that can mainly cause bruising, pinching, crushing, amputation and, in the extreme case, death.

3.2 Risk Assessment

When applying the three risk assessment methodologies for the 503 risks identified, were obtained the overall results presented in Fig. 2.

A first approach to the results enables a verification that there is no agreement on the level of risk between the three methodologies. Although most risks have a low and medium risk classification, there are several differences in the percentage obtained by the three methods.

According to the WTF and IRMM, more than 85% of the risks are classified as low and medium, whereas the NTP 330 only classifies 52% of the risks with the same level, that is, with level III and IV.

However, some risks are classified as very high and extreme, but the discrepancy between methods remains. The WTF methodology identifies 5 risks (1%) as extreme risk, NTP 330 considers level I—maximum risk—60 risks (12%), and IRMM does not identify any situation in extreme risk level.

The differences between the methodologies as well as the prioritisation assigned by them, explain these results. The WTF assesses consequences, exposure, and severity (percentages for each parameter being equally distributed). The NTP 330, in addition to the probability of occurrence, places a strong emphasis on the consequences for the operator at risk. In IRMM, the number of exposed workers is an evaluated parameter and, in this case, this parameter is neutral because the number of exposed workers is always one. The main hazards associated with the use of hand controls were related to:

- The poor condition of controls, including damaged electrical cables;
- No emergency button;
- Tampering with the triggering of the command using objects or parts of the body;
- Tampering machine safety devices;
- Use of validation device and simultaneously perform cleaning or cleaning tasks of the machine;
- The machine allows manual control activation with open doors.

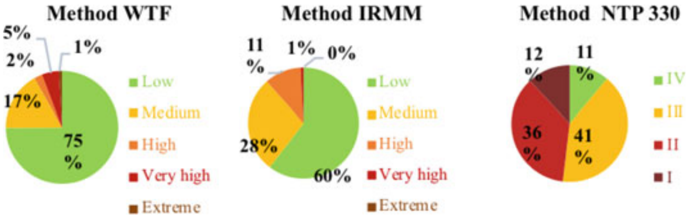

Fig. 2 Risk assessment results from the three methods

The typology of manual control may be related to the number of risks associated with its use, as well as its severity. A comparative analysis of manual command typologies allows us to verify this possible relationship (Figs. 3, 4 and 5).

Through observation and comparative analysis of the different commands, it notes that the two-hand commands associated with the use of robots (teach pendant) are the typology that presents fewer risks and lowers classification. However, it is essential to take into consideration that these commands are used sporadically and only by skilled workers.

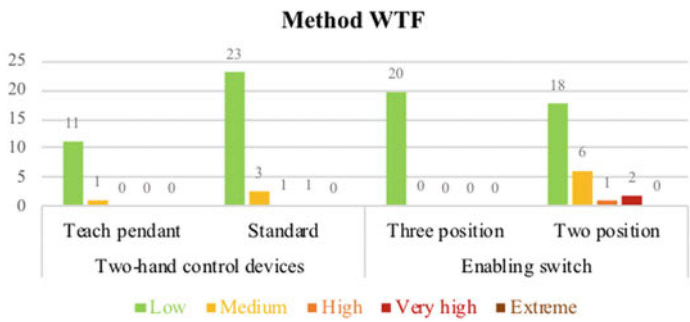

Fig. 3 Comparative analysis of manual command typologies by WTF

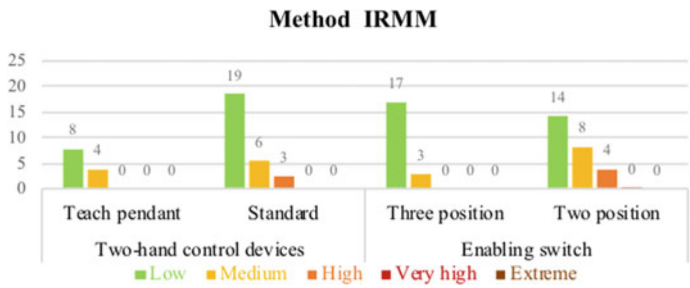

Fig. 4 Comparative analysis of manual command typologies by IRMM

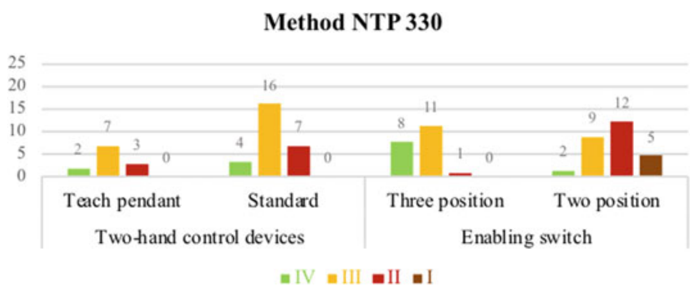

Fig. 5 Comparative analysis of manual command typologies by the NTP 330

Considering the two-hand robot controls, the standard two-hand controls and the three-position validation devices, the latter has the lowest risk levels.

When comparing the three-position validation devices with the recent standard bimanual controls, there are slight differences. In the three risk assessment methodologies, a slightly more severe risk arises in standard's two-hand controls.

These risks are associated with the fact that standard's two-hand controls do not foresee the need to operate the control at the same time as interventions the machine. Thus, it may provide the intervention of another operator who has no safety device to protect himself. In some cases, given the big size of the machines, the operator performing the intervention may not be continuously observed by the operator of the two-hand control.

In contrast, the three-position validation devices allow an operator's hand to be free and to come into direct contact with the machine. However, the time for activating the emergency stop is expected to be shorter.

Two-position validation devices are the manual controls with the highest number of associated risks and the highest risk levels. Some models of two-position validation devices do not have an emergency button, which may delay the machine shutdown procedure if this occurs [6].

Other serious risks that two-position validation devices present are associated with the security of the machines themselves, such as activating the manual mode with the safety doors open and so, easily breaching these doors. Two-position validation devices are associated with older machines, which may have been a determining factor in the final result.

The design and operation of some typologies of two-position validation devices are not very complex or confusing to activate, as the machine will operate "step by step" simply by pressing a button. On the other hand, the three-position validation devices, to allow the machine to work in the step by step mode, have to continuously press two buttons embedded in the validation device itself.

4 Conclusion

The results of the application of the three risk assessment methodologies were not in agreement, especially the NTP 330 method that evaluated the risks with a more severe classification. After the risk assessment for manual controls, the results obtained by NTP 330 were discarded. In the evaluators' opinion, this method was not adequate for the assessment in question. The results were considered as misfits of reality, as it classifies 48% of high-level risks. Given the results obtained by the other two methods, there was no significant need to replace the validation devices in use with two-handed controls. In terms of the risks assessed, three-position validation devices are equivalent to two-hands controls, so it cannot be concluded that substitution should be performed. However, two-hands validation devices present several risks classified as high and require special attention.

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References

1. Fukui, H., Yonejima, S., Yamano, M., Dohi, M., Yamada, M., Nishiki, T.: Development of teaching pendant optimized for robot application. In: 2009 IEEE Workshop on Advanced Robotics and its Social Impacts, pp. 72–77 (2009)
2. Fukui, T., Nobuhiro, M., Sekino, Y., Maeda, I., Matsumoto, A., Fujita, T.: Requirement of three-position enabling switches for installing in enabling devices to achieve operational safety of robotics and automation applications. In: Proceedings of 3rd International Conference Automation Science Engineering IEEE CASE 2007, pp. 111–116 (2007)
3. Rocha, V.E.C.: Avaliação de Riscos em Trabalhos de Manutenção num Edifício do Tipo Hospitalar (2014)
4. Fukui, T., Nobuhiro, M., Sekino, Y., Maeda, I.: Matsumoto, A., Fujita, T.: Requirement of three-position enabling switches for installing in enabling devices to achieve operational safety of robotics and automation applications. In: Proceedings of 3rd International Conference Automation Science Engineering IEEE CASE 2007, pp. 111–116 (2007)
5. Chinniah, Y., Aucourt, B., Bourbonnière, R.: Safety of industrial machinery in reduced risk conditions. Saf. Sci. **93**, 152–161 (2017)
6. Caputo, A.C., Pelagagge, P.M., Salini, P.: AHP-based methodology for selecting safety devices of industrial machinery. Saf. Sci. **53**, 202–218 (2013)
7. ABB: ABB Safety Handbook Machine Safety—Jokab Safety products ABB Safety Handbook (2013)
8. Bessa, R., Baptista, J.S., Oliveira, M.J.: Comparing three risk analysis methods on the evaluation of a trench opening in an urban site. In: Occupational Safety and Hygiene III, pp. 429–433. CRC Press (2015)
9. Górny, A.: Assessment of compliance with minimum safety requirements in machine operation: a case of assessing the control devices of a press. In: Occupational Safety and Hygiene—Proceedings of the International Symposium on Occupational Safety and Hygiene, SHO 2013, pp. 497–501 (2013)
10. Toth, A., Nyitrai, D., Jurak, M., Merksz, I., Fazekas, G., Denes, Z.: Safe robot therapy: Adaptation and usability test of a three-position enabling device for use in robot mediated physical therapy of stroke. In: 2009 IEEE International Conference on Rehabilitation Robotics, pp. 940–945 (2009)
11. Batalha, A.: Projeto Individual Identificação de Perigos e Avaliação de Riscos (2012)
12. Fine, W.T.: Mathematical Evaluations for Controlling Hazards. Naval Ordnance Laboratory (1971)
13. Belloví, M., Malagón, F.: NTP 330: Sistema simplificado de evaluación de riesgos de accidente (1991)
14. Artilheiro, F., Baptista, J.S., Tato, M.: Metodologia de avaliação integrada de riscos ambientais e ocupacionais Methodology of integrated evaluation of environmental and occupational risks. In: International Symposium on Occupational Safety and Hygiene—SHO2010, pp. 75–79 (2010)

FRAM-AHP: A Resilience Engineering Approach for Sustainable Prevention

Lucio Villarinho Rosa, Paulo V. R. Carvalho and Assed N. Haddad

Abstract The Traditional tools for occupational risk assessment like preliminary hazard analysis, hazard checklists, fault trees are based on the isolation of hazard activities from the entire process and the development of specific measures to avoid or minimize the occupational risk. This strategy makes the results of such evaluations distant from real situations. The Functional Resonance Analysis Method (FRAM) defines a systemic framework to model complex systems based on combinations of function variabilities during normal work. FRAM which aims to describe how function couplings may be combined in such a way that variability of performance, rather than failure or poor functioning, creates an occupational risk. In order to minimize the subjectivity associated with the qualitative analyses of the functions performed by experts' judgments required by FRAM, a multi-criteria decision-support method was added. Analytic hierarchy process (AHP) are used in situations involving multiple objectives, various decision-makers, and the simultaneous treatment of complex issues. In this sense, this research contributes to the evolution of FRAM, by proposing the application of the AHP, to investigate the relative importance of the criteria and alternatives for the identification of phenotypes of performance variability, as well as the aggregation of variability. The results of this study demonstrate that this combined technique FRAM-AHP can be used to assess and quantify the performance variabilities that may lead to occupational or environmental accidents and provide new recommendations about how work processes should function, minimizing production losses, incidents and accidents.

Keywords Resilience engineering · Occupational safety · Risk management

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1 Introduction

Safety and health at work is everyone's concern. It's good for worker, business and society, thus supporting the concept of sustainable prevention in occupational health and safety [1]. To achieve sustainable prevention, people should understand how safety is embedded in their daily work activities rather than thinking about safety only after an accident [2, 3]. Conventional explanations for adverse events only see the problems that are inevitable, widespread and inherent in all systems [4]. Therefore, they do not account for small variations that may be combined, resulting in a complete system failure [5]. This fact argues for the need to develop approaches that can be used for systems that are dynamic, incompletely described, and therefore underspecified [6–8]. Understanding the complexity of a risk, or a portfolio of risk, is crucial when selecting the appropriate option for the risk assessment [9].

Resilience is the ability of the system to adjust prior to, or following changes and disturbances, and thereby to support the operation, even after a disruptive event, or the presence of a continuous stress [10, 11]. Resilience engineering has promoted a new approach for the treatment of dynamic systems in complex environments. In these environments, the daily, routine activities need to be both dynamically stable and flexible rather than rigid. From this paradigm, sustainable prevention must emerge from the joint cognitive human-system functioning [12]. Functional Resonance Analysis Method (FRAM) has been developed under the concepts and principles of the resilience engineering, providing a method that analyses the nature of daily work activities, instead of the model of failures. FRAM does not identify what can go wrong, nor the probability of failure of a single component or function, but rather develops the description of what may happen during a typical daily work activity. FRAM seeks to establish how the variability in performance may affect this situation positively or negatively. According to FRAM, failures emerge as the resonance of the normal variability of the functions or tasks [4, 8]. Currently, in the FRAM methodology, analyses related to the identification of performance variability, as well as for the variability aggregation to find potential resonances, are based on the judgment of specialists—a highly subjective evaluation. Thereby, it is completely feasible to use a multi-criteria decision support method for dealing with subjective evaluations in a more adequate way [13]. Among the most widely used of the Multiple Criteria Decision Analysis (MCDA) approaches in the various research domains, the Analytic Hierarchy Process (AHP) is the one that provides a good compromise between targets, understanding and objectivity [14, 15].

This research aims to demonstrate an alternative approach to risk assessment that fits the sustainable prevention concept. This approach uses the Functional Resonance Analysis Method (FRAM) combined with Analytic Hierarchy Process (AHP) to conduct risk assessment. FRAM-AHP method is based on system functioning, not in the identification of specific hazards as traditional tools. Thus, managing sustainable prevention is concerned with understanding how the system is functioning, how it adapts to different types of disturbances and how it uses the following resilient capacities: buffering capacity, flexibility, margin, tolerance and cross-scale interactions [16].

2 Materials and Methods

The development and demonstration of how sustainable prevention can be applied followed two major research methods: literature reviews and case study. The first phase of this research, focused on the methodologies that could be used for risk assessment, considering the premises for sustainability and resilience engineering to achieve a sustainable prevention framework. The second part of the literature review focused on Multi criteria decision Analysis (MCDA) methodologies aiming at the quantification of considerations (qualitative) and factors (quantitative) within the former subjective FRAM evaluation. Finally, a comprehensive case study demonstrates how risk assessment, according to the sustainable prevention framework (FRAM-AHP), can be used in complex socio-technical systems.

2.1 Risk Assessment in Complex Socio-Technical Systems

The approaches of risk assessments are structured from the engineering tradition, represented by methods such as hazard and operability analysis (HAZOP), and fault tree analysis (FTA) that were developed for technological systems and then adapted to include human actions and organizational functions. While the sociotechnical systems and technology are developing rapidly, this is not happening with the repertoire of methods used for treatment of associated risks [17]. Traditional models consider the chain of events in a static way from a postulated design basis. An accident or accident evolution are represented as a sequence of well-defined events, in which one or more triggering events (main cause) combine in a static way, leading to well-defined effects [18]. Resilience engineering (RE) has become a new way of understanding and managing safety in sociotechnical systems and provides an alternative approach to coping with system complexity, instead of linear-based conventional risk management models [11, 16]. RE seeks to understand the entire process, without focusing on specific faults, because complex systems usually fail in complex ways. The safety processes contribute to safety when they are viewed according to the other objectives of the company, including environmental and operational efficiency [19].

The sustainable prevention of a system can be characterized as an emergent property, that is, it is something that cannot be designed like the component parts of the system [20]. In this sense, the occupational and environmental accidents can be characterized as emergent properties of complex systems [21]. Virtually all risk assessments are conducted in a state of relative ignorance about the full operation of the system in question, and in some cases in a state of complete ignorance regarding its typical functioning [8, 10]. To deal with the problems of current risk assessment tools, many researchers have developed new methods [22–26]. One of these methods is the FRAM, which is established in resilience engineering, providing an empirical approach that aims to describe and analyze emerging fault in complex socio-technical systems [26–28]. With the use of FRAM methodology which is structured on the principles of resilience engineering it was possible to consider it pays to invest in performance variability management as it allows better monitor and mitigate the variability that can lead to undesired outcomes. Moreover, it allows taking actions to anticipate, monitor and enforce the variability that can lead to positive results or successes, i.e., the ones that should be to encourage.

The knowledge required to analyze and evaluate complex system functions or work situations is often characterized by being complex, imprecise, uncertain, and vague. Such way of human thinking based on inherently inexact human concepts is required coping with the complexity of the environment/situation, because with an incomplete information set, humans may give satisfactory answers [20]. However, a structured method to support judgment and decisions may minimize the problems due to the excessive subjectivity in the evaluation process [29]. Multi criteria decision support methods are used in scenarios where there are numerous and perhaps conflicting goals, several decision-makers and a concomitant handling of complex matters [30–32]. AHP is a method for choosing the best alternative that incorporates qualitative considerations and quantitative factors into subjective decision-making. The theory aims to reflect what seems to be the method of natural functioning of the human mind; that is, when faced with a complex situation with many variables, people divide it into groups that share common characteristics [14].

2.2 Method Description

The main steps of a FRAM-AHP analysis are:

- Setting the goal for modeling and describing the situation to be analyzed.
- Identifying the main functions of the process, and characterizing them, according to input, output, preconditions, resources, time, and control. According to FRAM, the basis for risk assessment and the analysis of accidents is the design of functional entities relevant to the scenarios or tasks. Functional entities are characteristic functions, and not system structures or physical units. Inputs (I) provide links to previous functions. Inputs may transform or be used by the function to produce outputs. Outputs (O) provide links to subsequent functions. Resources (R) are necessary for the function to process the input (hardware, procedures, software, energy, and labor) to create the output. Controls (C) are the restrictions or controlling elements that serve to supervise or limit function (monitoring and tuning). Preconditions (P) are system

conditions that must be satisfied before performance of a function (another process or step, and specific condition) can occur. Time (T) or time window (duration) is a special type of resource or constraint based on an allowed amount of time.

- Identification of phenotypes of performance variability. According to FRAM manifestations of variability are identified from outputs of functions, according to the "elaborate solution." The "elaborate solution" uses phenotypes, or failure modes, normally used in safety studies. The necessary analyses involve four basic groups (time/duration; force/distance/direction; object; and sequence). This step is supported by AHP, given the participation of multiple decision-makers (experts), and the concurrent treatment of complex issues. The phase of collecting the judgment values starts following the hierarchical structuring of the problem shown in Fig. 1. This phase seeks to answer three main questions: What will be judged? How is it judged? Who should judge it? With regard to the first question, the appraiser must conduct a pairwise comparison of the elements on the same layer of the hierarchy, viewed from the perspective of elements positioned on the layer immediately above. Evaluators must have broad knowledge of the study area, as well as some experience concerning value judgments. The choice of experts is critical to the achievement of good results because AHP enables the capture and synthesis of individual knowledge. A questionnaire based on AHP hierarchical structure is used to obtain value judgments.
- Aggregation of variability. According to FRAM the variability of a function can result from coupling to upstream functions, where outputs from upstream functions (used as input, precondition, resource, control, or time) may vary and therefore can affect the variability of downstream functions. Characterizing the

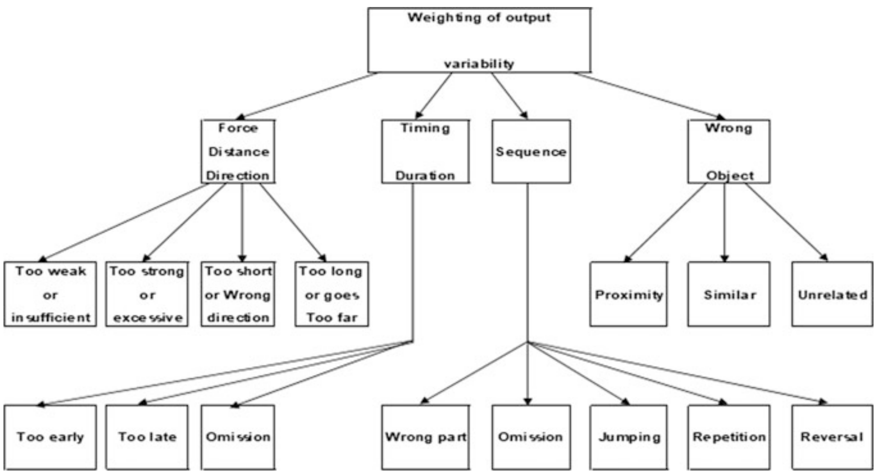

Fig. 1 AHP hierarchical structure for characterizing actual or potential variability

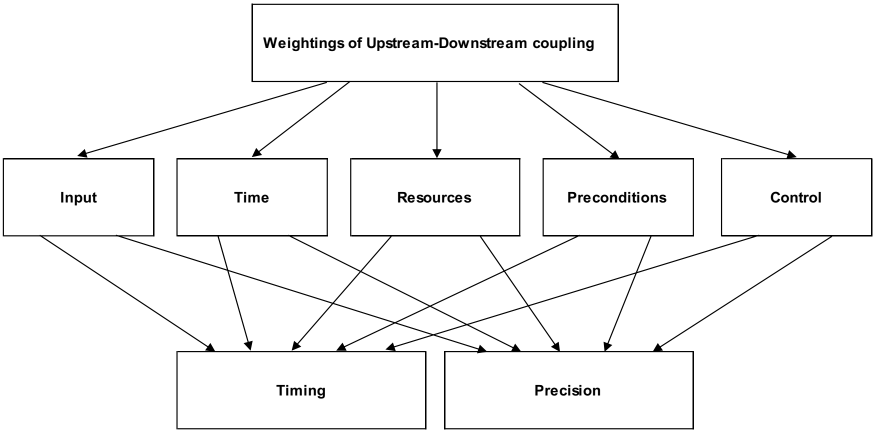

Fig. 2 AHP hierarchical structure for characterizing variability aggregation

actual or potential variability of each function involves analysis of five criteria, namely: input, preconditions, resources, time, and control under two alternatives (timing and precision). The analyses were also supported by AHP using the hierarchical structure shown in Fig. 2. A questionnaire based on AHP hierarchical structure is used to obtain value judgments.

- Defining functional resonances, based on potential/actual couplings among functions and providing ways to monitor and minimize the variability of performance. According to FRAM the determination of possible functional resonances is based on potential or actual couplings among functions. Analysis to determine functional resonance provides the necessary basis for identifying potential problem areas in the system's functioning, in addition to the more traditional analyses of failure modes or malfunctions. The high-priority coupling emerges as the simultaneous presence of a certain basic group of phenotypes, or failure modes in the output of a function, and in one of the downstream function entrances. These priority groups are used to characterize potential functional resonances in the system.

The last step is to propose ways to damper functional resonance. According to FRAM this model can be used to identify the conditions where developments may potentially get out of control. This model can, therefore, be used as a basis for proposing indicators, hence as a basis for monitoring.

2.3 Case Study

The pilot deployment of FRAM-AHP in the construction industry occurred in partnership with a large construction company involved in the venue for the World Cup, in the city of Rio de Janeiro. A detailed explanation of this case study was done in [33]. Two groups of construction workers participated in the FRAM-AHP modelling/assessment. One group was formed by three Health, Safety and Environment (HSE) specialists, to deal with questions related to the overall process, and three workers' representatives, to deal with questions related to the specific work activities. These workers were part of the team responsible for the reuse and recycling of waste generated by the construction, mainly involving the use of the crusher machine. This activity posed risks of accidents involving factors like noise, vibration, dust, thermal overload, postures, and other work accidents.

As a result, the multidisciplinary working group, after the analysis of the different resonant links found that the efficacious performance of the system requires perfect levelling of the equipment. Perfect levelling leads to low consumption of energy, low noise level, low dispersion of pollutants, high productivity, and a good level of safety for workers. If levelling becomes too variable, then charging and unloading will occur in adverse conditions, and without adequate control. This can lead to a situation that is out of control. In this sense, the damping of functional resonance for this case study should primarily consider modifications in the crusher incorporating an anchoring system and its respective automated control (reducing output variability).

3 Conclusion

The main aim of this study was to demonstrate an alternative approach to risk assessment that fits the sustainable prevention concept using resilience engineering concepts and methods. Our findings indicated that FRAM is able to support the identification of functional performance variability that can generate positive or negative impacts for environmental and occupational safety generating recommendations at design level and thereby ensure better effectiveness of environmental and occupational safety management strategies.

The adoption of AHP in risk assessments with FRAM allowed the exploration of new perspectives of the method to promote the participation of multiple stakeholders and quantifying some results. It is worth highlighting that the use of AHP also served as the basis for the necessary collaboration among the analysis team as well as present in a clear way the most likely and important scenarios. FRAM-AHP enabled the simultaneous participation of multiple experts, including the workers, in different steps of analysis, and led to the reduction of subjectivity associated with the process of risk assessment in complex socio-technical systems. A FRAM-AHP model can be used to identify the conditions where developments may potentially get out of control. It can, therefore, be used as a basis for proposing indicators, hence as a basis for monitoring. In this study considering the initial checklist function that aims at ensuring the proper functioning of the vital equipment items (identification of variabilities), FRAM—AHP can also be used to develop performance monitoring indicators associated with the, qualification issues, training and certification for operators and supervisors.

References

1. Boileau, P.: Sustainability and prevention in occupational health and safety. Ind. Health **54**(4), 293–295 (2016)
2. Rasmussen, J.: Risk management in a dynamic society: a modelling problem. Saf. Sci. **27**(2), 183–213 (1997)
3. Taubitz, M.: How safety fits with sustainability. Occup. Health Saf. **79**(9), 18 (2010)
4. Carvalho, P.: The use of functional resonance analysis method (FRAM) in a mid-air collision to understand some characteristics of the air traffic management system. Reliab. Eng. Syst. Saf. **96**(11), 1482–1498 (2011)
5. Shiralia, G., Motamedzadeb, M., Mohammadfama, I., Ebrahimipourc, V., Moghimbeigid, A.: Challenges in building resilience engineering (RE) and adaptive capacity: a field study in a chemical plant. Process Saf. Environ. Prot. **90**(2), 83–90 (2012)
6. Simon, A., David, B., Susanne, T.: Advantages for risk assessment: evaluating learnings from question sets inspired by the FRAM and the risk matrix in a manufacturing environment. Saf. Sci. **89**(1), 180–189 (2016)
7. Saurin, T.: The FRAM as a tool for modelling variability propagation in lean construction. In: 24th Annual Conference of the International Group for Lean Construction Proceedings on Proceedings, Sect. 11 pp. 3–12. IGLC-24, Boston, MA, USA (2016)
8. Hollnagel, E.: FRAM—The Functional Resonance Analysis Methods: Modeling Complex Socio-technical Systems, 1st edn. Ashgate, Aldershot, UK (2012)
9. Fung, I., Tam, V., Lo, T., Lu, L.: Developing a risk assessment model for construction safety. Int. J. Project Manage. **28**(6), 593–600 (2010)
10. Hollnagel, E.: Barriers and Accident Prevention, 1st edn. Ashgate, Aldershot, UK (2004)
11. Steen, R., Aven, T.: A risk perspective suitable for resilience engineering. Saf. Sci. **49**(1), 292–297 (2011)
12. Mitropoulos, P., Namboodiri, M.: New method for measuring the safety risk of construction activities: task demand assessment. J. Constr. Eng. Manag. **137**(1), 30–38 (2011)
13. Rosa, L., França, J., Haddad, A., Carvalho, P.: A resilience engineering approach for sustainable safety in green construction. J. Sustain. Dev. Energy, Water Environ. Syst. **5**(4), 480–495 (2017)
14. Saaty, T.: The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation, 1st edn. McGraw-Hill, New York, USA (1980)
15. Costa, H.: Multicriteria Decision Aid—AHP (in Portugese), 1st edn. Abepro, Rio de Janeiro, Brasil (2006)
16. Hollnagel, E., Woods, D., Levenson, N.: Resilience Engineering: Concepts E precepts. Ashgate, Aldershot (2006)
17. Badri, A., Nadeau, S., Gbodossou, A.: Proposal of a risk-factor-based analytical approach for integrating occupational health and safety into project risk evaluation. Accid. Anal. Prev. **48**, 223–234 (2012)
18. Pereira, R., Morgado, C., Luquetti dos Santos, I., Victor, P.: Safety analysis of the deepwater horizon blowout based on the functional resonance analysis model (FRAM). In: Proceedings on the 5th International Conference on Applied Human Factors and Ergonomics—AHFE, pp. 327–337, Kraków, Poland (2014)

19. Carvalho, P., Gomes, J., Huber, J., Vidal, M.: Normal people working in normal organizations with normal equipment: system safety and cognition in a mid-air collision. Appl. Ergon. **40** (3), 25–340 (2009)
20. Grecco, C., Vidal, M., Cosenza, C., Luquetti dos Santos, I., Carvalho, P.: Safety culture assessment: a fuzzy model for improving safety performance in a radioactive installation. Prog. Nucl. Energy **70**, 71–83 (2014)
21. Dekker, S., Cilliers, P., Hofmeyr, J.: The complexity of failure: implications of complexity theory for safety investigations. Saf. Sci. **49**(6), 939–945 (2011)
22. Aneziris, O., Topali, N., Papazoglou, I.: Occupational risk of building construction. Reliab. Eng. Syst. Saf. **105**, 36–46 (2012)
23. Ayoub, N., Musharavati, F., Pokharel, S., Gabbar, H.A.: Risk based life cycle assessment conceptual framework for energy supply systems in large buildings. J. Clean. Prod. **107**, 291–309 (2015)
24. Gurcanli, G., Mungen, U.: An occupational safety risk analysis method at construction sites using fuzzy sets. Int. J. Ind. Ergon. **39**(2), 371–387 (2009)
25. Sovacool, B.K., Andersen, R., Sorensen, S., Sorensen, K., Tienda, V., Vainorius, A., Schirach, O.M., Bjørn-Thygesen, F.: Balancing safety with sustainability: assessing the risk of accidents for modern low-carbon energy systems. J. Clean. Prod. **112**(5), 3952–3965 (2016)
26. Aguilera, M., Fonseca, B., Ferris, T., Vidal, M., Carvalho, P.: Modelling performance variabilities in oil spill response to improve system resilience. J. Loss Prev. Process Ind. **41**, 18–30 (2016)
27. Al, R., Andrea, S., Jamie, K., Wendy, G., Janet, A., Leigh, D., Lorna, M.: A systems approach using the functional resonance analysis method to support fluoride varnish application children attending general dental practice. Appl. Ergon. **68**, 294–303 (2018)
28. Fabio, P., Tarcisio, S.: Applying FRAM for problem solving in complex sociotechnical systems: case study of a hospital unit. Revista Produção Online **19**(1), 102–128 (2019)
29. Saurin, T., Junior, G.: Evaluation and improvement of a method for assessing HSMS from the resilience engineering perspective: a case study of an electricity distributor. Safaty Sci. **49**, 355–368 (2011)
30. Gomes, L., Araya, M., Carignano, C.: Decision-making in Complex Scenarios: Introduction to Discrete Methods of Multicriteria Decision (in Portugese). Pioneira, São Paulo, Brasil (2004)
31. Ali, H., Nsairat, S.: Developing a green building assessment tool for developing countries: case of Jordan. Build. Environ. **44**(5), 1053–1064 (2008)
32. Tiwari, D., Loof, R., Paudyal, G.: Environmental-economic decision-making in Lowland irrigated Agriculture using Multi-criteria analysis Techniques. Agric. Syst. **60**(2), 99–112 (1999)
33. Rosa, L., Haddad, A., Carvalho, P.: Assessing risk in sustainable construction using the functional resonance analysis method (FRAM). Cogn. Technol. Work. **7**(4), 559–573 (2015)

Prediction Model of Construction Accidents During the Execution of Structures Using Decision Tree Technique

María Martínez-Rojas, Juan Antonio Torrecilla-García and Juan Carlos Rubio-Romero

Abstract Construction is recognized as a dangerous industry. For this reason, in the Literature can be found a large number of studies with the aim of identifying the causes in order to devise mitigation strategies. In recent decades, the emergence of Information and Communication Technologies is providing a new research framework with this objective. This framework includes different techniques that allow, among other things, the analysis of large amounts of data efficiently. In this work, occupational accidents in Spain from 2003 to 2015 are explored. The objective of the present study is to develop a predictive model which not only could predict the occupational incidents but also provide a decision tree view in order to analyze the model. To achieve this objective, the KNIME Analytics Platform is used. The obtained results are good since a 99% of accuracy is obtained.

Keywords Construction · Occupational accidents · Prediction · Decision tree · Structure work

1 Introduction

Occupational accident is a major problem in every industry and concretely in the construction where the number of accidents is higher than others [1]. This issue of concern has drawn the attention of the research community and diverse proposals have been developed during last decade. Among them, one of the ways to increase awareness of how accidents are caused is by accident investigation technique [2]. This technique is intended to obtain accurate and objective information to improve

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the identification of risks and control them sufficiently and adequately. Research methods to predict and manage construction accidents are necessary given that understanding the factors affecting accidents is key to designing prevention and mitigation strategies. In addition, it has been discovered that prediction in the field of occupational accident investigation, is an important approach that works under the basic assumption that accidents can be prevented, if they could be predicted [3].

To this end, past data might be very useful to predict the future occurrences of events. The authorities are aware of the importance of this data and mechanisms for the acquisition of this data have been designed. Also, in Europe, Framework Directive 89/391/EEC, obliges employers to keep a list of occupational accidents resulting in a worker being unfit for work for more than three working days. In Spain, these notifications must be sent through the electronic system "DELT@" which involves the completion of an official workplace incident notification form with a total of 58 variables. The emergence of Information and Communication Technologies (ICT) has opened a new research framework that provides very efficient techniques to analyze large amounts of data.

Then, this study proposes a prediction model using the decision tree technique, which is a supervised data mining method that can serve as an effective tool for multivariate data analysis [4]. This technique can be used to explore relationships of a large number of variables to an output (target) attribute. The method creates a top-down branching structure, consisting of a root node that is split into a number of branches. As the construction process comprises a very long period of time and includes different activities that overlap in time, this paper focuses in occupational accidents that occurred during the execution of structures, which is one of the most dangerous.

After this introduction, the remainder of the paper is structured as follows. Section 2 presents some previous work from two perspectives. Section 3 details the methodology and data source and Sect. 4 presents results. Finally, Sect. 5 presents the conclusions and guidelines for future research.

2 Background

In this section, related works from two perspectives are detailed. First, from the construction one where many authors have explored the variables that contribute to the high rate of occupational construction accidents in last ten years. Secondly, from the technology perspective, concretely, the use of Data Mining (DM) that has increased in recent years for analyzing occupational accidents.

As can be seen in Table 1, most of the proposals in the literature focus on personnel variables when analyzing accidents. However, the variables related to the accident itself and the company have also drawn the attention of the research community.

On the other hand, as mentioned in the introduction, the ICT provide new techniques, as it is the case of Data Mining (DM), which allows to detect, interpret

Table 1 Variables grouped by categories

	Personnel	Company	Accident	Project
[5]	x	x	x	
[6]	x		x	
[7]	x	x		
[2]	x	x		
[8]	x			
[9]	x	x		x
[10]			x	x
[11]	x	x		x
[12]			x	
[13]	x			
[14]	x			
[15]			x	

and predict qualitative and quantitative patterns in large amounts of data, providing new information and knowledge. DM includes different methods and algorithms, such as Support Vector Machines (SVM), Neural Networks (NN) and Decision Trees (DT) to perform data classification tasks and predictive modeling [16]. It is believed that DT shows excellent potential for analyzing and modeling construction accident data. In the literature, some proposals are found focusing in this topic:

– The authors develop a predictive model with the aim of predicting the occupational incidents. In addition, the proposal also provides rules for explaining accident scenarios like near-miss, property damage, or injury cases [4].
– The authors discuss the process of transforming existing safety decision-making data into an event tree pathway [17].
– The authors demonstrate the utility of the decision tree technique in analyzing roofer fall accident data [18].

3 Data Source and Methodology

In this section, firstly, we explain the data used in this paper and then we develop the proposed methodology.

In Spain there is a repository given that, from 2003, all accidents resulting in one or more days off work must be notified through the electronic system "DELT@" [19]. This process involves the completion of an official workplace incident notification form where each accident is identified by 58 attributes. These attributes refer to diverse aspects of the accident: details of the worker, general and specific information about an accident, data of the construction site and data of the company, etc. Table 2 details each of these attributes.

Table 2 Variables considered

	Variable		Variable
1	Type of accident	30	Class. of econ. activities of center
2	Sex	31	Accident date
3	Nationality code	32	Off sick date
4	Professional situation	33	Weekday
5	Occupancy code	34	Time of day
6	Service length (months)	35	Work time
7	Service length (days)	36	Regular work
8	Type of contract	37	Risk assessment
9	social security scheme	38	Type of place code
10	Class. of econ. activities of company	39	Type of work code
11	Company staff	40	Specific physical activity code
12	Company province code	41	Associate agent specific activity
13	Contractor	42	Deviation code
14	Temporal company	43	Deviation associated agent
15	Preventive org. personal assumption	44	Code form_contact
16	Preventive org. designated worker	45	Agent associated—the form contact
17	Preventive org. own service	46	If has affected more than one worker
18	Preventive org. joint service	47	Code description of the lesion
19	Preventive org. external service	48	Degree of injury
20	Preventive org. none	49	Code of part of the injured body
21	Location of the accident	50	Type of assistance
22	Traffic accident	51	If worker has been hospitalized
23	If the center belongs to the company	52	Amount subsidy
24	If center belongs to another company	53	Degree of injury
25	Contractor/subcontractor	54	Discharge date
26	User of temporary company	55	Diagnostic code
27	Other	56	Days not worked
28	Center province code	57	Age
29	Center staff	58	Province code of the labor authority

The database contains a total of 1.525.865 occupational accidents occurred during the period 2003 and 2015 in the construction sector. Following, the dataset will be divided in order to select those related with the execution of structures. The number of accidents of this phase is 291.273 and include work related to foundations and structure.

To build the predictive model, we use the KNIME Analytics Platform is the open source software for creating data science [20]. This platform based on modular data pipelining concept facilitates the development of models. Figure 1 shows the workflow created for this article. Firstly, the CSV reader allows to read the csv file in order to load the data. The next step consists on identifying and renaming the

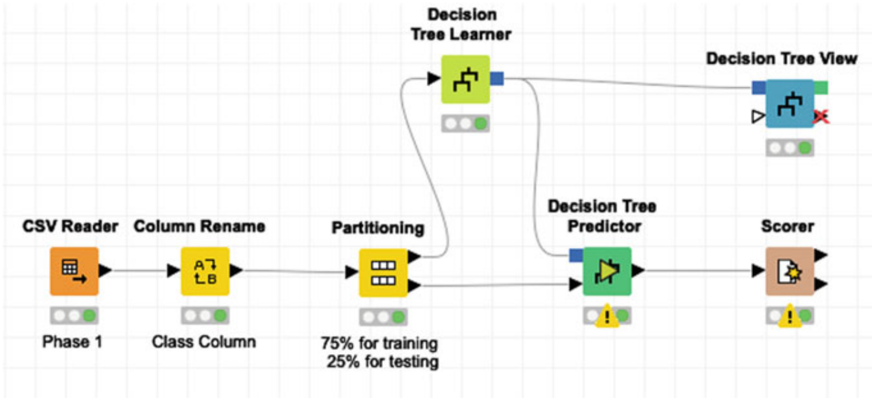

Fig. 1 Workflow to obtain a decision tree model

class variable among all variables. In our proposal, it is the variable corresponding to the degree of injury (light, serious, very serious, fatal). Then, the dataset is divided in order to use one part as learning (75%) and the rest as training (25%). Finally, the results of the classification process and the decision tree view are obtained. The view shows a decision tree consisting of a number of nodes. Next section details the obtained results.

4 Research Results

Before showing the decision tree, Table 3 shows the accuracy statistics of the model. As can be observed, the first column represents the class, the second the degree of injury, the third the number of cases for each class, the fourth the precision and the fifth the total accuracy. Notice that the precision means the fraction of relevant instances among the retrieved instances [21]. The general obtained result is good since the overall accuracy is 99%. However, there are differences in the results of each group of this class. As can be observed, group 1 achieves a 0.99%, meanwhile the rest of classes obtain a lower result. Notice that this lower result coincides with those groups with a smaller number of instances.

Following, once the model has been developed, the Decision Tree View node is applied in order to visualize and interpret the generated decision tree. Figures 2 and 3 illustrate the decision tree view from two perspective. The first one allows to see in detail the information contained in each node and, the second allows to explore how the tree is developed.

As can be observed in Fig. 2, the first target output in the root node is the “If the worker has been hospitalized” variable (51). This variable takes values 0 (has not been hospitalized) and 1 (if has been hospitalized). A total of 212532 (97%) instances refers to accidents where the worker has not been hospitalized. The

Table 3 Accuracy statistics

Class	Degree of injury	Instances	Precision	Accuracy
1	Light	286,662	0.994	
2	Serious	3947	0.593	
3	Very serious	470	0.778	
4	Fatal	194	0.615	
Overall				99%

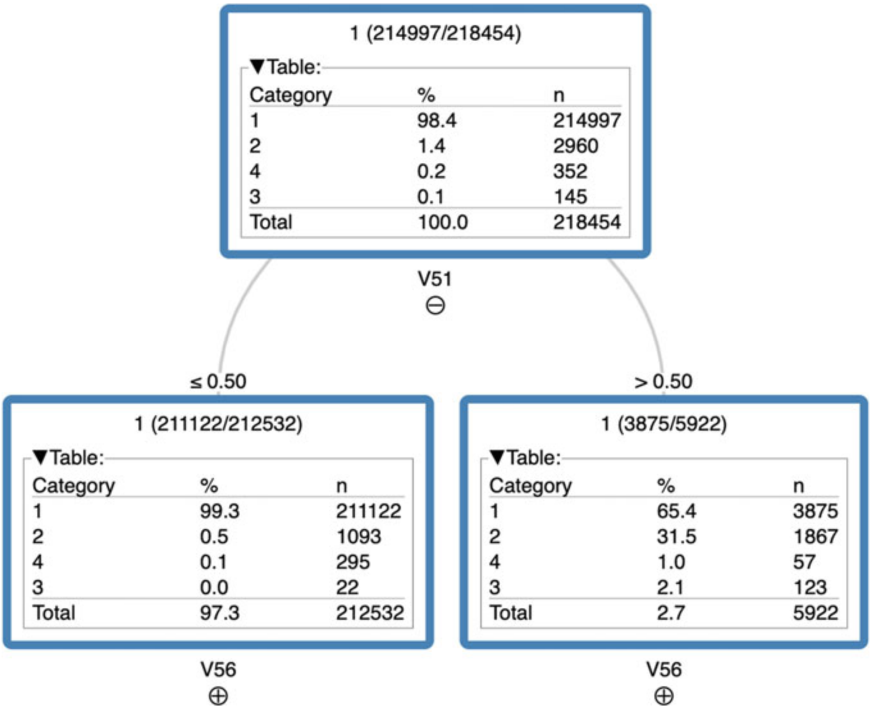

Fig. 2 Decision tree view

second level of the tree corresponds to “Days not worked” variable (V56) in both branches of the root node, as can be seen in Fig. 2. If the branches of this node are deployed, the decision values obtained can be seen in Fig. 3. For example, in the case that the worker has not been hospitalized, the decision value corresponds to 129.5 days (left part of the tree). However, if the worker is hospitalized, the decision value is 116.5 (right part). In each node, the number of instances for each group of classes is detailed. Unfortunately, it is not possible to represent the tree completely due to its extension.

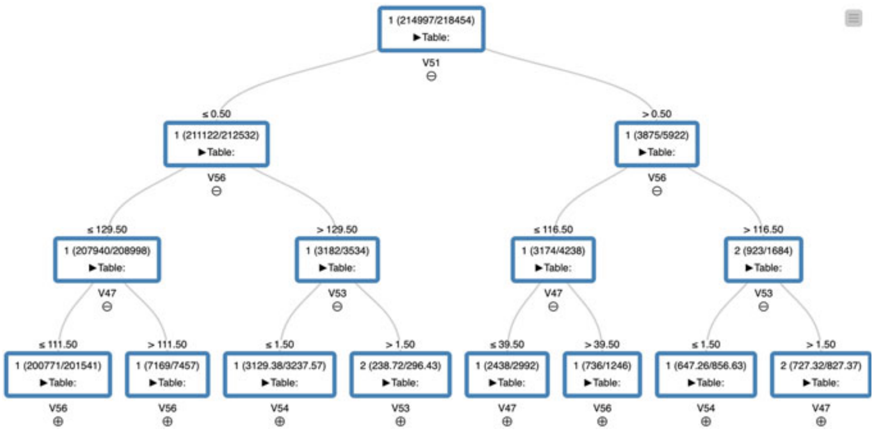

Fig. 3 Extended decision tree view

5 Conclusions

The prediction of occupational accidents is an important objective in the construction industry, as it could help to implement preventive measures for the reduction of accidents. In this work, we have developed a predictive model using the KNIME platform focuses on the accidents that occurred during the structure phase. Moreover, the degree of injury class has been fixed in order to build the model. The results are promising since an accuracy of 99% is obtained. As future work, other predictive models like support vector machines, k-nearest neighbor, or other ensemble techniques could be used. Additionally, a predictive model will be performed for each group of type of injury class in order to compare the results with the current work.

References

1. Xia, N., Wanga, X., Griffin, M.A., Wu, C., Liu, B.: Do we see how they perceive risk? An integrated analysis of risk perception and its effect on workplace safety behavior. Accid. Anal. Prev. **106**, 234–242 (2017)
2. López-Arquillos, A., Rubio-Romero, J.C., Gibb, A.: Accident data study of concrete construction companies' similarities and differences between qualified and non-qualified workers in spain. Int. J. Occup. Saf. Ergon. **21**, 486–492 (2015)
3. Boraiko, C., Beardsley, T., Wright, E.: Accident investigations one element of an effective safety culture. Prof. Saf. **53**(09) (2008)
4. Sarkar, S., Patel, A., Madaan, S., Maiti, J.: Prediction of occupational accidents using decision tree approach. In: 2016 IEEE Annual India Conference (INDICON), pp. 1–6. IEEE (2016)
5. Cheng, C.-W., Leu, S.-S., Lin, C.-C., Fan, C.: Characteristic analysis of occupational accidents at small construction enterprises. Saf. Sci. **48**, 698–707 (2010)

6. Rivas, T., Paz, M., Martín, J., Matías, J., García, J., Taboada, J.: Explaining and predicting workplace accidents using data-mining techniques. Reliab. Eng. Syst. Saf. **96**, 739–747 (2011)
7. López-Arquillos, A., Rubio-Romero, J.C., Gibb, A.: Analysis of construction accidents in Spain, 2003–2008. J. Saf. Res. **43**, 381–388 (2012)
8. Stoilkovska, B.B., Zileska Panˇcovska, V., Mijoski, G.: Relationship of safety climate perceptions and job satisfaction among employees in the construction industry: the moderating role of age. Int. J. Occup. Saf. Ergon. **21**, 440–447 (2015)
9. Martínez-Rojas, M., Marín, N., Molina, C., Vila, M.: Cost analysis in construction projects using fuzzy OLAP cubes. In: 2015 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), pp. 1–8. IEEE (2015)
10. Kang, Y., Siddiqui, S., Suk, S.J., Chi, S., Kim, C.: Trends of fall accidents in the U.S. construction industry. J. Constr. Eng. Manage. **143**, 04017043 (2017)
11. Mohammadi, A., Tavakolan, M., Khosravi, Y.: Factors influencing safety performance on construction projects: a review. Saf. Sci. **109**, 382–397 (2018)
12. Shao, B., Hu, Z., Liu, Q., Chen, S., He, W.: Fatal accident patterns of building construction activities in china. Saf. Sci. **111**, 253–263 (2019)
13. Hasebe, T., Sakai, T.: Are elderly workers more likely to die in occupational accidents? Evidence from both industry-aggregated data and administrative individual-level data in Japan. Jpn. World Econ. **48**, 79–89 (2018)
14. Al-Bayati, A.J., Abudayyeh, O., Albert, A.: Managing active cultural differences in US construction workplaces: perspectives from non-Hispanic workers. J. Saf. Res. **66**, 1–8 (2018)
15. Zhang, F., Fleyeh, H., Wang, X., Lu, M.: Construction site accident analysis using text mining and natural language processing techniques. Autom. Constr. **99**, 238–248 (2019)
16. Kim, Y.S.: Comparison of the decision tree, artificial neural network, and linear regression methods based on the number and types of independent variables and sample size. Expert Syst. Appl. **34**(2), 1227–1234 (2008)
17. Mosher, G.A., Keren, N.: Analysis of safety decision-making data using event tree analysis (2011)
18. Mistikoglu, G., Gerek, I.H., Erdis, E., Usmen, P.M., Cakan, H., Kazan, E.E.: Decision tree analysis of construction fall accidents involving roofers. Expert Syst. Appl. **42**(4), 2256–2263 (2015)
19. del Estado (BOE), B.O.: Orden tas/2926/2002, de 19 de noviembre, por la que se establecen nuevos modelos para la notificación de los accidentes de trabajo y se posibilita su transmisión por procedimiento electrónico. Spanish Government (2002)
20. KNIME: (2019). https://www.knime.com/
21. Martínez-Rojas, M., Marín, N., Vila, M.A.: A preliminary approach to classify work descriptions in construction projects. In: 2013 Joint IFSA World Congress and NAFIPS Annual Meeting (IFSA/NAFIPS), pp. 1090–1095. IEEE (2013)

Teachers' Perceptions of the Safety Competence of Process Operator Students

Noora Nenonen, Sari Tappura, Sanna Nenonen and Susanna Mattila

Abstract In the safety-critical process industry, the safety competence of process operators is essential. Process operators are educated at vocational education and training (VET) organizations. The reform of vocational upper secondary education in Finland emphasizes the role of on-the-job learning; thus, the process operator education program has changed. Early adoption of correct safety skills enables them to be followed in the workplace. Thus, it is important to study the safety competence of process operator students and related educational requirements in the current circumstances. Seven teachers from five VET organizations were asked to estimate their students' safety competence using a previously published framework. Overall, the interviewees considered that more safety competences were easy rather than difficult for their students. Knowledge and skills related to production processes, special and high-risk work tasks, exceptional and fault situations, general view, identification of own skills, and proactive mindset were most often viewed as difficult for students.

Keywords Process industry · Vocational education and training · Workplace learning · Safety competence

1 Introduction

In the safety-critical process industry, safety competence is essential for ensuring safe operations. In this industry, work typically involves dangerous materials, under extreme conditions, and with potential for major accidents. Thus, safety competence is an important skill for process operators. Furthermore, the increasing complexity of processes makes the safety-focused aspects of the process operator

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role significant [1]. A focus on safety and continuous competence development can also be a key determinant of company performance [2–4]. However, young and inexperienced workers typically encounter accidents more often than other employees [5, 6]. Therefore, new workers and students must be introduced to safe work practices from the very beginning of their careers [5].

Competence is defined as having an ability to transform knowledge and skills into practice in a qualified manner [7]. Competence also refers to specific knowledge, experiences, abilities, skills, traits, values, attitudes, understandings, and behaviors that are necessary for achieving a required level of performance [8–11]. Tappura et al. [12] developed a framework for process safety competence of vocational students.

Process operators working in the process industry are educated by vocational education and training (VET) organizations. If students learn to value process safety early in their education, then they are more likely to subsequently take this attitude into their workplaces [13]. Therefore, ensuring that students have sufficient safety competence is emphasized from the beginning and throughout the education process.

The education of process operators consists of studies arranged by VET organizations and involves workplace learning periods at process industry companies. As a result of vocational upper secondary education reform, learning in the workplace has increased [14, 15]. Close collaboration between students, VET providers, and workplaces has been found to be beneficial for improving student learning in general [16]. Similarly, cooperation is essential when students' safety competence is being developed. A basic understanding of safety and related practices is imparted to process operator students during their education in VET organizations [17]. Companies expect that students will have obtained basic safety knowledge before they proceed with further training or employment [18]. Training for company-specific safety requirements, cultures, and practices is provided in the workplace.

The objective of this paper is to increase understanding of how teachers view the safety competence of process operator students. Additionally, the factors that teachers think affect student safety competence are discussed.

2 Methods

This study is part of a larger study called Young Professionals in the Process Industry (NuPro) that focuses on workplace learning and safety in the process industry [see, e.g., 12, 18]. Due to the descriptive and contextual nature of the study, a qualitative approach [19] was employed. Interviews (see Table 1) were carried out in all five VET organizations participating in the project, which, to the authors' knowledge, totaled 23% of all VET organizations providing process operator education in Finland. Seven processing industry teachers were

Table 1 Background information of the VET organizations and interviewees

VET organizations (n = 5)	VET providers represented different geographic areas in Finland
	One to three processing industry teachers at each VET organization
	40–100 process operator students at each VET organization
	Process operator students mainly adults in two VET organizations, mainly young students in two, and one had adult and young students
Interviewees (7)	Six teachers and one training officer
	Two men and five women
	Work experience in current position from 3 to 18 years (average 11 years)

Table 2 Excerpt of the safety competence requirement framework used in the interviews

Category	Safety competence requirement	Description
Knowledge and skills	Production processes	Understanding the operating principles of the process (e.g., how the automation works, what energies are involved, and how to react to process alarms)
Values and attitudes	Serious attitude toward safety	Taking safety into account in all activities Active participation in developing safety (e.g., reporting safety observations) Following rules and reacting to unsafe behaviors
Abilities and traits	Courage	Courage to work in hazardous work environment business Courage to ask for help if the task at hand is new or beyond one's own competencies The confidence to act safely even under pressure

interviewed. This is the majority of the processing industry teachers in the collaborating VET organizations because there was only a few in each VET organization.

The interviews were based on the safety competence requirement framework (Table 2 and the Appendix) compiled in the previous phases of the NuPro study [12]. The safety competence requirements for basic process safety education of process operator students at VET institutions were originally compiled through interviews and a workshop with representatives of process industry companies, VET organizations providing education for process operators, and other expert organizations. Competence requirements were categorized as (1) knowledge and skills, (2) values and attitudes, and (3) abilities and traits, using the competence classifications presented in previous literature [8–11]. Each competence requirement was described in more detail.

In the interviews, safety competence requirements were discussed with the interviewees, who were asked to give their opinion on whether a certain requirement is easy, and students possess the basic competence related to it, or whether this competence is difficult for most process operator students, and could be improved.

The interviewees were asked to base their opinions on their overall experiences gained from different sources (e.g., discussions with students, seeing their behavior at work and exams covering some safety aspects) during their teaching careers. In addition, the reasons why some of these requirements are more difficult were discussed. All interviews were recorded and transcribed. The interviewees' views were categorized and summarized according to the safety competence framework and according to the themes arising from the data.

3 Results

3.1 Teachers' Appraisal of the Safety Competence of Process Operator Students

The views of the interviewed teachers on the safety competence of process operator students are summarized in a table in the appendix, according to the safety competence framework used in this study. Overall, most interviewees considered that there were more items in which the students would gain sufficient knowledge in than those items that were considered to be difficult for students.

In terms of the knowledge- and skill-related competences, the interviewees considered more than half of the 14 total items to be easy, and the remaining items (slightly less than half) difficult. For competences related to values and attitudes, most of the interviewees considered only one of the six items to be difficult—namely, admitting own mistakes—while the rest of the items were thought of as easy for the students. Concerning safety competences related to abilities and traits, five out of ten items were more often rated as easy rather than difficult. With respect to abilities and traits, the interviewees often pointed out that these competences vary considerably among students.

The items most often considered to be easy for students were all related to the knowledge and skills aspects of safety competence requirements. All interviewees believed that students gain sufficient competences related to general practices in the workplace. Furthermore, the majority of the interviewees believed that students either already have or would have sufficient competences concerning the operational environment, companies' safety procedures, and learning from experience. Similarly, all items that the interviewees most often considered to be difficult for students were related to safety knowledge and skills. Adopting knowledge and skills related to production processes, special and high-risk work tasks, exceptional and fault situations, general view, identification of own skills, proactive mindset, and hazard identification were all emphasized as being difficult for students. There were three items that the respondents equally often considered as either easy or difficult—items related to consequences of own actions, rationality, and carefulness.

3.2 Factors Affecting the Safety Competence of Process Operator Students

The interviewees mentioned that most items related to safety knowledge and skills were basic issues that are included in process operator education. Consequently, students should receive at least basic knowledge and skills related to these items, often during their education at VET organizations, before they move on to workplace learning. In addition, the interviewees reasoned that, e.g., because special and high-risk work tasks (as well as exceptional and fault situations) occur less often and are less emphasized during studies, these tasks are then more difficult for the students.

With respect to the competences related to values and attitudes, the interviewees mentioned that students learn these competences, at the latest, during workplace training. In companies, a serious attitude toward safety is unquestionable. The interviewees emphasized that there is a noticeable difference in safety values and attitudes of students before and after they participated in workplace learning or otherwise gained work experience, e.g., through a summer job. This particularly applies to younger students, who may first downplay safety issues while learning at a VET organization. Once students have experienced the workplace, they do not question the importance of safety and follow safety instructions better at VET than they did before. Nevertheless, some interviewees emphasized the importance of theoretical studies as well, indicating that they enable better practical learning results. Some interviewees noted that VET organizations should be as firm as companies about safety rules and behavior compliant with these rules. Moreover, acknowledging positive safe behaviors, such as making safety observations, was highlighted.

The interviewees emphasized that student competence varied a great deal, particularly regarding safety-related abilities and traits. These competences were regarded as important as the other competences. The interviewees pointed out the impact of age and previous work experience on safety-related abilities and traits. Adult students can reflect on the issues to be learned in light of their previous work experience. Younger students usually have less work experience that they could use as a background for their learning.

The interviewees also mentioned that some issues in the safety competence framework are more difficult to teach while others are easier. For example, some of the safety-related skills and abilities, such as stress tolerance, were considered to be less emphasized in process operator education. In addition, the interviewees mentioned production processes. The difficulty is that the same process element, such as steam, can be hazardous in some process environments but harmless in others, and students need to be able to estimate this depending on the given environment.

The interviewees summarized that adult students mostly have better safety competence than younger students. However, adult students may have previously adopted a less correct safety attitude, which they then need to try to change. The interviewees pointed out that adult students may sometimes, for instance, believe that a zero-vision goal is impossible to achieve.

4 Discussion

This study contributes to previous literature by providing teachers' perceptions of the safety competence of process operator students. The results can be used to guide the development of safety education for process operator students during VET. Companies may use the results to improve the competence of their current workforce.

Many of the safety competencies the teachers considered difficult for students were similar to those mentioned in previous studies. Congruent with previous studies, competences related to hazard identification [20, 21] and exceptional and fault situations, such as emergency response [21], were emphasized as difficult for students. Moreover, previous studies concluded that students' safety attitudes are poor and need improvement [21]. Similarly, this study showed that before workplace learning students' safety values and attitudes could be better.

In addition, the teachers' pointed out some industry-specific competences related to understanding of production processes and individual characteristics of the students that require special attention in the education of process operator students. As automation systems and technologies become more complicated, the importance of related safety competencies, such as situational awareness [1] and systems thinking [22], become even more important to ensure safe operations. Many safety researchers consider humans to be heroes in resolving system vulnerabilities [23–25], and the human factors approach has gained increasing attention in the process industry [1, 13].

This study has several limitations. The appraisal of the safety competence of process operator students was based on subjective opinions of only a small number of teachers. Further research should apply and compare different ways of assessing students' safety competence, such as assessments based on examinations or self-assessments of students with larger and more comprehensive data. The impact of students' background (e.g., work experience) on safety competence should be studied. Moreover, the framework used in this study describes safety competences on a general level while technical competence requirements vary across process industry companies.

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Appendix

Teachers' views of the safety competence of process operator students

Safety competence requirements	No. of interviewees			
	E*	D*	V*	-*
Knowledge and skills related to				
Production processes	2	5	0	0
Chemicals and chemistry	4	3	0	0
Special and high-risk work tasks	2	5	0	0
Exceptional and fault situations	2	5	0	0
Reading and following instructions	4	3	0	0
General practices in the workplace	7	0	0	0
Operational environment	6	1	0	0
General view	1	5	1	0
Consequences of own actions	3	3	1	0
Learning from experience	5	1	1	0
Identification of own skills	2	5	0	0
Proactive mindset	1	5	1	0
Companies' safety procedures	6	1	0	0
Hazard identification	4	3	0	0
Values and attitudes				
Serious attitude toward safety	4	2	1	0
Prioritizing safety	4	3	0	0
Zero-vision mindset	4	3	0	0
Lifelong learning	4	2	1	0
Professional attitude toward work	4	2	1	0
Admitting own mistakes	3	4	0	0
Abilities and traits				
Perceptual ability	3	1	2	1
Concentration	3	4	0	0
Stress tolerance	2	4	1	0
Rationality	2	2	2	1
Carefulness	2	2	2	1
Humility	3	2	2	0
Prudence	3	1	2	1
Vigilance	3	1	2	1
Calmness	3	1	2	1
Courage	2	3	1	1

*E: Easy for students; they already have good or basic competence or gain it during their education. D: This can be or is often difficult for students. V: Varies among students. |-: Do not know/No assessment

References

1. Nazir, S., Sorensen, L.J., Øvergård, K.I., Manca, D.: How distributed situation awareness influences process safety. Chem. Eng. Trans. **36**, 409–414 (2014)
2. Suikki, R., Tromstedt, R., Haapasalo, H.: Project management competence development framework in turbulent business environment. Technovation **26**(5–6), 723–738 (2006)
3. Swuste, P., Theunissen, J., Schmitz, P., Reniers, G., Blokland, P.: Process safety indicators, a review of literature. J. Loss Prev. Process Ind. **40**, 162–173 (2016)
4. Weick, K.E., Sutcliffe, K.M.: Managing the unexpected. resilient performance in an age of uncertainty, 2nd edn. Jossey-Bass, San Francisco (2007)
5. Laberge, M., Ledoux, E.: Occupational health and safety issues affecting young workers: a literature review. Work **39**(3), 215–232 (2011)
6. Salminen, S.: Have young workers more injuries than older ones? An international literature review. J. Saf. Res. **35**(5), 513–521 (2004)
7. Dreier, A.: Organizational learning and competence development. Learn. Organ. **7**(4), 206–220 (2000)
8. Boyatzis, A.R.: The Competent Manager: A Model for Effective Performance. Wiley, New York (1982)
9. Königová, M., Urbancová, H., Fejfar, J.: Identification of managerial competencies in knowledge-based organizations. J. Competitiveness **4**(1), 129–142 (2012)
10. Pickett, L.: Competencies and managerial effectiveness: putting competencies to work. Public Pers. Manage. **27**(1), 103–115 (1998)
11. Rothwell, W.J., Lindholm, J.E.: Competency identification modelling and assessment in the USA. Int. J. Training Dev. **3**(2), 90–105 (1999)
12. Tappura, S., Nenonen, S., Nenonen, N., Kivistö-Rahnasto, J.: Process safety competence of vocational students. In: Arezes, P. (eds.) Advances in Safety Management and Human Factors, AHFE 2019. Advances in Intelligent Systems and Computing, vol. 969, pp. 383–392. Springer, Cham (2020)
13. MKOPSC (Mary Kay O'Connor Process Safety Center): Process Safety for the 21st Century and Beyond. Texas A&M Engineering Experiment Station. Texas A&M University, TX, USA (2017)
14. European Commission: High-Performance Apprenticeships & Work-Based Learning: 20 Guiding Principles. http://ec.europa.eu/social/main.jsp?catId=1147&langId=fi&moreDocuments=yes. Last accessed 24 Oct 2019
15. Ministry of Education and Culture: Reform of Vocational Upper Secondary Education. https://minedu.fi/en/reform-of-vocational-upper-secondary-education. Last accessed 24 Oct 2019
16. Mikkonen, S., Pylväs, L., Rintala, H., Nokelainen, P., Postareff, L.: Guiding workplace learning in vocational education and training: a literature review. Empirical Res. Vocat. Educ. Training **9**, 9 (2017)
17. Tappura, S., Kivistö-Rahnasto, J.: Annual school safety activity calendar to promote safety in VET. In: Arezes, P.M., et al. (eds.) Occupational Safety and Hygiene VI: Proceedings of the 6th International Symposium on Occupation Safety and Hygiene (SHO 2018), pp. 131–135. CRC Press, London (2018)
18. Tappura, S., Nenonen, S., Nenonen, N.: Developing safety competence process for vocational students. In: Ahram, T., Karwowski, W., Taiar, R. (eds.) Human Systems Engineering and Design, IHSED 2018. Advances in Intelligent Systems and Computing, vol. 876, pp. 668–674. Springer, Cham (2018)
19. Denzin, N.K., Lincoln, Y.S.: Introduction: the discipline and practice of qualitative research. In: Denzin, N.K., Lincoln, Y.S. (eds.) The SAGE Handbook of Qualitative Research, pp. 1–19. SAGE Publications Inc., Thousand Oaks (2011)

20. Andersson, I.-M., Gunnarson, K., Rosèn, G., Moström Åberg, M.: Knowledge and experiences of risks among pupils in vocational education. Saf. Health Work **5**(3), 140–146 (2014)
21. Walters, A.U.C., Lawrence, W., Jalsa, N.K.: Chemical laboratory safety awareness, attitudes and practices of tertiary students. Saf. Sci. **96**, 161–171 (2017)
22. De Rademaeker, E., Suter, G., Pasman, H.J., Fabiano, B.: A review of the past, present and future of the European loss prevention and safety promotion in the process industries. Process Saf. Environ. Prot. **92**(4), 280–291 (2014)
23. Teperi, A.M., Puro, V., Lappalainen, J.: Promoting a positive safety culture in the maritime industry by applying the Safety-II perspective. In: Bernatik, A., Kocurkova, L., Jørgensen, K. (eds.) Prevention of Accidents at Work: Proceedings of the 9th International Conference on the Prevention of Accidents at Work (WOS 2017), pp. 197–203. CRC Press/Balkema, Leiden (2017)
24. Reason, J.: The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries. Ashgate Publishing Ltd., Cornwall (2008)
25. Hollnagel, E., Woods, D.D., Leveson, N. (eds.): Resilience Engineering: Concepts and Precepts. Ashgate Publishing Ltd., Hampshire (2006)

The Impact of Lean Tools on Safety—Case Study

Patrício Cordeiro, J. C. Sá, A. Pata, M. Gonçalves, G. Santos and F. J. G. Silva

Abstract The purpose of this work was to implement selected *Lean* tools—*5S*, *Visual Management* and *One Point Lesson* (OPL) considering the problems identified in the contract under the study, to promote the change of workers' behaviours, improve the work environment and consequently Safety and Health Conditions at Work (SHCW). Another objective was to analyse the impact of *Lean* tools on SHCW, taking into account the real perception of workers. To this end, a questionnaire on safety culture was made available to workers before and after the implementation of some *Lean* tools, as referred above. It was found that *Lean Thinking* and its *tools* are an added value for improving work conditions. Benefits such as the best warehouse organization and physic location (e.g., reduction in about 80% of the route and time in travel to search for materials and tools are highlighted); better organization of infrastructure workshops I and II (e.g., elimination of unnecessary items, tools' organization, layout changes); 41 and 38% increase in the results of *5S audits* to infrastructure workshops I and II, respectively; improvement of working practices with the creation of OPL's for the wagons transport and purge of the *oxiperm system* pump. Concerning employees' perception of the *Lean* tools implementation and their impact on the work conditions, it was found that 83.4% of workers agree that the work environment has been improved.

Keywords Lean tools · Lean · Safety · Lean safety · 5S · Visual management

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1 Introduction

Regarding the implementation of *Lean Practices* and looking at published papers, many of them present productivity benefits, cost reduction and increased quality of products and services. But few refer to the benefits related to safety and health in the workplace. According to the well-known *Lean Thinking* pillars, they are essentially related to the respect for people and continuous improvement. Respect for people is an organized, clean and risk-controlled work environment without workers' injuries or health risks [1]. Another aspect is to encourage workers to use all their capabilities to improve their work and their involvement with the work of others. On the other hand, there are many barriers to the implementation and consolidation of a safety culture in organizations. It is necessary to demonstrate the importance of the impact of lean tools in improving safety conditions to promote safety culture. The authors consider that investments in the area of safety are still low, compared to those made in the area of production. Training on safety and health at work is also unusual in many industrial atmospheres and cultures. Top management of organizations has been slow to understand the importance and impact that safety management has on their processes.

2 Literature Review

2.1 Lean Thinking and Tools

In an increasingly competitive and innovative market, it is essential for the survival of organizations the existence of strategic management with a focus on improving their production processes. Producing more, with better quality, at the lowest cost, with lower *lead time,* with increased safety and motivation, are today's challenges for all organizations. The adoption of *Lean Thinking Philosophy* is one of the strategies of change that, over the past few years, has been used by several organizations [2, 3]. *Lean Thinking* is a philosophy to create value and at the same time eliminate excesses, not being a goal or a purpose, but rather a path to achieve increased efficiency and effectiveness [4, 5]. *Lean Thinking* is a management and leadership model with a view to continuous improvement, encouraging people to think and solve problems, creating value [6].

2.2 Lean Application at Occupational Safety and Health

The fundamental principle of *Lean* is the identification of wastes/excesses in the system and reducing or eliminating them. During *Lean* implementation, there is a concern that the focus on productivity will result in ignoring how health and safety issues or excesses [7], lean-driven changes may introduce risks. The relationship between *Lean* and *Safety* should be compatible with improving processes. Both are in contradiction of occupational risks and workers' injuries, *Safety* by definition and *Lean* because money spent on applications for people assistance is thought a waste [8].

If safety does not properly consider organization's efforts to become *Lean*, eliminating wastes, can be penalized. This is because, if *Safety* concerns are not adequately addressed in *Lean* change, waste will be inadvertently introduced into the system and therefore unacceptable risks should be corrected. It is not possibly got skinny without *Safety* [9].

2.3 Impact of Lean Practices on Safety and Health at Work

Many health and safety benefits are obtained as result of implementing tools and practices of *lean*.

In a metallurgical company, all the known problems were analysed in a working cell used in the crane welding process. 5S methodology was implemented to make it more efficient and safer. The implementation of this tool allowed simple problem solving, without major investments and producing an extremely positive impact [9]. In the metallurgical area (Computer Numerical Control lathes) the Visual Management and Single Minute Exchange Die (SMED) were used to organize the CNC sector and reduce the *setup time* of these machines, evaluating the use of visual devices in combating losses during the *setup process*, within the concept of quick tooling. As a result, a reduction of the time loss generated by the tools' demand and a reduction of the *setup* times were obtained in 3 machines. It also allowed identifying flaws in the tool implementation process such as absence of training on the tool handling, the non-existence of periodic meetings and the absence of various implementation steps because no clear performance targets nor overall implementation plan were set-up [10].

Unitau [11] analysed the waste of time in the operational process and implemented improvements to increase production capacity by eliminating bottlenecks in the assembly area of mechanical and hydraulic equipment. From the *Kanban* implementation, improvements in the level of the operating system have been achieved in the synchronization and alignment of production and supply, programming flexibility, increased production capacity, reduction in the payment of parts to the supplier, immediate detection of production or supply bottlenecks, timely detection of non-quality problems, load visualization and working capacity of each sector, favouring decision-making in corrective action and implementation of improvements in the process.

At a University Engineering Laboratory, Jiménez et al. [12] implemented the 5S methodology to optimize work and safety. It resulted in the development of an organizational culture of all resources in laboratories. University laboratories have become an industrial laboratory, adapting to the safety and organization conditions that are usually found in the metallurgical industry. The knowledge, control and maintenance of the resources and activities involved are carried out in a shorter time and with considerable cost reduction. There was also an increase in the available space for the resources location.

In the construction sector (art works and high-speed railway) the principles of *Lean Construction* (*Last Planner® System* and percentage index of work performed (PTR)) were implemented in the integrated management of the production and safety at work. The application of *Last Planner* had as its main impact the possibility of predicting the activities that can actually be carried out each week, subject to the conditions found on the ground, as well as the analysis and registration of the reasons for the non-completion of scheduled activities and the presentation of a new production performance indicator, the PTR. The values of this indicator allow to pay attention to the existing problems that can thus be solved in real-time, avoiding their repetition. Also, Wu et al. [13] simulated data from 448 projects in China to determine the correlations between five types of *lean tools* and the four sub-construction systems (environmental system, equipment system, management system and overall system) through the implementation of 5S, Visual Management, *Just In Time* (JIT) and *Last Planner® System.* 5S management has significant positive impacts on the control of key locations and facilities in construction sites and contributes to mitigating environmental impacts. Visual management can significantly improve safety compliance and safety management. *JIT* management has significantly positive influences on the *layout* of safety facilities and formulation of the safety plan using *Last Planner® System* and the management of conferences are effective in improving safety training and implementation of the safety plan. These findings provide new insights into using *"slim" construction* to improve construction safety by implementing a *lean approach*. In the metallurgical sector, 5S methodology has been implemented to optimize work and safety. There were improvements in the level of reduction in the number of operations, reduction of unnecessary work, reduction of waiting times and travelling times, and also of stocks and excessive production.

Carvalho et al. [14] implemented a six-sigma project, using the *lean practice* of reducing/eliminating the seven losses, which initially aimed only at gaining productivity. Productivity benefits were obtained, decreased risk in carrying out packaging activity, better organization of the work environment, flow adequacy and stocks and, mainly, a greater approach with leadership have been achieved. Greater clarity was shown when workers should stop production and ask for help, thereby reducing the risk of producing non-compliant products or even performing improvisations that may increase the risk of injuries. In a pharmaceutical laboratory, the use of *Overall Equipment Effectiveness* (OEE) was evaluated as a tool for performance assessment, loss identification and as a basis for the development of continuous improvement actions. In addition to measuring the individual performance of equipment, it allowed the identification of waste that impacted the production process. The OEE also allowed managers to prioritize actions targeting the elimination of the main identified wastes, being used as a tool to support production management [15]. Leino and Helfenstein [16] implemented the *5-why tool* in incident analysis. The tool provided managers with the identification of latent failures that could be corrected before the occurrence of serious workers' injuries.

To improve the conditions that generate the health and safety of workers of a textile company, Castanheira and Loos [17] implemented the *kaizen* methodology. The results show that the *kaizen* tool assisted in improving methods and processes, and safety issues were addressed together, making the process safer and more robust, concluding that *lean* and SHW are allies and not opponents within the industrial process. Pedrosa [18] evaluated the risks applied to an industrial dryer by implementing the combined *Failure Mode and Effect Analysis* (FMEA) and *Analytic Hierarchy Process* (AHP) method. As a result, it is possible to measure and prioritize the recommended improvement actions that are intended to take on the analysis object, to reduce the risk associated to failure modes. The incorporation of the AHP method allows decision-making elements to have a tool relatively simple, specific and a mathematical decision support. The results indicated actions that led to product improvement (96% improvement was achieved for a door sealing cut problem caused by door assembly). Another door seal reduces the problem caused by mounting the instrument panel and the problem of the noisy door window, caused by the riveting hole position was completely avoided. Gonçalves et al. [19] created a methodology based on VSM (*Value Stream Mapping*) [5] and WID (*Waste Identification Diagram*) [20] called *Safety Steam Mapping* (SSM). The methodology allows, through the observation of a colour scheme, to perceive in the areas/processes belonging to the productive flow of the organization, what is the level of risk associated with each of them and what are the main causes for lack of safety, becoming easier the understanding about the organization's risk assessment. It can be concluded that the company presents a high risk related to each sector/process, mainly because most processes are painted red and orange, corresponding to intervention levels I and II, respectively, presenting serious risks. Moreover, the lack of safety is usually induced by human failures, followed by lack of space and finally due to equipment failures. A special not needs to be highlighted regarding the shipping warehouse, since 100% of the lack of safety are usually caused by human failures. Transport shows a satisfactory level, level of intervention III, but it is possible to improve it.

The main objective of lean tools is the improvement of production processes. The goal of this article is to show, globally, that all lean tools have a positive impact on safety, and therefore, also in working conditions. In this case study, only three lean tools have been used.

3 Methodology

The development of this work was supported by an exploratory methodology looking for greater familiarity with the studied subject and later by a quantitative methodology, resulting from data collection and contact with the organization.

Brainstormings were performed by the teams and the existing problems/waste in each area/task/process were pointed out. According to this survey and, considering the tools studied (*5S*, *Visual Management* and *One Point Lesson* (OPL) [21]), selected tools were implemented.

To evaluate the impact of *lean tools* on safety and workers' perception, a questionnaire on the company's safety culture was made available to everyone at the beginning of the project. This questionnaire covered several themes such as tasks characterization, SHW responsibilities, risk assessment for SHW, factors affecting work performance, risk prevention, safety procedures, the involvement of employees, motivation, training, leadership support, as well as influence and importance of safety conditions in the workplace. At the end of the project, the questionnaire was made available again to measure the project impact. The methodology implemented followed the *Plan-Do-Check-Act* (PDCA) cycle, involving a detailed implementation process, oriented to all employees: Involvement of all people and team training; Analyse, in-depth, the areas and activities to be intervened; Record what is important; Implement improvement actions (5W2H plan); Communicate the results; Implementation of the *Lean Safety* steps. To evaluate the initial state of the facilities and processes to be improved and subsequently measure the evolution of the implementation phases, 5S audit reports were carried out during the project (five audits). After the *lean* tools implementation, a questionnaire was distributed to workers—"Questionnaire about *lean* tools implementation", to analyse the workers' perception regarding the *lean* tools influence: 5S, Visual Management and OPL in the work environment and the benefits arising from this implementation.

4 Results—Case Study

The case study shows the implementation of *lean tools*: 5S, visual management and OPL, in the real context in a company providing hospital maintenance services (Fig. 1).

Before	After

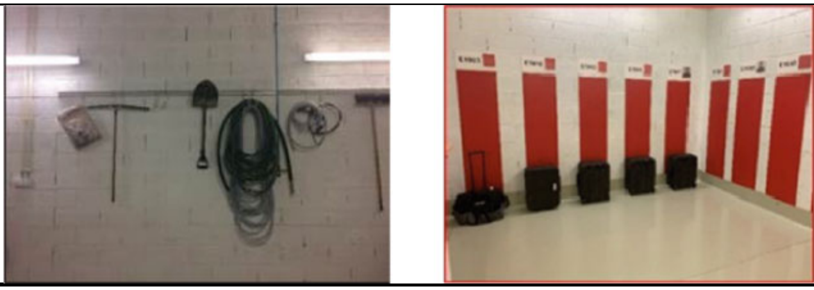

Fig. 1 Technicians room

4.1 Implementation of Lean Tools

From the observation of the equipment, work tools and different places under this study (e.g., Transport carts, Technician Room, Infrastructure Warehouse, Infrastructure Workshops 1 and 2 and Technical Rooms), opportunities for improvement were identified in organization issues and cleaning of areas, materials storage, people and materials movement, processes improvements, reduction of the number of injuries and improvement of the work environment. These changes also resulted in the decrease in the travelling distance of the warehouse manager when searching for the materials that made up the service orders of the tasks to be carried out, namely 83.3 and 81.8% in the route to be carried out and in the time spent daily, respectively.

4.2 Questionnaire on Implementation of Lean Tools

After implementation of the three *Lean* tools above-mentioned (5S, visual management and OPL), 83.4% of the workers surveyed agree that the work environment has been improved due to the posting of visual information in the workplace for communication of the risks prevention (e.g., safety rules, work procedures, maintenance plan) and 76.5% of workers also think that a better work environment is due to the tools organization through a visual management system such as shadow frames, in boxes or shelves, organized suitcases, transport trolleys and codified tools.

Regarding the benefits brought from the implementation of *lean* tools, 88.2% of the workers reported that this is due to the "workplace organization by eliminating unnecessary items", while 82.4% reported as main reason the "improvement in storage because there is more room to the tools" and "improving work practices". Otherwise, 77.8% refer that the "improvement in worker safety (more organized locations, tools and cleaner locations, rule-setting, safety instructions, and working procedures)" and "greater cleaning efficiency – organized tools and floor/floor free of unnecessary objects" are the main factor whose contribute to the benefits brought by Lean tools.

In terms of quantifying the impact of *Lean* tools on safety culture realized by workers, there was an impact of 25%, the highest of all on the factors affecting work performance, in which 75% of the workers realized that their work performance is affected by factors such as lighting, noise, vibrations, biological risks, etc. Also, on the subject responsibility in terms of SHW, workers feel now more responsible (increase by 6%). About training there was also an increase of 8% compared to the original survey. Finally, there was no impact on the influence of working conditions for performance in the workplace, as well as on general satisfaction with hygiene, safety and equipment conditions. This is because in the company, at least 84.8% of workers are already satisfied with existing safety conditions, facilities and, equipment.

4.3 5S Audits

Regarding 5S audits, the initial audit performed based on a checklist developed in this work context resulted in a quantitative result of 31 and 26% for infrastructure workshop 1 and 2, respectively. The final goal for implementation, 67%, was attained. The purpose of the audits was verifying the results of the implemented tools.

5 Conclusion

5S management has positive impacts on improving the organization and cleaning of areas, storing materials, movement of people and materials, reducing employee travelling distances, process improvements, reducing the number of injuries and improvement of the work environment. *Visual Management* has had strong impact on safety compliance and safety management, once by improving communication and visual information to workers, for example using, photographs, frames, schemes, graphics, allows any worker to be able to understand a functioning process. The *One Point Lesson tool* (OPL) had more impact on simplifying safety instructions/procedures, making them more accessible and understandable by workers. In conclusion, the implementation of *Lean* tools brings benefits in the field of safety action, in the context of continuous improvement, encouraging the participation of all, focusing on Top Management. It is essential to give feedback to teams, because only in this way they can be involved, motivated and participatory.

References

1. Silva, F.J.G., Gouveia, R.M.: Cleaner Production—Toward a Better Future. Springer, Switzerland (2020)
2. Rosa, C., Silva, F.J.G., Ferreira, L.P.: Improving the quality and productivity of steel wire-rope assembly lines for the automotive industry. Proc. Manuf. **11**, 1035–1042 (2017)
3. Sousa, E., Silva, F.J.G., Ferreira, L.P., Pereira, M.T., Gouveia, R., Silva, R.P.: Applying SMED methodology in cork stoppers production. Proc. Manuf. **17**, 611–622 (2018)
4. Farinha, L.S.B.: Lean manufacturing–Uma História de Sucesso em Portugal. Master thesis, Escola Superior de Gestão de Tomar. Portugal (2015) (in Portuguese)
5. Oliveira, J., Sá, J.C., Fernandes, A.: Continuous improvement through 'Lean Tools': an application in a mechanical company. Proc. Manuf. **13**, 1082–1089 (2017)
6. Neves, P., Silva, F.J.G., Ferreira, L.P., Pereira, T., Gouveia, A., Pimentel, C.: Implementing lean tools in the manufacturing process of trimmings products. Proc. Manuf. **17**, 696–704 (2018)
7. Bastos, A., Sá, J., Silva, O., Fernandes, M. C.: A study on the reality of Portuguese companies about work health and safety. Occup. Saf. Hygiene II. 687–691 (2014)

8. Pai, P., Cudney, E., Murray, S.: An analysis of integrating of lean and safety. In: 30th Annual National Conference of the American Society for Engineering Management 2009, ASEM 2009 (2009)
9. Costa, C., Ferreira, L.P., Sá, J.C., Silva, F.: Implementation of 5S Methodology in a metalworking company. DAAAM Int. Sci. Book **2018**(17), 001–012 (2018)
10. Rech, G.C.: Dispositivos visuais como apoio para a troca rápida de ferramentas: a experiência de uma metalúrgica. Universidade Federal do Rio Grande do Sul, Brasil (2004)
11. Unitau, V.F.: Implantação do *Kanban* na Linha de Montagem de Sistema e Equipamentos Hidráulicos e Eletromecânicos, 1–8 (2006) (in Portuguese)
12. Jiménez, M., Romero, L., Domínguez, M., del Mar Espinosa, M.: 5S methodology implementation in the laboratories of an industrial engineering university school. Saf. Sci. **78**, 163–172 (2015)
13. Wu, X., Yuan, H., Wang, G., Li, S., Wu, G.: Impacts of lean construction on safety systems: A system dynamics approach. Int. J. Environ. Res. Public Health **16**(2) (2019)
14. Carvalho, K.M.P., Picchi, F., Camarini, G., de Oliveira Chamon, E.M.Q: Benefícios para a segurança e saúde ocupacional em práticas *Lean* – Estudo de caso na siderurgia. Latin Am. J. Bus. Manage. **7**(1), 139–151 (2016) (in Portuguese)
15. Silva, B.M.S.R., Medina, F., Rocha, H.V.A., Oliveira, A.R.: Uso do indicador de eficácia global de equipamentos como ferramenta para melhoria contínua: estudo de caso aplicado à produção farmacêutica. Sistemas & Gestão, **11**(1), 49–60 (2016) (in Portuguese)
16. Leino, A., Helfenstein, S.: Use of five whys in preventing construction incident recurrence. In: 20th Annual Conference of the International Group for Lean Construction (2012)
17. Castanheira, P.Z., Loos, M.J.: The benefits of applying a Kaizen in the area of health and safety at work: a case study in a textile industry. J. Lean Syst. **4**(1), 02–21 (2019)
18. Pedrosa, B.M.M.: Análise dos Modos de Falha e seus Efeitos (FMEA) aplicada a um Secador Industrial. Master thesis, ISEL, Portugal (2014) (in Portuguese)
19. Gonçalves, I., Sá, J.C., Santos, G., Gonçalves, M.: Safety stream mapping—a new tool applied to the textile company as a case study. In: Occupational and Environmental Safety and Health, pp. 71–79. Springer (2019)
20. Sá, J.C., Carvalho, J.D., Sousa, R.M.: Waste Identification diagrams. In: CLME'2011-IIICEM – 6º Congresso Luso-Moçambicano de Engenharia – 3º Congresso de Engenharia de Moçambique, Moçambique, Maputo, pp. 207–208 (2011)
21. Santos, G., Sá, J.C., Oliveira, J., Ramos, D.G., Ferreira, C.: Quality and safety continuous improvement through lean tools. Chapter of the Book "Lean Manufacturing: Implementation, Opportunities and Challenges". Nova Science Publisher, New York (2019). ISBN 978-1536157253

Occupational and Environmental Hygiene

Indoor Radon Levels in Thermal Spas and the Compliance with the European BSS Directive: A Portuguese Case Study

Ana Sofia Silva, Maria de Lurdes Dinis and Alcides Pereira

Abstract Radon is a radioactive gas produced from the decay of uranium. It can be found in many types of soils and rocks, such as granite. Radon is the most important cause of lung cancer after smoking. The aim of this study was to evaluate continuously the radon concentration in two Portuguese thermal spas (A and B) between December 2018 and August 2019 (average of 107 days). The indoor air radon concentration was measured using CR-39 passive detectors in the following spaces: thermal pool, spa pool, ORL (inhalation therapy rooms), vichy shower, vichy nozzle, berthelot, whirlpool cabin and reception. The results showed that the radon concentration values at thermal spa A are much higher than the indoor air radon concentration values obtained at thermal spa B. In fact, 90% (17 values) of the indoor air radon concentration values at thermal spa A do not comply with the reference level established in the EURATOM Directive 2013/59 (300 Bq/m^3) and within the Portuguese legislation the Decree-Law 108/2018, of December 3. Therefore, generic and immediate actions should be adopted to reduce the exposure namely: strengthening the ventilation system, providing workers with personal protective equipment, and, informing the workers about the "existing exposure situation". Long-term actions should also be adopted as foreseen in the Decree-Law 108/2018, of December 3, including developing a radiological control plan for the facilities and workers.

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1 Introductions

Radon (^{222}Rn) is a colourless, odourless, tasteless radioactive gas, which may be found in indoor environments such as caves, homes, schools, and workplaces. It is produced from the natural radioactive decay of uranium (^{238}U), which is found in several types of soils and rocks such as granite and volcanic ones [19].

Radon can also be found in groundwater, and although radon in water does not pose a direct health risk, the use of water containing dissolved radon can enhance the levels of radon in the indoor air of dwellings and workplaces such as hydrotherapy centres or thermal spas [16].

In Portugal, the geological settings are mostly comprised of granite rocks with uranium mineralization, which represents a potential risk for the exposure to high indoor radon levels, particularly in some specific regions [10]. The presence of radon in thermal and in mineral waters may result in an additional exposure to natural radiation due to both indoor radon and radon decay products present in the environmental air of spas facilities; health effects from exposure to radon in thermal spas depend mainly on radon inhalation [12, 17].

Most of the existing thermal springs in Portugal are located in the North/Center regions, due to the geological and structural characteristics quite different from the remaining part of the territory. In 2019, 41 thermal spas were operating in Portugal, with an emergence temperature predominantly between 20 °C and 40 °C, never exceeding 80 °C [20].

The highest number of thermal spas appears in the North region (21), as Portugal is divided into large areas of significantly different geological and structural features. The Center region is the second one with more spas (20) in operation. The regions of Lisbon, Alentejo and Algarve areas together represent 12% of the national supply, with five spas.

The concentration of radon in indoor air depends on many factors such as uranium content in the underlying rocks and soils and the exchange rate between indoor and outdoor air, which in turn will depend on the type of construction, the ventilation habits of the inhabitants and the air-tightness of the building [6, 11].

This work focus on: (i) the health effects of radon; (ii) radon in workplaces; (iii) radon in drinking water, and, (iv) the regulatory framework of radon exposure.

1.1 Health Effects of Radon

Radon escapes easily from the ground into the air, where it decays emitting alpha particles and producing several solid radioactive products called radon daughters or "progeny". As we breathe, the particles are deposited on the cells lining the airways, where they can damage DNA and potentially cause lung cancer. The exposure to radon is considered to be a public health problem, since it is responsible for more than a half of the total dose of radiation received by the human population [3, 4, 8, 9, 18, 23, 25].

Radon is the most important cause of lung cancer after smoking. It is estimated that radon causes between 3–14% of all lung cancers in a country, depending on the average radon level and the smoking prevalence in a country [13, 24]. An increased rate of lung cancer was first seen in uranium miners exposed to high concentrations of radon. However, some studies in Europe, North America and China have confirmed that low concentrations of radon, such as those found in homes, also pose health risks and contribute significantly to the occurrence of lung cancer worldwide.

Every 100 Bq/m^3 increase in the radon concentration is estimated to increase the relative risk for lung cancer by 8–16%. After cigarette smoking, radon is the second main cause of lung cancer in the general population without occupational exposure [15, 24, 25].

Radon is much more likely to cause lung cancer in people who smoke. Smokers are estimated to be 25 times more at risk from radon than non-smokers. To date, no other cancer risks have been established with radon.

For this reason, radon has been classified by the International Cancer Research Agency (IARC) as a Group 1, a known cause of cancer in humans (ICRP [9]).

1.2 Radon in Workplaces

Radon enters in buildings through cracks in the floor or floor wall joints, gaps around pipes or cables, small pores in hollow-block walls, or sumps or drains. Radon levels are generally higher in basements and spaces in contact with the ground. Nevertheless, radon concentrations may vary between adjacent workstations as well as within a building on the same day and at different times.

In a study conducted in Portugal [23], 88% of indoor air radon concentrations of spas were found to be above the EU reference level and the protection threshold of national legislation. The main reason for these results is due to the geological setting of the thermal spas, located in granitic regions with uranium mineralizations.

In order to protect the workers, some generic and also specific actions should be taken: (i) enhance the buildings' ventilation by opening doors and windows; (ii) isolate the building from the ground; (iii) acquire and provide workers with personal protective equipment, in particular masks, to be used in thermal spas, where appropriate, thereby optimizing exposure; and (iv) implement a surveillance, monitoring and radiological protection system for workers in thermal spas [11].

1.3 Radon in Drinking Water

In many countries, drinking water is obtained from groundwater sources such as springs, wells and boreholes. These groundwater sources, namely natural mineral water, typically have higher radon concentrations than surface waters such as reservoirs, rivers or lakes.

To date, epidemiological studies have found no association between consumption of radon-containing drinking water and an increased risk of stomach cancer. Radon dissolved in drinking water can be released into the indoor air. Typically, a higher dose of radon is received by inhaling radon compared with ingestion.

Occupational exposure to radon in thermal spas occurs during drink cure, spa or dry spa thermal cure, and inhalation therapy. This burden additionally affects spas' staff with long-term impact due to longer and longer exposure periods over time [20].

1.4 Legislation Applicable to Radon Exposure

In Portugal, the increasing concern about indoor air as a vehicle for pollutants and contaminants has become so important in recent years that a more specific law was published (Ordinance Nº 353-A/2013 [14]) to replace a previous non-specific one (Decree-Law Nº 79/2006), in order to standardize all procedures related to the operation and maintenance of the IAQ (Interior Air Quality) in several settings. However, both are not adapted to this type of indoor environment, regarding the population attending the facilities. The Decree-Law 108/2018, of December 3, which transposes into national law the EURATOM Directive 2013/59 of December 5, 2013, establishes the legal regime for radiological protection, setting the rules safety precautions for protection against the dangers arising from exposure to ionizing radiation [5].

Activities involving the use of ionizing radiation give rise to situations of exposure to ionizing radiation, such as (i) planned exposure situations (situations arising from the planned operation of a radiation source or human activity causing exposure of persons or environment, such as the use of radiation sources in medicine or industry); (ii) existing exposure situations (the exposure to radiation already exists when the decision to control radiation is made). In such cases urgent action is not required: (iii) emergency exposure situations (arising from radiological emergencies, for example).

On the other hand, the EU approved as a reference concentration to limit the exposure to radon by 300 Bq/m^3 (annual average—Directive 2013/59/Euratom) in indoor air, including housing and workplaces. This benchmark has changed the previous recommendations from 400 and 200 Bq/m^3, for existing buildings and new construction, respectively [8].

However, the WHO has recommended reducing indoor air radon to below a level of 100 Bq/m^3 (annual average) or, if this is not possible, proposing that the threshold of 300 Bq/m^3 be adopted in the first step and to act progressively reducing the exposure [25].

1.5 Methods

For the implementation of the methodology to follow, a systematic review was carried out in several databases with Metalib tool. The search was done using a combination of a pair of keywords: "radon", "thermal spa" "indoor air" and "cancer" refined with "exposure" or "lung" in the subject research field.

Radon concentration was assessed with a passive method, for all therapy rooms and technical areas. Therefore, radon measurements were carried out by using CR-39 radon detectors during approximately 12 months covering continuous periods. The CR-39 detectors are enclosed in small cylindrical (5-cm height, 3-cm diameter) diffusion chambers and placed at approximately 1.5 meters from the floor [1, 2, 12, 18]. After the period of exposure, the detectors were retrieved and sent to a certified laboratory (UC-LRN).

The assessment of the indoor air radon concentration was performed at two Portuguese thermal spas, designated "A" and "B", as a follow up of a previous research work in 14 Portuguese thermal spas [18]. Spa "B" consists of two buildings, identified as Building 1 and Building 2.

In the case of the thermal spa "A", the measurements took place in two periods: (i) winter—21/12/2018 to 15/04/2019 (113 days); (ii) Spring/Summer—04/15/2019 to 08/26/2019 (102 days).

In the thermal spa "B" the measurements took place simultaneously in the two buildings between 15-04-2019 to 26/08/2019 (102 days).

2 Results and Discussion

In total, 22 results of indoor air radon concentration were obtained from two Portuguese thermal spas.

In the case of spa "A", the mean indoor air radon concentration is slightly higher in winter, 847 Bq/m^3, than in summer, 862 Bq/m^3. However, the highest value was obtained in the ORL (inhalation therapy room) during the summer period, 1941 Bq/m^3 (see Fig. 1).

Thus, it was found that 94% (17/18) of the indoor air radon concentration values of spa A do not comply with Portuguese legislation (300 Bq/m^3) and that 100% of the sites do not comply with WHO recommendations for radon concentration in indoor air (100 Bq/m^3).

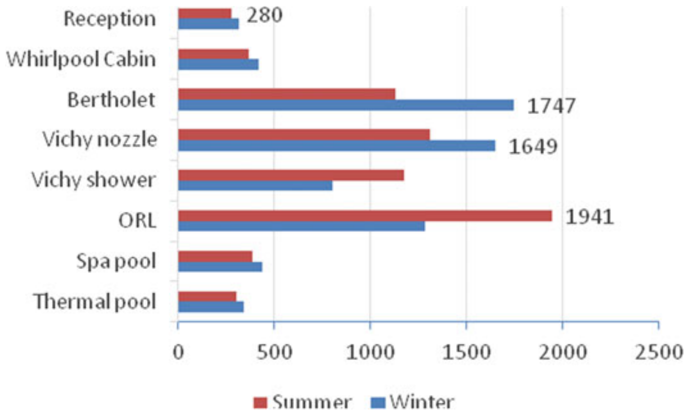

Fig. 1 Indoor air radon concentration values at spa A (Bq/m^3)

However, concentrations within the thermal spa vary widely, with a minimum of 280 Bq/m^3 and a maximum of 1941 Bq/m^3. In Bertholet (application of the heat and thermal steam in the vertebral region), nozzle shower, vichy shower and ORL spaces the indoor air radon concentrations are higher than the other spaces.

The explanation for these results is due to the fact that in these places there is the use of natural mineral water, where radon is also present [17, 18, 20, 21, 22].

In what concerns to the thermal spa "B", the indoor radon concentrations are significantly lower than the radon concentrations obtained at thermal spa "A". The average radon concentration in both buildings is 112 Bq/m^3, lower than foreseen in legislation and very close to WHO recommendations (see Fig. 2).

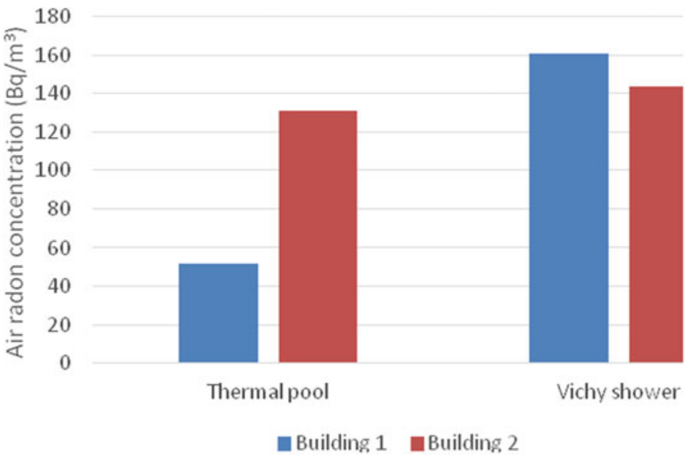

Fig. 2 Indoor radon concentration at spa "B"—Building 1 and 2 (Bq/m^3)

Table 1 Indoor air radon concentration at thermals spas A and B

	Thermal spa A		Thermal spa B		Average	Maximum	Minimum
	Winter	Summer	Building 1	Building 2			
Thermal pool	344	305	52	131	201	344	22
Spa pool	437	383	–	–	–	–	–
ORL	1283	1941	89	92	851	1941	89
Vichy shower	801	1175	161	144	570	1175	144
Vichy nozzle	1649	1310	–	–	–	–	–
Bertholet	1747	1133	–	–	–	–	–
Whirlpool cabin	415	366	–	–	–	–	–
Reception	313	280	–	–	–	–	–
Average	868		122		–	–	–
Maximum	1941		161		–	–	–
Minimum	280		52		–	–	–

Table 1 shows all values obtained for the indoor air radon concentration for the spa “A” and for the buildings 1 and 2 of spa “B”.

As the thermal spa “A” is located in a region with a potential to generate high indoor radon levels due to the geological setting as those that were obtained in this study, this facility could start to improve the ventilation system.

3 Conclusions

The indoor air radon concentration values at spa “A” are much higher than the indoor air radon concentration values at spa “B”.

Although thermal spa “B” is located in a geologically granitic area, and therefore it could be expected potential high radon levels, the values for both buildings comply with the legislation.

However, in the thermal spa “A”, 90% of the values for indoor air radon concentration do not comply with the legislation (300 Bq/m^3) which it is necessary to take some actions, namely: (i) inform and surveille the workers; (ii) implement a radiological protection system, in particular in what concerns to an “existing exposure situation” according to the Best Safety Standards [7].

References

1. Abo-Elmagd, M., Daif, M.M.: Calibration of CR-39 for radon-related parameters using sealed cup technique. Radiat. Prot. Dosimetry **139**(4), 546–550 (2010). https://doi.org/10.1093/rpd/ncp300
2. Alberigi, S., Pecequilo, B.R., Lobo, H.A., Campos, M.P.: Assessment of effective doses from radon levels for tour guides at several galleries of Santana Cave, Southern Brazil, with CR-39 detectors: preliminary results. Radiat. Prot. Dosimetry. **145**(2–3), 252–255 (2011). https://doi.org/10.1093/rpd/ncr054
3. EPA: Building Radon Out. A Step-by-Step Guide on How to Build Radon-Resistant Homes (2001)
4. EPA: Health Effects Assessment Summary Tables, Radionuclide Carcinogenicity Slope Factors: HEAST. United States Environmental Protection Agency (1997)
5. EURATOM: Diretiva 2013/59/ EURATOM (2013)
6. Godinho, M.M., Neves, L.J.P.F., Pereira, A.J.S.C.: O gás radão: um inimigo público… mas não na cidade de Coimbra, Actas do II Colóquio de Geografia de Coimbra Nº Especial de “Cadernos de Geografia”, pp. 65–70 (1999)
7. IAEA: Safety Standards Radiation for protecting people and the environment. In: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards Interim edition Nº GSR Part 3 (Interim), Vienna (2011). http://www-pub.iaea.org/MTCD/publications/PDF/p1531interim_web.pdf
8. ICRP: Lung Cancer Risk from Radon and Progeny and Statement on Radon, vol 40, no. 1. ICRP Publication 115 Ann, ICRP (2010) http://download.journals.elsevierhealth.com/pdfs/journals/0146-6453/PIIS0146645311000273.pdf. Accessed 04/2013
9. ICRP (1994): “Protection against 222Rn at home and at work”, ICRP Publication 65, Ann ICRP, 23
10. ITN: Radão um Gás radioactivo de origem natural (2011). Disponível em www.itn.pt/docum/relat/radao/itn_gas_radao.pps
11. LAO, K.Q.: Controlling indoor Radon—Measurement, Mitigation and Prevention, p. 2720. Van Nostrand Reinhold, New York (1990)
12. Madureira, J., Paciência, I., Rufo, J., Moreira, A., de Oliveira Fernandes, E., Pereira, A.: Radon in indoor air of primary schools: determinant factors, their variability and effective dose. Environ. Geochem. Health **38**, 523–533 (2016)
13. OMS: Radon and cancer. In: Fact Sheet Nº. 291. WHO, Geneve (2007)
14. Ordinance n.º 353-A/2013 de 4 Dezembro. Regulamento de desempenho energético dos edifícios de Comércio e Serviços (RECS) Requisitos de ventilação e qualidade do ar interior. Diário da República, 1ª Série - N.º235- 4 de dezembro de 2013 (2013)
15. Schmid, K., Kuwet, T., Drexler, H.: Radon in indoor spaces. An underestimated risk factor for lung cancer in environmental medicine. Deutsches Ärzteblatt Int. **107**(11), 181–186 (2010). https://doi.org/10.3238/arztebl.2010.0181
16. Silva, A.S., Dinis M.L.: Measurements of indoor radon and total gamma dose rate in Portuguese thermal spas. In: Arezes, P., Baptista, J.S., Barroso, M., Carneiro, P., Cordeiro, P., Costa, N., Melo, R., Miguel, A.S., Perestrelo, G. (eds.) Book chapter in: Occupational Safety and Hygiene IV, pp. 485–489. Taylor & Francis, London (2016). ISBN 9781138029422. https://doi.org/10.1201/b21172-93
17. Silva, A.S., de Lurdes Dinis, M.: Avaliação da concentração de radão nas águas minerais naturais nos estabelecimentos termais Portugueses. Int. J. Working Conditions, Publication Edited by RICOT, Institute of Sociology, University of Porto, Nº 13, June 2017 (2017). ISSN 2182-9535
18. Silva, A., Dinis, M.L., Pereira, A.J.S.C.: Assessment of indoor radon levels in Portuguese thermal spas. Radioprotect. EDP Sci. (2016). https://doi.org/10.1051/radiopro/2016077

19. Silva, A.S.: Occupational exposure to radon in thermal establishments. Doctoral dissertation on occupational safety and health. Faculty of Engineering, University of Porto (2016)
20. Silva, A.S., Dinis M.L.: The presence of radon in thermal spas and their occupational implications—a review. In: Arezes, P., Baptista, J.S., Barroso, M., Carneiro, P., Cordeiro, P., Costa, N., Melo, R., Miguel, A.S., Perestrelo, G. (eds.) Book Chapter in: Occupational Safety and Hygiene III, pp. 353–355. Taylor & Francis, London (2015a). ISBN 978-1-138-02765-7
21. Silva, A.S., Dinis, M.L.: Evaluation of the concentration of radon in the natural mineral water of Portuguese thermal spas. In: Arezes, P., Baptista, J.S., Barroso, M., Carneiro, P., Cordeiro, P., Costa, N., Melo, R., Miguel, A.S., Perestrelo, G. (eds.) Book Chapter in: Occupational Safety and Hygiene III, pp. 353–355. Taylor & Francis, London (2015b). ISBN 978-1-138-02765-7
22. Silva, A.S.: Exposição Ocupacional ao Radão em Estabelecimentos Termais. Tese de Doutoramento em Segurança e Saúde Ocupacionais, FEUP, Porto (2015)
23. Silva, A.S., Dinis M.L., Fiúza, A.: Research on occupational exposure to radon in Portuguese thermal spas. In: Arezes, P., Baptista, J.S., Barroso, M., Carneiro, P., Cordeiro, P., Costa, N., Melo, R., Miguel, A.S., Perestrelo, G. (eds.) Book Chapter in: Occupational Safety and Hygiene II, pp. 323–328. Taylor & Francis, London (2014). ISBN 978-1-138-00144-2
24. UNSCEAR: Sources and effect of ionizing radiation. United Nation Scientific Committee of the Effect Atomic, Radiation Report on The General Assembly, United Nation, New York (2000)
25. WHO: In: Zeeb, H., Shannoun, F. (eds.) Handbook on Indoor Radon: A Public Health Perspective (2009). ISBN 978 92 4 154767 3. (http://www.nrsb.org/pdf/WHO%20Radon%20Handbook.pdf. Accessed 04/2013

Occupational Exposure to Saw Dust: A Case Study

B. Duarte and M. L. Matos

Abstract Occupational exposure to saw dust is associated with the development of oncological diseases, namely nasopharyngeal cancers (about 44% are from nasal cavity and paranasal sinus cancers), in the wood and furniture industries, about 55.000, according to the (*Associação das Indústrias de Madeira e Mobiliário de Portugal*) AIMMP. It should be noted that since 1995 these dusts have been classified as carcinogenic, by The International Agency for Research on Cancer (IARC). The main objective of this study is to evaluate the exposure to saw dust, quantifying its concentration, comparing with values stipulated by existing legislation and standardization. In order to reach the objectives described above, total dust sampling was performed following the NIOSH0500 methodology, in several jobs, in three different carpentries. From the samplings performed, an average value of saw dust concentration was obtained in each workstation. After analyzing the values obtained in the measurements, performed in the real work context, it was verified there was legal non-compliance in the *Garlopa* workstation and values of the order of magnitude of the NP 1796 exposure limit values ELV, in the Manual Polishing workstation, in some of the Carpentry Workshops. However, if we consider the Scientific Committee on Occupational Exposure Limit (SCOEL) ELV we can state that only the Trimmer complies with the established ELV. Thus, corrective and/or preventive measures should be implemented by employers and preventive measures should be receptive by workers by implementing/complying to ensure the health and well-being of all, will be proposed.

Keywords Occupational exposure · Saw dust · Exposure limit values · Cancer

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1 Introduction

Occupational exposure to saw dust is a reality in our country, as the wood and furniture industry is one of the main manufacturing industries in Portugal and employs thousands of workers [1]. There are several international studies that indicate that occupational exposure to saw dust is closely linked to the development of occupational diseases, particularly oncological pathologies such as nasopharyngeal cancer. It is known that cases of onset and development of cancer diseases in Portugal have been increasing [2].

Observing the wood and furniture industry in Portugal, it is possible to find that the distribution of this sector is more frequent in the north of the country, with approximately 50%, followed by the central zone with 22% of total companies, according to the NUTS II classification in 2005 [3].

This manufacturing industry is characterized by its small size, since most of the existing companies are small to medium sized, since they are mostly family run. However, at national level it accounts for around 5% of turnover in the manufacturing industries [1, 3], employing thousands of workers, approximately 55,000, spread over different areas of the wood and furniture industry (e.g. sawmill, Carpentry, furniture…), in a total of 6000 companies [4, 5]. It can be said that in 2004, 10.2% of the assets employed in Portugal were working in this sector [3].

Regarding the characterization of this sector taking into account Safety, Hygiene and Health at Work, it can be stated that workers of this type of industry are exposed to several risks, highlighting the physical risks (noise, vibration, lighting and thermal environment), chemical hazards (paint and solvent vapors and dust resulting from the production process) and ergonomic hazards (adoption of incorrect postures, stress, repetitive movements, among others).

From exposure to saw dust workers may develop cancer pathologies, and it can be stated that in Portugal, about 44% of nasal cavity tumors and paranasal sinuses are associated with this occupational exposure [6], and that about 7% of Head and neck cancers in northern Portugal are nasopharyngeal [7].

The main objective of this project is to quantify the exposure to saw dust in wood processing industries and comparing it with existing studies, as well as the values stipulated by current legislation, in order to understand if these values will be alarming, with the possibility of increasing the incidence rate of occupational—oncological diseases. Preventive measures that can be implemented to protect workers will also be proposed.

1.1 Health and Safety Characterization in This Industrial Sector

As mentioned above, workers in this type of industry are exposed to saw dust resulting from the production process. Given that saw dust particles were considered carcinogenic by IARC in 1995, it is of utmost importance that the values obtained from on-site sampling are not only compared with particle exposure limit values (ELVs) but also with carcinogenic exposure limit values [8–10].

It is also noted that the European Union Scientific Committee on Occupational Exposure Limit (SCOEL) states that exposure to saw dust above 0.5 mg m^{-3} causes lung symptoms such as respiratory disease, occupational asthma and decreased pulmonary function [10, 11].

It should be noted that according to studies, the second leading cause of death in the European Union (EU) is cancer, as this disease causes 1 in 4 deaths, representing about 8.8 million of people. Cancer deaths in 2015, with 4–8% of these deaths being from occupational cancer. It is noted that occupational cancer in 2014 killed 666,000 people and in 2017, 742,000 people. Thus, there is an increase in the number of deaths associated with this type of occupational pathology, although it is considered that between 30 and 50% of cancers can be prevented [6].

It is also noted that several studies correlate exposure to saw dust, in various concentrations, with the onset of cancer diseases, including nasal and lung cancers. This relationship is verified, since dust produced during the production process, with sizes up to 5 μm, called breathable particles, are airborne and can penetrate into the lungs, depositing in the bronchi and alveoli [12, 13], while larger particles (10–20 μm) deposit on the walls of the nose and pharynx [14].

This occupational exposure to saw dust, in addition to oncological diseases is also associated with decreased lung capacity [11] and oxidative DNA damage of exposed workers [14, 15]. Regarding the development of cancer pathologies, it is important to mention that, according to clinical history studies, that 99% of patients diagnosed with nasal cavity adenocarcinoma were exposed to saw dust, with an exposure time ranging from 2 to 65 sometimes the pathology appeared long after the exposure ended and 18% of the users were still exposed at the time of diagnosis [16]. Furthermore, cumulative exposure to saw dust strongly increases the risk of developing nasal adenocarcinoma, especially when combined with exposure to formaldehyde [8].

Finally, it is essential to note that exposure to carcinogenic agents under consideration should be kept to a minimum. Workers exposed to these agents must be adequately protected to eliminate all exposure to the agent to its full extent. Based on the stipulated ELVs, worker exposure should be reduced as low as possible [17]. This reduction could be achieved by replacing working processes and/ or methods, by substituting less harmful substances and agents used, by reducing the number of workers exposed, implementing effective collective protection measures, training and information both the employer and all exposed employees [6].

2 Legal and Regulatory Framework

Decree-Law 88/2015 of 28/05 regulates the protection of workers against the risks associated with exposure to carcinogenic or mutagenic agents during work.

Directive (EU) 2017/2398 of the European Parliament and of the Council of 12/12 2017.

NP 1796: 2014—Occupational safety and health. Limit values and biological indices of occupational exposure to chemical agents. This Standard adopts as ELV and Exposure biological indices (EBI) the exposure limit values, and biological exposure indices proposed by the American Conference of Governmental Industrial Hygienists (ACGIH).

NIOSH0500: Particulates not otherwise regulated, total August 15, 1994.

3 Materials and Methods

The study presented assumed the sampling of total dust, whose collection equipment should simulate, as real as possible, the respiratory function of the employees, since the collected dust should be the same as those that would have the possibility to invade and accumulate in the respiratory tract [18].

To this end, three protocols were established with three different companies, considered as small to medium in size.

Carpentry A, located in *Guilhufe—Penafiel*, is part of a construction company, responsible for the manufacture of all kitchen furniture that equips the residential buildings they build and to produce necessary wood parts/structures for the execution of civil works. Carpentry B is in *Avanca—Aveiro* and manufactures hospital furniture in series and could respond to the smaller customer, being able to manufacture and assemble residential furniture. Carpentry C is in *Grijó—Vila Nova de Gaia—Porto*, working on the production of wood structures and furniture that will be used in the construction and remodeling of housing works.

The sampling method used, and the total dust sampling method was the *NIOSH0500—Particulates not otherwise regulated, total*, considering that saw dust particles are inhalable.

The sampling was performed with the aid of sampling pumps (Brand SKC Inc. Models 224-PCTX4) (Fig. 1) to which are coupled, through a plastic tube, cassettes of a three-piece, equipped with PVC filters of 37 mm in diameter, where the total dust will be retained.

The samplings were performed in the three companies in four similar jobs, by taking 3 samples at each workstation on different days, of which, as an example in Fig. 2, the Manual Polishing Workstation.

4 Results and Discussions

The final average concentrations obtained are the result of several samples at each workstation. These concentrations were compared with the legal and normative values: NP 1796:2014 (1 mg m^{-3}), Decree-Law 88/2015 (5 mg m^{-3}),

Fig. 1 Suction pumps and cassettes used for sampling

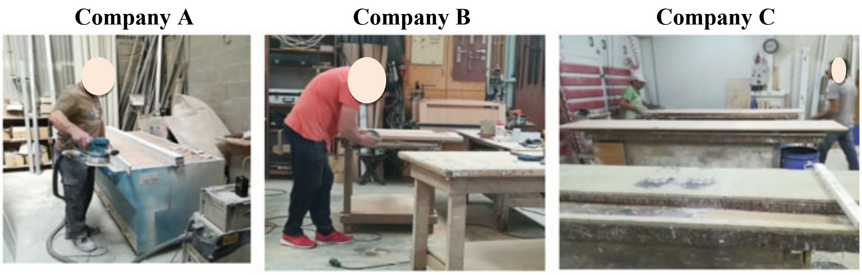

Fig. 2 Workstation manual polishing

Directive 2017/2398 (in 2020: 3 mg m^{-3} and from 2023: 2 mg m^{-3}) and SCOEL (0.5 mg m^{-3}).

Figure 3 presents the results obtained.

From the analysis to the graphs in Fig. 3, we can conclude that in the Manual Polishing workstation, the NP1796:2014 ELV is exceeded in Company A, which is justified because it is near the spray booth and away from any natural ventilation point. This is followed by the higher value found in Company C, which is justified by the fact that more than one worker is in this job. Concerning the recommendation of SCOEL (0.5 mg m^{-3}), higher values were found in all companies.

Regarding the *Garlopa* workstation, and since the samples were taken in the real work context, only Company B was available for sampling, and it was not possible to compare the results with the other companies. The *Garlopa* under study has an aspiration system, but it proves to be ineffective, since all ELVs were exceeded.

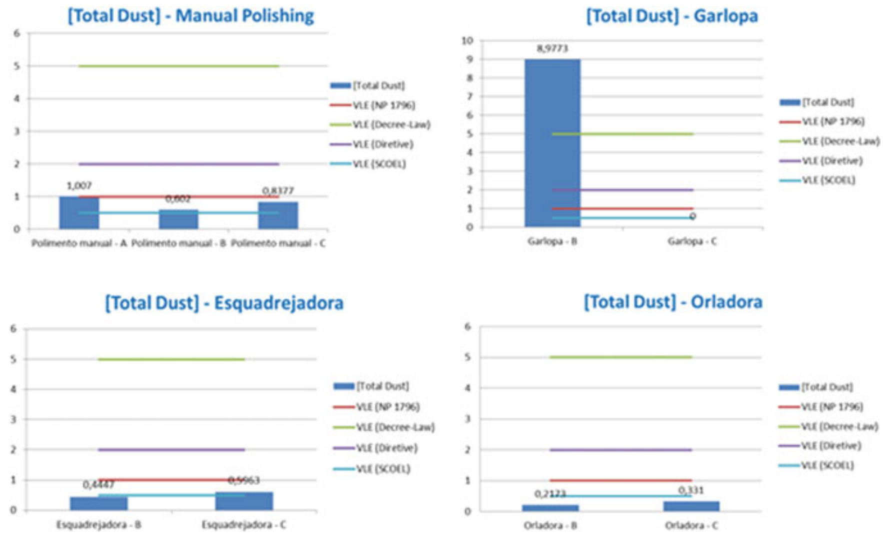

Fig. 3 Results obtained from average concentration per job

Company C square is the only one that exceeds the ELV (SCOEL) which can be justified by the fact that the suction system is under the cutting table and not near the blade, as is the case with Company B. Company B’s ELV (SCOEL) is not reached, because in addition to the above reason, it is also near the entrance gate that was open on the measurement days.

Finally, the work *Orladora*, it turns out that no ELV has been reached, since the function of this machine is to just paste and cut the wood sheets on the wood boards. However, Company C achieved slightly higher values, which may be justified by the fact that in the middle of the measurement a worker started cleaning the job next to *Orladora*.

4.1 Preventive Measures

The companies under study may adopt some preventive measures, such as medical surveillance of workers’ health, with complementary examinations, as well as providing, informing and making employees aware of the importance of using Personal Protective Equipment (PPEs) as dust protection masks to reduce occupational exposure to saw dust, thus preserving the health and well-being of workers. Table 1 also shows some specific measures for each job and/or company.

Table 1 Preventive measures

Workstations	Preventive measures
Manual polishing	– Change Company A *Layout* by placing this workplace in a place with natural ventilation and away from other jobs that may contribute to reducing occupational exposure to saw dust – Ensure that all companies have an effective saw dust extraction system – Evaluation/control of the effectiveness of existing aspiration systems in Company A and C - Provide Company B with a suction system (e.g. chimney type).
Garlopa	– Evaluation/control of the effectiveness of the existing suction system and which should be maintained/intervened if necessary – If possible, give preference to the use of other work equipment that performs the same function (e.g.: molding machine)
Esquadrejadora	– Evaluation/control of the effectiveness of the existing suction system and which should be maintained/intervened at *Esquadrejadora* in Company C

5 Conclusions

Of the jobs assessed, only *Garlopa* is in legal breach, the Manual Polishing job, in one of the companies obtained values of the order of magnitude of NP ELV and the other jobs, Orladora and Esquadrejadora, are in legal compliance.

It should be noted that the values obtained for the total dust concentrations obtained in each workplace and company are not comparable with other studies, since in the developed bibliographic review, they were not contemplated.

Based on the SCOEL, which states that exposure to values above 0.5 mg m^{-3} already negatively affects workers' health, this study shows that only the Orladora job in both companies and Company B *Esquadrejadora* do not reach this value. Therefore, all other jobs and workers associated with them may or may demonstrate pathology associated with the respiratory system.

References

1. EGP: Escola de Gestão do Porto. Estudo Estratégico das indústrias da madeira e mobiliário (2007)
2. LUSA Homepage: https://www.publico.pt/2018/09/12/sociedade/noticia/mais-de-58-mil-novos-casos-de-cancro-este-ano-em-portugal-e-quase-29-mil-mortes-1843880. Last accessed 02 Nov 2019
3. Eurisko – Estudos, Projectos e consultoria, S.A., Prevenção: Caracterização do sector Indústria da Madeira e do Mobiliário Segurança, Higiene e Saúde no Trabalho (2007)
4. Associação das Indústrias da Madeira e Mobiliário de Portugal, Caracterização estatística do sector da madeira e mobiliário: a economia portuguesa (2006)
5. Associação das Indústrias da Madeira e Mobiliário de Portugal Homepage. https://aimmp.pt/. Last accessed 27 Oct 2019
6. Barata, P., Cancro Ocupacional - poeiras de madeira - cancro da cavidade nasal e seios perinasais. Diálogos Técnicos sobre agentes químicos cancerigenos (2018)

7. Estevão, R.S., Ferreira, T., Machado, A., Fernandes, A., Monteiro, J.E.: Características epidemiológicas e demográficas dos doentes portadores de tumores da cabeça e pescoço no norte de Portugal: Impacto na sobrevivência, Acta médica Portuguesa, **29**, 597–604 (2016)
8. Siew, S.S., Martinsen, J.I., Kjaerheim, K., Saprén, P., Tryggvadottir, L., Weiderpass, E., Pukkala E.: Occupational exposure to saw dust and risk of nasal and nasopharyngeal cancer: a case-control study among men in four nordic countries—with an emphasis on nasal adenocarcinoma. IJC Int. J. Cancer 2430–2436 (2017)
9. Valliéres, E., Pintos, J., Parent, M., Siemiatycki, J.: Occupational exposure to saw dust and risk of lung cancer in two population-based case-control studies in Montreal, Canada. Environ. Health: Glob. Access Sci. Source **14**(1), 1–9 (2015)
10. Lee, T., Harper, M., Slaven, J., Lee, K., Rando, R., Maples, E.: Saw dust Sampling: field evaluation of personal when large particles are present. Br. Occup. Hygiene Soc. **55**(2), 180–191 (2011)
11. Badirdast, P., Azari, M.R., Salehpour, S., Ghadjari, A., Khodakarim, S., Panahi, D., Fadaei, M., Rahimi, A.: The effect of wood aerosols and bioaerosols on the respiratory systems of wood manufacturing industry workers in Golestan Province. Tanaffos **16**(1), 53–59 (2017)
12. Marková, I., Mracková, E., Ockajová, A., Ladomersky, J.: Granulometry of selected saw dust species od fust from orbital sanders. Wood Res. **61**(6), 983–992 (2016)
13. Alonso-Sardón, M., Chamorro, A., Hernández-García, I., Iglesias-de-Sena, H., Martín-Rodero, H., Herrera, C., Marcos, M., Mirón-Canelo, J.A.: Association between occupational exposure to saw dust and cancer: a systematic review and meta-analysis. PLoS ONE **10**(7), 1–16 (2015)
14. Staffolani, S., Manzella, N., Strafella, E., Nocchi, L., Bracci, M., Ciarapica, V., Amati, M., Rubini, C., Re, M., Pugnaloni, A., Pasquini, E., Tarchini, P., Valentino, M., Tomasetti, M., Santarelli, L.: Saw dust exposure induces cell transformation through EGFR-mediated OGG1 inhibition. Mutagenesis **30**(4), 487–497 (2015)
15. Bruscweiler, E.D., Wild, P., Huynh, C.K., Savova-Bianchi, D., Danuser, B., Hopf, N.B.: DNA damage among wood workers assessed with the comet assay. Environ. Health Insights **10**, 105–112 (2016)
16. Galleta, P., Nguyena, D.T., Russela, A., Jankowskia, R., Vigourouxc, C., Rumeau, C.: Intestinal and non-intestinal nasal cavity adenocarcinoma: Impact of saw dust exposure. Eur. Ann. Otorhinolaryngol. Head Neck Dis. **135**(6), 383–387 (2018)
17. Miguel, A.: Manual de Higiene e Segurança no Trabalho, p 477. Porto Editora (2014)
18. Barbosa, F., Matos, L., Santos, P.: As diferentes metodologias de recolha e análise de Poeiras Ocupacionais: Equipamentos e Técnicas. International Symposium on occupational safety and hygiene, pp. 570–574 (2010)

Noise Management in the Construction Industry Using Building Information Modelling Methodology (BIM): A Tool for Noise Mapping Simulation

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Abstract Noise pollution has a major impact on society since it causes both occupational and environmental disturbance. Long-term noise exposure may cause adverse health effects in workers. Nowadays, the construction industry is one of the economic activities that generates the most noise pollution. So that the construction industry contributes to sustainable development and minimizes its impact on society, it is necessary to evaluate the noise pollution construction generates. In this context, Building Information Modelling is a new methodology that offers enormous challenges and opportunities for the construction industry. The use of the BIM methodology can be applied to the field of acoustics and noise prevention. The purpose of this study is to propose a BIM tool to assist noise management in construction industry workplaces. This tool is intended as a primary step for providing advice on acoustic management. The results provided can be useful in supporting decision making and strategic plans can be designed to reduce the impact of noise generated by construction activities.

Keywords Construction · Noise map · BIM · Decision support · Noise management

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1 Introduction

Unpleasant physical conditions in some workplaces have adverse effects on productivity, performance, comfort and workers' health [1]. Noise pollution is one of the workplace environmental conditions that may result in decreasing employee performance, such as following organization rules, quality, cooperating to solve task problems, concentrating on tasks, creativity and absenteeism [2]. Sound pressure level and frequency characteristics have an impact on task performance [3].

The construction industry is one of the main sources of noise and vibration pollution [4–6] and these factors can affect the health of workers and people in the immediate vicinity of the construction activities. Noise pollution generated by construction equipment has a major social and environmental impact [7]. Noise may cause both occupational disturbance to onsite workers and environmental disturbances in the surrounding areas. Considering the large impact of noise on society, European policies have been developed for noise control and methods of assessing the impact of environmental noise [8] and minimum health and safety requirements [9].

In this regard, construction activities require a balance to be achieved between economic, social and environmental impacts in order to achieve sustainability in the construction industry. For that purpose, it is essential to manage noise based on an analysis of the sources and the effects on workers' health. Noise mapping is an efficient spatial database tool for quantifying and visualizing noise effects. Traditionally, Geographical Information Systems (GIS) and specialized software (e.g. CadnaA) are used to compute the distribution of sound pressure levels in large areas [10, 11]. However, the use of these software applications for small areas has a high time cost, as it involves modeling of different facilities and buildings and reintroduces data.

In this context, Building Information Modelling (BIM) is a new methodology that offers enormous challenges and opportunities for the construction industry [12, 13]. Many studies have shown the benefit of using BIM to improve many aspects of the construction process and buildings [14, 15]. BIM, as a methodology, can provided rich geometry and non-geometric data that can be used to perform noise simulation.

The purpose of this study is to propose a BIM tool to assist noise management in construction industry workplaces. This tool uses statistical interpolation methods to make noise maps from the data contained in the model. The goal is to provide a global point of view using a single software application for noise assessment. The results obtained support decision making and noise exposure management. As a result, a strategic plan can be designed to reduce the impact of noise generated by construction industries.

2 BIM-Tool Proposed

2.1 BIM Methodology

The tool developed in this research is based on BIM methodology. BIM provides capabilities such as 3D, 4D time, 5D cost modelling, 6D facilities management and sharing information/data [13]. BIM integrates the life cycle of the building, from conceptualization of the project to demolition [16]. Figure 1 shows the synthesis of aspects integrated in BIM.

The 3D parametric model is a solid and reliable database of the building and facilities. All the project information is stored in a single model. In this research, data contained in the 3D model have been used to develop a tool for noise management to improve risk control and workers' health and safety. As acoustic data can be integrated into the parametric BIM model, noise mapping can be performed in different facilities areas.

The BIM tool has been developed on Autodesk Revit® [17] (a BIM software tool) and the visual programme environment Dynamo (version 2.1.0) [18]. Revit software allows complex geometries to be created using parametric design and data contained in the 3D model to be managed. Although Revit® creates a solid database, this information can be difficult to access outside of the interface. To facilitate the development of tools, Revit® includes Dynamo visual programming tool.

In this study, the noise mapping tool has been created through the use of Dynamo nodes and Python scripting. The geometry data (facilities, buildings, etc.) and non-geometric data (acoustic data, project information, etc.) are extracted from

Fig. 1 Building information modelling lifecycle view

the BIM model. The noise mapping simulation tool is integrated in an automatic workflow that enables the sound pressure level distribution to be simulated according to the data extracted from the BIM model.

Noise map resolution and equivalent continuous sound levels L_{eq} are required as user input. The noise map resulting from the simulation is shown in the same interface of the BIM software. Figure 2 shows the diagram of the noise mapping simulation tool.

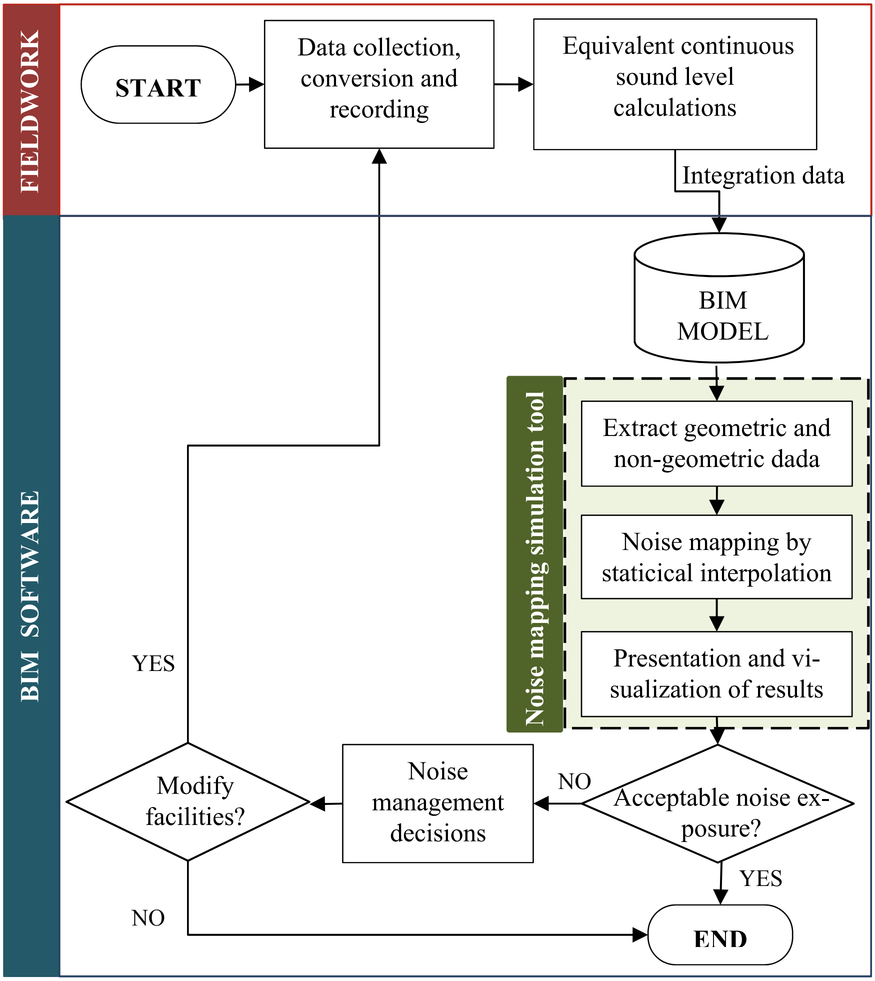

Fig. 2 Diagram of the noise mapping simulation tool developed

2.2 Noise Mapping

The noise pollution is analysed in this tool by geostatistical and kriging interpolating methods to generated noise maps. Kriging methods refer to several least-squares methods to provide the Best Linear Unbiased Predictions (BLUP) with minimum variance [19, 20]. Ec. 1 shows the general equation of the kriging method [21]:

$$N_0 = \sum_{i=1}^{n} W_i N_i$$

where

N_0 represents the noise value for interpolation at (x_0, y_0),
W_i represents the weights that correspond to each N_i at (x_i, y_i) used in the calculation of N_0 (W_i value is a direct function of the variogram model)
N_i represents noise values of the reference points.

The noise map is calculated using the ordinary kriging method; however, the user can choose between ordinary, spherical, exponential, Gaussian or power interpolation methods [22].

3 Case Study for the Tool Proposed

The tool has been applied to a case study. Data from a concrete plant were used for this purpose. Figure 3 shows the distribution of the facilities and Fig. 4 shows the noise map resulting from the tool. The resulting noise map is displayed on the same interface as the BIM software.

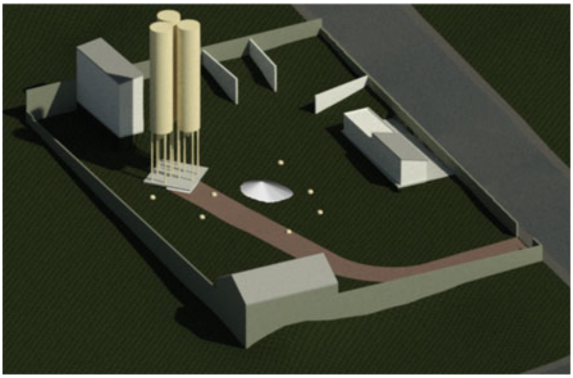

Fig. 3 Distribution of concrete plant facilities

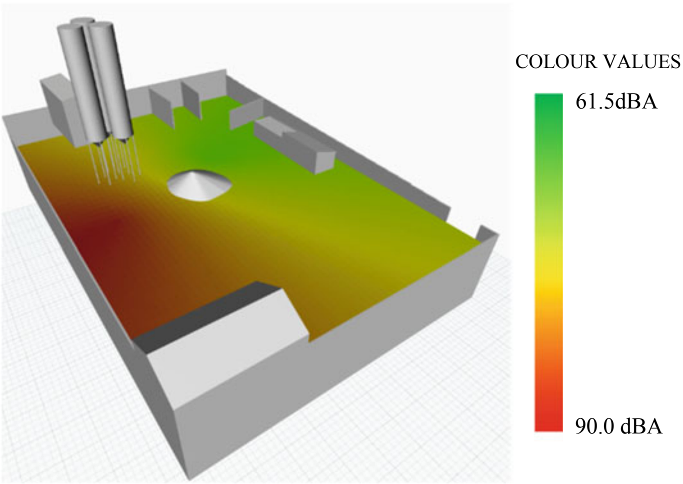

Fig. 4 Noise map generated by the proposed tool

The integration of all data in a single model avoids constant export/import processes, and, consequently, inefficiency and instantaneous lack of information. This tool integrates the results obtained in the structure of the BIM model, thus offering a solution and resources to improve decision making in terms of workers' health and safety in relation to noise exposure.

4 Conclusions

Considering the results obtained in this research, it can be stated that the BIM tool suggested is appropriate to assess the noise pollution in construction industry workplaces. In this study we have proposed a tool for supporting a decision-making process for noise management to improve risk control and workers' health and safety.

After analysing the results obtained, the following advantages can be highlighted: (1) no need to use a different software application, (2) as the BIM tool extracts data from the model, human errors associated with data re-entry are avoided and (3) visualizing the results in the same interface facilitates an comprehensive management of noise. Therefore, the tool can help to obtain a better visualization of the analysis without exporting or regenerating the model in different software. The BIM tool developed in this research is intended as a primary step in the Construction industry to provide advice on acoustic management.

References

1. Ismail, A.: Multiple linear regressions of environmental factors toward discrete human performance. In: Proceedings of the 4th International Conference on Environmental and Geological Science and Engineering (EG'11). WSEAS Press, Spain (2011)
2. Kahya, E.: The effects of job characteristics and working conditions on job performance. Int. J. Ind. Ergon. **37**(6), 515–523 (2007)
3. Nassiri, P., Monazzam, M.R., Asghari, M., Zakerian, S.A., Dehghan, S.F., Folladi, B., Azam, K.: The interactive effect of industrial noise type, level and frequency characteristics on occupational skills. Perform. Enhancement Health **3**(2), 61–65 (2014)
4. Ballesteros, M.J., Fernández, M.D., Quintana, S., Ballesteros, J.A., González, I.: Noise emission evolution on construction sites. Measurement for controlling and assessing its impact on the people and on the environment. Build. Environ. **45**(3), 711–717 (2010)
5. De La Hoz-Torres, M., López-Alonso, M., Ruiz Padillo, D., Martínez-Aires, M.: Analysis of whole-body vibrations transmitted by earth moving machinery. In: Proceedings of International Symposium on Occupational Safety and Hygiene, SHO, pp. 453–456 (2017)
6. De la Hoz-Torres, M., Martínez-Aires, M., Martín-Morales, M., Padillo, D.R.: Whole body vibration and acoustic exposure in construction and demolition waste management. In: Occupational Safety and Hygiene VI: Book Chapters from the 6th International Symposium on Occupation Safety and Hygiene (SHO 2018), 26–27 March 2018, Guimarães, Portugal, p. 273 (2018)
7. Priede, T.: Noise in engineering and transportation and its effect on the community. SAE Trans. 213–233 (1971)
8. Directive 2002/49/ec of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise—declaration by the commission in the conciliation committee on the directive relating to the assessment and management of environmental noise
9. Directive 2003/10/ec of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). Doue, February 2003
10. De Kluijver, H., Stoter, J.: Noise mapping and GIS: Optimising quality and efficiency of noise effect studies. Comput. Environ. Urban Syst. **27**(1), 85–102 (2003)
11. Barber, J.R., Burdett, C.L., Reed, S.E., Warner, K.A., Formichella, C., Crooks, K.R., Theobald, D.M., Fristrup, K.M.: Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. Landscape Ecol. **26**(9), 1281 (2011)
12. Porwal, A., Hewage, K.N.: Building information modeling (BIM) partnering framework for public construction projects. Autom. Constr. **31**, 204–214 (2013)
13. Smith, P.: BIM implementation—global strategies. Procedia Eng. **85**, 482–492 (2014)
14. Aguilera, A.A., López-Alonso, M., Martínez-Rojas, M., Martínez-Aires, M.: Review of the state of knowledge of the BIM methodology applied to health and safety in construction. In: Occupational Safety and Hygiene V: Selected Papers from the International Symposium on Occupational Safety and Hygiene (SHO 2017), 10–11 April 2017, 1st edn., p 447. Guimarães, Portugal (2017)
15. Martinez-Aires, M.D., Lopez-Alonso, M., Martinez-Rojas, M.: Building information modeling and safety management: a systematic review. Saf. Sci. **101**, 11–18 (2018)
16. BuildingSMART Australasia: National Building Information Modelling Initiative. Vol. 1, Strategy: A strategy for the focussed adoption of building information modelling and related digital technologies and processes for the Australian built environment sector, report to the Department of Industry, Innovation, Science, Research and Tertiary Education, Sydney, June (2012)
17. Autodesk Revit: http://www.Autodesk.Es/products/revit-family/overview. 25 October
18. Dynamo Version 2.1.0. https://dynamobim.Org. 25 October

19. Isaaks, E.H., Srivastava, R.M.: An Introduction to Applied Geostatistics. Oxford University Press, New York, USA (1989). Jones, D.R., A taxonomy of global optimization methods based on response surfaces. J. Glob. Optim. **23**, 345–383 (2001)
20. Oliver, M., Webster, R.: A tutorial guide to geostatistics: Computing and modelling variograms and kriging. Catena **11**, 356–369 (2014)
21. Harman, B.I., Koseoglu, H., Yigit, C.O.: Performance evaluation of IDW, kriging and multiquadric interpolation methods in producing noise mapping: a case study at the city of Isparta, Turkey. Appl. Acous. **112**, 147–157 (2016)
22. Oliver, M.A., Webster, R.: Kriging: A method of interpolation for geographical information systems. Int. J. Geogr. Inf. Syst. **4**(3), 313–332 (1990)

Thermophysiological Behavior of the Human Body in Ceramic Industrial Environments

António M. Raimundo, A. Virgílio M. Oliveira and Divo A. Quintela

Abstract The objective of the present study is to perform a detailed analysis of the effect of a hot thermal environment on the human body. For that purpose, a sample of eight Portuguese ceramic industries comprising twenty-one workplaces was considered. The choice for this activity sector is due to its relevance in social and economic terms but also due to its manufacturing characteristics, which are prone to expose the workers to severe thermal environments. Therefore, this activity sector is, among others, particularly adequate for the purpose of this study. The Predicted Heat Strain model (PHS) and a 111-node Human Thermoregulation model (HuTheReg) were used to describe the level of heat exposure. Based on parameters of the human body predicted by the two models, the heat stress risk is estimated and analyzed. The assessment of the compliance level between the PHS and the HuTheReg models is based on a statistical analysis. The agreement between the results estimated by both models is good; however further enhancements are required. Nevertheless, both are valid and very useful tools to assess the level of thermal stress in hot environments. The fact that both models are independent and that complementary information is obtained, results in very positive outcomes thus leading the authors to recommend their joint use whenever detailed assessments of work environments is foreseen.

Keywords PHS model · HuTheReg model · Ceramic industry

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1 Introduction

The social and economic importance of the ceramic industry is very significant. Therefore, the assessment and analysis of its thermal environments have justified the efforts of research teams in the recent years [1, 2]. The intrinsic manufacturing procedures and the equipment of the ceramic industry contribute to the severe thermal environments that characterize this activity sector. Heat stress conditions are thus common and, besides the well-known decrease in productivity, often disregarded, heat disorders such as heat cramps, heat exhaustion by water and salt depletion, heat syncope or even heat stroke represent additional difficulties that, depending on the level of the exposure, have to be overcome.

The goals of the present study are to perform a detailed evaluation of the level of thermal stress that can be reached when working in hot environments of the ceramic industry and to compare the results obtained with two methodologies of assessment, the Predicted Heat Strain model (PHS) [3] and a 111-node Human Thermoregulation model (HuTheReg) [4]. This analysis is based on a field survey carried out in the Portuguese ceramic industry and represents a follow up of previous studies [1, 2]. In [1] the Wet Bulb Globe Temperature (WBGT) index was considered while in [2] the PHS model was used. Now, the heat stress level is also assessed using a thermoregulation model. In a complementary perspective, the agreement between the results of the two models is analyzed using statistical tools.

2 Methods

2.1 Predicted Heat Strain Model

The Predicted Heat Strain model (PHS) [3, 5], extensively tested and validated [5, 6], provides reasonably accurate heat stress predictions. For acclimatized and non-acclimatized subjects, the human exposure to a given thermal environment is assessed based on the comparison between a set of parameters predicted by the model with their corresponding limits (vd. [3]). If the value of a predicted index (w_p, Sw_p, SWTOTg and t_{re}) is equal or higher than its limit (w_{max}, Sw_{max}, D_{max} and $t_{re,max}$), it means that the acceptable exposure time in the work environment has been exceeded. Therefore, the occurrence of a heat stress condition might happen.

The PHS model has limits of validity, namely in terms of air temperature, partial water vapor pressure, difference between the mean radiant and air temperatures, air velocity, metabolic rate and intrinsic clothing insulation that must be taken into account. More details about the PHS model can be found elsewhere [3, 5].

2.2 Human Thermoregulation Model

The software HuTheReg, implemented by the authors [4], is composed by several modules; its main module, which simulates the human body thermophysiological response, is based on the original Stolwijk model [7], improved with recent knowledge of the literature [8, 9]. It was validated for a wide range of conditions, namely in [10, 11].

With the HuTheReg software a significant number of data can be obtained, both for the human body as a whole and for each of the segments. Due to space restrictions, this paper focuses only a limited number of parameters, namely the rectal, hypothalamus and skin temperatures and the evaporation rate. More descriptions of this model can be found in [4].

2.3 Experimental Data

In a former field survey within the Portuguese ceramic industry [1, 2], 21 workplaces were identified as potentially problematic in terms of heat stress. The data collected in that field survey represents the basis of the present analysis, which are shown in Table 1, namely the values of the individual and physical parameters of the workplaces: activity level (M), clothing insulation (I_{cl}), air (T_a), globe (T_g) and mean radiant (T_{mr}) temperatures, water vapor partial pressure (p_a) and relative humidity (HR).

3 Results and Discussion

In both models (PHS and HuTheReg) a sudden exposure to the hot thermal environment is assumed, fact that does not necessarily corresponds to a common scenario and to the actual real conditions. In fact, a gradual and progressive exposure is quite common and, as the worker moves towards the workplace, both body temperature and activity level increase. The HuTheReg allows the simulation of this initial stage but, as the PHS does not and the objective of the present work is also to compare the two simulation models, that initial stage was not considered in the HuTheReg. Thus, both models assume that the human body is initially at a status of thermal neutrality.

The HuTheReg assumes the water intake as equally distributed over the four hours working period; in the PHS, the simulations were performed every 15 min during the same 4 h working period. The global comparison that was performed is based on the predicted values of the rectal temperature and the evaporation rate obtained at the same instant. Since all workplaces were assessed on the bases of its heat stress potential risk, it was necessary to normalize the rectal (T_{re}) and the

Table 1 Field data of the 21 problematic workplaces of the ceramic industry (adapted [2])

Workplace	M (W)	I_{cl} (clo)	T_a (°C)	T_g (°C)	T_{mr} (°C)	p_a (kPa)	HR (%)
C01	297	0.90	29.0	35.7	44.7	1.2	30.0
C02	297	0.90	34.9	35.8	37.1	2.0	35.3
C03	180	0.65	34.5	37.1	40.6	2.3	41.6
C04	180	0.65	36.2	52.3	70.1	1.4	23.7
C05	239	0.60	27.8	34.1	42.7	1.3	33.8
C06	297	0.65	39.3	63.0	86.2	1.2	16.8
C07	239	1.00	37.8	41.8	47.0	1.3	19.4
C08	180	0.90	29.9	44.8	62.4	1.1	25.9
C09	273	0.65	41.3	42.1	43.1	1.4	18.1
C10	224	0.65	37.3	39.5	42.4	2.1	32.5
C11	310	0.41	41.6	43.0	44.8	1.7	21.0
C12	235	0.41	30.6	30.9	31.3	1.8	40.7
C13	280	0.41	30.6	31.0	31.6	2.2	49.7
C14	310	0.60	27.6	28.3	29.3	2.2	59.5
C15	338	0.60	25.7	26.6	28.0	1.7	51.0
C16[d]	407	0.61	34.2	33.7	33.0	2.7	49.5
C17	407	0.60	33.1	36.4	40.9	2.1	41.2
C18	355	0.60	32.0	34.7	38.5	2.1	44.3
C19	400	0.60	32.3	33.1	34.2	2.1	43.5
C20	254	0.60	31.6	38.3	47.1	1.4	29.8
C21	254	0.60	37.1	45.2	55.1	1.4	22.0

hypothalamus temperatures (T_{hyp}), for which the following equations were assumed:

$$RT_{re} = \frac{T_{re} - T_{re,n}}{T_{re,\max} - T_{re,n}} \tag{1}$$

$$RT_{hyp} = \frac{T_{hyp} - T_{hyp,n}}{T_{hyp,\max} - T_{hyp,n}} \tag{2}$$

where RT_{re} and RT_{hyp} represent the thermal state of the subject, values that allow the assessment of the potential risk of the workplace [12].

In Eq. (1) $T_{re,n}$ corresponds to the rectal temperature at rest in a neutral thermal environment ($T_{re,n}$ = 36.8 °C) and $T_{re,\max}$ to the one of the onset of a heat stress condition (defined as $T_{re,\max}$ = 38 °C in the PHS model [3]). In Eq. (2) $T_{hip,n}$ represents the hypothalamus temperature at rest in a neutral thermal environment ($T_{hip,n}$ = 36.8 °C) and $T_{hip,\max}$ to the one above which a heat stress condition should be assumed ($T_{hip,\max}$ = 39 °C) [10]. To define the level of heat stress based on RT_{re} and RT_{hip} values, the following criteria proposed by [12] was adopted:

$0 < RT \leq 0.5 \rightarrow$ favorable thermal state;
$0.5 < RT \leq 1.0 \rightarrow$ acceptable thermal state;
$1 < RT \leq 2.0 \rightarrow$ critical thermal state;
$RT > 2.0 \rightarrow$ very critical thermal state.

3.1 Normalized Values

Table 2 shows the normalized values of the rectal (predicted by the PHS) and the hypothalamus (predicted by HuTheReg) after 4 h of exposure, that characterize the working period of the ceramic industries included in this study.

If the RT_{re} values are considered, workplace C06 is very critical being by far the hardest condition. None of the workplaces is classified as critical. The thermal conditions at C01, C02, C05, C07, C09, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20 and C21 workplaces are rated as acceptable and at C03, C04 and C08 as favorable. If attention is focused on the RT_{hyp} results, none of the workplaces is classified as very critical. The thermal conditions at C01, C02, C06, C09, C11, C16, C17, C18, C19 and C21 workplaces are rated as critical; including C06 (the most severe, following the RT_{re} criterion). Nine situations are acceptable (C04, C05, C07, C08, C10, C13, C14, C15 and C20) and two are favorable (C03 and C12). These results highlight that 10 of 21 workplaces are rated as "critical" by one of the models.

Comparing the results of the ceramic industry with the ones of the glass industry [12], where the same normalized parameters were used for assessment, in heat stress terms this activity sector is clearly not as severe as the glass industry.

Table 2 Rectal and hypothalamus normalized values of the workers of the 21 ceramic industry workplaces

Workplace	RT_{re}	RT_{hyp}	Workplace	RT_{re}	RT_{hyp}
C01	0.70	1.12	C12	0.52	0.38
C02	0.68	1.08	C13	0.62	0.58
C03	0.42	0.50	C14	0.66	0.80
C04	0.48	0.96	C15	0.71	0.74
C05	0.56	0.53	C16[(d)]	0.88	1.73
C06	7.38	1.95	C17	0.94	1.78
C07	0.59	0.89	C18	0.82	1.35
C08	0.45	0.78	C19	0.90	1.51
C09	0.72	1.01	C20	0.64	0.78
C10	0.55	0.77	C21	0.69	1.04
C11	0.83	1.17			

(d) Beyond the limits of the PHS model due to the difference between the mean radiant and air temperatures

3.2 Situations with High Heat Stress Potential

Due to space restrictions, the results shown here are only a very small sample of a wide research. In workplace C11, T_a and T_{mr} are high, as shown in Table 1. According to RT_{re} and RT_{hip} indexes this workplace is rated as Acceptable and Critical, respectively. This difference was considered interesting for a more detailed analysis throughout the 240 min of exposure. Therefore, workplace C11 was selected.

Figure 1 shows the results of the evolution of the rectal, hypothalamus and maximum skin temperatures of a human being working in the C11 place. The introversion and the heat stroke limits are also depicted. Figure 2 shows the evolution of the rectal temperature and of the evaporation rate predicted by PHS and HuTheReg models.

Figure 1 shows that the hypothalamus temperature reaches the limit value of 39 °C close to the 90th minute of exposure, thus suggesting that the worker might experience an introversion condition [10]. If so, psychological consequences might appear which do affect work efficiency. In this workplace the metabolic rate of the worker is high (≈3.0 met) and the air temperature is higher than 40 °C, values that suggest a critical condition. However, the results of the PHS model do not reveal such a critical scenario. In fact, the predicted and the required evaporation and sweat rates predicted by the PHS model are equal, which shows that the human

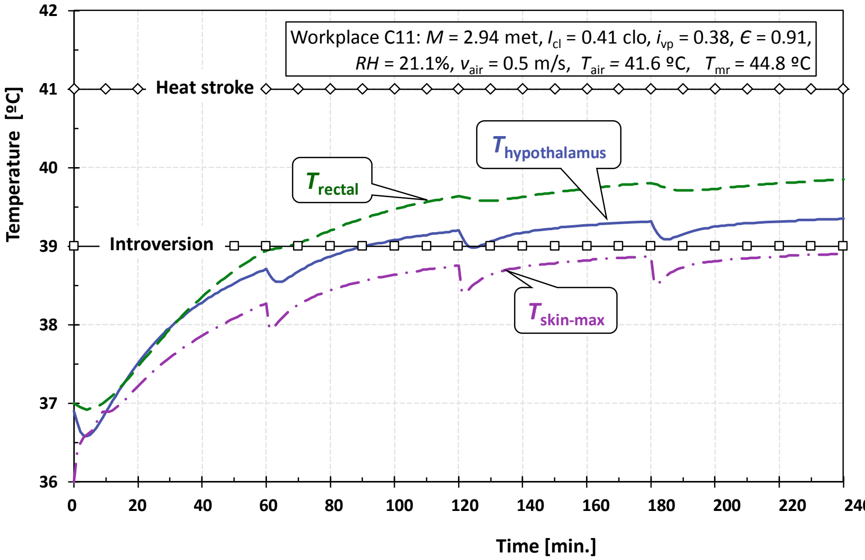

Fig. 1 Rectal, hypothalamus and maximum skin temperatures predicted by the HuTheReg model for workplace C11

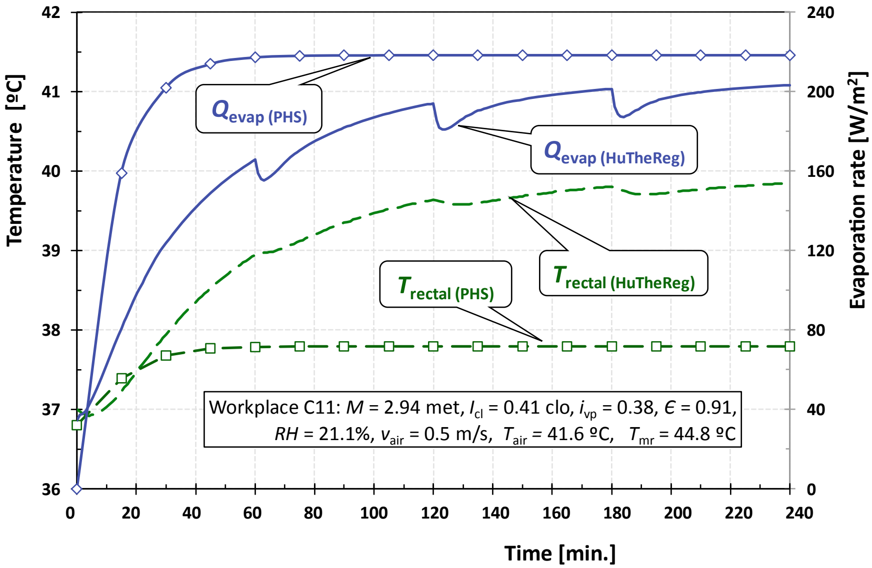

Fig. 2 C11: Rectal temperature and evaporation rate predicted by PHS and HuTheReg

body is capable of coping with the thermal environment. The PHS model detailed results are presented elsewhere [2].

Figure 2 reveals that the PHS model predicts a rectal temperature of 37.8 °C at the end of 240 min, value that is slightly lower than the 38 °C limit. Therefore, under the PHS perspective, an exposure period of 240 min in this workplace is not critical. For the rectal temperature, the predictions of the PHS and HuTheReg models are quite different; at the end of the exposure that difference is close to 2 °C, value that can be considered significant. In the PHS model, the value of the rectal temperature assumes a steady-state condition after 60–70 min of exposure, while the values predicted by the HuTheReg model are higher and show a continuous increase. In this case, the predictions of the HuTheReg seem more realistic, since because of the high metabolic rate and the high air temperature of the workplace, a steady-state rectal temperature during most of the exposure period is not expectable.

A small difference was observed between the predictions for the evaporation rate by both models, despite the more significant increase in the beginning of the exposure shown by the PHS curve.

3.3 Comparison Between the Predictions of the Two Models

To compare the results obtained with the PHS and the HuTheReg models, the mean arithmetic difference (δ), the standard deviation (σ), the mean quadratic deviation

Table 3 Comparison between the predictions of the PHS and HuTheReg models for the rectal temperature and for the evaporation rate

	Rectal temperature				Evaporation rate			
	δ (°C)	σ (°C)	*MQD* (°C)	r (–)	δ (W/m^2)	σ (W/m^2)	*MQD* (W/m^2)	r (–)
Maximum	1.63	1.49	2.28	0.94	60.59	30.88	66.77	0.89
Mean	−1.03	0.68	1.36	0.77	39.74	21.66	45.51	0.84
Minimum	−2.02	0.30	0.56	0.69	13.95	14.33	30.75	0.80

(*MQD*) and the Pearson correlation coefficient (r) were used [12]. Table 3 shows the rectal temperature and the evaporation rate maximum, mean and minimum values obtained for these statistical parameters.

In the case of the rectal temperature Table 3 and Fig. 2 show that, in average, the predictions of the PHS model are lower than those of the HuTheReg software. As highlighted by the standard deviation and the mean quadratic deviation, the differences between the predictions of the two models are significant. This is mainly due to the quick steady-state condition achieved by the rectal temperature when the PHS model is considered which, in the authors' opinion, is not realistic. The reasonable values of the Pearson coefficient reveal the same trend between the two models. Otherwise, the values of the Pearson coefficients for the evaporation rate are always high ($0.8 < r < 0.9$). However, the δ differences are quite high (with significant standard deviations), which are more pronounced in the beginning of the exposure. It is important to point out that the PHS model only reveal one critical workplace (C06), while the HuTheReg software attributes that same severe condition to 10 of the 21 (C01, C02, C06, C09, C11, C16, C17, C18, C19 and C21).

4 Conclusions

In the present study, the Predicted Heat Strain model (PHS) and a Human Thermoregulation software (HuTheReg) were used to assess the level of heat exposure in 21 workplaces of the ceramic industry. The results show that the predictions of the PHS are more conservative while the ones predicted by the HuTheReg reveal higher heat stress levels, which can be considered as positive in the workers' health and safety perspective. For instance, 9 of the 17 workplaces rated as "acceptable" by the PHS were considered "critical" by the HuTheReg. The agreement of the predictions obtained with the two models were not as high as expected. Even though, in 8 workplaces, the agreement between both approaches was good, providing enough motivation for further studies in this field. According to expectations, it has been demonstrated that there are workplaces in the ceramic industry with the potential for the onset of acute levels of hot thermal stress. Of the 21 workplaces analyzed, 10 of them were rated as "critical" by one of the models.

To enhance knowledge about adverse working conditions, more field data [12] and numerical work is necessary. As emphasized by [13] the potential impacts of workplace heat exposure are to some extent underestimated due to the underreporting of heat illnesses; it is also stated that if effective prevention measures are taken in the workplace, workers may not be physically challenged by heat stress. The present work is only one more contribution to this matter.

References

1. Oliveira, A., Virgílio M., Gaspar, A.R., Raimundo, A.M., Quintela, D.A.: Assessment of thermal environments: working conditions in the Portuguese ceramic industry in 1994 and 2012. Work: J. Prev. Assess. Rehabil. **51**(3), 457–470 (2015). https://doi.org/10.3233/wor-141938
2. Rodrigues, J., Oliveira, A., Virgílio M., Gaspar, A.R., Raimundo, A.M., Quintela, D.A.: Working conditions in the ceramic industry: assessment of the heat exposure with the Predicted Heat Strain (PHS) index. In: Arezes, P., Baptista, J., Barroso, M., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Miguel, A.S., Perestrelo, G. (eds.) Occupational Safety and Hygiene IV, pp. 249–254. CRC Press, Taylor & Francis Group, London. (2016). ISBN 978-1-138-02942-2
3. ISO 7933:2004: Ergonomics of the thermal environment—Analytical determination and interpretation of heat stress using calculation of the predicted heat strain. In: International Standard, 2nd edn. Geneve (2004)
4. Raimundo, A.M., Quintela, D.A., Gaspar, A.R., Oliveira, A., Virgílio M.: Development and validation of a computer program for simulation of the human body thermophysiological response. In: Portuguese Chapter of IEEE EMBS 1–4, Coimbra, Portugal (2012)
5. Malchaire, J., Piette, A., Kampmann, B., Mehnert, P., Gebhardt, H., Havenith, G., Den Hartog, E., Holmér, I., Parsons, K., Alfano, F., Griefahn, B.: Development and validation of the predicted heat strain model. Ann. Occup. Hyg. **45**, 123–135 (2001)
6. Malchaire, J.B.: Occupational heat stress assessment by the predicted heat strain model. Ind. Health **44**, 380–387 (2006)
7. Stolwijk, J.A.J.: A mathematical model of physiological temperature regulation in man. NASA Contractor Report CR-1855, NASA, Washington DC (1971)
8. Fiala, D., Lomas, K.J., Stohrer, M.: A computer model of human thermoregulation for a wide range of environmental conditions—the passive system. J. Appl. Physiol. **87**, 1957–1972 (1999)
9. Tanabe, S., Kobayashi, K., Nakano, J., Ozeki, Y., Konishi, M.: Evaluation of thermal comfort using combined multi-node thermoregulation (65MN) and radiation models and computational fluid dynamics (CFD). Energy Build. **34**, 637–646 (2002). https://doi.org/10.1016/S03787788(02)00014-2
10. Raimundo, A.M., Figueiredo, A.R.: Personal protective clothing and safety of firefighters near a high intensity fire front. Fire Saf. J. **44**, 514–521 (2009). https://doi.org/10.1016/j.firesaf.2008.10.007
11. Raimundo, A.M., Pereira, C.D., Oliveira, A., Virgílio, M., Quintela, D.A.: Human body thermoregulation: test and validation of a computer program. In: Arezes, P.M., Baptista, J.S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Miguel, A.S., Perestrelo, G. (eds.) Occupational Safety and Hygiene III, pp. 99–103. CRC Press, Taylor & Francis Group, London (2015). ISBN 978-1-138-02765-7

12. Oliveira, A., Virgílio, M., Gaspar, A.R., Raimundo, A.M., Quintela, D.A.: Assessment of Thermal Environments: Working Conditions in the Portuguese Glass Industry, Industrial Health. Natl. Inst. Occup. Saf. Health Jpn (JNIOSH) **56**(1), 62–77 (2018). https://doi.org/10.2486/indhealth.2017-0048
13. Xiang, J., Bi, P., Pisaniello, D., Hansen, A.: Health impacts of workplace heat exposure: an epidemiological review. Ind. Health **52**, 91–101 (2014). https://doi.org/10.2486/indhealth.2012-0145

Risk Analysis of Water Blasting Activity in the Automobile Industry

Bruno Azevedo Dobbin, Tomi Zlatar, Felipe Mendes da Cruz, Bianca M. Vasconcelos, Ana Rosa Bezerra Martins, Béda Barkokébas Jr. and Eliane Maria Gorga Lago

Abstract In the automobile industry, in order to clean paint from structures on which cars-bodies are transported and painted, the ultra-high water blasting is used on regular basis. The objective of this study was to identify and analyze the safety and health risks related to the water blasting activity, and give suggestions in order to eliminate or reduce those risks. For this purpose, a study was conducted in an automobile industry in Brazil, using two self-made questionnaires, one checklist, the Preliminary Risk Analysis and the Hazard Rating Number. In total ten risks were identified and analyzed, giving recommendations on additional measures to be applied in order to eliminate or reduce the risks for the worker. By analyzing the Brazilian norms considering water blasting, it was identified that workers should rotate after water blasting of each skid. Further studies should be conducted in order to quantify the level of noise during the activity, to evaluate the risk of hearing loss, and give specific suggestions in order to improve the conditions.

Keywords Occupational safety and health · Risk management · High-pressure water jet

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1 Introduction

The number of vehicles being produced in Brazil has increased almost 90 times in 60 years, from about 30 thousand units in 1957 to almost 2.7 million cars in 2017 [1]. Brazil adopted an expansionary policy supplying the neighboring markets of South and Central America, which reached the production record in 2017 when 766,013 auto vehicles were exported (automobiles, light commercial vehicles, trucks and buses).

The flowchart of a car's production process has 4 main phases: presses; body shop; painting; and assembly. In the press phase the steel plates and coils reach the stamping where they are molded until they reach the shape of the car body part. In the body shop the moving parts (hood, parts of the doors, among others) produced in the previous unit are joined forming the body skeleton. The welded body from the body shop goes to the painting phase, where the body receives some chemical baths to prepare for painting. Finally, the body leaving the painting unit moves to the final assembly, where the body receives all the accessories and components that make up the vehicle: seats; wheels; electric cables; motor; exchange; among others.

In the painting unit the bodies are transported on top of structures called skids. When painting the bodies, the skids are also painted, requiring the removal of this painting, which is performed through ultra high pressure water jetting (over twenty thousand psi) [2].

It is important to notice that the pressure of 40 bars is enough to pierce the full skin [3], while high and ultra high-pressure water is able to cause wounds similar to those of high-velocity projectiles, causing fatal penetrating injuries in only few seconds of exposure [4]. One study reviewing 42 clinical cases of incidents, noted that most common scenarios were: the limb injury (hand or foot) where the patient was clinically stable; a dissection of a great vessel, commonly the femoral artery, and soft tissue blunt trauma due to a high-energy impact; and third, a severe traumatic brain injury or decapitation [5]. Further complications in treatment of this type of injuries may come based on the source from which the water was supplied to a high-pressure water jetting system. For example, when water is supplied from lakes, it can result in many viral, protozoal, parasitic, and bacterial pathogens [5].

In Brazil, the legal requirements related to Personal Protective Equipment (PPE) for the water jacker (worker who performs the water blasting) are specified by Technical Standard SABESPNTS 185: 2002 [6], while additional criteria related to the maintenance of equipment used in the activity of water blasting and activity-related procedures are determined by the Regulatory Standard 34—Working conditions and environment in the shipbuilding, repair and dismantling industry [2].

Due to a lack of studies concerning the topic, the present study aim to further the knowledge on the water blasting activity, focusing primarily on the identification and analysis of risks of water blasting in the automotive industry. Further-on, the study aims to verify if the current measures correspond to the legal requirements and to offer additional solutions to eliminate or reduce the risks for occupational safety and health.

2 Methodology

The site chosen for the development of the study was the cabin for skids water blasting, located in the paint unit of the automotive industry located in Goiana/Pernambuco/Brazil. The cabin and the worker in the water blasting position, cleaning the skid is illustrated in Fig. 1.

To achieve the objectives of this study, two questionnaires were first developed. Based on the responses of the questionnaires, a checklist was created to identify the risks, which were further-on assessed through the Preliminary Risk Analysis (APR) performed by the Hazard Rating Number (HRN) method.

2.1 *Questionnaires*

Two not-yet-validated questionnaires were developed, one for managers with the purpose of obtaining managerial information, and another for the water jacker. The objective was to obtain operational information of the activity, thus obtaining valuable information to be used in the risk assessment process (the sources of hazards).

The first questionnaire developed for managers was applied with the company safety technician responsible for the skid washing (water blasting) activity. This questionnaire included the following questions: number of workers participating in the activity; number of skids washed per day; time required to wash a skid; workday for each worker; rest time per day; PPE used during the development of the activity; and the chemicals used in the activity.

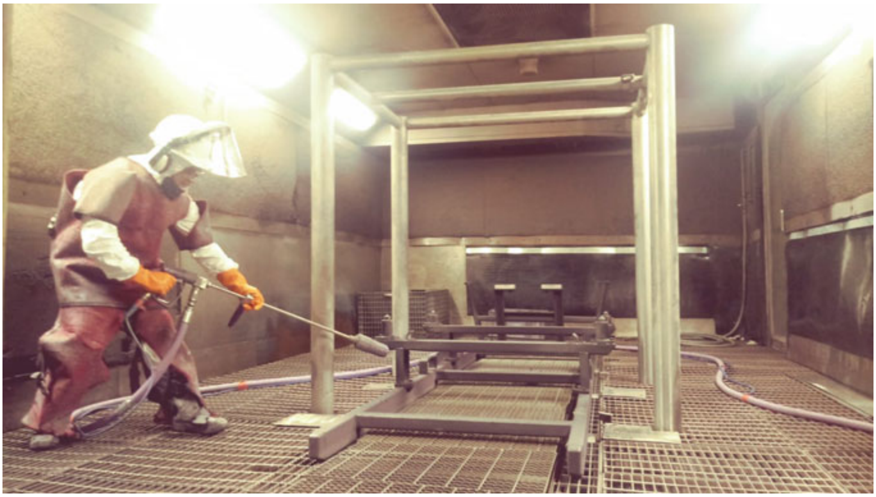

Fig. 1 Position during water blasting of skids

The second questionnaire designed for water jackers, included the following questions: detailing the activity (step by step) of skid washing, the machines and equipment in the skid-washing cabin, the posture during the activity, the existence of stairs to access higher levels, the existence of contact with electricity during the activity, among others.

2.2 Checklist for Identifying Hazards

The checklist was developed based on the information obtained through the applied questionnaires, in order to prove and identify the risks for the safety and health of the worker during the water blasting activity.

2.3 Hazard Rating Number

After qualitative mapping, hazards were assessed and quantified by the HRN APR. The risk class (RC) was calculated by multiplying the 4 factors: degree of severity; exposure frequency; probability of damage occurring; and number of people at risk. The risk characterization and the required action based on the final value was defined as:

- from 0 to 5, the risk is negligible, no action required;
- from 5 to 50, the risk is low, but significant, recommended improvement action;
- from 50 to 500, the risk is high, improvement action required;
- 500, the risk is unacceptable, improvement action required.

Degree of severity (DS). Eight levels of severity were given: no damage (0); slight scratch, injury or bruise (0.1); injury, laceration or moderate disease (0.5); injury, minor fracture or mild—temporary illness (2); more serious injury, fracture or illness—temporary (4); injury, loss of limb, eye or hearing—permanent (6); loss of two limbs or eyes—permanent (10); fatality (15).

Exposure Frequency (EF). Seven levels of frequency degree were given: rarely (0.1); annual (0.5); monthly (1); weekly (1.5); daily (2.5); hourly (4); constantly (5).

Likelihood of damage (LD). Eight levels of degree of occurrence were given: impossible—will not occur (0); almost impossible—only in extreme circumstances (0.033); not expected—although conceivable (1); possible—but it is not common to occur (2); some chance—may occur (5); likely—it would not be a surprise or something unexpected (8); expected (10); certainly—no doubt (15).

Number of people at risk (NP). Five levels of number of people were given: 1–2 people (1); 3–7 people (2); 8–15 (4); 16–50 people (8); more than 50 people (12).

3 Results and Discussion

3.1 Questionnaires

Through the first questionnaire, performed with the safety technique, management information was collected for the skid water blasting activity. The water jackers work in pairs, daily performing those activities with a typical 8-h workday from 06:00 until 14:00, with one hour for lunch. While one worker is inside the cabin water blasting the skid, the other is outside the cabin performing the organization of the area and supervising the employee inside the cabin. Each time after water blasting two skids, the employees alternate positions, that is, the employee who was inside the cabin water blasting the skids becomes the supervisor and the worker who was outside as a supervisor becomes the water jacker. On average, ten skids are washed daily, with an average skid wash time of 40 min. The PPE used in the activity are the visor helmet and ear muffs.

Through the second questionnaire conducted with the water jackers, the operational information was collected on the activity of water blasting of the skids. The water jacker stands on one side of the skid and washes all the important parts (2 pins, 2 butterflies, 1 spring and 1 nylon support). For each skid water blasting, it is necessary to low-down 4 times, and remain in that position for one minute. This means that the water jackers daily perform 20 lowering lasting approximately 20 min. For cleaning higher parts of skids, the stairs with 5 steps are climbed approximately 5 times a day. During the activity there is no contact with electricity.

3.2 Checklist for Identifying Hazards

The checklist consisted of 61 questions, 18 on environmental hazards, 8 on ergonomic hazards and 35 on accident hazards. The agents/hazards/risks which were identified during the development of the water blasting activity were: physical (noise); ergonomic (inadequate postures for pushing and pulling skids; inappropriate postures for washing certain skid regions); accident (non-standard ladders; heavy material stored on shelves with a risk of falling; handling of pressurized equipment, risk of particle projection due to skid solid dirt; lack of escape route in case of emergency, lack of emergency light inside the cabin).

3.3 APR and HRN

The ten risks identified through the checklist were included and analyzed in Table 1 by using the APR with the HRN method. In green the insignificant risks were illustrated, in yellow the low risks, and in red the high risks.

Table 1 APR by HRN method for the water jacker performing the water blasting activity

Nr	Activity	Hazard	Risk/cons[a]		Applied control measures	DS	EF	LD	NP	RC	Risk classification
1	Supervision	(A) slippery floor	Falls of people	Before	Signalization of the wet area	4	0.5	5	1	10	Low
				After	Repair the machine from leaking	4	0.1	1	1	0.4	Insignificant
2		(A) poorly organized shelves	Falls of objects	Before	None	2	2.5	5	1	25	Low
				After	Separate materials by weight	4	2.5	1	1	10	Low
3	Water blasting and supervision	(A) no escape route	Not evacuating the area in case of emergency	Before	None	15	0.5	2	1	15	Low
				After	Escape route placement	15	0.1	1	1	1.5	Insignificant
4	Water blasting	(A) no emergency light signal		Before	None	15	0.5	2	1	15	Low
				After	Installation of the rotary beacon on walls	15	0.1	1	1	1.5	Insignificant
5		(E) inadequate posture	Musculoskeletal disorders	Before	None	2	4	8	1	64	Low
				After	Installation of skid spinning frames	2	4	1	1	8	Low
6		Noise	Hearing loss	Before	Working in shifts; ear muffs	6	4	10	1	240	High
				After	Active noise control system; train for adequate blasting; recovery chamber walls	6	1.5	2	1	18	Low
7		(E) defective furniture	Accident with skid	Before	None	4	4	5	1	80	High
				After	Recovery of doors and security sensors	4	4	1	1	16	Low
8		(A) not adequate staircase	Falls of people	Before	None	4	4	5	1	80	High
				After	Renovate staircase according to the standard	4	4	1	1	16	Low

(continued)

Table 1 (continued)

Nr	Activity	Hazard	Risk/cons[a]		Applied control measures	DS	EF	LD	NP	RC	Risk classification
9		(A) high water pressure	Injuries	Before	Use of aramid clothing, boot, gloves and visors	15	4	5	1	300	High
				After	Minimum blasting pressure (1500 bar)	15	4	2	1	120	High
10		(A) particle projection	Injuries	Before	Use of aramid clothing, boots, gloves and visors	10	4	8	1	320	High
				After	Minimum basting pressure (1500 bar)	10	4	5	1	200	High

[a](Cons) = consequence; (A) = accident; (E) = ergonomic; (DS) = Degree of severity; (EF) = Exposure frequency; (LD) = Likelihood of damage; (NP) = Number of people at risk; (RC) = Risk class

For low and high risks, mitigation actions were recommended: organization of the area; skid rotating frame installation; repair of machine leakage; separation of materials by weight; escape route placement; installation of the rotary beacon on walls; recovery of machine doors and security sensors; suitability of stairs as suggested by the standard; increase employee rotation; use minimum necessary water blasting pressure ($\approx$1500 bar).

As illustrated in Table 1, some risks can be mitigated by applying appropriate control measures. For example, the risk posed by noise can be reduced from the initial high risk to low risk by applying training, active noise control systems, or recovering chamber walls. Other examples of significantly decreasing the risk level were related to the risk of falls and skid accidents.

Even with the lowering of the risk level through the application of different control measures, the risks related to high water pressure and particle projection remain high. Therefore, it is necessary to follow strict procedures and maintain the supervision of the worker whenever conducting this activity.

In Table 2 are illustrated the requirements for high and ultra high water blasting, as defined by SABESPNTS 185:2002 Technical Standard and NR 34. The requirements were analyzed and verified if were in accordance with the case considered by this study.

The injuries caused by water blasting are often not diagnosed correctly and in time, due to the damage of the skin surface appear minor. However, those injuries are often deep, and without an early and effective treatment, can lead to catastrophic consequences such as amputation or death [5].

Therefore, it is of great importance for those working with water blasting to have with them the medical card containing information in case of emergency attending, in order to inform accordingly the medical staff, and get adequate treatment. This is of major importance as high-pressure water jet injuries should always, without exception, be considered contaminated wounds and treated as surgical emergencies [7].

It was identified one irregularity with standards. The activity of water blasting in the analyzed study includes continuous water blasting of two skids for each workers. As for water blasting of each skid takes around 40 min, it means that each worker continuously conducts water blasting for 1 h 20 min, which exceeds the limits given by the NR 34 (maximum continuous time of up to one hour).

Future studies are needed to assess the noise level to which water jackers are exposed during the water blasting activity, calculating the dose of noise exposure and comparing it with regulatory and legal requirements. A study could evaluate the cost-benefit of investing in the improving hydroblasting chamber walls and reducing the level of noise. Additional studies are needed in the assessment of different water blasting activities, taking into consideration the additional risk posed by the use of different types of high pressure hydraulic or spray guns such as paint, gasoline, grease and fuel oil. For future studies it is also suggested to validate the two questionnaires used in this study in order to develop them to have a better level of confidence in data collection.

Table 2 Standard requirements for the water blasting activity

Nº	Requirements	Present study	Standard
1	Safety glasses and/or face shields	✓	Norma Técnica SABESPNTS 185:2002 [6]
2	Inflated, fully sealed, waterproof or abrasion impact resistant jacket clothing	✓	
3	Suitable ear protector	*✓	
4	Activity only performed by skilled workers	✓	NR 34 [2]
5	Mandatory use of specific card containing information required for emergency care	✓	
6	Maintenance of equipment by qualified workers	✓	
7	Activity performed in continuous time of up to one hour, with intervals of equal period, in a maximum working time of eight hours	×	
8	It is prohibited to lock the trigger of the equipment gun; the gun safety device (lock) must be actuated when work is interrupted, especially during level or compartment	✓	
9	Operate equipment as recommended by manufacturer	✓	
10	Prevent bending, twisting and placing hoses/hoses on unprotected edges	✓	
11	Maintain eye contact between water jacker and the supervisor	✓	
12	Rotation of water jackers according to their physical resistance	✓	
13	It is forbidden for the water jacker to divert the jet from his work focus	✓	
14	Utilization of low voltage lighting	✓	
15	The use of compressed air line adduction equipment is mandatory for blasting activities; It is ensured that the air quality employed in compressed air line adduction respiratory protection equipment is as established by the PPR	✓	

*✓ = the ear protector is in used. However, in order to check if the provided ear protection is adequate, there is a need to conduct an additional study in order to verify the noise level and exposure dose of the worker

4 Conclusion

The present study analyzed the safety and health risks related to the water blasting activity in the automotive industry.

The identified hazards in the analyzed water blasting activity were: slippery floors, poorly organized shelves, no escape route, no emergency light signal, inadequate posture, noise, defective furniture, not adequate staircase, high water pressure, and particle projection. Those hazards might lead to different risks/consequences: falls of people, falls of objects, not evacuating the area in case of emergency, musculoskeletal disorders, hearing loss, accident with skid, and injuries. It is important to notice that the identified hazards, risks and consequences could also be applicable to other automotive industries and industries conducting water blasting activities.

While some of the risks could be reduced to low risks, the risks of high water pressure and projection of particles remained high, and therefore it is mandatory to follow rigorous procedures in order to minimize the risk for safety and health of workers.

All recommendations given by the Brazilian standards SABESPNTS 185:2002 and NR 34, were applied in the analyzed industry. However, in order to evaluate if the ear protection is suitable, there is a need to further the research and measure the level of noise and dose of noise to which the worker conducting the water blasting activity is exposed. By analyzing the Brazilian norms considering water blasting, it was identified that workers should rotate after water blasting of each skid.

References

1. ANFAVEA. Anuário da Indústria Automobilística Brasileira [Internet] (2018). Available from http://www.anfavea.com.br/anuarios.html
2. Ministério do Trabalho: NR-34 - Condições e meio ambiente de trabalho na indústria da construção, reparação e desmonte naval [Internet] (2018). Available from https://enit.trabalho.gov.br/portal/images/Arquivos_SST/SST_NR/NR-34.pdf
3. The Water Jetting Association: Code of Practice for the Use of High-Pressure Water Jetting Equipment. The Water Jetting Association, London (2015)
4. Radojevic, N., Radnic, B., Curovic, I.: Fatal penetrating injuries sustained by high-pressure. Water jet unit. J. Forensic Sci. **60**(6), 1652–1653 (2015)
5. Rodríguez-Villar, S., Kennedy, R.C., Dall'Antonia, M., Menichetti, C.P.: Management of industrial high-pressure fluid injection injuries (IHPFII): the Water Jetting Association (WJA) experience with water driven injuries. Eur. J. Trauma Emerg. Surg. [Internet]. **45**(3), 507–15 (2019). Available from http://dx.doi.org/10.1007/s00068-019-01106-4
6. Norma Técnica SABESP NTS 185. Preparo de superfícies metálicas – Métodos alternativos ao jato de areia seca [Internet]. São Paulo (2002). Available from http://www2.sabesp.com.br/normas/nts/NTS185.pdf
7. Rosenwasser, M.P., Wei, D.H.: High-pressure injection injuries to the hand. J. Am. Acad. Orthop. Surg. **22**(1), 38–45 (2014)

Practical Use of Noise Mapping to Reduce Noise Exposure in the Construction Industry

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Abstract Noise exposure is prevalent in many workplaces; however, not all economic sectors are equally affected. Some construction activities are among the productive processes that cause the most noise pollution. This study aims to provide construction industry practitioners with a better understanding of the impacts of occupational noise to improve the management of construction activities. This research starts from the premise that noise maps can be used for acoustic management in construction workplaces. The noise map is presented as a quantitative tool that supports management by providing information to evaluate the noise safety-related performance of construction activities using a risk-analysis-based approach. For this purpose, the possible use of sound maps as a tool in plans for noise protection where construction activities are taking place is discussed. Noise measurements were collected in a concrete production facility. A noise map has been drawn up and the possibility of using it as part of a strategic plan to protect workers' health has been analysed.

Keywords Construction · Noise · Noise map · Decision support · Noise management

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1 Introduction

Characteristics of developed countries, such as production models, population growth and technological development are key factors which contribute to increasing noise pollution. The World Health Organization [1] reported in 2018 that rates of hearing loss are increasing and estimated that the number of people with disabling hearing loss at the global level could rise to 630 million by 2030 and may be over 900 million in 2050 (9.6%).

Occupational noise exposure is the second most common risk factor in the workplace in Europe (22% of the occupational burden of disease), behind workplace injuries [2]. Long-term excessive noise exposure causes several diseases. It may result in damage to the auditory system, permanent hearing loss [3] and psychological effects such as depression and even insomnia [4]. Moreover, exposure to levels above 80 dB(A) for 8 h per day may cause a potential risk of permanent damage to inner hair cells ribbon synapses, changes in midbrain, thalamus and cortex and accelerates the risk of cognitive impairment [5–7].

Noise exposure is prevalent in many workplaces [8]; however, not all economic sectors are equally affected by noise. The construction sector is characterized by a significant presence of physical contaminants such as noise and vibrations [9–11]. Research conducted by Barrero [12] in 2018 shows that Spanish construction workers are less likely to have good hearing due to the noise level present on the job. In the US, in 2018 the industries with the highest occupational noise exposure were mining (61%), construction (51%) manufacturing (47%), utilities (43%) and transportation and warehousing (40%). The occupations with the highest occupational noise exposure were production (55%), construction and extraction (54%), installations maintenance and repair (54%), transportation and material moving (44%) [13]. Arve [14] state in their study that construction workers are among the occupational groups at high risk of noise-induced hearing loss. Many studies developed measurement strategies and assessment methods of environmental noise [15–17] and occupational noise [18–23]. However, noise assessment often does not have an impact on reducing workers' exposure if appropriate strategic actions are not taken. Strategic plans are needed to minimize noise exposure and protect workers' health. Implementing such plans would help to reduce the number of workers affected and the social and economic consequences.

In this context, noise maps can be a useful tool to make workers aware of the importance of the measures adopted in strategic plans. A strategic noise map is defined as "a map designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area" [24]. Noise maps are already being used by European Governments to determine exposure to environmental noise and adopt action plans based on noise mapping in road, railways and airports, according to the Environmental Noise Directive [24]. This study discusses the possible use of sound maps as a tool in plans for noise protection in the construction industry. For this purpose, noise measurements were collected in a concrete production facility. A noise map has been drawn up and the possibility of using it as part of a strategic plan to protect workers' health has been analyzed.

2 Methods and Collection Data

2.1 Study Area

Onsite noise exposure data of a concrete production facility were collected. The concrete plant was selected because it is among the most common activities involved in the process of civil and building construction. The concrete production facility is arranged as a tower plant system. Although these facilities are generally highly automated and with little human intervention, the accident rate indicates that injuries of very different types occur [25]. Several activities are carried out around the production tower: (1) Reception, transport and storage of aggregates, (2) Reception, transport and storage of cement, (3) Dosage of aggregates, cement, water and additives, (4) Concrete mixing, (5) Maintenance and (6) Transit areas. There are multiple sources of noise in this area: concrete mixer truck, falls of aggregates, aggregate transport trucks, pneumatic elements of the automatisms, compressor, etc.

2.2 Data Collection

An analysis based on sound level measurements was carried out with the plant in full operation. In order to obtain a guidance of the physical sound level (dBA) in different locations, a Squadriga I recorder was used. In addition, a global positioning system (GPS) instrument was used to record the positions at which the measurements were made.

2.3 Data Processing

Noise map calculation required an interpolation of the levels at the different points. From these data, the kriging geo-statistical interpolation method was used. The theory of regionalized variables is the foundation of the kriging method and it has proved its applicability in many areas [26, 27]. A software extension for Environmental Systems Research Institute's (ESRI's) ArcMap has been used in this analysis.

3 Results

Figure 1 shows the elements of the concrete facility (silos, storage areas, compressors, etc.). The concrete facility has staff access to the office and work area. Also, it has vehicle access to the loading/unloading area and garage.

Workers access this area through the office. They use a specific route depending on the task they have to perform. The SPL obtained for each point is shown in Table 1. This data is used for meshing and post-processing map.

All the areas where measurements were taken are transit areas for workers during the plant's operating periods. The points closest to the tower and the cement silo structures are those with the highest Sound Pressure Level (SPL). In this case, it is not possible to act on the source to minimize the SPL generated in the concrete production process.

The measurement results are used as input for interpolation in the ArcMap software. The result obtained is shown in Fig. 2.

It should be noted that the range of colors in a noise map depends on the maximum and minimum value of the different areas represented. Therefore, noise map colors are not comparable if they do not share the same scale. As a result, it is not easy to compare at a glance different noise maps; workers may relate a color to a low SPL at a given point without considering range.

From this result, the noise map can be used as a tool to minimize the effect of noise on workers' health. On the one hand, noise maps provide information about workplace safety necessary to effectively perform construction hazard prevention through design. In this sense, it is possible to influence worker safety using prevention through design of facilities and activities to minimize noise exposure and accidents in the workplace [28]. In this case study, workers' routes have been

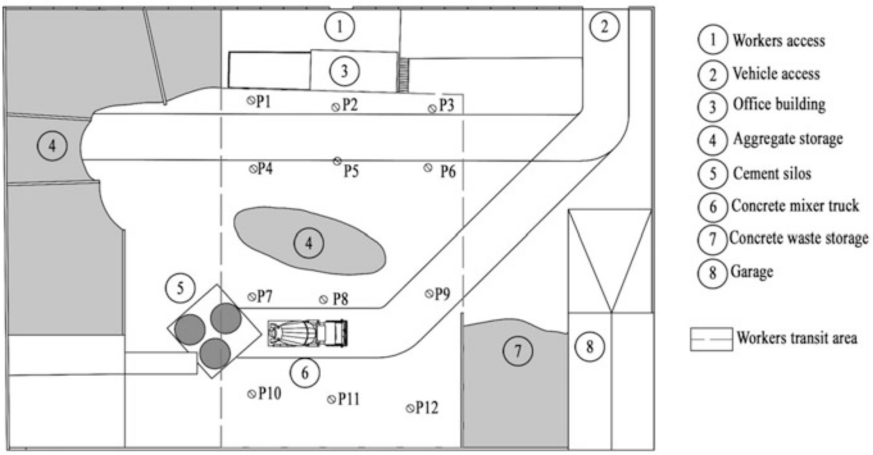

Fig. 1 Distribution of concrete facility elements and measuring points

Table 1 SPL data

Point	*SPL* (dBA)	Point	*SPL* (dBA)
P1	67.7	P7	89.8
P2	59.6	P8	80.3
P3	58.5	P9	73.8
P4	70.6	P10	90.1
P5	61.5	P11	82.5
P6	60.0	P12	78.2

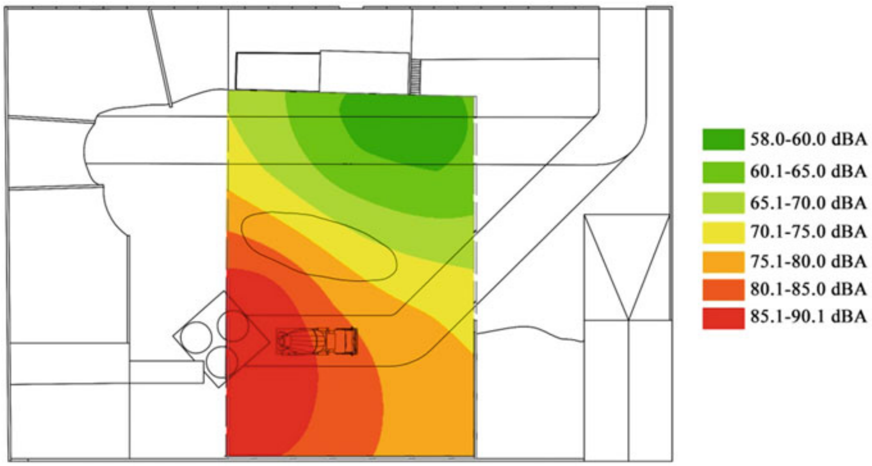

Fig. 2 Acoustic map of the zone

analyzed and safer alternative routes have been proposed to reduce workers' exposure to noise.

The noise map is presented as a quantitative tool that supports management by providing information to evaluate the noise safety-related performance of construction activities using a risk-analysis-based approach.

The spatial distribution of the SPL in the facility area enables the calculation of the daily equivalent level of noise exposure of each worker according to where they are located during the working day. Although the SPL fluctuates over time, quantifying its distribution under the most unfavourable conditions ensures that the worst scenario is considered for activity management. This information can be used to determine the safest routes, modify working routes, manage collection points and organize tasks in a way that reduces noise exposure. Therefore, the use of noise maps as a tool allows for better working conditions in construction sector activities which expose workers to particularly high noise levels.

In addition, it can be used as an educational tool for workers so that they can detect the most dangerous areas in a simple and intuitive way. It can be used to educate workers on the importance of using personal protective equipment or performing an activity on a safer route.

4 Conclusions

Among the productive activities that cause the most noise pollution are some processes in the construction sector. This study is a step forward in the current efforts to encourage construction companies to use noise maps to reduce noise exposure.

The use of noise maps has a high cost for the employer due to the large number of measurements that it requires (the resulting noise map will become more accurate as more measurement points are selected and if they are distributed over a regular mesh). This is one reason why this method is not widely used in the sector. However, it can be a key tool in strategic noise protection plans.

Based on the information provide by noise maps it is possible to organize tasks, modify routes and adapt work shifts to ensure workers' safety. The change in organisational patterns mitigates construction safety risks associated with noise using prevention through design. Therefore, noise maps have proved to be a tool to support activity management to minimize exposure to noise. In addition, noise maps are a very useful tool for the education and training of workers in the prevention of noise exposure in the construction sector.

For all these reasons, noise maps have been shown to be an important tool that should form part of strategic noise protection plans in the construction sector. Noise maps provide information to define measures to minimise the impact of noise on workers' health, contribute to raising awareness of its importance and enhance workers' safety culture.

References

1. World Health Organization: Addressing the rising prevalence of hearing loss (2018)
2. World Health Organization: Europe gbd data and statistics—occupational health (2017). Available at: http://www.euro.who.int/en/health-topics/environment-and-health/occupational-health/data-and-statistics. Accessed 18 Sept 2019
3. Seidman, M.D., Standring, R.T.: Noise and quality of life. Int. J. Environ. Res. Public Health **7**(10), 3730–3738 (2010)
4. Kwon, N., Park, M., Lee, H.-S., Ahn, J., Shin, M.: Construction noise management using active noise control techniques. J. Constr. Eng. Manag. **142**(7), 04016014 (2016)
5. Kujawa, S.G., Liberman, M.C.: Adding insult to injury: cochlear nerve degeneration after "temporary" noise-induced hearing loss. J. Neurosci. **29**(45), 14077–14085 (2009)
6. Eggermont, J.J.: Effects of long-term non-traumatic noise exposure on the adult central auditory system. Hearing problems without hearing loss. Hear. Res. **35**, 212–222 (2017)

7. Jafari, Z., Kolb, B.E., Mohajerani, M.H.: Noise exposure accelerates the risk of cognitive impairment and alzheimer's disease: adulthood, gestational, and prenatal mechanistic evidence from animal studies. Neurosci. Biobehav. Rev. (2019)
8. Verbeek, J.H., Kateman, E., Morata, T.C., Dreschler, W.A., Mischke, C.: Interventions to prevent occupational noise-induced hearing loss: a cochrane systematic review. Int. J. Audiol. **53**(sup2), S84–S96 (2014)
9. De La Hoz-Torres, M., López-Alonso, M., Ruiz Padillo, D., Martínez-Aires, M.: Analysis of whole-body vibrations transmitted by earth moving machinery. In: Proceedings of International Symposium on Occupational Safety and Hygiene, SHO, pp. 453–456, (2017)
10. de la Hoz-Torres, M., Martínez-Aires, M., Martín-Morales, M., Padillo, D.R.: Whole body vibration and acoustic exposure in construction and demolition waste management. In: Occupational Safety and Hygiene VI: Book chapters from the 6th International Symposium on Occupation Safety and Hygiene (SHO 2018), 26–27 March 2018, Guimarães, Portugal, p. 273 (2018)
11. Fernández, M.D., Quintana, S., Chavarría, N., Ballesteros, J.A.: Noise exposure of workers of the construction sector. Appl. Acoust. **70**(5), 753–760 (2009)
12. Barrero, J.P., García-Herrero, S., Mariscal, M.A., Gutierrez, J.: How activity type, time on the job and noise level on the job affect the hearing of the working population. Using bayesian networks to predict the development of hypoacusia. Saf. Sci. **11**, 1–12 (2018)
13. Kerns, E., Masterson, E.A., Themann, C.L., Calvert, G.M.: Cardiovascular conditions, hearing difficulty, and occupational noise exposure within us industries and occupations. Am. J. Ind. Med. **61**(6), 477–491 (2018)
14. Lie, A., Skogstad, M., Johannessen, H.A., Tynes, T., Mehlum, I.S., Nordby, K.-C., Engdahl, B., Tambs, K.: Occupational noise exposure and hearing: a systematic review. Int. Arch. Occup. Environ. Health **89**(3), 351–372 (2016)
15. Kephalopoulos, S., Paviotti, M., Anfosso-Lédée, F., Van Maercke, D., Shilton, S., Jones, N.: Advances in the development of common noise assessment methods in Europe: the cnossos-eu framework for strategic environmental noise mapping. Sci. Total Environ. 48, 2400–2410 (2014)
16. Gulliver, J., Morley, D., Vienneau, D., Fabbri, F., Bell, M., Goodman, P., Beevers, S., Dajnak, D., Kelly, F.J.; Fecht, D.: Development of an open-source road traffic noise model for exposure assessment. Environ. Model. Softw. **74**, 183–193 (2015)
17. Ruotolo, F., Maffei, L., Di Gabriele, M., Iachini, T., Masullo, M., Ruggiero, G., Senese, V.P.: Immersive virtual reality and environmental noise assessment: an innovative audio–visual approach. Environ. Impact Assess. Rev. **41**, 10–20 (2013)
18. Seixas, N.S., Sheppard, L., Neitzel, R.: Comparison of task-based estimates with full-shift measurements of noise exposure. AIHA J. **64**(6), 823–829 (2003)
19. Quintana, S., Fernandez, M.D., Chavarria, N., Ballesteros, J.A., Gonzalez, I.: Measurement method for noise exposure of jobs of the construction sector. J. Acoust. Soc. Am. **123**(5), 3678 (2008)
20. Arezes, P.M., Geraldes, J.: Assessing differences in methodologies for effective noise exposure calculation. Int. J. Occup. Saf. Ergon. **15**(2), 183–191 (2009)
21. Arezes, P.M., Bernardo, C., Mateus, O.A.: Measurement strategies for occupational noise exposure assessment: a comparison study in different industrial environments. Int. J. Ind. Ergon. **42**(1), 172–177 (2012)
22. Bullock, W.H., Ignacio, J.S: A Strategy for Assessing and Managing Occupational Exposures. AIHA (2006)
23. Golmohammadi, R., Eshaghi, M., Khoram, M.R.: Fuzzy logic method for assessment of noise exposure risk in an industrial workplace. Int. J. Occup. Hyg. **3**(2), 49–55 (2011)
24. 2002/49/E. Eu. Directive 2002/49/ec of the european parliament and of the council of 25 June 2002 relating to the assessment and management of environmental noise—declaration by the commission in the conciliation committee on the directive relating to the assessment and management of environmental noise

25. Carreras, P.S.: NTP 94: Plantas de hormigonado: Tipo torre. Instituto Nacional de Seguridad e Higiene en el Trabajo (1984)
26. Harman, B.I., Koseoglu, H., Yigit, C.O.: Performance evaluation of idw, kriging and multiquadric interpolation methods in producing noise mapping: a case study at the city of Isparta, Turkey. Appl. Acoust. **112**, 147–157 (2016)
27. Aumond, P., Can, A., Mallet, V., De Coensel, B., Ribeiro, C., Botteldooren, D., Lavandier, C.: Kriging-based spatial interpolation from measurements for sound level mapping in urban areas. J. Acoust. Soc. Am. **143**(5), 2847–2857 (2018)
28. Aires, M.D.M., Gámez, M.C.R., Gibb, A.: Prevention through design: the effect of european directives on construction workplace accidents. Saf. Sci. **48**(2), 248–258 (2010)

Risk Assessment and Control in a Small Chemical Industry in Brazil

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Abstract The chemical industry is a strategic sector for the sustainable development of countries. Although occupational safety and health prevention practices in the chemical sector have generally improved, there is concern about risk gaps in small and medium enterprises. The International Chemical Control Toolkit (ICCT) methodology proposed by the International Labor Organization (ILO) focuses resources on controlling chemical exposure. ICCT was used to assess chemical hazards in a small Brazilian chemical industry. The results show that 47.36% of the evaluated chemicals have low damage potential, 42.11% have medium damage potential and 10.53% have high damage potential. Thus, control approaches have been proposed for all chemicals evaluated. Control measures proposed by the ICCT method for the chemicals analyzed include general ventilation and good practice for small, medium and large storage of solids and liquids; good practice for weighing solids and reducing exposure to an appropriate level such as using Glove Box; best practices for weighing medium quantities of solids such as using Laminar Flow Cabinet; and replacement of some substances with less toxic ones.

Keywords Chemical industry · Small business · Classification and identification by risk substances · Products and materials

1 Introduction

The chemical industry has a relevant player in the sustainable development of national economies [6]. It is responsible for producing a wide variety of substances and compounds essential for applications in almost every sector of the economy [2].

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In 2017 the world chemical industry had net sales of $ 4250 billion. Brazil was ranked 6th with $ 104 billion in net sales [1].

The International Labour Organization (ILO) estimates that the various sectors of the chemical industry employ 20 million workers worldwide. However, improper use of chemicals can have adverse consequences for humans and the environment [6].

In 2004 the World Health Organization (WHO) estimates that 4.9 million deaths (8.3% of all deaths) were due to environmental exposure to chemicals [11]. While in Brazil, in 2017, there were a total of 107,378 accidents and 174 deaths from chemical exposure [10].

There is currently a concern about risks in large and small companies in the chemical sector, although occupational safety and health prevention practices have generally improved [6].

According to the Health and Safety Executive (HSE) small and medium-sized enterprises (SMEs) offer major risk capacity as their business models shift from mass production of chemicals to storage and formulation [4].

The increase in the risk capacity of SMEs is due to a trend towards the use of low skilled workers who may not have a good understanding of the risks they are exposed to; an increase in significant incidents on and off site; the reluctance of employers to accept the risks arising from their activities; and the need for better competence and risk management outside the company [4].

The chemical industry has one of the highest rates of occupational diseases such as asthma, dermatitis and cancer. These rates are linked to inaccurate or insufficient information about the use of chemicals, lack of knowledge of their health effects, lack of competence in end-user risk assessment and selection of appropriate control measures [4].

For ILO [8] one of the classic steps of Occupational Hygiene (OH) practice is the recognition of possible health risks in the workplace. Thus, if the health risks are obvious, control should be recommended before carrying out quantitative assessments. Therefore, the classic concept of "recognition-evaluation-control" may change to "recognition-control-evaluation" or even "recognition-control" [8].

To help SMEs recognize chemical health risks in their workplaces and advise them on control measures, the Health and Safety Executive (HSE) developed in 1999 the "COSHH Essentials: Easy Steps to Control Health Risks from Chemicals". This pragmatic approach technique is based on Control Banding (CB) which categorizes risks and their forms of control into bands [3].

COSHH Essentials has been adapted by ILO, WHO, HSE and the International Occupational Hygiene Association (IOHA) for use by all countries. This international version was called the "International Chemical Control Toolkit (ICCT)" which was updated to include the Globally Harmonized System for Classification and Labeling of Chemicals (GHS) [3, 9].

Thus, the objective of this exploratory study was to conduct a qualitative risk assessment and propose their respective control measures by applying the International Chemical Control Toolkit (ICCT) in a small chemical industry in Rio Grande do Norte, Brazil.

2 Methodology

This research is characterized as exploratory and descriptive. It was based on one of the classics OH steps that is “recognition-control” of the risk [8]. For the qualitative analysis and its respective risk control of the researched small chemical industry, the International Chemical Control Toolkit (ICCT) was used [3, 5, 7].

As this research is only composed of an observational analysis of the work environment, there was no need to submit it to a Research Ethics Committee.

The ICCT implementation methodology consists of five stages [7]:

– Stage 1—Hazard classification and matching to a hazard group: substances can be allocated into six different groups. Five groups (“A” to “E”) relate to health damage caused by inhalation or ingestion of substances. The sixth group (“S”) is used to allocate chemicals that can cause skin or eye damage.
– Stage 2—Scale of use the chemicals: the amount of chemical used determines how the product is handled. The amount used also affects worker exposure. In this stage, the amount of chemicals used is classified as small, medium or large.
– Stage 3—Ability to become airborne. The ability of a product to dissipate in air depends on its physical form. At this stage the spread of chemicals in the air are classified as low, medium and high according to their volatility (liquids) and dustiness (solids).
– Stage 4—Selection of the control approach. At this stage it is already possible to define the most appropriate control approach based on the information collected in the previous stages. The control approaches adopted by ICCT are divided into 1—general ventilation and good practices; 2—engineering control (local ventilation); 3—closure of the process; and 4—special (need for expert advice to define the most appropriate control measures).
– Stage 5—Find the task-specific control guidance sheet(s). At this stage a specific form provided by ICCT with guidelines for the task control sheet is located.

In this research, all substance allocations to hazard groups and their respective volatilities were based on the GHS classification contained in the Material Safety Data Sheet (MSDS) of each chemical.

All information collected in the 5 stages is noted in the “Chemical Control Toolkit Checklist” provided by ICCT.

3 Results

The research was conducted in a small chemical industry located in the city of Parnamirim, state of Rio Grande do Norte, Brazil.

The researched chemical industry markets chemicals in fractionated quantities to serve SMEs in the textile sector in the states of Rio Grande do Norte and Paraíba.

To carry out the research, visits were made in the research industry to understand its routine.

The production of small industry varies according to its demand of your clients. However, the activities evaluated in this research that are performed regardless of the production requested. These common activities include receipt of raw material, storage of raw material, large amount fractionation, and the storage of fractionated chemicals.

The use and variety of chemicals is wide and demand dependent. Thus, 19 chemicals were selected for this research.

Table 1 shows the 19 chemicals used by industry during the research. For each product analyzed, the risk group, the amount used, the propagation form and its corresponding control measure were determined according to the ICCT.

For all chemicals analyzed, the amount used was determined as average. Regarding chemical propagation in the environment, 6 chemicals (1–6) have low volatility or dustiness, 12 chemicals (7–18) have medium volatility or dustiness, and 1 chemical (19) have high volatility or dustiness.

As for classification in groups of hazards, 8 chemicals (42.11%) were classified in hazard group "A" and 1 chemical (5.26%) was classified in hazard group "B" because they have a lower potential for causing health damage. Another 8 chemical products (42.11%) were classified in group "C", presenting average damage potential. In addition, 2 chemicals (10.53%) need for expert advice to define the

Table 1 Chemicals analyzed by the ICCT

Order	Products	Hazard group	Control approach
1	Citric acid ($C_6H_8O_7$)	A & S	1
2	Sulfonic acid (H_2O_3S)	C & S	2
3	Sodium benzoate ($C_7H_5NaO_2$)	A & S	1
4	Trisodium citrate ($C_6H_5Na_3O_7$)	A & S	1
5	Magnesium hydroxide (H_2MgO_2)	C & S	2
6	Disodium oxosilanediolate (Na_2O_3Si)	C & S	2
7	Ammonium bicarbonate (CH_5NO_3)	C & S	3
8	Sodium bicarbonate ($CHNaO_3$)	A & S	1
9	Calcium carbonate ($CCaO_3$)	A & S	1
10	Sodium carbonate (CNa_2O_3)	A & S	1
11	Sodium chloride ($ClNa$)	A & S	1
12	Formaldehyde (CH_2O)	E & S	4
13	Sodium hydroxide ($HNaO$)	E & S	4
14	Sodium metabisulfite ($Na_2O_5S_2$)	C & S	3
15	Hydrogen peroxide (H_2O_2)	C & S	3
16	Aluminium chloride hydroxide hydrate ($H_7Al_2ClO_6$)	C & S	3
17	Propylene glycol ($C_3H_8O_2$)	A & S	1
18	Sodium lauryl ether sulfate ($C_{24}H_{50}Na_2O_5S$)	C & S	3
19	Dioxotitanium (O_2Ti)	B & S	2

most appropriate control measures and were classified as in group "E". Of the 19 chemicals analyzed, all products (100%) were also classified in the group "S", as these substances can cause damage when in contact with the skin and eyes.

Table 2 shows the task control sheets selected for the 19 chemicals evaluated. All task control sheets are made available by the ICCT method.

The control approach 1 should be adopted for the use of 8 (42.11%) chemicals. Based on the Control Approach 100 the layout inside the company has been altered improving air circulation. A schedule has also been created for cleaning roof wind exhausters. With Control Approach 101 guidance, the company adopted a sign for the chemical storage area, also implemented a cleaning service schedule in the storage industry; training was provided for workers on good chemical handling practices; improved labeling of chemicals; and purchased a sump pallet to prevent spillage.

The control approach 2 was adopted for the use of 4 (21.05%) chemical products. Following the direction of Control Approach 211, the chemical industry requested a budget for the purchase of a Laminar Flow Cabinet for the weighing area. The acquisition of Laminar Flow Cabinet will help ensure that workers, products and processes are protected from dust.

The control approach 3 was adopted for the use of 5 (26.31%) chemicals. For this Control Approach 301 the chemical industry has also requested a quote for the purchase of a Glove Box for weighing chemicals.

The control approach 4 was adopted for the use of 2 (10.53%) chemicals. Regarding Control Approach 400 the chemical industry has initiated studies to substitution the two chemicals classified as Control Approach 4 by less toxic substances.

Skin and/or eye protection should be used when handling 19 (100%) chemicals of the total analyzed. Eye and face protection are influenced by all control measures cited above. But the company also followed the Control Approaches Sk100 and R100 guidelines and reinforced the training and availability of personal protective equipments for all workers.

Table 2 Task control sheets selected by the ICCT

Control approach	Task control sheet	Task description
1	100	General ventilation
	101	Good practice on storing small, medium and large quantities of solids and liquids
2	211	Good practice on weighing medium quantities of solids
3	301	Good practice on weighing solids to reduce exposure to an adequate level (Glove Box)
4	400	The process needs more specific and specialist advice than ICCT can provide
S	Sk100	Eliminate or minimize the amount of material in contact the skin and eyes. Select appropriate personal protective equipment
	R100	Selection and use of respiratory protective equipment (RPE)

4 Conclusion

This research used Recognition of Hazards, which is one of the preliminary steps of Occupational Hygiene (OH), to recognize the risks and to suggest their respective control measures [8].

The International Chemical Control Toolkit (ICCT) method adopted by ILO, IPCS, and WHO (2003) was used to qualitatively assess chemical hazards in a small chemical industry located in Parnamirim, Rio Grande do Norte state, Brazil.

ICCT has been applied to 19 chemicals used by the chemical industry that are considered hazardous by the GHS.

After the recognize, it was concluded that 42.11% (8 chemicals) were classified in hazard group "A" and 5.26% (1 chemical) was classified in hazard group "B" because that have lower potential to cause health damage; 42.11% (8 chemicals) were classified in group "C", presenting average damage potential; and 10.53% (2 chemicals) need for expert advice to define the most appropriate control measures and were classified as in group "E". In addition, 100% have potential for skin and/or eye damage (risk group S).

Control measures were proposed, and interventions were performed for all chemicals analyzed. These proposed control measures were obtained from the task control sheets provided by the ICCT method. Among the proposed control measures, were implemented the general ventilation and good storage practices for small, medium and large quantities of solids and liquids (42.11%); good practices on weighing solids and key points to follow to reduce exposure to an appropriate level, such as the use of Glove Box (26.31%); good practice in weighing average quantities of solids and using a Laminar Flow Cabinet (21.05%); and studies are underway to substitution two chemicals with less toxic ones (10.53%).

The limitations of the present study include the difficulty in obtaining the Material Safety Data Sheet (MSDS) of the chemical products in Brazil and the absence of quantitative evaluations that indicate the amount inhaled by the workers and the efficiency of the proposed control measures.

References

1. ABIQUIM: Associação Brasileira da Indústria Química: O Desempenho da Indústria Química Brasileira em 2018. Abiquim, São Paulo (2018)
2. EU-OSHA: European Agency for Safety and Health at Work: E-fact 67: Maintenance and hazardous substances – Maintenance in the chemical industry. EU-OSHA, Bilbao (2012)
3. FUNDACENTRO: Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho: Avaliação qualitativa de riscos químicos: orientações básicas para o controle da exposição a produtos químicos. FUNDACENTRO, São Paulo (2012)
4. HSE: Health and Safety Executive: Chemicals sector strategy 2012–15. http://www.hse.gov.uk/aboutus/strategiesandplans/sector-strategies/chemicals.htm. Last accessed 30 Oct 2019
5. HSE: Health and Safety Executive: COSHH essentials: controlling exposure to chemicals—a simple control banding approach. HSE, Bootle (2017)

6. ILO: International Labour Organization: Chemical industries. https://www.ilo.org/global/industries-and-sectors/chemical-industries/lang–en/index.htm. Last accessed 30 Oct 2019
7. ILO: International Labour Organization: International Chemical Control Toolkit: Draft Guidelines. ILO, Geneva (2006)
8. ILO: International Labour Organization: Occupational Hygiene: Goals, Definitions and General Information. In: Encyclopedia of Occupational Health and Safety, 3rd edn. ILO, Geneva (2011)
9. ILO: International Labour Organization. IPCS. International Programme on Chemical Safety. WHO. World Health Organization: IPCS (WHO, ILO) Cooperation on Control Banding, Geneva (2003)
10. MPT: Ministério Público do Trabalho. ILO. International Labour Organization. Observatório Digital de Saúde e Segurança no Trabalho (MPT-ILO), http://observatoriosst.mpt.mp.br. Last accessed 10 Nov 2018
11. WHO: World Health Organization. Global Health Observatory (GHO). Chemicals. https://www.who.int/gho/phe/chemical_safety/en/. Last accessed 30 Oct 2019

Occupational and Environmental Health

Air Quality Assessment in Kitchens and Effects on Workers Health

Ana Ferreira, João Paulo Figueiredo, Fábio Pêgo, António Loureiro and Sílvia Seco

Abstract Air quality tells us how much air pollution we breathe daily. This level of pollution is caused by various chemicals present in the air, which modify the natural composition of the earth's atmosphere bringing negative consequences for humans. In school canteens it is essential to ensure the health and professional and student well-being and the quality of made-up products. In these places, it's important to take care of Indoor Air Quality (IAQ) as a determinant of public and occupational health. The main objective of this present study is the evaluation of IAQ in kitchens before, during and after the confection and/or food preparation, as well as analyzing the symptoms perceived by professionals working in these spaces. We notice that the average concentrations of $PM_{2.5}$ and PM_{10}, registered in some kitchens study exceeded the protection threshold. The symptoms/diseases with the highest prevalence were allergies (rhinitis), headaches and sneezing crisis. In this study, it was concluded that action is needed to improve the quality of in-door air in the kitchens of canteens, since there were air pollutants on average higher than the legally established values, as was the case of $PM_{2.5}$ and PM_{10}. It is essential that institutions implement continuous IAQ evaluation in order not to expose workers to hazardous conditions.

Keywords Indoor air quality · Air pollutants · Occupational health

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1 Introduction

Currently, the multiplicity of factors that contribute to our well-being and quality of life not only influence our daily lives, but also affect future generations. Thus, we can affirm that environmental issues increasingly become a worldwide concern. One of the factors with great importance that deserves our full attention is the air quality [1].

Air quality shows us the level of air pollution we breathe daily, which is caused by several pollutants present in the air that change the natural composition of the atmosphere, bringing negative consequences for humans [2]. The most abundant pollutants in the atmosphere and caused mostly by humans, are particulate matter (including $PM_{2.5}$ and PM_{10}), carbon monoxide (CO), carbon dioxide (CO_2), formaldehyde (CH_2O) and Volatile Organic Compounds (VOC) [2].

Currently, most of the world population, mainly in developed countries, spends much of his time in interior spaces, some of which are associated with insufficient ventilation and air exchange such as homes, workplaces, schools, leisure and entertainment spaces and transportation. There are many potentially harmful compounds released within these spaces, because of emissions from building materials, cleaning products and equipment, combustion, consumer products, among others. If, on one hand, the buildings protect people and property, on the other hand they also degrade human health due to pollution from them [3].

According to Word Health Organization (WHO), the various problems of Indoor Air Quality (IAQ) are recognized as important risk factors regarding human health, both in the developed and developing countries [3].

Taking into account the many allergic diseases, it is quite remarkable the effects of multiple environmental variables, either as primary determinants, either as aggravating the clinical conditions, particularly when the respiratory system is compromised [4].

Air quality in school canteens can affect both the health and well-being of professionals and students as well as the quality of products confectioned. In these places, it is important to heed the importance of IAQ as a determinant of public and occupational health [5]. In the meal preparation and confection, workers are constantly exposed to many substances considered dangerous. The impact of these in the human body can be diversified according to the confection process, the type of food cooked and substances that are consequently released from them and their concentration, time and exposure intensity by the worker [6–9].

Given the above, this study aims to monitoring IAQ in kitchens before, during and after the confection and/or food preparation, as well as analyzing the symptoms perceived by professionals working in these spaces.

2 Materials and Methods

2.1 Research Design, Population and Sample

The present study was observational (descriptive), cross-sectional and knowledge level II. The target population consisted of four kitchens that are part of higher education institutions canteens located in Coimbra, as well as 30 workers that integrate. The sampling used was non-probabilistic and the technique used was by convenience.

2.2 Instruments and Data Collection

The study was conducted in the academic year 2018/2019 and the data collection period was carried out over the months of June and July 2019.

Data collection consisted in three stages of investigation. The first stage was to describe of the assessed areas; the second stage was the application of a questionnaire addressed to all employees of the assessed canteens; and the third stage was the evaluation of air quality, using for such the assessment of atmospheric pollutants (CO_2, CO, VOCs, $PM_{2.5}$, PM_{10} and CH_2O) weather and temperature variables (T°) and relative humidity (RH) at station summer.

For the structural characterization of the kitchens was applied a checklist related to the general characteristics of the building under consideration. The sample was taken from four different canteens. It is noteworthy that the four canteens were located in urban areas, which is common indicator to all.

For the evaluation of the environmental parameters were selected initially the sampling points, taking into account the areas of space to evaluate and respective layouts, as well as the existence of doors, windows and ventilation systems, exhaust and/or air conditioning and potential sources indoor and outdoor contamination.

The questionnaire was conducted to analyze the symptoms perceived by workers of kitchens. This was divided into three important parts. The first one for evaluated the sociobiography characteristics of workers. The second one was intended to obtain data about the health condition, if they had or not they had symptoms of respiratory or chronic work-related illnesses. The third and last part, proposed to give information regarding the smoking habits.

With regard to the third stage of research, the measurements were performed in a 30 min period, with a sampling for minute. Measurements were made at three different times, that is, before, during and after the confection and/or food preparation between 09:00 and 17:30. The measuring equipments was placed on a central position of each rated space and approximately equal to the airways of workers [10].

To carry out the analytical collection of evaluated criteria, specific portable reading devices were used in real time, and in particular multi-gas analyzer, brand Critical Environment Technologies (CETCI), YES-AIR model, serial number: YA1901K00947 for evaluation the concentration of CO, CO_2, VOCs, CH_2O and weather variables T° and RH Dust Trak DRX measuring mark TSI model 8534, serial No. 8534190207 for assessing concentrations of $PM_{2.5}$ and PM_{10}. For the transfer of data collected between the measuring devices and the computer used to the specific software for each of the equipment used. It was considered as a reference for maximum CO concentration, 10.0 mg/m^3 (9 ppm) for CO_2, 2250 mg/m^3 (1250 ppm) for VOC, 0.6 mg/m^3 (600 ppb) for $PM_{2.5}$, 0,025 mg/m^3 for PM_{10}, 0.05 mg/m^3 and CH_2O, 0.01 mg/m^3 (0.08 ppm) as mentioned in Order 353-A/2013 of 4 December. According to Decree-Law No. 243/86 of 20 August, the environmental conditions of reference comfort for T° to should range between 18 and 22 °C, while the RH shall be between 50 and 70% [11, 12].

2.3 Statistical Analysis

Data were processed using the IBM SPSS 25 software. At the level of statistical inference, we used Student's t-test for one sample, Chi-square of Adherence and Odds Ratio. Finally, the inference was based on a confidence level of 95% for a random error up to 5%.

3 Results

The sample consisted to four canteen kitchens incorporating higher education institutions located in Coimbra, a total of 30 workers and also the outside space of the four canteens evaluated. It should be noted that this 30 workers evaluated, twelve worked in the Canteen 1, six in Canteen 2, five in Canteen 3 and seven in Canteen 4. With regard to gender, 8 were male and 22 female, with an average age of 42.90 (standard deviation = 13.54) years.

After the application of tools for collecting predefined data, the next table compares the overall shape of the analytical values of the concentrations of CH_2O, CO, CO_2, VOCs, $PM_{2.5}$ and PM_{10} indoor air of various canteens evaluated values legally set (safety threshold) (Table 1).

It was observed that there were statistically significant differences between the mean values of analytical CH_2O protection threshold and in Canteens 1, 2 and 4, while in the Canteen 3, there were no significant differences. Analytical average values of this pollutant were below the protection threshold. It was Canteen 2 that had higher average values, unlike Canteen 3 which had the lowest. Relatively, the average analytical values of CO concentration, it was found that there were significant differences between the average analytical values and the protection

Table 1 Average concentrations of air pollutants, in the different evaluated canteens

Canteen	CH_2O	CO	CO_2	VOC	$PM_{2,5}$	PM_{10}
	M± (SD)	M± (SD)	M± (SD)	M± (SD)	M± (SD)	M± (SD)
C_1	0.013 (0.04)**	0.52 (0.86)**	594.64 (106.99)**	188.74 (161.56)**	0.041 (0.07)**	0.046 (0.07)
C_2	0.035 (0.15)**	0.37 (0.42)**	544,37 (130.22)**	313.74 (415.18)**	0.015 (0.01)**	0.018 (0.01)**
C_3	0.001 (0.001)	0.18 (0.32)**	445.49 (133.66)**	107.41 (79.47)**	0.031 (0.02)**	0.035 (0.02)**
C_4	0.0001 (0.01)**	0.28 (0.33)**	530.10 (99.31)**	114.04 (66.18)**	0.066 (0.16)**	0.071 (0,16)**

C: Canteen; M: Average; SD: standard deviation; PL: protection limit; PL CH_2O = 0.08 ppm; PL CO = 9.0 ppm; PL CO_2 = 1250 ppm; PL VOC = 600 ppb; PL $PM_{2.5}$ = 0.025 mg/m^3; PL PM_{10} = 0.05 mg/m^3
Test: Student t test for population mean. *$p \leq 0.05$; **$p \leq 0.01$

threshold in all canteens, whereby the average values were below the protection threshold. Differences were found in mean concentration being Canteen 1 that exhibited higher values, while the Canteen 3 the lowest average values. As regards the analytical average values of CO_2 concentration, it was found that there were statistically significant differences between the estimated mean values and the protection threshold in all Canteens, whereby the average values of CO_2 were below the protection threshold. Referring to the average analytical values of VOCs, there were statistically significant differences between the estimated mean values and threshold protection in all evaluated Canteens, and the average values of the pollutant concentration were below the protection threshold.

With regard to the average concentrations of $PM_{2.5}$, it was observed that there were statistically significant differences compared to the protection threshold in all Canteens under study. Canteens 1, 3 and 4 showed average values of $PM_{2.5}$ concentration higher than the protection threshold, while the Canteen 2 showed values below the protection threshold. Regarding the average concentrations of PM_{10}, there was the presence of significant differences between the analytical values and the protective threshold Canteens 2, 3 and 4, while in the Canteen 1, no significant differences. Canteen 4 were recorded in average values of PM_{10} concentration above the protection threshold, as in Canteen 1.

We set out then evaluate the average concentration CH_2O, CO, CO_2, VOCs, $PM_{2.5}$ and PM_{10} kitchens, at the different measurements (Table 2).

It was found that there were statistically significant differences between the mean values of analytical CH2O in the morning and noon. It was the morning that showed higher average values, unlike the afternoon that had the lowest. Relatively, the analytical mean values of CO concentration, it was observed that there were significant differences between the analytical mean values for all periods, and the morning exhibited higher values, while the afternoon average values over low. As regards the analytical values of average CO_2 concentration was found that there

Table 2 Average concentrations of air pollutants, canteens evaluated in different periods

Canteen	CH_2O	CO	CO_2	VOC	$PM_{2,5}$	PM_{10}
	M± (SD)	M± (SD)	M± (SD)	M± (SD)	M± (SD)	M± (SD)
Morning	0.02 (0.13)**	0.51 (0.72)**	505.65 (141.01)**	224.78 (360)**	0.06 (0.13)**	0.07 (0.14)*
Noon	0.01 (0.04)**	0.39 (0.049)**	579.98 (132.95)**	234.31 (170)**	0,03 (0,07)*	0.04 (0.07)**
Evening	0.001 (0.0001)	0.12 (0.21)**	500.32 (95.84)**	83.86 (68)**	0.02 (0.01)**	0.02 (0.01)**

M: Average; SD: standard deviation; PL: protection limit; PL CH_2O = 0.08 ppm; PL CO = 9.0 ppm; PL CO_2 = 1250 ppm; PL VOC = 600 ppb; PL $PM_{2.5}$ = 0.025 mg/m^3; PL PM_{10} = 0.05 mg/m^3
Test: Student t test for population mean. $*p \leq 0.05$; $**p \leq 0.01$

were statistically significant differences between the mean values estimated in all periods. The period morning was exibed highest average values, while the period afternoon exibed lowest average values. Referring to the average analytical values of VOCs, there were statistically significant differences between the estimated average values. It was noon period which showed the average value of higher VOC, unlike the afternoon that had the lowest value. With regard to the average concentrations of $PM_{2.5}$, it was observed that there were statistically significant differences in all periods studied. The morning was what registered higher values and the afternoon the lowest average values. Regarding the average concentrations of PM_{10}, there was the presence of significant differences between the analytical values.

It was subsequently sought to ensure if there were exceedances of the reference value imposed by the legislation for meteorological variables (T° and Hr) in the indoor air of the evaluated kitchens (Table 3).

Analyzing the data relating to T° we found that the four kitchens evaluated, measured over a period of 1080 min total, 803 (74.4%) had temperature amended,

Table 3 Meteorological variables T° and RH inside the canteen

Canteen	Temperature		Relative humidity		
	TN [18–22] °C	TA <18 °C and >22° C	HA <50%	HN [50–70%]	HA >70%
	n (%)	n (%)	n (%)	n (%)	n (%)
Canteen 1	160 (59.3%)	110 (40.7%)	121 (44.8%)	149 (55.2%)	0 (0.0%)
Canteen 2	2 (0.7%)	268 (99.3%)	240 (88.9%)	30 (11.1%)	0 (0.0%)
Canteen 3	90 (33.3%)	180 (66.7%)	0 (0.0%)	188 (69.6%)	82 (30.4%)
Canteen 4	25 (9.3%)	245 (90.7%)	27 (10.0%)	231 (85.6%)	12 (4.4%)
Total	277 (25.6%)	803 (74.4%)	388 (35.9%)	598 (55.4%)	94 (8.7%)

TN: Normal Temperature; TA: Temperature Amended; HN: Normal humidity HA < 50%: Altered humidity below 50%; HA > 70%: Altered humidity greater than 70%

that is, outside the legally established range (18–22 °C), while 277 (25.6%) were within the normal temperature range. The place where there was a greater number of amended values was Canteen 2. With regard to the meteorological variable RH, it was observed that the evaluated 4 kitchens, 388 min (35.9%) had RH below the reference range [50–70%] and 94 (8.7%) above the reference range. It was Canteen 2 which presented a higher number of amended values moisture.

The following table is intended to evaluate the presence or absence of symptoms/diseases according to the canteen where workers labored (Table 4).

According to the analysis of Table 4, with regard to asthma disease, Canteen 4 showed the highest prevalence (42.9%) and Canteen 3 didn't showed. Regarding sneezing crisis Canteen 1 exhibited a higher percentage (41.7%), while the Canteen 4 didn't showed percentage. With regard to allergies (rhinitis), it was Canteen 3 that showed greater percentage (80.0%), contrary to that presented Canteen 2 (16.7%). Regarding the symptom of headache, Canteen 3 indicated the largest percentage (60.0%), while the Canteen 4 indicated only 14.3%. Regarding the symptom of dizziness Canteen 3 showed the greater percentage (40.0%) and Canteen 4 the lowest percentage (14.3%). As regards the sensitivity to odors, Canteen 3 showed the greater percentage (40.0%), contrary to Canteen 4 not indicated this symptom. With respect to respiratory difficulties was the Canteen 3 with the highest percentage (40.0%) and the Canteen 1 that showed the lowest percentage (8.3%). Posteriorly, we sought to deter-mine whether workers have reported that symptoms/

Table 4 Presence/absence of symptoms depending on the canteen frequented by workers

Symptoms/diseases		Canteen where the employee labor			
		Canteen 1	Canteen 2	Canteen 3	Canteen 4
Asthma	Yes	1 (8.3%)	1 (16.7%)	0 (0.0%)	3 (42.9%)
	No	11 (91.7%)	5 (83.3%)	5 (100.0%)	4 (57.1%)
Chronic bronchitis	Yes	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	No	12 (100.0%)	6 (100.0%)	5 (100.0%)	7 (100.0%)
Sneezing crisis	Yes	5 (41.7%)	2 (33.3%)	1 (20.0%)	0 (0.0%)
	No	7 (58.3%)	4 (66.7%)	4 (80.0%)	7 (100.0%)
Allergies (rhinitis)	Yes	5 (41.7%)	1 (16.7%)	4 (80.0%)	3 (42.9%)
	No	7 (58.3%)	5 (83.3%)	1 (20.0%)	4 (57.1%)
Headaches	Yes	6 (50%)	2 (33.3%)	3 (60.0%)	1 (14.3%)
	No	6 (50%)	4 (66.7%)	2 (40.0%)	6 (85.7%)
Dizziness	Yes	3 (25.0%)	2 (33.3%)	2 (40.0%)	1 (14.3%)
	No	9 (75.0%)	4 (66.7%)	3 (60.0%)	6 (85.7%)
Sensitivity to odours	Yes	4 (33.3%)	1 (16.7%)	2 (40.0%)	0 (0.0%)
	No	8 (66.7%)	5 (83.3%)	3 (60.0%)	7 (10.0%)
Cough	Yes	2 (16.7%)	0 (0.0%)	0 (0.0%)	1 (14.3%)
	No	10 (83.3%)	6 (100.0%)	5 (100.0%)	6 (85.7%)
Respiratory difficulties	Yes	1 (8.3%)	2 (33.3%)	2 (40.0%)	2 (28.6%)
	No	11 (91.7%)	4 (66.7%)	3 (60.0%)	5 (71.4%)

diseases, left or not manifest when displaced to the outside of each of the evaluated canteens. It was found that there were no statistically significant differences between the presence of symptoms/diseases when workers moved to the outside in Canteens on study. It was found that 75.0% of workers no longer manifest the symptoms when displaced outwardly Canteen 4 and 28.57% of Canteen 1. In what concerns Canteens 2 and 3 indicated that all workers have any symptoms/diseases continued to manifest them even after they moved abroad.

4 Discussion and Conclusion

After the analysis of the average values of CH_2O concentration, it was found that all canteens showed values below the protection threshold, or less than 0.08 ppm. This fact can be explained by the absence of this pollutant emission sources [1]. From the analysis of the average values of CO concentration inside the kitchens, it was observed that were below the protection threshold value. Some studies indicate that predominantly rural sites showed higher values of CO compared to mildly or predominantly urban areas [13]. Regarding the values of CO_2 concentration it was found that all kitchens studied had average concentration values below the protection threshold. As referenced in one study, this agent is a good indicator of the efficiency of ventilation systems. Thus, it can be verified that the ventilation of all evaluated areas is adequate and sufficient [6]. Regarding the concentration of VOCs, it was found that there is no risk to the health of workers, as the average values of the pollutant concentration within the evaluated kitchens, remained lower than what is legally established. In previous studies, it is referred that in kitchens it is not advisable to use cleaning and disinfectant products having in their composition VOC concentration, which indicates a reduced probability of VOC accumulation [14]. Concerning the average concentrations of $PM_{2.5}$, it was observed that Canteens 1, 3 and 4 had average values higher than the concentration threshold of protection, that is, 0.025 mg/m^3. When analyzing for periods, the one that showed, on average, higher concentrations of $PM_{2.5}$ was the morning period. With regard to average concentrations of PM_{10}, it was found that the Canteen 4 showed average concentration values above the threshold value of protection, which represents a danger for employees since it can cause health problems such as respiratory failure, as indicated by some studies carried out in Portugal [15]. Another study, led in catering establishments, states that there are other factors that may have contributed to the average concentrations of $PM_{2.5}$ and PM_{10} registered, such as the increasing number of occupants and greater movement of people that may have originated the shaking of particles which were originally deposited on surfaces [6]. The T° and RH are also relevant factors regarding the comfort of indoor air levels and may contribute to the development and progression of microbiological contaminants, which can influence the health of workers. From the analysis of the average values of T° found within canteens, it was found that 74.4% had a temperature above the legislated reference value. Some studies indicate that this fact can be explained by insufficient ventilation and air renewal rate [1]. In this study, the symptom/disease with the highest prevalence indicated by the workers were allergies (rhinitis), followed by headaches, dizziness and crisis of sneezing, runny or stuffy nose. These results can be similar to those found in a study carried out in primary schools in the municipality of Coimbra, where the symptoms most suitable for the children who attend the schools are the crisis of sneezing, followed by lack of concentration, allergic rhinitis, cough and asthma [16]. In the study, with the analysis of the presence of diseases/symptoms, when workers moved outside the canteens, it was found that in Canteens 1 and 4, workers have revealed symptomatology that disappeared when they were away from the building. This may be due to several factors, including the presence of assessed pollutants such as $PM_{2.5}$ and PM_{10} [16].

The results obtained in this study, led to the conclusion that it is necessary to take measures to improve the IAQ in kitchens canteens, since air pollutants exist, as in the case of $PM_{2.5}$ and PM_{10}, in which the concentrations were, on average, higher than those evaluated in some legally established kitchens. Thus, it is essential that institutions perform frequently monitoring not to expose workers to dangerous conditions. Evaluation of IAQ is critical to ensure the health of workers. Workplaces to which workers are exposed must have salubrious conditions to ensure their health, performance and the reduction of absenteeism, not having high concentrations of contaminants that are harmful to health. The indoor air quality must be periodically evaluated to ensure these conditions.

References

1. Loureiro, A.: Qualidade do Ar Interior em Lares de Idosos e a Exposição Ocupacional aos Poluentes Atmosféricos (2014)
2. Sofuoglu, S., Toprak, M., Inal, F., Cimrin, A.: Indoor air quality in a restaurant kitchen using margarine for deep-frying. Environ. Sci. Pollut. Res. **22**(20), 15703–15711 (2015)
3. Matos, J., Brantes, J.: Qualidade do Ar em Espaços Interiores Um Guia Técnico (2010)
4. Santos, J.: Avaliação da Qualidade do Ar Interior em Jardins-de-Infância. Faculdade de Engenharia da Universidade do Porto (2010)
5. Almeida, M., Lopes, I., Nunes, C.: Characterization of indoor air quality in Portugal—habitar study. Rev. Port. Imunoalergologia. **18**(1), 21–38 (2010)
6. Ferreira, D., Rebelo, A., Santos, J., Sousa, V., Vieira da Silva, M.: Estabelecimentos de Restauração e Bebidas: estudo sobre a Qualidade do Ar Interior em Cozinhas. Occup Saf Hyg - SHO 2012 - B Abstr; 189–91 (2012)
7. Silva, L.: Avaliação do conforto térmico e da qualidade do ar interior nos edifícios A e B do Instituto Pedro Nunes (2015)
8. Coentro, S.: Qualidade do Ar Interior em habitações: Fontes emissoras de poluentes. Diss Mestr em Eng do Ambient da Univ Nov Lisboa (2015)
9. Carneiro, P.: Ambiente térmico e Qualidade do Ar em Cozinhas Professionais. Dissertação de Mestrado em Engenharia Mecânica da Universidade de Coimbra (2012)
10. NT-SCE-02 NT. Metodologia para auditorias periódicas de QAI em edifícios de serviços existentes no âmbito do RSECE (2009)

11. Portaria n. 353-A/2013. (Regulamento de Desempenho Energético dos Edifícios de Comércio e Serviços (RECS) - Requisitos de Ventilação e Qualidade do Ar Interior). Diário da República. 2013;1.ª série(2):2–9
12. Portugês, G.: Decreto-Lei n.º 243/86 de 20 de Agosto. Diário da República n.º 190/1986 - I Série, Lisboa: Ministério do Trabalho e da Segurança Social, 1986. Diário da República I (190), 2099–20105 (1986)
13. Ferreira, A., Cardoso, S.M.: Estudo exploratório da qualidade do ar em escolas de educação básica, Coimbra, Portugal. Rev. Saude Publica. **47**(6), 1059–1068 (2013)
14. Matos, J.: Qualidade do Ar Interior em Ambiente Hospitalar : Identificação de Poluentes, Fontes e Estratégias para a Otimização dos Serviços de Saúde 1–124 (2014)
15. Fernandes, S.F.P.: Análise das Condições Higrotérmicas e da qualidade do ar interior na Biblioteca Joanina da UC (2014)
16. Ferreira, A., Cardoso, M.: Qualidade do ar interno e saúde em escolas. J. Bras. Pneumol. **40** (3), 259–268 (2014)

The Effects of a Passive Exoskeleton on Muscle Activity and Discomfort in Industrial Tasks

André Cardoso, Ana Colim and Nuno Sousa

Abstract Work-related musculoskeletal disorders (WMSD) have been progressively increasing. Specifically, Low back disorders (LBD) are the most predominant of all musculoskeletal disorders. In order to reduce the incidence of these problems, new auxiliary devices called exoskeletons have been introduced. This work provides a real context study of a back-support exoskeleton on industrial tasks in a furniture manufacturing company. The perception of eight participants regarding their experience with a passive back exoskeleton Laevo® was measured through a questionnaire that includes the assessment of perception of range of motion, reduction of backloading, interference with the task, overall physical effort, and discomfort. We also meresured the electromyography for the back muscles of five participants who performed an industrial task. Psychophysical results show that the exoskeleton gives back support. However, it also interferes with the execution of the task, limits movements, increases the overall effort and causes discomfort in the neck, shoulders, thoracic region, lumbar region and hips, and thighs. Electromyographic results show a decrease in muscle activity between 0.8 and 3.8% of the back muscles when wearing the exoskeleton. In conclusion, the exoskeleton used in this study does not seem appropriate for industrial tasks with a great diversity of movements.

Keywords Passive exoskeleton · Industrial tasks · Musculoskeletal disorders · Psychophysics · EMG

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1 Introduction

The number of cases of work-related musculoskeletal disorders (WMSD) have been progressively increasing in industrialized societies [1]. Specifically, Low back disorders (LBD) are the most predominant of all musculoskeletal disorders [2]. The occurrence of work-related LBD is a complex condition that involves contributions from both personal and work-related factors, among others lifting and carrying of loads and awkward body postures like trunk flexion and rotation [3]. Many preventive measures have been proposed in order to reduce the occurrence of LBD, such as adjustments of workstations, specific training in task execution and the use of mechanical aids [4].

In order to reduce the incidence of these problems, new auxiliary devices called exoskeletons have been introduced. An exoskeleton is a wearable device supporting the human to produce the physical power required for manual tasks [5].

Exoskeletons, according to the articulation mechanism, can be classified into two types: ‘active‘ and ‘passive’. The first type has one or more power-capable mechanisms (such as electric motors and hydraulic cylinders) that actively increase the power of the human body. The second one uses materials with elasticity or viscosity, such as springs or shock absorbers, which have the ability to accumulate energy from human movements and discharge it to assist users with a particular movement [6].

Active systems with an industrial purpose are being developed, but these are mainly in a laboratory stage now. The passive devices are already being studied and some are already being implemented in the workplace [5]. These include the Personal Lift Assist Device® (PLAD) and Laevo®. For the PLAD®, significant reductions on back muscle activity during lifting has been reported [7, 8] and during static bending [2]. For the Laevo®, the back-muscle activity and discomfort were studied in a simulated assembly task. It has found a decrease in muscle activity between 35 and 38% and lower discomfort in the low back when wearing the exoskeleton.

Most of the previous studies [1, 5, 7, 8] evaluated this type of equipment in simulated tasks in a laboratory. Therefore, there is still some controversy regarding the use in real work context. Therefore, with the current study we aim to assess the effect of a passive exoskeleton on WMSD risk factors in industrial trunk bending tasks in a furniture manufacturing industry in Portugal. For this purpose, qualitative and quantitative data were collected, namely: (i) psychophysical assessment of the exoskeleton’s use; and (ii) surface electromyography (EMG) assessment before and during the use of a passive back support exoskeleton.

2 Methods

2.1 Subjects and Industrial Tasks Studied

All participants were experienced workers from a large furniture manufacturing industry from Portugal. In this study, for each assessment trial distinct samples were considered. The psychophysical test included seven healthy participants (five males, two females; mean age was 33 ± 11 years old; mean body mass was 69.45 ± 14.04 kg and mean height 1.74 ± 0.07 m). The EMG assessment included five healthy participants (two males and three females; mean age was 29 ± 8 years old; mean body mass was 76.00 ± 14.64 kg and mean height 1.65 ± 0.13 m) also volunteered to participate in this study. All participants were introduced to the exoskeleton before the trials. None of the participants reported low back pain in the previous three months. Subjects signed an informed consent after the experimental trials.

In this work, we include three different tasks chosen by the company managers considering the nature of the tasks (manual handling loads with constant back flexion). The first task consisted of palletizing wooden pieces (weight between 2 and 4 kg) coming from a conveyor belt about 0.3 m from the floor to a pallet that was on top of a stacker. The worker flexed frontally and laterally the trunk in order to lift the pieces. Sometimes this handling was performed with only one hand (Fig. 1a).

The second task consisted of adjusting wooden slats coming from a cutting machine by pulling the slats so that the end of the slats coincided with the pallet limit. During this adjustment, the employee flexed the trunk to be able to pick it up to two-thirds of its length. The filled pallet was moved using a pallet truck and a new pallet was put in place (Fig. 1b).

(a) **(b)** **(c)**

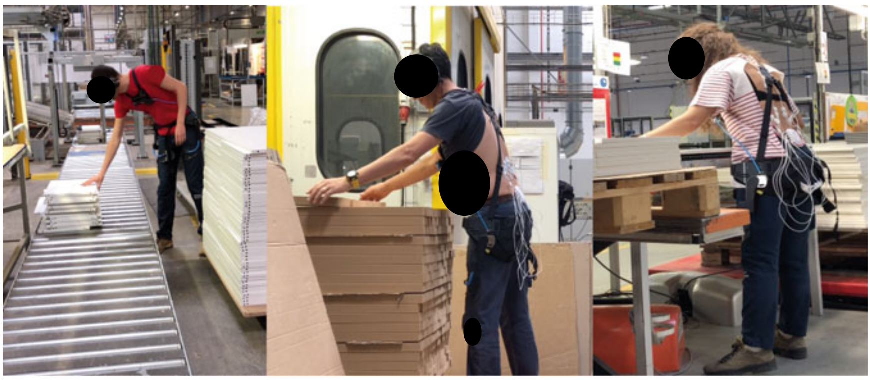

Fig. 1 Industrial tasks assessed: **a** Task 1: palletizing; **b** Task 2: wood slat adjustment; **c** Task 3: visual inspection of wooden boarders

The third task consisted of inspection of painted wooden boards weighing 3.9 kg. First, the wooden boards are dragged from a lifting table (positioned at the right side of the employee) to an inspection table (in the center). While executing this step it was noticeable that sometimes there were trunk flexion movements. Afterwards, the employee inspects the piece and it was noticeable that flexion and lateral inclination of the trunk occurred. Finally, they lift the inspected wooden board to another lifting table located on their left. Since the wooden board was already inspected, they did this movement more carefully. Due to this, a greater trunk flexion was observed (Fig. 1c).

2.2 Data Acquisition

The psychophysical test was planned to occur during three consecutive weeks for each task, increasing the time of utilization each day. On the first day, the participants only use the exoskeleton for 0.5 h. On the last day, the participants use the exoskeleton during the entire work period (8 h). We ask the participants to answer a questionnaire regarding their experience with the utilization of the back-support exoskeleton Laevo® over the three weeks. The intention was to assess their perception of range of motion, reduction of backloading, interference with the task, overall physical effort, and discomfort. This questionnaire included Borg CR-10 Scale [9], Likert Scale [10] and a body map [11] with a Visual-Analog Scale [12]. These scales range from 1 and 5 or 1 and 10, depending on the type of used for each of the questions. Due to the discomfort felt by the users during the use of the exoskeleton and the resistance of its use, it was decided to evaluate users' perceptions in two moments: the shortest time and the longest time of use. In mean, the shortest time of use was 0.54 ± 0.09 h and the longest time was 1.40 ± 0.56 h.

The EMG assessment was applied only for the third task (visual inspection of wooden borders), because it presented greater postural diversity. On the other hand, it was not possible to perform EMG tests at the places where the remaining tasks were considered. In these factory places the thermal conditions were very hot, which increased the skin's sweat, compromising the electrodes fixation. The sampling period was 20 min, for two conditions: with and without Laevo®. The adoption of this data acquisition time period is justified by the study of Carnide et al. (2012), where it is shown that a minimum acquisition of 20 min is sufficient to reliably estimate the "Amplitude Probability Distribution Function" (APDF). The APDF is validated to assess the muscle load of a particular task [13]. In order to achieve a balanced design, we randomly started in a with or without Laevo® condition.

EMG data were recorded using a wireless 8-channel biosignals Plux HUB® (biosignalsPlux, Lisbon, Portugal) with a sampling frequency of 1000 Hz, 100 GΩ input impedance, 110 dB common rejection factor and 16-bit analog collection channels. We collected data at six muscles on low back and upper back: left and right *Trapezius pars Ascendens* (TA), *Erector Spinae Longissimus* (ESL), *Erector*

Spinae Illiocostalis (ESI). Bipolar Ag/AgCl surface electrodes were positioned according to *Surface Electromyography for the Non-Invasive Assessment of Muscles* (SENIAM) recommendations with an inter-electrode distance of 20 mm [14]. A reference electrode was placed on the C7 spinous process. Before the electrodes fixation, the skin was shaved, scrubbed and cleaned with alcohol.

In order to normalize the EMG data, the Maximum Voluntary Contraction (MVC) was collected, for each participant at the beginning of the test. For the lower back muscles, we asked the participants to do back extension and a lateral inclination (right and left) during 5 s [15]. For the upper back muscles, participants were asked to raise their arms also for 5 s [16].

2.3 Data Analysis

Statistical analysis was performed using IBM® SPSS® Statistics 25.0 software. Psychophysical data analysis was performed according to an exploratory descriptive analysis. For each variable (scores attributed by participants after each time of use) the median was considered as a measure of central tendency.

The EMG data were processed through the OpenSignals (r)evolution® 2017 software application. This computer application has a "muscle load" add-on. It allows to assess the muscle load while performing a given task, providing information on whether the muscle is tired or fatigued, thus allowing to assess whether a worker is working in safe or risky conditions. This application uses the MVC in order to calculate the APDF. Thus, the amplitude of the EMG signal, as well as the probability distribution, are related to the MVC, which allows comparing several muscles or between several tasks and also to estimate mean values of tasks in function of APDF. For both conditions, data were quantified based on mean percentile activation amplitudes obtained from APDF [17].

Relatively to the EMG data, the normality was verified by the Kolmogorov-Smirnov test. Finally, the difference of the mean values of the muscle activation amplitudes between the two conditions tested (with and without LAEVO®), for each of the muscle, was verified by the t-student test for two paired samples.

3 Results and Discussion

3.1 Psychophysical Assessment

As mentioned before, we compare the perception of the participants regarding their experience with the utilization of the back-support exoskeleton Laevo® in the shortest time (0.54 ± 0.09 h) and with the longest time (1.40 ± 0.56 h) of use.

Table 1 Workers' perceptions (n = 7)

	Shortest time of use Median (Min.; Max.)	Longest time of use Median (Min.; Max.)	Scale
Range of motion	4 (3;5)	4 (1;5)	0 = Not restricted 5 = Heavily restricted
Reduction of back loading	3 (2;5)	4 (3;5)	
Interference with the task	4 (4;5)	4 (3;5)	

The workers' perceptions about the exoskeleton interference on the range of motion, reduction of backloading, task performance and physical effort are summarized in Table 1.

The participants' perception of the range of motions shows that they consider that the use of the Laevo® exoskeleton limits their movements. Although with increasing time fuse the assigned minimum value decreases from 3 to 1, evidencing that overtime at least one participant disagrees with the lack of freedom of movements. These results do not agree with the study of Näf et al. [1]. On a scale from 0 ("not restricted") to 10 ("very restricted"), the participants in this study gave a score of 1.4 for this parameter. The difference can be explained by the fact that exoskeleton used in Näf et al. [1] has flexible beans that track users' movements. This evidence shows that Laevo® manufacturers' need to improve the range of motions of their equipment.

In terms of reduction of backloading, overtime it seems that the participants' perception of this parameter is more positive. This result supports the effectiveness of Laevo® in reducing back loading.

The results concerning interference with the task performance show no change with increase usage time. The participants consider that the exoskeleton interferes with the task. This result is not in accordance with the results reported by Näf et al. [1] and Graham et al. [2]. This can be explained by the fact that the tasks tested in the mentioned studies are very simple compared to the tasks tested in this study.

Regarding the overall effort of the tasks, we cannot find differences in the rating attributed to the different time usage scenarios. But we found differences between the participants' overall effort perception for using or not using the exoskeleton. The global median score, in a scale from 0 ("no effort") to 10 ("maximum effort") for without exoskeleton was 3 (min.: 3; max.: 4) and 5 (min.: 2; max.: 6) for with the exoskeleton. This may be explained by the fact that the exoskeleton interferes with the task performance, which may require a greater effort to accomplish the task, for example walking or reaching objects and machines.

Finally, concerning the discomfort, we found that the participants felt discomfort on the neck, shoulders, thoracic region, lumbar region and hips, and thighs. Overtime, the discomfort increased for shoulder, lumbar region (although the number of participants that reported discomfort had decreased with time), and hips and thighs. For the thoracic region, the discomfort decreased. These results show new evidence of perceived discomfort with the use of the Laevo® exoskeleton since in the previous study focused on the assessment of discomfort related to the Laevo® users, the findings only show discomfort on back legs and chest [5].

3.2 EMG Test

In order to compare the muscle activity of the two tested conditions, Fig. 2 summarizes the EMG results.

The condition with exoskeleton produces a decrease in the EMG values, although not statistically significant. These results are well below the studies of occupational assessment of lumbar support exoskeletons [2, 5, 7, 8].

A possible explanation for the differences found in the results of this study compared to the referred studies may be related to the fact that the tasks evaluated in the referenced studies are restricted. However, the reduction in terms of musculoskeletal overload does not seem to be relevant, since there is maintenance of fatigue or tiredness in muscles studied in both conditions tested, according to the limit values (horizontal lines in Fig. 2) defined in the study of Jonsson [17]. However, the tasks tested involved some postural variability which may have influenced these results.

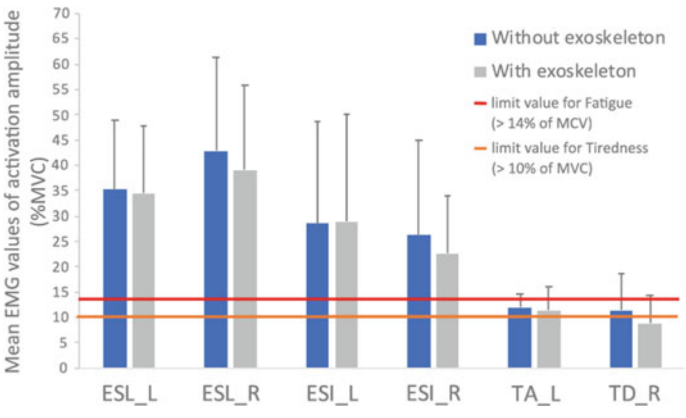

Fig. 2 Mean EMG values of activation amplitude (% of MVC) for *Erector Spinae Longissimus* (ESL_L), right *Erector Spinae Longissimus* (ESL_R), left *Erector Spinae Illiocostalis* (ESI_L), right *Erector Spinae Illiocostalis* (ESI_R), left *Trapezius pars Ascendens* (TA_L) and right *Trapezius pars Ascendens* (TA_R). The red line indicate the limit value for fatigue (>14% of MCV) and the orange line indicate the limit value for tiredness (>10% of MCV). Error bars indicate standard deviation

4 Conclusions

Actually, the topic of occupational exoskeletons has received considerable attention. However, despite their apparent promising potential, the widespread use of exoskeletons in the industrial context should be questioned. There is a need to understand the effects of the use of this equipment on workers' health, in particular on the physiological, psychophysical and biomechanical parameters.

The psychophysical data show good results on the workers' perceptions about back support of the exoskeleton Laevo®. However, they consider that the exoskeleton limits their range of motion, interfering with the industrial tasks performed and increases the physical effort perceived. In terms of discomfort, workers indicate discomfort in the neck, shoulders, thigh, and hip and in the thoracic region and lumbar region. The number of workers who experience discomfort in the lower back tends to decrease with increasing use time. Even so, it is recommended the redesign of contact parts of the equipment by its manufacturer, in order to reduce the discomfort perceived by users.

The EMG data generally point out that the use of the exoskeleton results in a decrease in muscle activity of 0.8–3.6% of the back muscles compared with not using the exoskeleton (despite not being statically significant). However, this reduction in terms of musculoskeletal overload does not seem to be relevant, since there is maintenance of fatigue or tiredness in muscles studied in both conditions tested. However, the tasks tested involved some postural variability which may have influenced these results.

Globally, the results showed that the use of passive exoskeletons does not significantly decrease exposure to the WMSD risk. However, results that prove the opposite were not found. In conclusion, the exoskeleton used in this study is not particularly useful for the assessed industrial tasks, since there is postural variability in short cycles. Therefore, the use of this equipment will be more suitable to industrial contexts where tasks require the maintenance and/or repetition of the sagittal trunk flexion, without performing other movements, such as rotation or lateral inclination.

This study was limited to the time that the participants used the exoskeleton and the different samples used in the two tests. Further work should include a long period of utilization of the equipment and the same samples in the two tests in order to link the results.

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References

1. Näf, M.B., Koopman, A. S., Baltrusch, S., Rodriguez-Guerrero, C., Vanderborght, B., Lefeber, D.: Passive back support exoskeleton improves range of motion using flexible beams. Front Robot AI 1–16 (2018)
2. Graham, R.B., Agnew, M.J., Stevenson, J.M.: Effectiveness of an on-body lifting aid at reducing low back physical demands during an automotive assembly task: assessment of EMG response and user acceptability. Appl. Ergon. 936–942 (2009)
3. Roffey, D.M., Wai, E.K., Bishop, P., Kwon, B.K., Dagenais, S.: Causal assessment of workplace manual handling or assisting patients and low back pain: results of a systematic review. Spine J. 639–651 (2010)
4. Beeck, R., Hermans, V.: Research on Work-Related Low Back Disorders. European Agency for Safety and Health at Work Research, Luxembourg (2000)
5. Bosch, T., van Eck, J., Knitel, K., de Looze, M.: The effects of a passive exoskeleton on muscle activity, discomfort and endurance time in forward bending work. Appl. Ergon. 212–217 (2016)
6. Lee, H., Kim, W., Han, J., Han, C.: The technical trend of the exoskeleton robot system for human power assistance. Int. J. Precis. Eng. Manuf. 1491–1497 (2012)
7. Abdoli E.M., Agnew, M.J., Stevenson, J.M.: An on-body personal lift augmentation device (PLAD) reduces EMG amplitude of erector spinae during lifting tasks. Clin. Biomech. 456–465 (2006)
8. Whitfield, B.H., Costigan, P.A., Stevenson, J.M., Smallman, C.L.: Effect of an on-body ergonomic aid on oxygen consumption during a repetitive lifting task. Int. J. Ind. Ergon. 39–44 (2014)
9. Borg, G.: Psychophysical scaling with applications in physical work and the perception of exertion. Scandinavian J. Work Environ. Health 55–58 (1990)
10. Likert, R.: A technique for the measurement of attitudes. Arch. Psychol. 5–55 (1932)
11. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., Jørgensen, K.: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. 233–237 (1987)
12. Ghaderi, F., Banakar, S., Rostami, S.: Effect of pre-cooling injection site on pain perception in pediatric dentistry: "A randomized clinical trial.". Dent. Res. J. 790–794 (2013)
13. Carnide, F., Veloso, A., Lourenço, A., Fred, A., Gamboa, H.: Determination of the minimum acquisition time for obtaining muscular load profile by Apdf function. J. Biomech. (2012)
14. SENIAM: http://www.seniam.org/. Last accessed 15 Apr 2019
15. Butler, H.L., Hubley-Kozey, C.L., Kozey, J.W.: Electromyographic assessment of trunk muscle activation amplitudes during a simulated lifting task using pattern recognition techniques. J. Electromyogr. Kinesiol. 505–512 (2009)
16. Ekstrom, R.A., Donatelli, R.A., Soderberg, G.L.: Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. J. Orthop. Sports Phys. Ther. 247–258 (2003)
17. Jonsson, B.: Measurement and evaluation of local muscular strain in the shoulder during constrained work. J. Hum. Ergol. 73–88 (1982)

Medical Emergency Resource Classification Instrument (*MERCI*) in the Oil Industry, Brazil

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Abstract The area of medical urgency and emergency is an important component of health care. Oil and Gas companies exist in a variety of locations in Brazil. The quality of medical infrastructure and specialties differs, and it is important to ensure optimal workers medical care. This paper describes the development of an objective tool for classifying levels of medical emergency response services in the oil industry, Bahia, Brazil, based on the steps that make up a complete cycle of medical emergency care: emergency detection, specifically requested resources, first aid on site, specialized care, and assisted removal to definitive treatment unit. A committee of 12 recognized occupational health and medical emergency experts with at least five years' experience participated in content validation through the Delphi Technique. The indicator was subdivided into 4 indices based on the risk profiles observed from the internal risk analysis documents. Medical Emergency Resource Classification Instrument (*MERCI*) aimed to reduce the subjectivities of the assessment and allocation of resources in medical emergencies, considering the characteristics of oil and gas companies regarding the assessment of risk scenarios, location and exposed population. The proposed methodology can lead top management to routinely adopt *MERCI*, ensuring the maintenance of medical emergency response resources, with a level of service appropriate to the needs of industry and workers.

Keywords Occupational medical urgency · Oil industry · Tool validation

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1 Introduction

The area of medical urgency and emergency is an important component of health care [1]. It relates health situations with risk of loss of life, aggravation and degrees of suffering at varying levels of criticality and complexity, which therefore require safe and immediate intervention. In 2002, the publication of the technical regulation of urgency and emergency care [2], defined some concepts of this area in relation to the components of mobile fixed pre hospital care, comprising basic and advanced support units. In addition, it classified hospital units and introduced Medical Regulation as the ordering and guiding element of the Urgency and Emergency Systems.

In the business area, the Ministry of Labour and Employment [3] established minimum parameters for urgency and emergency, through Regulatory Standard No. 7 [3], item 7.5.1—First Aid: Every establishment must be equipped with material necessary for the provision of first aid, considering the characteristics of the developed activity; keep this material stored in a proper place and in the care of a person trained for this purpose. The needs of corporate outpatient care range from meeting the simplest demands to emergency situations that require rapid and safe response. Thus, the user should be properly oriented to ensure continuity of treatment, paying attention to the limits of the service [4].

Oil and Gas companies exist in a variety of locations in Brazil where the quality of medical infrastructure and specialties differs, and it is important to ensure optimal medical care for the workers. For this reason, health professionals need to assess local health facilities to ensure they can provide the health needed for the workers [5]. More specifically, the scope of a particular company may range from operating in remote areas to administrative services in offices, allocating support and management teams, making it difficult to provide materials, treatment drugs, and maintaining skilled staff appropriate to the scenarios and risks posed. However, regardless of where it operates, emergency situations must be anticipated and dealt with quickly and effectively in order to minimize their effects. In order to develop an effective Medical Emergency Response, it is important to first determine the expected standard of care. There are several standards, most using a tiered approach based on response time [6]. In 2017, the Oil Spill Response Joint Industry Project [5], an international association that gathers and publishes good practices for Oil and Gas companies, published a health services assessment checklist to a qualitative assessment, guiding internal decisions of companies without however claiming to be a scoring tool.

This paper describes the process of developing an objective tool for classifying levels of medical emergency response services in the oil industry, Bahia, Brazil, based on the steps that make up a complete cycle of medical emergency care: emergency detection, specifically requested resources, first aid on site, specialized care, assisted removal to definitive treatment unit.

2 Materials and Methods

The study deals with the development of a Medical Emergency Resource Classification Instrument (*MERCI*) in the Brazilian Oil Industry. Carried out from February to June 2019, at the worker health service in the oil extraction and production industry in Bahia, Brazil, the study involved six medical emergency specialists with at least 10 years of experience in the oil industry to develop the *MERCI*. A committee of 12 recognized occupational health and medical emergency experts with at least five years' experience participated in content validation through the Delphi Technique [7]. Figure 1 details the *MERCI* elaboration process.

The study was approved by the Research Ethics Committee of the Bahiana School of Medicine and Public Health of Brazil and registered with CAAE 84318218.2.0000.5544.

2.1 MERCI *Development*

The development stage included the group of experts, 30% of each profession, including physicians and nurses. The literature review allowed the analysis of previously referenced instruments, as well as the theoretical framework for the decision and development of a new instrument based on current references. It was structured in its final version with two documents, namely "checklist" and "classification of service size", as follows. The Checklist consists in two steps: (i) identification of the emergency service to be studied and (ii) quantitative assessment, including three

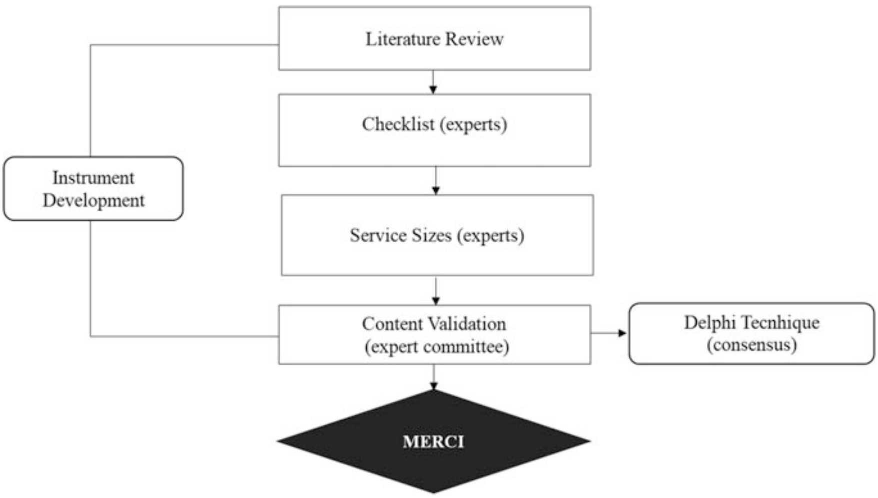

Fig. 1 Flowchart of *MERCI*'s content elaboration and validation process

criteria: risk scenarios (administrative and operational), accessibility (urban or remote area) and population. Corresponding scores were defined, which together generate a score for the service. To classify the five sizes of care, the following dimensions were considered: (i) time to cover specialized support, which may be 24 or 12 h, (ii) composition of the service team, (iii) ambulance support, (iv) materials, treatment drugs and equipment and (v) medical regulation centre.

2.2 **MERCI** *Validation*

To validate the content through the Delphi Technique [7], a panel was developed with 12 experts, using their knowledge, from five eight-hour meetings in which each member gave their opinion on the documents under discussion, until the group consensus.

3 Results and Discussion

The details of the *MERCI* quantitative assessment stage are presented in Table 1, allowing a clearer understanding about its organization.

The scenario indicator was subdivided into 4 indices based on the risk profiles observed from the internal risk analysis documents:

1. Administrative risk—characterized as a place with activities where the results of an accident are unlikely to cause serious injury, although other non-work-related acute medical conditions may occur. This is the case of offices, for example.

Table 1 *MERCI* checklist quantitative assessment

Indicator	Score	Indices
Risk scenario	1	Administrative risk
	2	Industrial risk—warehouses/workshops
	3	Industrial risk—thermoelectric/drilling rigs/oil transfer stations
	4	Industrial risk—offshore platform/oil treatment terminal
Accessibility	1	Urban area
	2	Remote area
Population	1	Up to 50 workers
	2	100–150 workers
	3	150–500 workers
	4	Over 500 workers
MERCI score		

2. Industrial risk—warehouses/workshops: characterized as a place where work activity can result in injury accidents that can lead to work leave and medical treatment, and physical distancing from specialized medical teams can delay the establishment of conducts within a reasonable time.
3. Industrial risk—thermoelectric/drilling rigs/oil transfer stations: characterized as a place where work activity can cause serious injury to multiple casualties related to heavy equipment, pressurized systems and important chemical/fuel inventory.
4. Industrial risk—offshore platform/oil treatment terminal: characterized by the same risk profile as onshore production facilities, compounded by the physical limitation of resource maintenance and access difficulties for emergency response.

Regarding the accessibility indicator, two indices were considered: urban area and remote area.

1. Urban area: companies located in an urban area tend to less influence score because they are close to resources provided by agencies outside the emergency response support organization. In addition, from the point of view of responding to medical emergencies, there is a reduced response time between emergency identification to hospital care for definitive treatment.
2. Remote area: the occurrence of emergency situations in remote areas leads to a greater need for attention, for reasons previously mentioned, besides the difficulties in accessing the last stage of an emergency care cycle (definitive treatment), access to external resources is not facilitated.

The population indicator starts from the notion of exposure. Exposure, in the context of technological accidents, is considered to be elements and/or systems (including people and property) that are present in risk areas and are therefore subject to potential losses. They may include the number of inhabitants or types of property in a given place which, when combined with the specific vulnerability of each target, provide input for estimating existing risks in the area of interest. The indicator consists of 4 indices based on population ranges: up to 50 workers, 51 to 150 workers, 151 to 500 workers and more than 500 workers.

The final score calculation (Eq. 1) is achieved by the sum of the all scores assigned to each of the three assessed indicators, namely: the risk scenario and the population indicators could have a score ranged 1–4 and the accessibility indicator could have a score ranged 1 to 2.

$$Risk\,Scenario_{Score} + Accessibility_{Score} + Population_{Score} = MERCI_{Score} \qquad (1)$$

By applying the scoring of Table 1, based on the characteristics of the operational installation, resource sizes will be defined, respecting the distribution below:

- Size 1–10 points—installations rated size 1 should have advanced 24-h support staff with dedicated removal capabilities. In addition, equipment, treatment drugs and consumables appropriate to the response capacity and, where applicable, resources for specific installation scenarios should be made available,
- Size 2–7 or 9 points—size 2 should be staffed with 24-h basic support personnel with dedicated on-site ground remediation capabilities, regulated by tele-medical facilities, with equipment, treatment drugs and consumable support appropriate for the responsiveness;
- Size 3–5 or 6 points—size 3, due to the characteristics of exposed population, location and profile of risk scenarios, should have the presence of a physician and nurse during their opening hours. The standard of equipment, treatment drugs and consumables appropriate to the responsiveness;
- Size 4—up to 4 points—size 4 must have the presence of a trained nursing professional for emergency response appropriate to the opening hours of the facility regulated by a remote physician, using telemedicine resources. In addition, it has a standard of equipment, treatment drugs and consumables suitable for its responsiveness and can request external resource for removal, when necessary, as well as in size 5;
- Size 5—up to 3 points—considering exposed population, risk rating, and location, the facility can be serviced by trained workforce personnel, with no specialization requirements supported by first-aid kits appropriate to their responsiveness for initial care. However, the rescuer may request an ambulance for removal if necessary (contracted public service resource, not dedicated to local emergency plan).

An example of *MERCI* application is:

- Risk scenario indicator: Industrial risk—offshore platform/oil treatment terminal (score 4);
- Accessibility indicator: Remote area (score 2);
- Population: 150–500 workers (score 3).

The final *MERCI* score would be 9, so a size 2 service should be applied.
To the five sizes classification, five dimensions were considered:

- Time to cover specialized support, which may be 24 h, 12 h or absence of urgency and emergency nurse's support;
- Composition of the team for primary care may include a physician specialized in urgency and emergency, an urgency and emergency specialized nurse, an ambulance driver or the absence of professionals in situ;
- Ambulance support may vary according to the availability of the resource, site fixed ambulance or by request when necessary, as well as the level of complexity of the ambulance service, which may be basic support (nurse and ambulance driver) or advanced support (physician, nurse and ambulance driver);
- Standardized materials, treatment drugs and equipment to meet the complexity of each service size;

Table 2 *MERCI* service size classification

Dimensions	Size I	Size II	Size III	Size IV	Size V
Time for expert support coverage	24 h assistance	24 h assistance	12 h assistance	12 h assistance	–
Care staff	Physician, nurse and ambulance driver	Nurse and ambulance driver	Physician and nurse	Nurse	–
Ambulance support	Site fixed ambulance	Site fixed ambulance	Drive ambulance	Drive ambulance	Drive ambulance
	Advanced life support	Basic life support	Advanced life support	Advanced life support	Advanced life support
Materials, treatment drugs and equipment	Size I standard	Size II standard	Size III standard	Size IV standard	First aid kit
Medical regulation centre	Aero medical rescue	Advanced life support	–	–	–

- Available medical regulation centre with advanced support ambulance (physician, nurse and ambulance driver) or with aero-medical rescue.

Table 2 shows the classification of the service size and main characteristics.

4 Conclusions

The developed *MERCI* tool aimed to reduce the subjectivities of the assessment and allocation of resources in medical emergencies considering the characteristics of oil and gas companies regarding the assessment of risk scenarios, location and exposed population. The dissemination of the proposed methodology can lead top management to adopt this system routinely, ensuring the maintenance of medical emergency response resources, with a level of service appropriate to the needs of industry and workers.

The application and implementation of *MERCI* at the oil extraction and production industry, as well as the development of statistical analyses to validate the reliability and reproducibility of the instrument, with scientific publication of results, is recommended in future works.

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References

1. Brasil: Ministério da Saúde. Secretaria de Atenção à Saúde. Protocolos de Intervenção para o SAMU 192 - Serviço de Atendimento Móvel de Urgência [Intervention Protocols for SAMU 192 - Mobile Emergency Care Service] [Internet], 482 p. Ministério da Saúde; Brasília (2016). Available from file:///C:/Users/Diogo/Desktop/protocolo_suporte_basico_vida.pdf
2. Brasil: Ministério da Saúde. Portaria 2.048 de 05 de novembro de 2002. Estabelece o Regulamento Técnico dos Sistemas Estaduais de Urgência e Emergência [Ordinance 2,048 of November 5, 2002. Establishes the Technical Regulation of State Emergency And Emergency Systems] [Internet]. Diário Oficial da União (2002). Available from http://bvsms.saude.gov.br/bvs/saudelegis/gm/2002/prt2048_05_11_2002.html
3. Ministério do Trabalho. Norma Regulamentadora 7 -Programa de Controle Médico e de Saúde Ocupacional [Regulatory Standard 7 -Occupational Health Medical and Medical Control Program], pp. 1–16. Diário Oficial da República Federativa do Brasil Brasil; 2013
4. de Melo MCB, da Silva NLC (2011) Urgência e Emergência na Atenção Primária à Saúde [Urgency and emergency in primary health care] [Internet], 132 p. Belo Horizon: Nescon UFMG (2011). Available from https://www.nescon.medicina.ufmg.br/biblioteca/imagem/3046.pdf
5. IPIECA—International Petroleum Industry Environmental Conservation Association (2017) Medical facilities assessment. Checklist for medical professionals in the oil and gas industry [Internet], 20 p. IPIECA, London. Available from http://www.ipieca.org/resources/checklist/medical-facilities-assessment-checklist-for-medical-professionals-in-the-oil-and-gas-industry/
6. IRHC—Institute of Remote Healthcare (2013) Remote healthcare guidance document for energy and associated maritime activities [Internet]. IRHC, London. Available from https://www.irhc.org.uk/page/irhcguidancedoc/Remote-Healthcare-GuidanceDocument-for-Energy-and-Associated-Maritime.htm
7. Okoli C, Pawlowski SD (2004) The Delphi method as a research tool: an example, design considerations and applications. Inf Manag [Internet] **42**(1), 15–29. Available from http://www.sciencedirect.com/science/article/pii/S0378720603001794

The Prevalence of Self-Reported Respiratory Symptoms and Related Diseases in Different Agricultural Sectors: Findings from a Cross-Sectional Survey in Finland

Eetu N. Suominen and Tuula M. Putus

Abstract Respiratory diseases and symptoms are well-recognized occupational problems among farmers. Our objective was to compare the current prevalence and occurrence trends of respiratory symptoms and disorders between different Finnish agricultural sectors and to, more specifically, determine the risk factors leading to the development of the symptoms. A questionnaire was e-mailed randomly to 10,000 members of The Farmers' Social Insurance Institution in Finland. The response rate was 25.1%. Farmers working with animals reported more respiratory symptoms than farmers working in haying, crop farming or forestry. Organic dust exposure was associated significantly with a higher prevalence of wheezing, asthma, allergic rhinitis and allergic alveolitis. Chronic bronchitis was associated with exposure to cattle, animal excrement, organic dust and fodder exposure. The prevalence of asthma was equal compared to the general population. The sectors of farming associated with an elevated prevalence of respiratory symptoms in Finland include dairy, beef and pig farming. The trend in the increase of asthma among farmers seems to follow the development of asthma in the general population. These results remind that respiratory protection should be considered especially during exposure to agricultural organic dusts and microbes.

Keywords Agriculture · Occupational exposure · Respiratory illness

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1 Introduction

Finland has approximately 48,000 farms with an average arable area being 47 hectares. With dairy and crop farming being the largest agricultural sectors, agriculture and horticulture provide employment approximately for 100,000 people. Since joining the European Union in 1995, the number of farms has decreased by 2.8% per year [1]. Agriculture workers have a high risk for exposure to respiratory hazards. Because only a small portion of the overall population is employed in agriculture, respiratory disease in farmers is not a major public health issue. Despite this, the health and well-being of farmers as well as their health risk reduction in their working conditions needs to be examined, especially because a farming environment has been thought to prevent the development of allergies [2].

Respiratory diseases and symptoms are well-recognized occupational problems among farmers [3]. Agricultural workers in all sectors of farming are exposed to various types of airborne toxins and allergens in their work, including organic dust, pesticides and microbes [4]. Several different types of gases (e.g., ammonia, methane and carbon dioxide) may also be present in their working environments. Inhalation of biological dusts, which are composed of organic material from straw, hay, animals and microbes, can cause changes in pulmonary function, induce antibody formation and lead to the development of respiratory disease. Several studies have indicated a higher prevalence of respiratory symptoms among agricultural workers [5, 6]. Statistics have shown that farmers have higher morbidity and mortality for certain respiratory diseases [7, 8].

Research about respiratory symptoms and diseases in Finnish farmers during the past decades is scarce. Our primary objectives, in this population survey of Finnish farmers, were to compare the current prevalence and occurrence trends of self-reported respiratory symptoms and disorders in different Finnish agricultural sectors and, more specifically, to determine risk factors in the development of the symptoms. Determining these risk factors can improve health recommendations and other preventive actions.

2 Materials and Methods

This cross-sectional study was conducted throughout Finland in the winter of 2017–2018. The Farmers' Social Insurance Institution (MELA) e-mailed the questionnaire originally to 5000 of its members selected by simple random sampling. The questionnaire sought to obtain information about work history, work conditions and several symptoms, including respiratory symptoms. It was formulated by the discipline of Occupational Health at the University of Turku and based on the questionnaire used in the VTH project [9] including also the Örebro questionnaire and adequate parts of the Tuohilampi questionnaire [10]. During the first month, the questionnaire was answered by 1060 subjects. After this, a reminder was sent, and the sampling was expanded to 10,000 members of MELA. During the winter a total of 2513 questionnaires were returned with the final response rate being 25.1%.

The data obtained with the e-mail-based questionnaire was analyzed with SPSS Statistics for Windows, version 25.0 (IBM Corp: Armonk, NY). Categories of farm exposures were derived from analyses of self-reported exposures. The statistical differences of dichotomous variables were tested with a chi-square test, and multivariate models were run using logistic regression models. Multivariate analyses were adjusted for sex, age group and smoking. Differences with a $p < 0.05$ were considered statistically significant.

Of the 2513 people who originally answered the questionnaire, only the ones representing the largest agricultural sectors (i.e. dairy, hay, crop, cattle, pig and forest farming) were selected for further analysis. Farming sectors of poultry, greenhouse farming and undefined farming types had a low answering rate (with 45, 6 and 153 subjects, respectively) and were excluded. The remainder was a target population of 2309 farmers. In the target population, 76% of subjects were full-time farmers, and 14% were part-time farmers.

3 Results

In contrast to many modern Finnish farms, the average area of the farms in this study was relatively large with 42% of the farm area above 50 hectares. The mean age of farmers ranged from 47.1 to 52.4 years. The study population in the farming sectors were different in their sex and age distributions ($p < 0.001$). The prevalence of young farmers was significantly lower in each farming sector. In the overall target population, 6% were smokers, 5% were occasional smokers, 18% were ex-smokers and 71% had never smoked.

The overall prevalence of doctor-diagnosed asthma was 10.8% in the farmers but was higher for crop farmers (13.1%), pig farmers (12.0%), cattle farmers (11.9%) and dairy farmers (11.4%). However, the differences among different farming types were not significant. Doctor-diagnosed allergic rhinitis was reported by 12.3% of the farmers overall but was found somewhat higher in crop farmers (14.6%). Doctor-diagnosed allergic alveolitis (i.e., hypersensitivity pneumonitis) was reported by 1.2% of the farmers overall with the numbers being fairly similar in all farming sectors, except in forestry, where there were no cases reported. The differences in the prevalence of allergic rhinitis and allergic alveolitis among the farming sectors were not significant.

The respondent was classified as having chronic bronchitis if he or she had coughed up phlegm for at least three months annually for at least two consecutive years. Subjects, who had answered "yes" to the question about doctor-diagnosed asthma, were excluded. The overall prevalence of chronic bronchitis was 21.4% but was lower in the farmers who worked in haying or crop farming (16.3% and 17.2%, respectively, $p < 0.05$).

Table 1 Prevalence of respiratory symptoms in the last 12 months by reported farming type. The percentages of respondents who reported symptoms daily or every week

Symptom	Dairy	Beef	Pig	Haying	Crop	Forestry
Stuffed nose	34.0[c]	31.3	34.7	25.1[a]	23.6[b]	19.5[a]
Rhinitis	17.2[b]	17.7	15.5	9.4[c]	11.8	14.8
Purulent rhinitis	5.3	5.6	12.1[c]	1.9[b]	4.2	5.6
Sore throat	4.0	2.6	10.3[c]	3.9	2.5	0.9
Hoarseness	10.5	8.1	14.4[a]	7.5	6.7	9.3
Dry cough	11.4	9.9	19.8[c]	7.0[a]	6.9[a]	15.0
Phlegm	8.6	9.2	12.0	3.9[b]	5.6	13.0[a]
Dyspnea	13.4[c]	11.6	15.5	6.3[c]	8.7	6.5
Tightness of breath	7.5[b]	5.6	10.4[a]	3.1[a]	4.5	2.8
Wheezing	5.3	4.9	7.0	2.9	3.1	4.7

[a]$p < 0.05$, [b]$p < 0.01$ and [c]$p < 0.001$ for comparison with all other farmers

3.1 Respiratory Symptoms

The prevalence of respiratory symptoms in farmers during different farming types is presented in Table 1. Farmers working with animals reported more respiratory symptoms than farmers working in haying, crop farming or forestry. Dairy farmers reported more complaints about a stuffed nose, rhinitis and dyspnea during physical strain than all other farmers. Purulent rhinitis, sore throat, hoarseness and dry cough were associated with pig farming. A significant elevation was also observed in “tightness of breath”, which was associated with dairy and pig farming. Farmers working in haying reported less often a stuffed nose, rhinitis, purulent rhinitis, dry cough, phlegm, dyspnea in physical strain and tightness of breath than other farmers. Crop farming had a negative association with the prevalence of stuffed nose and dry cough. Forestry workers reported less often a stuffed nose but had an elevated level of phlegm compared to other farmers.

3.2 Work Exposures

Table 2 shows the prevalence of wheezing and respiratory diseases categorized by farming exposure factors. Exposure to cattle showed an increase in the prevalence of chronic bronchitis but otherwise animal exposure was not associated with an increase in the respiratory diseases. However, exposure to animal excrement and fodder was associated with an elevated prevalence of wheezing and chronic bronchitis. Those workers, who were exposed to animal fodder, also showed an increased prevalence of asthma. Organic dust exposure was associated significantly with a higher prevalence of wheezing, asthma, allergic rhinitis and allergic alveolitis. The usage of respiratory protective equipment was varied. Two out of three

Table 2 Prevalence of wheeze and respiratory diseases in the last 12 months by reported work related exposure. The percentages of respondents who reported symptoms daily or every week

Exposure category	n	Wheeze	Asthma	Allergic rhinitis	Allergic alveolitis	Chronic bronchitis
Cattle	1103	5.2	11.5	12.3	1.4	23.5[a]
Pigs	108	7.0	12.0	12.0	0.9	26.9
Cleaning chemicals	599	6.3[a]	10.5	13.4	0.5	23.9
Pesticides	690	4.0	9.9	13.3	1.2	20.3
Animal excrement	950	6.0[b]	11.8	12.8	0.9	23.9[a]
Fodder handling	1342	5.7[b]	11.8[a]	13.0	1.1	24.1[c]
Organic dust	786	7.1[c]	14.0[c]	16.4[c]	2.5[c]	27.6[c]
Inorganic dust	1053	4.8	10.5	13.7	1.0	21.1

[a]$p < 0.05$, [b]$p < 0.01$ and [c]$p < 0.001$ for comparison with all other farmers

pig farmers reported that they used a respirator mask. However, among dairy and beef farmers the numbers were 34.7% and 37.8%, respectively. The usage of a respirator mask was reported by 57.8% of hay-, 56.3% of crop- and 26.1% of forestry farmers.

3.3 Multivariate Analysis

We assessed the independent effect of the work-related exposures on the development of respiratory disorders by adjusting the farming categories by the age, sex and smoking, variables which all had impact on the respiratory disorders. Farmers working with cattle had an elevated risk to chronic bronchitis compared to all other farmers (aOR 1.44, 1.12–1.84). Disinfection and cleaning chemical exposure elevated the risk for wheezing (aOR 1.78, 1.17–2.70) and chronic bronchitis (aOR 1.31, 1.03–1.68). Elevation in the risk for asthma was observed in workers, who had exposure to fodder (aOR 1.49, 1.09–2.04) and organic dust (aOR 1.85, 1.39–2.46). The latter also elevated the risk for wheezing (aOR 2.41, 1.60–3.63), allergic rhinitis (aOR 1.77, 1.36–2.31), allergic alveoltis (8.95, 3.04–26.4) and chronic bronchitis (aOR 1.84, 1.46–2.32).

4 Discussion

Agriculture and farming cover a wide spectrum of activities, which vary in different sectors within the industry, depending, for example, on the type and size of the farm. Therefore, we studied the association between respiratory disorders and farming separately in different agricultural sectors.

There were three main findings of this study being firstly that the prevalence of respiratory symptoms was highest among dairy-, beef- and pig farmers, secondly that the occurrence of respiratory diseases was mostly associated with animal excrement, fodder handling and organic dust exposure and thirdly that the negative and positive associations between the work-related exposures and the development of symptoms were not explained by an individual's age, sex or smoking.

A high response rate increases the validity of population-based studies, because a low response rate might lead to selection bias. We e-mailed the questionnaire to 10,000 members of MELA with the final response rate being 25.1%. Although the response rate in our survey was low, we were able to acquire completed questionnaires from over 2500 farmers, the study population representing different farming sectors and all geographical areas in Finland. However, we focused on comparing the prevalence of symptoms and disorder between different occupational sectors instead of generating estimates to entire farming population. Possible bias might exist both in the selection and in the reporting of symptoms confounding the connection between a risk factor and the prevalence of a symptom/disease. It is possible that those with symptoms are more likely to respond to the questionnaire. Farmers can also influence their own working environment compared with, for example, industrial workers. Furthermore, the low response rate fails to explain the differences we observed in the prevalence of symptoms and disorders in several farming sectors.

Several factors can affect the quality of air in occupational environments. These factors include humidity, temperature, ventilation, dirt, material emissions and moisture damages. Working in these problematic environments and exposure to airborne impurities can cause various types of respiratory symptoms including shortness of breath, coughing and wheezing [11, 12]. Symptoms, such as a stuffy and runny nose, fatigue and irritation of eyes are also commonly reported [13].

The main findings of this study include the association of respiratory symptoms with animal exposure (Table 1). The symptoms seemed to be linked to heavy exposures of organic dust derived from various sources. Of all the farming sectors, pig farmers had the highest prevalence of work-related respiratory symptoms, and insufficient ventilation was reported more likely by dairy-, pig- and beef farmers than by farmers in other farming sectors. These findings are consistent with previous research conducted in Europe [14]. Working in these production fields requires a high-intensity exposure to barn air. The barn air is a mixture of dusts, gases and organic substances (e.g., methane, hydrogen sulfide, ammonia, endotoxin etc.) and is known to cause lung dysfunction and to be a major risk factor for respiratory symptoms [15, 16]. In barns containing swine, this barn air has been demonstrated to increase the bronchial responsiveness and levels of neutrophils as well as several proinflammatory factors in the serum in naïve, healthy volunteers [17].

The published data about the association between farmers and asthma are conflicting. Previous research has shown a lower prevalence of the development of asthma and allergies among farmers [18], but there are also findings suggesting that the highest risk of asthma, when analyzed by occupation, is among agricultural workers [19]. Among children who grow up on a farm, studies have drawn attention to the possible protective effect of a farming environment for these children against atopy and asthma [20, 21]. An important question is whether the protective effect persists into adulthood.

According to our study, adult farmers developed asthma equally compared to the general population. Importantly, the proportion of farming as an occupation in Finland has declined considerably after the Second World War. Before the 1940s, about 60% of the Finnish population followed this occupation and now less than 10% do. In the early 1980s, asthma was diagnosed only in 2–3% and chronic bronchitis in 5% of Finnish farmers [9, 22, 23]. In the early 1990s, the prevalence of asthma among Finnish farmers had raised to 4.4%. The trend in the increase of diagnosed asthma among farmers seems to follow the development of asthma in the Finnish population during the recent decades [24, 25]. Atopic asthma and non-atopic asthma were not differentiated in our study. There may, however, exist a protective effect of endotoxins and fungal spores on atopic asthma and, on the other hand, a positive association with non-atopic asthma [26]. Asthma was associated with microbial exposure and fodder handling. Previous research has associated asthma and pig farming due to possible causes such as organic dusts, endotoxins, ammonia and bacteria [16].

In our study, an increased prevalence of both allergic rhinitis and allergic alveolitis were associated with exposure to organic dust in the work environment. All of the respiratory diseases investigated in this study may be classified as syndromes with several possible mechanisms. In our study, the overall prevalence of allergic rhinitis (12.3%) in farmers was lower than in the Finnish population being 28.1% in men and 36.1% in women [25]. Previous studies have shown similar results with a prevalence of self-reported nasal allergies among farmers being lower than estimates in the general population [6, 27]. Extrinsic allergic alveolitis (also called hypersensitivity pneumonitis) often results from recurrent exposure to organic dust. The main causative agents in farming environments are microorganisms present in moldy plant materials [28].

The diagnosis of chronic bronchitis was based on symptoms according to the MRC questionnaire [29]. In a meta-analysis carried out by Guillien et al. [30], an increased prevalence of chronic bronchitis was found in farmers raising cattle, swine and poultry as well as in crop- and grain farmers. Our results show a positive correlation with chronic bronchitis and exposure to cattle, animal excrement and fodder handling. We also found a negative correlation between chronic bronchitis and crop/grain farming. A significant increase in the overall prevalence of chronic bronchitis in Finnish farmers was also observed in our study.

5 Conclusions

These results point to a health recommendation for respiratory protection of farmers, especially during activities where they are exposed to agricultural organic dusts and microbes. The education of farmers and improvements in dust control in their working environment are crucial. In addition, because barn air exposure has been recognized to be a risk factor, enhancements in the hygiene and ventilation in these barns could help in reducing harmful exposures.

References

1. Niemi, J., Ahlstedt, J.: Suomen Maatalous ja Maaseutuelinkeinot, 2nd edn. Luke, Finland (2015)
2. Schuijs, M.J., Willart, M.A., Vergote, K., et al.: Farm dust and endotoxin protect against allergy through A20 induction in lung epithelial cells. Science **349**(6252), 1106–1110 (2015)
3. Thelin, A.: Work and health among farmers. Scand. J Soc. Med. (Suppl. 22) (1980)
4. Nordgren, T.M., Charavaryamath, C.: Agriculture occupational exposures and factors affecting health effects. Curr. Allergy Asthma Rep. **18**(12), 65 (2018)
5. Radon, K., Opravil, U., Hartung, J., et al.: Work-related respiratory disorders and farming characteristics among cattle farmers in Northern Germany. Am. J. Ind. Med. **36**(4), 444–449 (1999)
6. Skórska, C., Mackiewicz, B., Dutkiewicz, J., et al.: Effects of exposure to grain dust in Polish farmers: work-related symptoms and immunologic response to microbial antigens associated with dust. Ann. Agric. Environ. Med. **5**, 147–154 (1998)
7. Heller, R., Kelson, M.: Respiratory disease mortality in agricultural workers in eight member countries of the European Community. Int. J. Epidemiol. **11**(2), 170–174 (1982)
8. Toren, K., Horte, L.G., Jarvholm, B.: Occupation and smoking adjusted mortality due to asthma among Swedish men. Br. J. Ind. Med. **48**(5), 323–326 (1991)
9. Vohlonen, I., Husman, K., Kalimo, E., Nuutinen, J., Raitasalo, R., Tupi, K. et al.: Viljelijöiden työ ja ter-veys. A:1. Kansaneläkelaitoksen Julkaisuja, Helsinki (1979)
10. Susitaival, P., Husman, T.: Tuohilampi-Questionnaire for Population Studies of Hypersensitivity Diseases of Respiratory Organs, Skin and Eyes. Orion, Kuopio (1996)
11. Redlich, C.A., Sparer, J., Cullen, M.R.: Sick-building syndrome. Lancet **349**(9057), 1013–1016 (1997)
12. Cherry, N., Beach, J., Senthilselvan, A., et al.: Pesticide use and Asthma in Alberta grain farmers. Int. J. Environ. Res. Public Health **15**(3), 526 (2018)
13. Reijula, K., Sundman-Digert, C.: Assessment of indoor air problems at work with a questionnaire. Occup. Environ. Med. **61**(1), 33–38 (2004)
14. Radon, K., Danuser, B., Iversen, M., et al.: Respiratory symptoms in European animal farmers. Eur. Respir. J. **17**(4), 747–754 (2001)
15. Zejda, J.E., Hurst, T.S., Rhodes, C.S., et al.: Respiratory health of swine producers: focus on young workers. Chest **103**(3), 702–709 (1993)
16. Iversen, M., Dahl, R., Korsgaard, J., et al.: Respiratory symptoms in Danish farmers: an epidemiological study of risk factors. Thorax **43**(11), 872–877 (1998)
17. Larsson, K.A., Eklund, A.G., Hansson, L.O., et al.: Swine dust causes intense airways inflammation in healthy subjects. Am. J. Respir. Crit. Care Med. **150**(4), 973–977 (1994)
18. Kimbell-Dunn, M., Bradshaw, L., Slater, T., et al.: Asthma and allergy in New Zealand farmers. Am. J. Ind. Med. **35**(1), 51–57 (1999)

19. Kogevinas, M., Antó, J.M., Sunyer, J., et al.: Occupational asthma in Europe and other industrialised areas: a population-based study. Lancet **353**(9166), 1750–1754 (1999)
20. Braun-Fahrlander, C., Gassner, M., Grize, L., et al.: Prevalence of hay fever and allergic sensitization in farmer's children and their peers living in the same rural community. SCARPOL team. Swiss Study on Childhood Allergy and Respiratory Symptoms with Respect to Air Pollution. Clin Exp Allergy **29**(1), 28–34 (1999)
21. Portengen, L., Sigsgaard, T., Omland, Ø., et al.: Low prevalence of atopy in young Danish farmers and farming students born and raised on a farm. Clin. Exp. Allergy **32**(2), 247–253 (2002)
22. Heinonen, O.P., Horsmanheimo, M., Vohlonen, I., et al.: Prevalence of allergic symptoms in rural and urban populations. Eur. J. Respir. Dis. Suppl. **152**, 64–69 (1987)
23. Terho, E.O.: Work-related respiratory disorders among finnish farmers. Am. J. Ind. Med. **18** (3), 269–272 (1990)
24. Hedman, J., Kaprio, J., Poussa, T., et al.: Prevalence of asthma, aspirin intolerance, nasal polyposis and chronic obstructive pulmonary disease in a population-based study. Int. J. Epidemiol. **28**(4), 717–722 (1999)
25. Jousilahti, P., Haahtela, T., Laatikainen, T., et al.: Asthma and respiratory allergy prevalence is still increasing among Finnish young adults. Eur. Respir. J. **47**(3), 985–987 (2016)
26. Eduard, W., Douwes, J., Omenaas, E., et al.: Do farming exposures cause or prevent asthma? Results from a study of adult Norwegian farmers. Thorax **59**(5), 381–386 (2004)
27. Danuser, B., Weber, C., KuÈnzli, N., et al.: Respiratory symptoms in Swiss farmers: an epidemiological study of risk factors. Am. J. Ind. Med. **39**(4), 410–418 (2001)
28. Costabel, U., Bonella, F., Guzman, J.: Chronic hypersensitivity pneumonitis. Clin. Chest Med. **33**(1), 151–163 (2012)
29. Definition and classification of chronic bronchitis for clinical and epidemiological purposes. A report to the Medical Research Council by their Committee on the aetiology of chronic bronchitis. Lancet **285**(1), 775–779 (1965)
30. Guillien, A., Soumagne, T., Dalphin, J., et al.: COPD, airflow limitation and chronic bronchitis in farmers: a systematic review and meta-analysis. Occup. Environ. Med. **76**(1), 58–68 (2019)

Health Monitoring and Intervention Plan on Oil Industry Workers: Results from a Case-Study

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Abstract Oil industry workers are particularly vulnerable to risks related to their especial working conditions like exposure to hazardous chemicals, explosions and fires, working in confined spaces and often in remote areas or in offshore platforms. Dedicated work health surveillance plans that take into consideration environmental risks are of the utmost importance to safeguard workers health and to communicate identified faults and gaps to other institutional departments to provide adequate intervention. This work presents an assessment case-study of an on-going health intervention and monitoring plan focused on oil industry workers and the quality of potable water distributed. In the assessment of risks to health, the quality of water for human use is case-sensitive as water is vital to life but may act as a transmission vector for several diseases whose symptoms may appear as acute (often as a consequence of water contamination by microorganisms or toxic substances) or chronic, usually more related to the ingestion of chemically contaminated water. In the study timeline, six parameters were identified as critical in the water quality: Total Coliforms, *Escherichia coli*, iron, pH, turbidity and colour. A global graphical distribution of nonconformity analysis by working service for each geographic location and for the entire period of the study highlighted the two worse water quality work sectors: 'Oil Extractions Stations' and 'Baths & Changing Rooms'. Corrective measures arising from this case-study of the on-going health monitoring and intervention plan focus on sensibilization for improvement of workers hygiene and for cleaning and sanitization procedures.

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Keywords Oil industry workers · Potable water quality · Health intervention monitoring plan

1 Introduction

Safety at work is determinant to provide for decent work conditions [1]. Workers' health (WH) has a direct and quantifiable positive impact on labour productivity, improving the sustainability of social security systems as these are dependent of healthy active populations. Keeping workers healthy implies occupational risk identification and prevention to promote safe and healthy workplace conditions. Oil industry workers are particularly vulnerable to risks related to their especial working conditions like exposure to hazardous chemicals, explosions and fires, working in confined spaces (underground or underwater) and often in remote areas or in offshore platforms. In addition to the harshness specificity of their work, oil industry workers are also subjected to poor environmental and sanitary conditions, which are occupational risks present in other working sectors. For these type of professions, dedicated WH surveillance considering environmental risks are of the utmost importance to safeguard workers health, to prevent damaging working conditions and to communicate identified faults and gaps to other institutional departments to provide adequate intervention.

This work presents an assessment case-study of an on-going health intervention and monitoring plan focused on oil industry workers using the quality of potable water distributed as an indicator of work safety conditions. In the assessment of risks to health, the quality of water for human use is case-sensitive as water is vital to life but may act as a transmission vector for several diseases whose symptoms may appear as acute (often as a consequence of water contamination by microorganisms or toxic substances) or chronic, usually more related to the ingestion of chemically contaminated water [2, 3]. However, the development of disease by ingestion of contaminated water is also dependent on the health condition and immunity of individuals. Frequently, in the oil industry sector, specially at offshore conditions or in remote areas, water supply and sanitation infrastructures are poor or even inexistent. In Brazil, in these situations, potable water is self-supplied by Alternative Collective Solutions (ACS) as defined by the Brazilian governmental decree on quality control on water for human use [4]. According to this regulation both public and private companies may provide potable water from these ACS supply systems and are also responsible for water treatment procedures to comply with potable water standards [5]. Usually, water supplied by ACS is captured from wells or superficial water sources and then submitted to several treatment stages namely sedimentation, filtration, flocculation and disinfection [4–6]. Treated water is kept in local reservoirs and distributed to different working sectors by internal piping systems.

2 Materials and Methods

2.1 Study Design

This study focuses on the quality of potable water supplied by ACS systems to ten oil field exploration locations in the northern Brazilian state of Bahia, covering the period 2015 to 2018. In this state, the on-going health monitoring and intervention plan includes 848 oil industry workers (91% males; 9% females). The geographic location of the ten oil exploration stations is presented in Fig. 1. In each oil field station, the water sampling plan included six points for collecting samples: (1) at water capture points-wells and reservoirs; (2) at oil extraction stations—water reservoirs; (3) taps in administrative facilities; (4) taps in medical offices; (5) taps in bath and changing rooms and (6) taps in areas for food preparation and consumption. All water samples were analysed for microbiological, physico-chemical

Fig. 1 Geographic location of the ten oil exploration stations included in this case-study. *Source* google maps

and organoleptic parameters according to the referred Brazilian regulation [4]. In the entire period of the study the total number of water samples collected at the six referred points amounted 39,399 water samples.

2.2 Data Analysis

Data analysis was performed using IBM® SPSS® Statistics for Windows v. 25.0. Water quality parameters and distribution of nonconformity cases by region, by year and by sampling point were analysed to identify critical situations. Variables distribution were found to be non-normal ($p < 0.05$) therefore, *Spearman's correlation coefficient* (r_s) was used to assess associations between variables. Rate of change in time (period 2015-2018) was calculated as well as medians of bulk non-conformity analysis. A graphical distribution of the water quality parameters by year and region was used for an easier interpretation of the results.

3 Results and Discussion

A descriptive analysis of nonconformity water quality analyses is presented in Table 1. In the observed timeline (2015–2018), six critical parameters were identified: Total Coliforms, *Escherichia coli*, iron, pH, turbidity and colour. These parameters

Table 1 Total nonconformity water quality analyses by parameters between 2015 and 2018. N is the total number of analysis in each year; n refers to the number of nonconformities for which the correspondent percentage value is in brackets

Water quality parameters (total number of analysis)	2015	2016	2017	2018
	N = 8809	N = 13,257	N = 10,344	N = 6946
Number (n) and % of nonconformity water analysis				
Total nonconformities	1180 (13.4)	1659 (12.5)	1253 (12.1)	1017 (14.6)
Total coliforms	301 (19.7)	569 (37.2)	363 (23.7)	297 (19.4)
Escherichia coli	136 (38.0)	68(19.0)	81 (22.6)	73 (20.4)
Aluminium	5 (55.6)	2 (22.2)	2 (22.2)	0 (0.0)
Ammonia	1 (33.3)	1 (33.3)	0 (0.0)	1 (33.3)
Benzene	0 (0.0)	1 (100)	0 (0.0)	0 (0.0)
Lead	1 (50.0)	1 (50.0)	0 (0.0)	0 (0.0)
Chloride	6 (37.5)	1 (6.3)	3 (18.8)	6 (37.5)
Total hardness	0 (0.0)	1 (100)	0 (0.0)	0 (0.0)

(continued)

Table 1 (continued)

Water quality parameters (total number of analysis)	2015	2016	2017	2018
	N = 8809	N = 13,257	N = 10,344	N = 6946
Iron	64 (35.2)	75 (41.2)	43 (23.6)	0 (0.0)
Total Iron	12 (52.2)	10 (43.5)	1 (4.3)	0 (0.0)
Manganese	16 (32.7)	22 (44.9)	11 (22.4)	0 (0.0)
Nitrate	0 (0.0)	0 (0.0)	2 (100)	0 (0.0)
Nitrite	0 (0.0)	0 (0.0)	2 (100)	0 (0.0)
pH < 6	125 (16.0)	229 (29.4)	236 (30.3)	189 (24.3)
pH > 9	5 (22.7)	5 (22.7)	7 (31.8)	5 (22.7)
Selenium	0 (0.0)	1 (100)	0 (0.0)	0 (0.0)
Sodium	4 (57.1)	1 (14.3)	2 (28.6)	0 (0.0)
Total dissolved solids	0 (0.0)	0 (0.0)	1 (16.7)	5 (83.3)
Sulphate	0 (0.0)	2 (100)	0 (0.0)	0 (0.0)
Carbon tetrachloride	0 (0.0)	0 (0.0)	7 (100)	0 (0.0)
Turbidity	115 (24.5)	151 (32.2)	104 (22.2)	99 (21.1)
Zinc	1 (100)	0 (0.0)	0 (0.0)	0 (0.0)
Colour	388 (23.7)	519 (31.7)	388 (23.7)	342 (20.9)

stand out throughout all period of analysis, worsening in the case of: Total Coliforms (+3.7%), pH < 6 (+8.3%) and Colour (+0.7%).

Figure 2 presents the global graphical distribution of nonconformity water analysis by working service for each geographic location and for the entire period of the study. Water samples collected at 'Oil Extractions Stations' (33.9 to 59.0%), and 'Baths & Changing Rooms' (4.4 to 35.7%) comprise most of nonconforming analyses for all geographic locations. These results suggest a post-contamination of water after capture and treatment or deficient cleaning and sanitizing procedures at bathrooms and changing rooms. Poor hygiene habits may also contribute to the degradation of water quality in these working facilities. On the other hand, the usual harsh conditions at oil extractions stations may be the cause for poor water quality at these points: here the contamination of treated water kept in reservoirs is likely to be of environmental origin [5, 7].

A detailed distribution of the nonconforming water analyses by parameters and by sampling point (working service category) is presented in Table 2.

Table 2 highlights that samples collected at 'Oil Extraction Stations' (31.9–45.5%) and 'Bath & changing rooms' (20.4–31.8%) systematically present the worse values (in bold) in all of the six previously identified critical parameters. This pattern is corroborated by parameters associations confirmed by the *Spearman correlation test* values presented in Table 3.

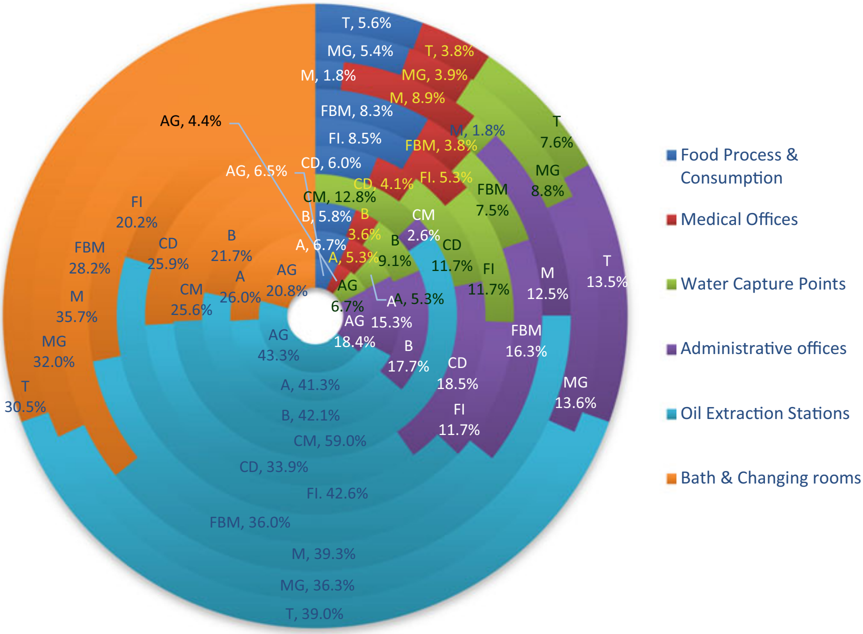

Fig. 2 Distribution of nonconformity analysis by working service for each geographic location and for the entire period of the study. Total number of nonconformity analysis N = 4977

Table 2 Nonconforming water quality analyses by parameters and by type of sampling point

	Water capture points	oil extraction stations	Bath & changing rooms	Food areas	Administrative offices	Medical areas
Total coliforms	137 (9.0)	**607 (39.7)**	**382 (25.0)**	94 (6.1)	247 (16.1)	63 (4.1)
E. coli	34 (9.5)	**152 (42.5)**	**73 (20.4)**	18 (5.0)	71 (19.8)	10 (2.8)
Turbidity	29 (6.2)	**176 (37.5)**	**131 (27.9)**	31 (6.6)	84 (17.9)	18 (3.8)
Colour	132 (8.1)	**617 (37.7)**	**441 (26.9)**	121 (7.4)	256 (15.6)	70 (4.3)
Iron	23 (12.6)	**58 (31.9)**	**55 (30.2)**	8 (4.4)	31 (17.0)	7 (3.8)
pH < 6	62 (8.0	**289 (37.1)**	**231 (29.7)**	51 (6.5)	115 (14.8)	31 (4.0)
pH > 9	1 (4.5)	**10 (45.5)**	**7 (31.8)**	0 (0.0)	3 (13.6)	1 (4.5)

Table 3 *Spearman* correlations among water quality parameters analysed

Parameters	A	B	C	D	E	F	G
A. Total Coliforms	1						
B. *Escherichia coli*	0.76**	1					
C. Colour	0.84**	0.74**	1				
D. Iron	0.65**	0.61**	0.63**	1			
E. pH < 6	0.34*	0.39*	0.34*	0.41**	1		
F. pH > 9	-0.08	-0.13	-0.09	-0.02	-0.25	1	
G. Turbidity	0.78**	0.76**	0.81**	0.65**	0.61**	-0.18	1

*significant at 0.05 level
**significant at 0.01 level

Strong positive correlations were identified between Total coliform and Colour ($r_s = 0.84$, $p < 0.01$), *E. coli* ($r_s = 0.76$, $p < 0.01$) and Turbidity ($r_s = 0.78$, $p < 0.01$). Other strong positive correlations were also identified between Colour and *E. coli* ($r_s = 0.74$, $p < 0.01$) and Turbidity ($r_s = 0.81$, $p < 0.01$). Another strong positive correlation was observed between *E. coli* and Turbidity ($r_s = 0.76$, $p < 0.01$). Moderate positive correlations were identified between Iron and Total Coliform ($r_s = 0.65$, $p < 0.01$), Colour ($r_s = 0.63$, $p < 0.01$), *E. coli* ($r_s = 0.61$, $p < 0.01$) and Turbidity ($r_s = 0.65$, $p < 0.01$). Turbidity and pH < 6 are positive moderate correlated too ($r_s = 0.61$, $p < 0.01$). Moderate-weak positive correlations between pH < 6 and Total Coliform ($r_s = 0.34$, $p < 0.05$), Colour ($r_s = 0.34$, $p < 0.05$), *E. coli* ($r_s = 0.39$, $p < 0.05$) and Iron ($r_s = 0.41$, $p < 0.05$) were observed.

Coliform organisms (reported as total coliforms) have for long been recognized as a suitable microbial indicator of water quality, largely because they are easy to detect and to quantify in water samples [8, 9]. Coliform bacteria can be found in both faeces and the environment (nutrient-rich waters, soil, decaying plant material) as well as in drinking-water containing relatively high concentrations of nutrients thus, the presence of total coliforms is related to contamination of environmental origin [2, 5]. High levels of turbidity may reduce the efficiency of disinfection and interfere with the measurement of total coliforms [10]. Nonconform sample analysis in turbidity and pH can be originated by deficient water treatment at the capture point, namely by inadequate use of water flocculants, poor filtration systems (or lack of filters maintenance) or by the absence of pH correction after using flocculant and disinfectant agents [5, 11]. Colour alterations in water samples may be associated with the presence of undesirable substances such as iron (which was identified as a non-conformity parameter until 2017); or may be an indicator of public health concern if associated to the presence of coliforms. Orange to brown colour may be caused by the presence of 'iron bacteria', which thrive in rich iron and manganese waters, and this situation occurs naturally in several Brazilian regions [5]. 'Iron bacteria' oxidize iron and manganese contributing to lower waters' pH [12] which may contribute to the considerable number of pH < 6 nonconform

Table 4 Rate of change (2015–2018) of water quality nonconformity analyses by location

Region	CM	CD	T	MG	FBM	A	AG	B	M	FI
Rate of change (%)	−84.4	−70.3	−34.3	−30.3	−3.5	6.7	21.5	66.3	66.7	212.5
Median (Mdn)	6	217	149	149	198	31	206	145	12	21
Q_1 (25th percentile)	4	104	114	122	193	24	152	102	6	10
Q_3 (75th percentile)	22	296	154	213	324	58	245	150	18	42

analyses (Table 2). These bacteria tend to form biofilms that clog filters and screens, reducing the effectiveness of water treatments and slimes that stick to wells casings, pumps and pipes, degrading water supply appliances. Measures to reduce this type of hazard require the installation of pH sensors and automatic pH correction devices and the implementation of a plan for frequent cleaning of piping and substitution of filters.

Table 4 presents the variation of nonconformity analysis by geographical location. These results point out two groups: in five locations (CM, CD, T, MG and FBM) water quality results have improved (−3.5% to −84.4%) and in the remain (A, AG, B, M and F) results are worse (6.7% to 212.5%).

The location which has experienced the greater improvement (CM) is simultaneously the one with the lowest median (Mdn = 6; Q_1 = 4; Q_3 = 22), however, best improvements are observed in locations presenting the highest medians (CD, T, MG, FBM). Results suggest that the origin of water quality problems is persistent in the second group of locations, probably because they are not being addressed in the most effective manner.

4 Final Remarks

Of the six parameters which were systematically nonconform, coliform bacteria are the most concern as they should not be detectable in treated water supplies and, if found, suggest inadequate treatment, post-treatment contamination, or excessive nutrients at the water source. Therefore, the coliform test can be used as an indicator both of treatment efficiency and the integrity of the distribution system. *Escherichia coli* is abundant in human and other animal faeces; it is commonly found in sewage, treated effluents, and waters and soils subjected to recent faecal contamination, whether from humans, wild animals, or agricultural activity. Because animals can transmit pathogens that are infective in humans, the presence of *E. coli* or thermotolerant coliform bacteria must not be ignored, because the presumption remains that the water has been faecally contaminated and that treatment has been ineffective. In this situation the presence of *E. coli* may represent a threat to human health, specially to those more vulnerable such as the immunosuppressed. Although coliform organisms may not always be directly related to the presence of faecal contamination or pathogens in drinking-water, the coliform test is still useful for monitoring the microbial quality of treated piped water supplies. If there is any doubt, especially when coliform organisms are found in the absence of thermotolerant coliforms and *E. coli*, identification to the species level or analyses of other indicator organisms may be undertaken to investigate the nature of the contamination. Treatment of very contaminated waters may be difficult and only partially successful. Regular sanitary inspections are needed because even a properly constructed water system may be the source of non-potable water if adequate maintenance, surveillance and routine water analysis are neglected [13]. Elimination of environmental risks in the oil activity sector is inherently difficult but, as measures to reduce risks by water contamination, it is strongly recommended: (1) the installation of monitoring devices and sensors along the water collecting and distribution system to detect defects and failures; and (2) the implementation of regular audits and surveillance plans for water treatment procedures by both internal services and independent companies, besides those responsible for water supply.

This case-study stresses the importance of health monitoring plans for work conditions specially in high-risk professions like oil industry workers. Education for improvement of workers hygienic procedures, handling of foods and cleaning and sanitization of bathrooms and changing rooms are corrective measures arising from this case-study of the on-going health monitoring and intervention plan.

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References

1. High-level commission on health employment and economic growth. Working for health and growth: investing in the health workforce. Report of the high-level commission on health employment and economic growth, p. 74. World Health Organization (WHO), Geneva, Switzerland (2016)
2. Bastos, R.K.X.: Revisão da Portaria MS nº 2914/2011: Tema II - Padrão de Potabilidade e Planos de Amostragem - Fundamentação e Linhas Norteadoras; Ministério da Saúde - Governo Federal do Brasil, Brasil, p. 35 (2018)
3. MacDonald Gibson, J., Pieper, K.J.: Strategies to improve private-well water quality: a north Carolina perspective. Environ. Health Perspect. **125**, 076001 (2017). https://doi.org/10.1289/EHP890
4. Ministério da Saúde - Gabinete do Ministro. Portaria de Consolidação nº 5 de 28 de setembro de 2017: Consolidação das normas sobre as ações e os serviços de saúde do Sistema Único de Saúde. Ministério da Saúde - Governo Federal do Brasil, Ed. Diário Oficial da União de 3 de outubro de 2017, Brasil, p. 926 (2017)
5. Ministério da Saúde do Brasil - Secretaria de Vigilância em Saúde. Vigilância e controle da qualidade da água para consumo humano [Surveillance and Control in Water Quality for Human Consumption]; Ministério da Saúde, Brasília, p. 212 (2006)

6. Brandt, M.J., Johnson, K.M., Elphinston, A.J., Ratnayaka, D.D.: Chapter 8-Storage, Clarification and Chemical Treatment. In: Brandt, M.J., Johnson, K.M., Elphinston, A.J., Ratnayaka, D.D., eds. Twort's Water Supply, 7th edn. Butterworth-Heinemann, Boston, pp. 323-366. https://doi.org/10.1016/B978-0-08-100025-0.00008-9 (2017)
7. Brandt, M.J., Johnson, K.M., Elphinston, A.J., Ratnayaka, D.D.: Chapter 7-Chemistry, Microbiology and Biology of Water. In Brandt, M.J., Johnson, K.M., Elphinston, A.J., Ratnayaka, D.D. (eds.) Twort's Water Supply, 7th edn. Butterworth-Heinemann, Boston, pp. 235–321. https://doi.org/10.1016/B978-0-08-100025-0.00007-7 (2017)
8. World Health Organization (WHO): Guidelines for Drinking-Water Quality, 4th ed. Geneve, Switzerland, pp. 564 (2011)
9. World Health Organization (WHO).: Guidelines for Drinking-Water Quality: First Addendum to the fourth edition, Geneve, Switzerland, p. 137 (2017)
10. LeChevallier, M.W., Evans, T.M., Seidler, R.J.: Effect of turbidity on chlorination efficiency and bacterial persistence in drinking water. Appl. Environ. Microbiol. **42**, 159–167 (1981)
11. Rice, E.W., Baird, R.B., Eaton, A.D.: Standard Methods For the Examination of Water and Wastewater. 23rd edn. American Public Health Association, American Water Works Association, Water Environment Federation (2017)
12. Natarajan, K.A.: Chapter 12-Biofouling and Microbially Influenced Corrosion. In: Natarajan, K.A. (ed.) Biotechnology of Metals, Elsevier, Amsterdam, pp. 355–393. https://doi.org/10.1016/B978-0-12-804022-5.00012-8 (2018)
13. Seltenrich, N.: Unwell: The Public Health Implications of Unregulated Drinking Water. Environ. Health Perspect. **125**, 114001 (2017). https://doi.org/10.1289/EHP2470

Ambulatory Blood Pressure Monitoring in Bakery Professionals

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Abstract Nighttime work is associated with changes in the chronobiological pattern of most physiological variables, including those related to the cardiovascular system, mainly blood pressure (BP) and heart rate (HR). Objectives. To evaluate BP in baking professionals working on a fixed night regimen, in order to study the circadian profile and the adaptation of the BP to the professional schedules. Methods. Thirty male and female individuals, aged between 22 and 66 years old, who work in the bakery sector in a permanent night regimen with work hours between 23 and 7 h were enrolled in a cross-sectional study. Ambulatory blood pressure monitoring (ABPM) was used to automatically obtain multiple indirect measurements of BP in a 24-hour period. Results. Ambulatory BP parameters showed average values within normal range to the majority of the study population. Females presented higher values compared to males. With the analysis of the questionnaires, it was possible to find out that 73.6% of the participants had smoking habits, 90% had coffee drinking habits and 30% consume caffeinated soft drinks. The 24 h BP pattern depicted a chronobiological adaptation to the activity/sleep cycles, and a similar pattern was accordingly found for HR. Conclusions. Nocturnal working activity promotes an adaptation of the chronobiological variation of BP through the 24 h, with higher average BP values during the activity periods and a sleep-related dipping of both systolic and diastolic BP. Long-term effect of such permanent adaptation is yet to be ascertained.

Keywords Blood pressure · Circadian rhythm · Permanent night work

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1 Introduction

Work is an activity developed by man from the beginning of time, in various ways to produce wealth and meet his diverse needs. After the industrial revolution there was progress in the organization of work, increasing demand for shift work and night work. The modernization of society has imposed night work in multiple areas [1].

According to the Sixth European Survey on Working Conditions carried out in 2015 by Eurofound, in Portugal there are about 19% of workers who work in a permanent nighttime regime [2].

The main characteristic of these workers is that their behavioral and environmental cycles are typically misaligned in relation to the endogenous circadian system.[1] Usually, these workers are more likely to have a lower quality of sleep, which leads to fatigue, reduced alertness, mental and physical alteration, social rupture and even family disharmony [3]. This work regime is associated with lower performance ratings and adverse health outcomes, such as cardiovascular disease, depression, reproductive disorders, cancer, among others [4].

Due to the Earth's rotational motion around its own imaginary axis, humans, like most other life forms on our planet, have an endogenous circadian system that optimally synchronizes physiology and behavior with the solar day [5]. The biological clock is coordinated by the suprachiasmatic nucleus that is located in the anterior hypothalamus, near the third ventricle. Luminosity is detected by photoreceptors and intrinsically photosensitive ganglion cells present in the retina that contain the photopigment designated melanopsin, and this information is subsequently transmitted to the central nervous system (CNS) neurons through the retinohypothalamic tract [6, 7]. After having received fitotic information, projections are sent to the dorsomedial hypothalamus that later transmits the indications for the peripheral oscillators [8].

Upon receiving the message on external luminosity, the CNS interprets and causes the upper cervical ganglion to follow a signal up to the pineal gland, whose main function is to transmit information about the sleep/wake cycle through the production of melatonin, which is characterized by a reduction in the presence of light and an increase at night, during which it induces and supports sleep, there are however other additional functions, such as antioxidant, vasodilator and vasoconstrictor properties [9]. At the same time, a few hours after the onset of melatonin production, another gland, the pituitary gland, initiates the secretion of growth hormone, whose peak of concentration in the body is around 3 o'clock in the morning cell renewal [10]. Corticotrophin, also called adrenocorticotrophic hormone, has like cortisol functions, this hormone stimulates the secretion of various hormones from the adrenal cortex, especially glucocorticoids [11].

As a result of the secretion of the various hormones, the chronobiological pattern of several physiological parameters including Blood Pressure (BP), characterized by an increase in the beginning of the day period with a slight reduction at around 12 o'clock, a rise during the afternoon and again a decrease clear during the night period [12]. This fall in BP during sleep is reflected in BP values and, subsequently, in ambulatory blood pressure monitoring (ABPM), which is normally greater than 10% of BP relative to wakefulness in about 95% of normotensive patients. the cardiovascular homeostasis [13].

It is speculated that these individuals have a higher BP during the resting period compared to the individual who rests at night, and this may have some impact on the development of hypertension (HT) [14].

High BP (Hypertension—HT) was defined as a mean 24 h BP $\geq$ 130 and/or 80 mmHg, a mean daytime BP $\geq$ 135 and/or 85 mmHg (respectively systolic and diastolic BP) or a mean night BP $\geq$ 120 and/or 70 mmHg, following the recommendations of the Seventh Report of the Joint (JNC7) [15]. BP dipping pattern was defined based on the drop in systolic BP during the sleep period in relation to the active period. A dipper status corresponded to a dipping between 10 and 20%; non-dipping was classified for a dipping between 0 and 10%; inverted dipping corresponded to cases with a dipping < 0%; extreme dippers were those participants with a dipping above 20% [16]. The estimated prevalence of HT across Europe is between 30 and 45% of the adult population [17].

Some authors have supported the generalized idea that there is great interindividual variability in tolerance to night work. This variability results, according to the investigation, from the identification of several factors such as: age, sex, amplitude of circadian rhythms and characteristics of the chronotype. Over time, although the worker has more experience and can better control his life in function of the work, the chronic alterations of its biological rhythms can seriously compromise the duration and the quality of sleep, as well as lead to the development of diseases and loss of quality of life. The difference between men and women in shift work tolerance seems to be more related to social and family roles than to biological determinants [18].

Thus, workers with higher amplitude rhythms tend to adapt more easily to shifts, demonstrating a greater capacity of resistance to the phase changes of the circadian system [19].

Due to the circadian misalignment of these workers, daytime rest and night work and all the changes that this causes to health, the present study investigates whether or not there is adaptation of the circadian rhythm of pressure response to this regime.

2 Methods

The study population consisted of 30 bakery workers between the ages of 22 and 66 who work in fixed night work hours between 11:00 pm and 7:00 am. Regarding the gender, the sample had the participation of 21 men and 9 women.

First, the participants read and signed the informed consent and then clarified any questions that may have arisen after reading, thus taking advantage of the information regarding the purpose of the project and the method of collection. Later, a researcher-customized questionnaire was applied in order to obtain demographic and anthropometric data (age, gender, weight, height and body mass index—BMI), lifestyle information (hours of daily sleep, napping, caffeine consumption and energy drinks) and other clinical information relevant to the study.

In order to perform a more efficient and coherent diagnosis, a 24 h ABPM was used. This non-invasive technique allows multiple automatic indirect measurements of BP to be obtained automatically in a 24-hour period. In this way, a number of relevant BP parameters were obtained, specifically the mean of systolic (SBP) and diastolic BP (DBP) for the 24 h, and for the activity and sleep periods, as well as the pulse pressure (PP) and the heart rate (HR). A Meditech ABPM-04 monitoring system was used, with appropriate cuff, and all aspects of protocol definition and data acquisition were operated in a laptop running the CardioVisions ABPM-04 program.

A standardized protocol was adopted, with the cuff placed in the non-dominant arm and connected through a rubber hose to the device positioned inside a protective bag at waist level. BP measurements were taken with 30 min intervals through the entire recording. The ABPM was initiated at the beginning of the working shift and prolonged for 24 h. Quality criteria for the ABPM recordings was defined as valid measurements above 80% of the total expected measurements.

2.1 Statistical Analysis

The statistical data obtained were firstly organized using Microsoft Office Excel, for further analysis and study using the statistical software IBM SPSS Statistics 25.0 (IBM Corp. Armonk, NY, USA). Regarding the statistical methods applied to the analysis of the values obtained through the ABPM technique, we used the T-student test for independent samples. The distribution of the continuous variables was tested for homogeneity by the Levene test. The Fisher test and the chi-square test were used in the comparisons involving categorical variables. The defined criterion for statistical significance is $p \leq 0.05$ for a 95% confidence interval.

3 Results

This study had a sample of 30 individuals (9 females and 21 males) who work in the bakery sector on a permanent night work regime. All participants completed a questionnaire about their age, height, weight, BMI, approximate number of hours of sleep, nap practice, and other data that could influence BP such as family history of cardiovascular disease, smoking, energy drinks and coffee. Of the total sample, 2 participants had HT without drug therapy, the remaining 28 reported having normal BP values.

Table 1 shows the characteristics of the sample showing the sociodemographic and anthropometric data of the participants.

Analyzing the table above we can observe that the age of workers is between 21 and 66 years, with a mean of 43.50 ± 13.34 years. Regarding the mean weight, we obtained a value of 76.10 ± 11.03 kg, with a mean BMI of 26.94 ± 3.65 kg/m2. In relation to the number of hours of sleep, it is observed that the male gender presents a higher average hours compared to the female gender, and these values may be related to family and social responsibilities inherent to the female gender.

Table 2 shows the various types of mean BP values obtained through the indirect measurements of ABPM.

Regarding the BP parameters obtained through ABPM in bakery workers who work in permanent night mode, it is possible to characterize the sample under study as to BP as normal given that the mean of the 24 h BP $\leq$ 130/80 mmHg, the mean daytime BP $\leq$ 135/85 mmHg and the mean night BP $\leq$ 120/70 mmHg.

The chart below shows the distribution of the different mean values of BP collected in the study sample.

In addition to assessing the integrity of the sample, comparisons were made between the female and the male gender, where it was possible to observe that the female gender has slightly higher BP values than the opposite gender, and this difference is not statistically significant (Fig. 1).

Analyzing Table 3 it is possible to verify that the mean PP and HR is higher in the female gender compared to the male gender, however, this difference is not statistically significant in any of the variables previously presented. In the measurements made to the volunteer workers, it was observed that only 2 subjects

Table 1 Characterization of the study sample

	Total (n = 30)	Female (n = 9)	Male (n = 21)	ρ
Age	43.50 ± 13.34	47.78 ± 10.22	41.67 ± 14.29	0.267
Weight	76.10 ± 11.03	69.11 ± 8.25	79.10 ± 10.86	0.020
Height	1.68 ± 0.08	1.62 ± 0.08	1.70 ± 0.07	0.008
BMI	26.94 ± 3.64	26.29 ± 2.88	27.22 ± 3.96	0.529
Number of hours sleep	5.68 ± 1.77	4.72 ± 1.90	6.09 ± 1.59	0.050
Hours of nap	1.20 ± 1.77	1.72 ± 2.05	0.98 ± 1.16	0.212

Table 2 Values obtained from blood pressure through the use of ABPM

Parameters obtained (mmHg)	Total (n = 30) mean ± SD
SBP 24H	123.60 ± 11.79
DBP 24H	73.40 ± 8.05
Daytime SBP	127.77 ± 10.78
Daytime DBP	76.87 ± 7.17
Night SBP	114.30 ± 14.36
Night DBP	64.83 ± 12.42

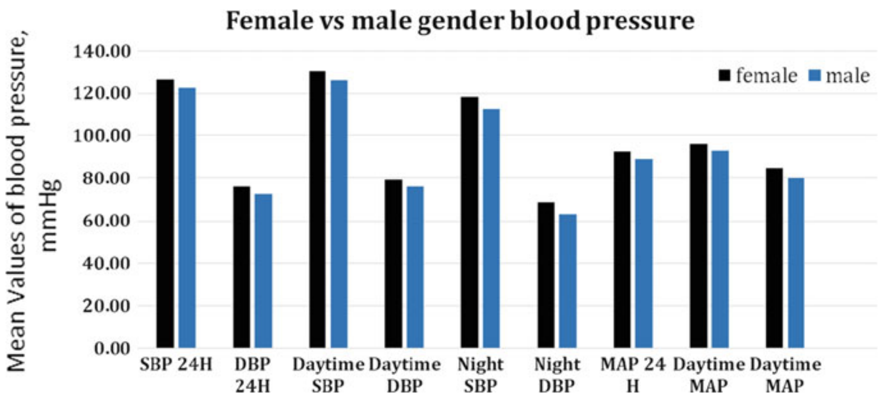

Fig. 1 Graphical representation of blood pressure in females and males

Table 3 Representation of pulse pressure, heart rate and nocturnal fall in the female and male gender

	Total	Female	Male	ρ
Pressure pulse 24H (mmHg)	50.40 ± 7.16	50.69 ± 9.19	50.29 ± 6.36	0.897
Daytime pressure pulse (mmHg)	50.73 ± 7.57	51.11 ± 10.15	50.57 ± 6.50	0.862
Night pressure pulse (mmHg)	49.10 ± 6.86	49.33 ± 5.89	49 ± 7.37	0.905
Heart rate 24H (bpm)	78.13 ± 10.70	82.11 ± 8.83	76.43 ± 11.16	0.187
Daytime heart rate (bpm)	82.70 ± 11.99	87.44 ± 12.48	80.67 ± 11.48	0.160
Night heart rate (bpm)	68.97 ± 11.93	71.89 ± 7.08	67.71 ± 13.45	0.389
SBP D/N %	10.83 ± 6.61	10.67 ± 6.48	10.90 ± 6.83	0.930

(6.7%) had no BP drop during rest period, of the remaining 17 individuals (56.6%) were classified as dipper, 9 individuals (30%) as non dipper and 2 individuals (6.7%) as extreme dipper.

Figure 2 shows the percentage of HT present during this investigation, being divided into known HT that came to be confirmed; an unknown HT that was diagnosed through this study; HT "Night" (in the rest period).

Considering all the individuals in the sample, only 2 professionals (6.6%) had a previous diagnosis of HT prior to the study, 8 professionals (27.6%) were diagnosed through ABPM and 3 professionals (10%) were considered hypertensive during the rest period (Fig. 2).

Finally, Fig. 3 represents the 24-hour BP obtained by ABPM.

Through the 24-hour BP schedule, it can be observed that, as expected, the highest values of SBP and DBP are observed during the work period between 11:00 pm and 7:00 am, followed by a clear decrease in the rest period between 7 am and 2 pm.

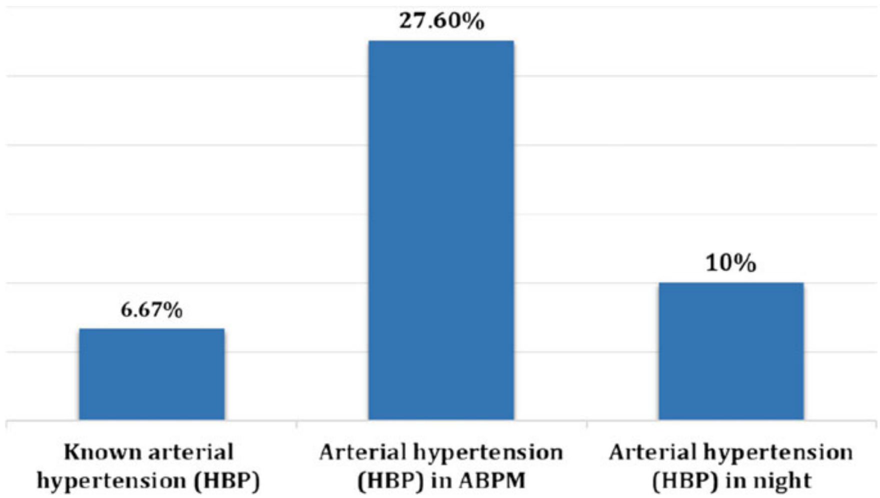

Fig. 2 Percentage of HT in total sample

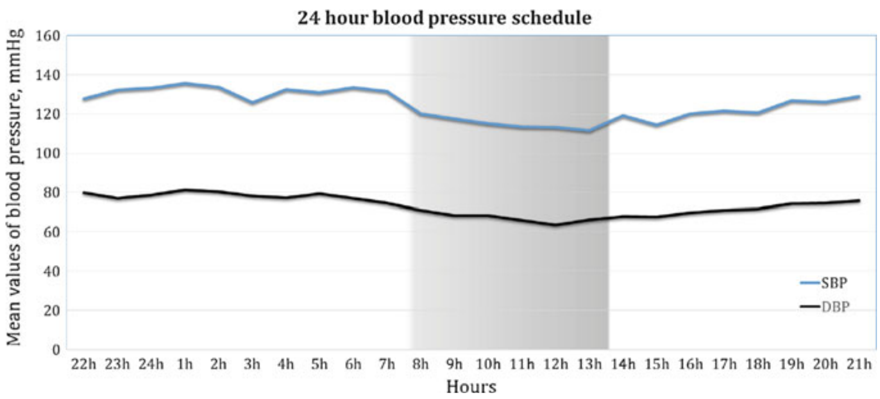

Fig. 3 Schedule of systolic and diastolic blood pressure in the 24-h period

4 Discussion

After the presentation and analysis of the results obtained, a critical reflection is made on them, confronting them with each other and with the review of the reference literature, highlighting the most important aspects of night work.

As previously mentioned, there is a biological relationship between exposure to night work and HT. In the present investigation, in permanent night workers, the circadian cycle of BP was altered by default, a change in the BP level curve occurred: in the beginning of the night, instead of a fall, the expected BP values for the daytime period, since in this period the labor activity of these employees occurs, in the beginning of the morning the BP has decreased since it is the resting period of the employees.

The values obtained through ABPM didn't sketch statistically significant differences between genders, however, the female gender had higher BP values, this could be due to the set of social and family responsibilities that are inherent to gender feminine, as advocated by existing literature [21].

It was possible to observe that the increase in age and BMI showed a concordance relation with higher BP values. In younger people, BP is determined largely by peripheral vascular resistance, while in older individuals it is determined to a greater degree by the rigidity of the central vessel [22].

Already published studies suggest that shift workers are more vulnerable to metabolic disorders, such as diabetes, metabolic syndrome [23], and cardiovascular disorders, such as HT [24, 25], compared to workers with "normal" work, although this study good adaptation since the mean values of BP during the 24 h, daytime and nighttime are within normal values.

According to the other data, it was verified that of the total sample, 10 workers (33.3%) had HT. These data are in agreement with the national panorama, since the percentage in Portugal is between 30–40% [17], this parameter confirms that there is no higher incidence of HT in night workers in the bakery sector.

5 Conclusion

The present study demonstrates that there is an inversion of the circadian rhythm of the BP, synonymous of a physiological adaptation of the organism to the permanent nocturnal exposure [26]. The adaptation in the circadian profile of BP and HR entails a wider scope of chronobiological adaptations that could set the ground for the manifestation of several nonspecific symptoms that lead them to the diagnosis of maladaptation syndrome [27]. The parameters of adaptation allow a phase delay of the circadian clock to be completely aligned with night work, thus maximizing daytime sleep quality and night performance [28].

Hence, the findings of our study are in line with previous research [29, 30], depicting the ability of the cardiovascular system to adapt to the awake/sleep cycles, although the long-term consequences of such adaptations are yet to be completely documented. Prospective studies are therefore needed to provide evidence regarding possible occupational hazards associated with the long-term night-time work physiological adaptations.

References

1. Rutenfranz, J., Knauth, P., Fisher, F.M.: Trabalho em turnos e noturno. São Paulo: Ed. Hucitec (1989)
2. Eurofound: Sexto Inquérito Europeu sobre as Condições de Trabalho (2015)
3. Burch, J.B., Tom, J., Zhai, Y., Criswell, L., Leo, E., Ogoussan, K.: Shiftwork impacts and adaptation among health care workers. Occup. Med. **59**(3), 159–166 (2009). (Lond)
4. Berger, A.M., Hobbs, B.B.: Impact of shift work on the health and safety of nurses and patients. Clin. J. Oncol. Nurs. **10**(4), 465–471 (2006)
5. Morris, C.J., Aeschbach, D., Scheer, F.A.J.L.: Circadian system, sleep and endocrinology. Mol. Cell. Endocrinol. **349**(1), 91–104 (2012)
6. Gooley, J.J., Lu, J., Chou, T.C., Scammell, T.E., Saper, C.B.: Melanopsin in cells of origin of the retinohypothalamic tract. Nat. Neurosci. **4**(12), 1165 (2001)
7. Lucas, R.J., Freedman, M.S., Lupi, D., Munoz, M., David-Gray, Z.K., Foster, R.G.: Identifying the photoreceptive inputs to the mammalian circadian system using transgenic and retinally degenerate mice. Behav. Brain Res. **125**(1–2), 97–102 (2001)
8. Van Someren, E.J., Riemersma-Van Der Lek, R.F.: Live to the rhythm, slave to the rhythm. Sleep Med. Rev. **11**(6), 465–484 (2007)
9. Borjigin, J., Zhang, L.S., Calinescu, A.A.: Circadian regulation of pineal gland rhythmicity. Mol. Cell. Endocrinol. **349**(1), 13–19 (2012)
10. Gamble, K.L., Berry, R., Frank, S.J., Young, M.E.: Circadian clock control of endocrine factors. Nat. Rev. Endocrinol. **10**(8), 466–475 (2014)
11. Smyth, J.M., Ockenfels, M.C., Gorin, A.A., Catley, D., Porter, L.S., Kirschbaum, C., Hellhammer, D.H., Stone, A.A.: Individual differences in the diurnal cycle of cortisol. Psychoneuroendocrinology. **22**(2), 89–105 (1997)
12. Van Mark, A., Weiler, S.W., Schröder, M., Otto, A., Jauch-Chara, K., Groneberg, D.A., Spallek, M., Kessel, R., Kalsdorf, B.: The impact of shift work induced chronic circadian disruption on IL-6 and TNF-alpha immune responses. J. Occup. Med. Toxicol. **5**, 18 (2010)
13. Rudic, R.D., Fulton, D.J.: Pressed for time: the circadian clock and hypertension. J. Appl. Physiol. (1985) **107**(4), 1328–1338 (2009)
14. Costa, G.: Saúde e segurança dos trabalhadores. In: Fischer, F.M., Moreno, C.R. de C., Rotenberg. Trabalho em turnos e noturno na sociedade 24 horas. São Paulo: Atheneu (2003)
15. Chobanian, A., Bakris, G., Black, H., Cushman, W., Green, L., Izzo, J., Jones, D., Materson, B., Oparil, S., Wright, J., Roccella, E.: Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. Hypertension **42**(6), 1206–1252 (2003)
16. O'Brien, E.: Dipping comes of age. The importance of nocturnal blood pressure. American Heart Association. Hypertension. **53**, 446–447 (2009)
17. Barreto, D.F.: Implicações do trabalho por turnos na saúde na vida social e familiar dos trabalhadores de turnos industriais (2008)
18. Filho, G.: Síndrome da Má-Adaptação ao Trabalho em Turnos - uma abordagem ergonómica. Revista Produção. **11**(2) (2002)
19. Sternberc, H., Rosenthal, T., Shamiss, A., et al.: Altered circadian Rhythm of blood pressure in shift workers. J. Hum. Hypertens. **9**, 349–353 (1995)
20. Hakola, T., Härmä, M.I., Laitinen, J.T.: Circadian adjustment of men and women to night work. Scand. J. Work Environ. Health. **22**(2), 133–138 (1996)
21. Suwazono, Y., Dochi, M., Sakata, K., Okubo, Y., Oishi, M., Tanaka, K., Kobayashi, E., Nogawa, K.: Shift work is a risk factor for increased blood pressure in Japanese men: a 14-year historical cohort study. Hypertension **52**(3), 581–586 (2008)
22. Gan, Y., Yang, C., Tong, X., Sun, H., Cong, Y., Yin, X., Li, L., Cao, S., Dong, X., Gong, Y., Shi, O., Deng, J., Bi, H., Lu, Z.: Shift work and diabetes mellitus: a meta-analysis of observational studies. Occup. Environ. Med. **72**(1), 72–78 (2015)

23. Mosendane, T., Mosendane, T., Raal, F.J.: Shift work and its effects on the cardiovascular system. Cardiovasc. J. Afr. **19**(4), 210–215 (2008)
24. Yeom, J.H., Sim, C.S., Lee, J., Yun, S.H., Park, S.J., Yoo, C.I., Sung, J.H.: Effect of shift work on hypertension: cross sectional study. Ann. Occup. Environ. Med. **29**, 11 (2017)
25. Sousa Uva, M., Victorino, P., Roquette, R., Machado, A., Matias, Dias C.: Epidemiological research on the incidence and prevalence of arterial hypertension in the Portuguese population: a scoping review. Rev. Port. Cardiol. **33**(7–8), 451–463 (2014)
26. Kitamura, T., Onishi, K., Dohi, K., Okinaka, T., Ito, M., Isaka, N., Nakano, T.: Circadian rhythm of blood pressure is transformed from a dipper to a non-dipper pattern in shift workers with hypertension. J. Hum. Hypertens. **16**(3), 193–197 (2002)
27. Chinoy, E.D., Harris, M.P., Kim, M.J., Wang, W., Duffy, J.F.: Scheduled evening sleep and enhanced lighting improve adaptation to night shift work in older adults. Occup. Environ. Med. **73**(12), 869–876 (2016)
28. Smith, M.R., Fogg, L.F., Eastman, C.I.: Practical interventions to promote circadian adaptation to permanent night shift work: study 4. J. Biol. Rhythms **24**(2), 161–172 (2009)
29. Sfreddo, C., Fuchs, S.C., Merlo, A.R., Fuchs, F.D.: Shift work is not associated with high blood pressure or prevalence of hypertension. PLoS One **5**(12), e15250 (2010)
30. Hublin, C., Partinen, M., Koskenvuo, K., Silventoinen, K., Koskenvuo, M., Kaprio, J.: Shift-work and cardiovascular disease: a population-based 22-year follow-up study. Eur. J. Epidemiol. **25**(5), 315–323 (2010)

Indoor Air Quality in Classroom Labs

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Abstract The indoor air quality of buildings is more than a comfort factor for their occupants. Breathing in polluted air has negative effects on the well-being of indoor occupants and can result in serious illness or even death. And this is all the more significant as the time these people spend inside interior spaces. Nowadays, we know that this time is preponderant. It is therefore essential to ensure good air quality in the workplace by eliminating risk factors. The main objective of this study was to monitor the indoor air quality of the laboratories of a higher education establishment before, during and after its normal activity, as well as to analyze the symptoms perceived by occupants of these spaces. We found $PM_{2.5}$, PM_{10}, VOC and CH_2O concentration averages recorded in some laboratories studied that exceeded the protection limits. The most prevalent symptoms were allergies, followed by the symptoms of "asthma", "bronchitis", "allergies" and "thyroidism". In this study, it was concluded that action is needed to improve the quality of indoor air in the educational labs, since there were air pollutants on average higher than the legally established values, as was the case of $PM_{2.5}$, PM_{10}, CH_2O e TCOV. It is essential that institutions implement continuous monitoring in order not to expose occupants to hazardous conditions.

Keywords Indoor air quality · Air pollutants · Educational labs · Occupational health

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1 Introduction

Currently, the multiplicity of factors that contribute to our well-being and quality of life not only influence our daily lives, but also affect future generations. Thus, we can say that more and more environmental issues become a concern worldwide. One of the factors with great importance that deserves our attention is the air quality [1].

Air quality, shows us that the air pollution level we breathe every day, which is caused by various pollutants present in the air, which, alter the natural composition of the atmosphere bringing negative consequences for humans [2]. The most abundant pollutants in the atmosphere and are caused, mostly by man, are particulate matter (including $PM_{2.5}$ and PM_{10}), carbon monoxide (CO), carbon dioxide (CO_2), formaldehyde (CH_2O) and Total Volatile Organic Compounds (VOC) [2].

Currently, most of the world population, mainly in developed countries, spends much of his time inside spaces some of which are associated with insufficient ventila-tion and air exchange such as homes, workplaces, schools, spaces for leisure and entertainment and transportation. There are many potentially harmful compounds released within these spaces because, emissions from building materials, cleaning products and equipment, combustion, consumer products, among others. If on one hand the buildings protect people and property on the other hand, also degrade human health due to pollution from them [3].

According to Word Health Organization (WHO), the various problems of Indoor Air Quality (IAQ) are recognized as important risk factors with respect to human health, both in the developed and the developing countries [3].

Taking into account the many allergic diseases, it is quite remarkable the effects of multiple environmental variables, either as primary determinants, either as aggravating the clinical conditions, particularly when the respiratory system is compromised [3].

The quality of school labs can affect both the health and well-being of professionals and students. In these settings, it is important to consider the importance of IAQ as a determinant of public and occupational health [4]. In laboratory activities, workers are exposed to many hazardous substances. The impact on the human body can be varied according to the technical or operative procedure, the methodology adopted, the type of reagents used and consequently released substances from them and their concentration, exposure time and intensity by the worker [5, 6].

Given the above, this study aims to monitor the IAQ in the laboratory before, during and after performing technical procedures, as well as analyze the symptoms perceived by professionals and students who work in these places.

2 Materials and Methods

2.1 *Research Design, Population and Sample*

The present study was observational (descriptive), cross-sectional and knowledge level II. The target population consisted of four labs that are part of higher education institutions, located in the district of Coimbra, referred to as Chemistry Lab, Microbiology Laboratory—Media Preparation (hereinafter referred to as Microbiology Lab. I), Microbiology Laboratory—Washing and Sterilization (hereinafter Microbiology Lab II) and Soil Laboratory, as well as 19 professionals and 32 students that regularly use these labs. The sampling procedure was not used probabilistic sampling technique was used for convenience.

2.2 *Instruments and Data Collection*

Data collection consisted of three research steps, the first describing the areas evaluated; the second administration of a questionnaire addressed to all users of the evaluated laboratories; third, the air quality assessment, using for this the evaluation of atmospheric pollutants (CO_2, CO, VOCs, $PM_{2.5}$, PM_{10} and CH_2O) meteorological and temperature variables (T°) and Relative Humidity (RH) at spring season.

For the structural characterization of the laboratories was applied a checklist related to the general characteristics of the building under consideration. The sample was collected in four different laboratories. It is noteworthy that the four laboratories are located on the same campus, which is a common indicator for all.

For the evaluation of the environmental parameters were selected initially, the sampling points, taking into account the areas of space to evaluate and respective layouts, as well as the existence of doors, windows and ventilation systems, exhaust and/or air conditioning and potential sources indoor and outdoor contamination.

The questionnaire was conducted to analyze the symptoms perceived by workers of laboratories and this was divided into three important parts: the first, evaluated the sociobiographic characteristics of professionals and students; the second was intended to obtain data about the health condition, this is, whether or not presented symptoms of respiratory or chronic diseases arising out of the work environment; the third part proposed information regarding the healthy lifestyle habits.

With regard to the third stage of research, the measurements were performed in a 30 min period, with one sample recorded per minute. Measurements were made at three different times, that is, before, during and after the usual activity of laboratories, between 09:00 and 17:30, placing the measuring equipment at the central position possible each rated space and approximately equal to the airways of occupants [7].

To carry out the analytical collection of evaluated criteria, specific portable reading devices were used in real time, and in particular multi-gas analyzer, brand Critical Environment Technologies (CETCI), YES-AIR model, serial number: YA1901K00947 for evaluation the concentration of CO, CO_2, VOCs, CH_2O and weather variables T° and RH Dust Trak DRX measuring mark TSI model 8534, serial No. 8534190207 for assessing concentrations of $PM_{2.5}$ and PM_{10}. For the transfer of data collected between the measuring devices and the computer used to the specific software for each of the equipment used. It was considered as a reference for maximum CO concentration, 10.0 mg/m3 (9 ppm) for CO_2, 2250 mg/m3 (1250 ppm) for VOC, 0.6 mg/m3 (600 ppb) for $PM_{2.5}$, 0.025 mg/m3 for PM_{10}, 0.05 mg/m3 and CH_2O, 0.01 mg/m3 (0.08 ppm) as mentioned in Order 353-A/2013 of 4 December. According to Decree-Law No. 243/86 of 20 August, the environmental conditions of reference comfort for Tº to should range between 18 and 22 °C, while the RH shall be between 50 and 70% [8].

2.3 Statistical Analysis

Data were processed using the IBM SPSS 25 software. At the level of statistical infer-ence, we used Student's t-test for one sample, Chi-square independence test and Kruskal-Wallis and one-way Anova. Finally, the inference was based on a confidence level of 95% for a random error up to 5%.

3 Results

The sample was confined to four laboratories that incorporated a higher education institution located in the municipality of Coimbra, a total of 19 professionals and 32 students and also the outer space of the four evaluated laboratories. It should be noted that 51 of the respondents, six worked in laboratory 1, seven in laboratory 2, three in laboratory 3 and thirty-five said they worked in more than one laboratory under analysis, with the same preponderance. Regarding gender, 15 were male and 36 female, with a mean age of 29.96 (standard deviation = 14.46) years.

After the application of tools for collecting pre-defined data, the following table compares the overall shape of the analytical values of the concentrations of CH_2O, CO, CO_2, VOCs, $PM_{2.5}$ and PM_{10} indoor air of various labs evaluated values legally set (safety threshold) (Table 1).

It was observed that here were statistically significant differences between the mean values of the CH_2O protection threshold in Laboratories 2 and 3, while in Laboratories 1 and 4 there were no significant differences. Analytical average values of this pollutant were above the protection threshold. It was Lab 2 that had higher average values, unlike Lab 1 which had the lowest. Relatively, the average analytical values of CO and CO_2 concentration, it was found that there were

Table 1 - Average concentrations of air pollutants, in the different evaluated labs

Lab	CH_2O (ppm)	CO (ppm)	CO_2 (ppm)	VOC (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)
	M ± (SD)	M ± (SD)	M ± (SD)	M ± (SD)	M ± (SD)	M ± (SD)
Lab_1	0.007 (0.018)**	0.225 (0.323)**	584.79 (108.51)**	161.94 (232.18)**	0.125 (0.438)**	0.153 (0.515)
Lab_2	0.229 (0.642)**	1.543 (0.42)**	673.20 (147.67)**	1719.44 (3516.80)**	0.036 (0.030)**	0.045 (0.030)**
Lab_3	0.569 (0.141)	0.830 (0.901)**	671.66 (85.61)**	655.88 (488.35)**	0.030 (0.034)**	0.047 (0.069)**
Lab_4	0.037 (0.087)**	0.377 (0.472)**	626.43 (156.117)**	113.77 (152.23)**	0.016 (0.007)**	0.026 (0.013)**

$Lab_{1:}$ Chemistry Lab; $Lab_{2:}$ Microbiology Lab. I; $Lab_{3:}$ Microbiology Lab. II; $Lab_{4:}$ Soil Laboratory; M: Average; SD: standard deviation; pl: protection limit; LP CH_2O = 0.08 ppm; LP = 9.0 ppm CO; LP = 1250 ppm CO_2; LP VOC = 600 ppb; $PM_{2.5}$ LP = 0.025 mg/m^3; LP PM_{10} = 0.05 mg/m^3
Test: Student t test for population mean
$^*p \leq 0.05$; $^{**}p \leq 0.01$; $Lab_{1:}$ Laboratório de Química

significant differences between the average analytical values and the protection threshold in all labs, whereby the average values were below the protection threshold. Referring to the average analytical values of VOCs, there were statistically significant differences between the estimated mean values and threshold protection in Lab 1 and 4, and the average values of the pollutant concentration were below the protection threshold. However, no Lab 2 e 3 the average values of the pollutant concentration were below the protection threshold.

With regard to the average concentrations of $PM_{2.5}$, it was observed that Labs 1, 2 and 3 showed average values of $PM_{2.5}$ concentration higher than the protection threshold, while the Lab 4 showed values below the protection threshold. Regarding the average concentrations of PM_{10}, Lab 1 were recorded in average values of PM_{10} concentration above the protection threshold.

We set out then evaluate the average concentration CH_2O, CO, CO_2, VOCs, $PM_{2.5}$ and PM_{10} labs, at the different measurements periods, considering the average values of the 4 laboratories, as the overwhelming majority of occupants said they cohabit equitably all laboratories under study during the work week (Table 2).

It was found that there were statistically significant differences between the mean values of analytical CH_2O in the morning and evening. It was the midday that showed higher average values, unlike the morning that had the lowest. Relatively, the analytical mean values of CO concentration, it was observed that there were significant differences between the analytical mean values for all periods, and the midday ex-hibited higher values, while the afternoon average values over low. As regards the analytical values of average CO_2 concentration was found that there were statistically significant differences between the mean values estimated in all periods. The period noon was noted that the average values of highest concentration

Table 2 - Average concentrations of air pollutants, labs evaluated in different periods

Period	CH_2O (ppm)	CO (ppm)	CO_2 (ppm)	VOC (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)
	M ± (SD)	M ± (SD)	M ± (SD)	M ± (SD)	M ± (SD)	M ± (SD)
Morning	0.07 (0.47)**	0.63 (1.187)**	541.67 (93.950)**	407.99 (1433.08)**	0.02 (0.008)**	0.04 (0.02)*
Midday	0.13 (0.344)**	0.76 (1.109)**	693.06 (113.326)**	532.37 (793.82)**	0.11 (0.38)*	0.14 (0.45)**
Evening	0.04 (0.072)	0.42 (0.486)**	682.01 (130.37)**	1047.66 (2801.58)**	0.03 (0.02)**	0.03 (0.02)**

M: Average; SD: standard deviation; pl: protection limit; LP CH_2O = 0.08 ppm; LP = 9.0 ppm CO; LP = 1250 ppm CO_2; LP VOC = 600 ppb; $PM_{2.5}$ LP = 0.025 mg/m^3; LP PM_{10} = 0.05 mg/m^3
Test: Student t test for population mean
$^{*}p \leq 0.05$; $^{**}p \leq 0.01$

and the lowest hours. Referring to the average analytical values of VOCs, there were statistically significant differences between the estimated average values. It was evening period which showed the average value of higher VOC, unlike the morning that had the lowest value. With regard to the average concentrations of $PM_{2.5}$, it was observed that there were statistically significant differences in all periods studied. The midday was what registered higher values and the morning the lowest average values. Regarding the average concentrations of PM_{10}, there was the presence of significant differences between the analytical values.

The following table is intended to evaluate the presence or absence of symptoms/disorders according to the lab where workers or students labored (Table 3).

According to the analysis of Table 3, it was found with regard to disease asthma, the occupants of all laboratories showed the highest prevalence (50%) and Lab 4 didn't showed. Regarding sneezing crisis also the occupants of various laboratories exhibited a higher percentage (55.5%), while the Lab 4 didn't showed percentage. With regard to allergies (rhinitis), it was the occupants who reported cohabiting all laboratories in an equitable manner, who presented the highest percentage (63.1%), as opposed to that presented in Laboratory 4 (5.2%). Regarding the symptom of headache, the occupants of various laboratories indicated the largest percentage (52.6%), while the Lab 4 indicated zero cases. Regarding the symptom of dizziness Lab 2 showed the greater percentage (50.0%) and Lab 4 the lowest percentage (14.3%). As regards the sensitivity to odors, the occupants of various laboratories showed the greater percentage (56.25%), contrary to Lab 4 that showed the lowest percentage (6.2%). With respect to respiratory difficulties was the local with occupants of various laboratories with the highest percentage (100.0%). Posteriorly, we sought to determine whether workers have reported that symptoms/disorders, left or not manifest when displaced to the outside of each of the evaluated labs. It was found that there were no statistically significant differences between the presence of disease/symptoms when workers moved to the outside in labs.

Table 3 Presence/absence of symptoms depending on the labs

Symptoms/Diseases		Lab where the occupant work			
		Lab 1	Lab 2	Lab 4	All Labs
Asthma	Yes	1 (16.7%)	2 (15.4%)	0 (0.0%)	3 (10.3%)
	No	5 (83.3%)	11 (84.6%)	3 (100.0%)	26 (89.7%)
Chronic bronchitis	Yes	0 (0.0%)	1 (7.7%)	0 (0.0%)	1 (3.4%)
	No	6 (100.0%)	12 (92.3%)	3 (100.0%)	28 (96.6%)
Sneezing Crisis	Yes	1 (16.7%)	7 (53.8%)	0 (00.0%)	10 (34.5%)
	No	5 (83.3%)	6 (46.2%)	3 (100.0%)	19 (65.5%)
Allergies (rhinitis)	Yes	2 (33.3%)	4 (30.8%)	1 (33.3%)	12 (41.4%)
	No	4 (66.7%)	9 (69.2%)	2 (66.7%)	17 (58.6%)
Headaches	Yes	3 (50%)	6 (46.2%)	0 (0%)	10 (34.5%)
	No	3 (50%)	7 (53.8%)	3 (100.0%)	19 (65.5%)
Dizziness	Yes	1 (16.7%)	3 (23.1%)	0 (0.0%)	2 (6.9%)
	No	5 (83.3%)	10 (76.9%)	3 (100.0%)	27 (93.1%)
Sensitivity to odours	Yes	2 (33.3%)	4 (30.8%)	1 (33.3%)	9 (31.0%)
	No	4 (66.7%)	9 (83.3%)	2 (66.7%)	20 (69.0%)
Cough	Yes	2 (33.3%)	4 (30.8%)	0 (0.0%)	5 (17.2%)
	No	4 (66.7%)	9 (69.2%)	3 (100.0%)	24 (32.8%)
Respiratory difficulties	Yes	0 (0.0%)	1 (7.7%)	0 (0.0%)	2 (6.9%)
	No	6 (100%)	12 (92.3%)	3 (100.0%)	27 (93.1%)

4 Discussion and Conclusion

After analyzing the average concentration of CH_2O, it was found that laboratory 2 presented values above the protection threshold, or higher than 0.08 ppm. This fact can be explained by the handling of reagents [1]. In the analysis of the mean values of CO concentration inside the laboratories, it was observed that they were below the protection threshold value. Regarding the CO_2 concentration values, it was found that all studies also presented average concentration values below the protection threshold. Regarding the VOC concentration, there was a risk to the health of the occupants of laboratories 2 and 3 since the average values of the concentration of pollutants in these laboratories were higher than those established by law. Regarding the average concentrations of $PM_{2.5}$, it was observed that laboratories 1, 2 and 3 presented average values above the protection concentration threshold, i.e. 0.025 mg/m^3. By analyzing the periods, which showed that, on average, the highest $PM_{2.5}$ concentrations were at noon. Regarding the average concentrations of PM_{10}, it was found that laboratory 1 had average concentration values above the protection limit value, which is a danger for professionals and students, as it can cause health problems, such as respiratory failure, such as indicated by some studies carried out in Portugal [9]. In this study, the most prevalent symptom/illness indicated by workers was “allergies” and “headaches” (52.8%), “sneezing attacks, runny nose or stuffy nose" (50%), "Odor sensitivity" (44.4%) and "mucosal irritation" (36.1%). Symptoms with less prevalent expression below 10% were: "chronic bronchitis", "breathing difficulties" and "wheezing".

Regarding the frequency of responses presented by our respondents, we found that out of the 128 manifestations we found that the most prevalent symptoms/diseases associated with the building were those previously indicated: "allergies", "headaches" and "seizures". sneezing, runny nose or stuffy nose". When analyzing the presence of diseases/symptoms when workers moved outside the building, it was found, after excluding occupants with a history of chronic disease, that there was no statistically significant association between the presence/absence of symptoms of sick building and the change in these same symptoms after occupants move outside the building ($p > 0.05$). However, with a prevalence of 75.86% of occupants with symptoms associated with sick building syndrome (n = 22), 63.6% found that they did not improve their initial health condition.

With the results obtained in this study, it was concluded that it is necessary to adopt measures to improve the IAQ in education laboratories, since there are air pollutants, as in the case of $PM_{2.5}$, PM_{10}, VOC and CH_2O in which the concentrations were, on average, larger than the legally established parameters. Therefore, it is essential that institutions conduct monitoring frequently so as not to expose professionals and students to hazardous conditions. IAQ assessment is critical to ensure the health of all occupants. Workplaces where professionals and students are exposed need to be healthy to ensure their health, performance and reduce absenteeism. No contaminants that contain high concentrations to harm health. Indoor air should be periodically evaluated to ensure these conditions.

References

1. Loureiro, A.: Qualidade do Ar Interior em Lares de Idosos e a Exposição Ocupacional aos Poluentes Atmosféricos (2014)
2. Sofuoglu, S., Toprak, M., Inal, F., Cimrin, A.: Indoor air quality in a restaurant kitchen using margarine for deep-frying. Environ. Sci. Pollut. Res. **22**(20), 15703–15711 (2015)
3. Santos, J.: Avaliação da Qualidade do Ar Interior em Jardins-de-Infância. Faculdade de Engenharia da Universidade do Porto (2010)
4. Almeida, M., Lopes, I., Nunes, C.: Characterization of indoor air quality in Portugal—habitar study. Rev. Port. Imunoalergologia. **18**(1), 21–38 (2010)
5. Coentro, S.: Qualidade do Ar Interior em habitações: Fontes emissoras de poluentes. Diss Mestr em Eng do Ambient da Univ Nov Lisboa (2015)
6. Valavanidis, A., Vatista, M.: Indoor Air Quality Measurements in the Chemistry Department Building of the University of Athens (2006)
7. NT-SCE-02 NT: Metodologia para auditorias periódicas de QAI em edifícios de serviços existentes no âmbito do RSECE (2009)
8. Portaria n. 353-A/2013: (Regulamento de Desempenho Energético dos Edifícios de Comércio e Serviços (RECS) - Requisitos de Ventilação e Qualidade do Ar Interior). Diário da República. 2013;1.ª série (2), pp. 2–9 (2013)
9. Fernandes, S.F.P.: Análise das Condições Higrotérmicas e da qualidade do ar interior na Biblioteca Joanina da UC (2014)

Shift Work: Work Ability and Quality of Life of Professionals from PSSI

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Abstract Shift work can influence the health and well-being of individuals due to changes in biological rhythms, causing psychological and physical disruption, hampering family, social, and work ability. The objective of this study was to evaluate the quality of life and the work capacity of workers doing shift work in PSSI (n = 29). Respondents were subjected a monitoring of the heart function PB —Blood Pressure for 24 h and answered a questionnaire (Work Ability Index and Quality of Life Index). Of the 29 workers 90% were women and 10% men, aged 46 years and exercise time of 7 years. We found that 24.1% of the participants were overweight and 13.7% obese. We found that overweight individuals have an increased Blood Pressure compared to normal weight individuals. Although the working class has a good ability to work 69%, they're not optimistic about the future. We conclude that workers can be adjusted the constant changes of schedules established by their institutions, are able to carry out their work, however, individuals with 6 or more years of work in the present-day regime shifts already feel some symptoms of physical and psychological wear.

Keywords Shift work · Work ability · Quality of life · Circadian rhythm

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1 Introduction

The Direct/Educational Auxiliary of the Private Social Solidarity Institution (PSSI) in Portugal are part of the professionals who are subject to rotating shift work. In our country there is a three-shift system consisting, in most cases, of the morning shift (8 am to 4 pm), afternoon (4 pm to midnight) and night (24 am to 8 am), and may undergo minor changes according each institution policies. This is due to the increasing demands in the health sector, arising from the evolution in the provision of the best hygienic and health care to the users of these Institutions, since the maintenance of activities during the twenty-four hours is fundamental. The consequences of shift work on the personal and family life of professionals are becoming clearer. At the end of 2018, 752,300 people worked in a shift base in Portugal, about 16% of the employees, so the effects of intolerance to shift work takes a high importance in terms of occupational health [1]. Shift work may have direct repercussions on the personal and family life of the worker, since the number of hours worked per week and the way they are distributed can affect the life quality.

The studies related to work and health are paramount, precisely for developing health promotion measures and maintaining the quality of life both in the work environment and outside it [2].

1.1 Quality of Life

Quality of Life (QL) is intimately linked to the human condition, being straightly connected to the degree of satisfaction in family, love, social and environmental life. These values reflect the set of elements that a given society considers to be its standard of comfort and well-being, and is therefore a social construction with the standarts of cultural relativity. Quality of life is an indicator used to describe the (quality of) life conditions taking into account factors such as health, education, physical, psychological, emotional and mental well-being, and life expectancy. QL also involves elements such as: family, friends, employment, or other life circumstances, and can be discussed from various points of view, individually or collectively, objectively or subjectively, defined in a generic or health-related way [3].

The definition adopted by the World Health Organization (WHO) reflects the generic form: “the individual’s perception of their position in life, in the context of the culture and value system in which they live and in relation to their goals, expectations, standards and concerns” [4]. This concept includes various aspects of life such as physical health, psychological state, level of independence, social relationships, personal beliefs, and relationship to environmental characteristics [5].

1.2 Work Ability

Our society has grown in several aspects, namely the need to work more hours with more physical and psychological demands. The concept of work ability is wide, complex and multidimensional. It understands the physical, psychological and social capacity of each worker to perform his task in his interaction with work. There is a balance between the specific worker characteristics and his resources, with the demands of the work, in healthy conditions [6].

Ability to work is a term used to ensure a correct match between an individual's functional skills and competencies, and the demands of the task and work environment, including the methods and tools used [7].

Therefore, the ability to work is the basis of our well-being. However, a number of studies [8, 9] have shown that in most workers, if no action is taken, there is a decline in the ability to work as they age. However, this decrease depends on many factors, changing greatly from individual to individual and throughout his professional life. According to Moura et al. [10], working conditions and the aging process of the population are two of the factors that influence the worker's ability to work, which reflects his well-being and his ability to perform work activities. According to the same author, there are professions that, in addition to mental demands, require physical, repetitive efforts, lifting and transport of weights (such as weakened persons) and incorrect postures, and in these cases preventive measures of promotion or even maintenance of health should be adopted [10].

Therefore, the great challenge will be being able to maintain a good capacity for work as changes in the individual happen. Prevention and adaptation are two key words to maintain the individual's level of performance throughout life.

2 Materials and Methods

This study was conducted in 2018/2019 and the data collection was carried out between October 2018 and January 2019. This study was presented as being level II, the analytical observational and prospective cohort.

The target population were shift workers from two Private Social Solidarity Institution (PSSI) in the Bairrada region, in the centre of Portugal. The type of sampling was non-probabilistic and the technique was for convenience.

2.1 Work Instruments and Data Collection

Data collection took place in two PSSI of Bairrada region, between October 2018 and January 2019, and included 29 of their fixed night shifts and fast rotating shifts workers. Initially, and so that all social shift workers were fully clarified, all the information regarding the project objective was transmitted. Respondents were asked to read and sign informed consent with all clarification of any questions that arose after reading. All tests were encoded with a code number. In addition, was provided a questionnaire to obtain demographic and anthropometric data.

In order to carry out a more assertive blood pressure measurement and, consequently, a more efficient diagnosis performed, the Ambulatory Blood Pressure Monitoring (ABPM) technique was used, this goal was to quantify the values of systolic and diastolic blood pressures and verify the relationship between the values obtained in two major periods, work period and the rest of the day and their differences. The evaluation of the values obtained we can conclude what is the impact of work on blood pressure in the health of these workers. A technique that, in a non-invasive way and through the oscillometric method, allowed to obtain multiple and indirect blood pressure (BP) measurements performed automatically during 24 h, every 30 min. Thus, values such as: mean BP of 24 h, mean day and night BP, pulse pressure (PP) and heart rate (HR) at the time of each measurement were obtained.

Arterial hypertension was defined as the reference values for the mean of 24 h PA $\geq$ 130/80 mmHg, for the mean daytime BP $\geq$ 135/85 mmHg and for the mean night BP $\geq$ 120/70 mmHg, following the recommendations of the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure *(JNC7)* [11].

On the other hand, the evaluation of the night profile allowed us to classify as an *inverted dipper* the individual with a fall <0% of blood pressure, a *non-dipper* with fall between 0–10%, as *dipper* between 10–20% and extreme dip-per >20%, according to the *American Heart Association*. BMI was calculated dividing weight by squared height (weight/height^2) and classified into four classes based on World Health Organization reference values: a BMI of less than 19 kg/m2 corresponds to low weight, a BMI between 19.0–24.9 kg/m^2 corresponds to normal weight, a BMI between 25.0–29.9 kg/m^2 to overweight and a BMI greater than 30.0 kg/m^2 to obesity. A questionnaire was applied to know demographic and anthropometric data (age, gender, weight, height), lifestyle data (daily sleep hours, caffeine consumption and risk factors), about work (working time on a regular basis shift, workload) and others relevant to the study.

The second part of the study had a questionnaire on the Work Ability Index (WAI) and Quality of Life Index (QLI). Work ability is the results from the equation between worker resources and job demands. And it is influenced by their sociodemographic condition, lifestyle, health status and aging process [12]. For its evaluation, the Work Ability Index could be operationalized, structured according to the studies of the Finnish Institute of Occupational Health, and then translated and adapted to Portugal, renamed for the Work Ability Index (WAI) [13]. The WAI is a measuring instrument easy to use. It's fast and reliable for use by occupational health teams to identify workers in need of support in order to prevent decreased work ability through health promotion projects, improved working conditions and skills development in workers [13, 14]; It can also be used to predict the risk of short-term disability. It's considered priority to be assessed workers with poor working capacity (maximum score 27); followed by those with moderate ability (scores between 28 and 36), who require measures to help improve work capacity; then those with a good WAI (score 37–43) who lack instructions on how to sustain their ability to work; and finally those classified as Excellent (44–49), who need to be informed about the facilitating and hindering determinants of their ability to work [13].

The QLI in this study was used as an indicator to measure the quality of life in terms of life satisfaction subjectively, which is adapted to the general population (generic version III). The first part was based on the respondents' level of satisfaction in the various life domains or areas, and the items are presented on a *Likert* scale ranging from 1 "very dissatisfied" to 6 "very satisfied". The second part was centered on the respondents perceived degree of importance in these same areas or domains of life, and items are also presented on a *Likert* scale ranging from 1 "unimportant" to 6 "very important" [15]. This tool is evaluated both globally and in four dimensions: Health and Functioning, Social and Economic, Psychological and Spiritual and Family, in a total of 36 items.

Statistical analysis

First of all, statistical data were organized under the Microsoft Office Excel for further analysis and study using the statistical software SPSS Statistics 25.0 (IBM Corp. Armonk, NY, USA). To characterize the sample and its variables, a descriptive analysis was performed and descriptive measures were applied: central location measurements (mean) and dispersion measurements (standard deviation). Categorical variables were presented as percentage and absolute frequency. For the statistical methods used for analysis of the values obtained by ambulatory blood pressure monitoring technique resorted to the Student's t-test for independent samples. The distribution of continuous variables was tested for homogeneity by Levene's test. Fisher's test and Chi-square test were used for comparisons involving categorical variables. The criterion set for statistical significance is $p \leq 0.05$ for a 95% confidence interval.

3 Results

The majority 90% of respondents were female; and only 10% male of which 55.2% were married, 24.1% were divorced and 20.7% were single. About their academic degree, 58.6% had a 12th grade or higher and 44.1% had only basic education. In turn, it was observed that the age of the study participants ranged from 23 to 66 years, and the total average age was 45.5 years old.

Physical examination revealed a mean systolic blood pressure of 119.3 mmHg (±11.8) and diastolic blood pressure of 72.6 mmHg (±7.3). The mean Body mass index (kg/m2) was 27.3 (±3.5), with 18 (62.1%) participants presenting normal weight, and 7 (24.1%) Overweight and 4 (13.8%) grade I obesity. Regarding daytime systolic blood pressure, it showed an average of 126.0 mmHg and daytime diastolic blood pressure 77.3 mmHg; in turn, nocturnal systolic blood pressure has

Table 1 Relationship between mean blood pressure and age

		Age					
		Normal		Higher		Total	
	p-v	M	SD	M	SD	M	SD
Blood pressure mean Systolic 24 h [a]	1.00	45.32	11.22	**46.75**	3.59	45.52	10.47
Blood pressure mean Diastolic 24 h [b]	0.60	45.12	10.98	**49.00**	2.65	45.52	10.47
Blood pressure mean Systolic daytime [c]	0.36	44.45	11.29	**48.86**	6.94	45.52	10.47
Blood pressure mean Diastolic daytime [d]	0.53	44.92	11.21	**48.40**	5.68	45.52	10.47
Blood Pressure Mean Systolic nocturn [e]	0.39	**46.00**	10.95	42.50	7.00	45.52	10.47
Blood pressure mean Diastolic nocturn [f]	0.86	45.58	10.98	45.20	8.56	45.52	10.47

Legend [a]PAMS; [b]PAMD; [c]PAMS_Daytime; [d]PAMD_Daytime; [e]PAMS_Nocturn; [f]PAMD_Nocturn

an average of 106.1 mmHg and a nocturnal diastolic blood pressure of 61.9 mmHg. About 85% of the examined population has a Mean Blood Pressure (MBP) Normal 24 h, the remainder has a MBP High 24 h. In turn, 75.9% of the population has a Normal MBP Daytime Systolic and 24.1% of the population has a High MBP Daytime Systolic and a Normal MBP Daytime Diastolic of 82.8%, considering "Daytime" the period during which workers are awake. As for the Night PBM 86.2% of the population has Systolic Normal values and 82.8% values Diastolic Normal; the remaining have a high value, considering "night" the rest period.

There were no variations in Mean Arterial Pressure when related to variables such as, Age, let's see following Table 1.

There were no significant differences between workers age and blood pressure parameters ($p > 0.05$). However, it can also be noted that workers with higher blood pressure (BPMS_24h, BPMD_24h, and BPMS_D BPMD_D) were the oldest.

We proposed to describe the distribution of workers in classes of years that perform shift work versus mean blood pressure classes. Let's look at the following chart (Tables 2 and 3).

There are no significant differences between the classification of the PBM by classes for years role in shifts workers of the PSSI, however the period between 5 and 10 years of service, is the period where there are more cases of people with some Mean blood Pressure deviations.

As we already said the second part of the study had a questionnaire on the ability to work index (WAI) and quality of life index (QLI).

Table 2 Relationship mean blood pressure with years role shift work

			Mean blood pressure		Total
			Normal	High	
Years per shiftwork	Until 5 years	n	10	1	11
		% column	45.5%	14.3%	37.0%
	6–10 years	n	7	6	13
		% column	31.8%	85.7%	44.0%
	>10 years	n	5	0	5
		% column	22.7%	0.0%	17.0%
Total		n	22	7	29
		% column	100.0%	100.0%	100.0%

Table 3 Chi-Square tests

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-Square	6.392[a]	2	0.041
Likelihood ratio	7.408	2	0.025
Linear-by-linear association	0.072	1	0.789
No. of valid cases	29		

[a]4 cells (66.7%) have expected count less than 5. The minimum expected count is 1.21

After the data collection there was an average of 38.330 ± 4.43 (range of 7–49) has been identified for the ability to work in the study group.

Regarding the classification of WAI, eleven of participants showed a work ability index moderate range (28–36), fifteen of the participants in the study are in the category Good (37–43) and three are with a work ability index Excellent (44–49), and none of the participants showed a poor work ability index (7–27).

There wasn't any correlation between age workers and the perception that they had for their work ability ($p > 0.05$). We obtained a significance level higher than 5%, then we assume that there are no significant differences in work ability index on medium terms in relation to age, therefore the work ability does not vary according to age. Also, there weren't any differences in work ability when related to marital status, so the work ability does not vary depending on marital status.

Observing Table 4 where we evaluate the number of years that the employees had in the institution in shift work regime and how this variable is related either with the subjective measure either with the objective measure of the work ability, we came to realize the lack of relationship between the number of working years to measures for the work ability in this study ($p > 0.05$).

However, there's a reduced work ability of employees between 6 and 10 years of service in these shifts compared to the global average. Already knowing the sociodemographic characteristics, in the Table 5 was described the averages of the quality of life values for the years on shifts work.

As it can be seen, both in QLI and in all its domains, workers between 6 and 10 years of service have the lowest Quality of Life Index.

Table 4 Relationship years role shift work and work ability

	N	M	SD
until 5 years	11	39.2	5.4
6–10 years	13	37.1	4.2
>10 years	5	39.5	2.2
Total	29	38.3	4.4

Legend M = Mean; DP = Standard Deviation

Table 5 Quality of life index

		N	M	SD
Quality of life index	Until 5 Years	11	26.56	2.03
	6–10 Years	13	23.31	3.37
	>10 Years	5	26.80	1.23
	Total	29	25.14	3.06
QLI—Health e functionality	Until 5 Years	11	26.74	2.07
	6–10 Years	13	23.36	3.41
	>10 Years	5	26.69	1.34
	Total	29	25.22	3.11
QLI—Social e economical	Until 5 Years	11	26.65	2.08
	6–10 Years	13	23.30	3.50
	>10 Years	5	27.47	1.46
	Total	29	25.29	3.24
QLI—Psychological e spiritual	Until 5 Years	11	25.45	2.81
	6–10 Years	13	22.34	4.17
	>10 Years	5	25.00	2.10
	Total	29	23.98	3.63
QLI—Family	Until 5 Years	11	27.72	2.37
	6–10 Years	13	24.67	2.89
	>10 Years	5	28.52	0.83
	Total	29	26.49	2.92

Legend M = Mean; DP = Standard Deviation

4 Discuss

No one was classified as underweight. However, there are some individuals who are overweight or obese. Overweight and obesity, as well as affecting the musculoskeletal capacity and encourage increased morbidity from chronic diseases, such as heart disease, diabetes and depression, may represent risk or limitation for the performance of occupational activities, especially activities with important physical requirements. In previous studies such as the study of Martinez and Latorre [16] BMI was inversely correlated with WAI, demonstrating that being overweight had a negative impact on work ability.

Regarding Life of Quality, the results were better for the Family domains, followed in the same level the health/functional and social/economic domains and with the lowest psychological/spiritual domain. Age, gender, marital status and having small children didn't influence significantly the participants' Work Ability scores and life of Quality either. The fact that some professionals have six or more years of work in these alternate schedules despite the significance level exceed 5%, the study has shown a tendency to physical and psychological stress. In addition, the work of direct/educational activity aids is extremely tiring, both in physical appearance and mental. Despite the fatigue that the job requires most workers, not associated with decreased functional capacity, physical aspects and social aspects. In other studies, for example to Gonzales et al. [17], the function time in the same job can be crucial to the physical and mental health, especially for professionals whose work can be both physical and mental requirements. The professionals in this study of these two Bairradina's institutions take care of three classes of users, some of them working nursing home as caring for the senior population whose daily physical requirements are higher than the mental demands, others working in a residential home to people who has disabilities more specifically children/young people with Down Syndrome and other motor/cognitive disabilities, whose demands are both physical and mental. And the last one, working in a temporary housing center (CAT) as a caregiver of children/young people who are rescued by social security from poor and needy families; where the mental demands of these workers are higher than physical ones since they often have to help these young people to do the school works. Regarding the classification of Work Ability Index, the total average was 38.3, corresponding to "good" capacity for work. The item with the lowest score was on point 6 "Will you be able to do your current work activity in 2 years?" part of the respondents, in especial who has more years working in that routines answered "Maybe" and there was who answered "Improbable" which has been shown that workers already feel some wear or even aging symptoms. According Tuomilehto [18] with aging, many body functions suffer decline, especially with regard to physical fitness. Sluiter et al. [19] referred that age is a determining factor in the decline of physiological functions. However as mentioned previously, the age and the time function does not affect the results of Work Ability and Life of Quality of study participants, however as mentioned previously, the age and years of service does not affect the results either Work Ability or Life Quality in the study, curiously in this study, there're individuals with ten years of service who has better Life Quality than individuals between six and ten years old. Tuomi et al. [6] They consider that the Work Ability does not remains satisfactory throughout the professional life, being affected by many factors, and that work conditions, life and healthy lifestyle can change this prognosis.

5 Conclusion

From the analysis, it can be concluded that workers adjust to changing schedules set by their institutions, are able to carry out their work. Although there is already a concern of these institutions to adjust the schedule of these shifts in order to minimize the worker's effort instead of practicing the standard shift schedules, however individuals with 6 or more years of work in the present-day regime shifts already feel some symptoms of physical and psychological wear. These assessments can assist in the prioritizing and identifying workers who need the support of occupational health services and direct interventions to improve the environment or working conditions.

References

1. https://www.dn.pt/edicao-do-dia/27-ago-2018/interior/ha-cada-vez-mais-portugueses-com-horarios-flexiveis-9764363.html. Last accessed 25 Dec 2019
2. Andrade, C.B., Monteiro, M.I.: Envelhecimento e capacidade para o trabalho dos trabalhadores de higiene e limpeza hospitalar. Rev da Esc Enferm. **41**(2), 237–244 (2007)
3. Vidotti, H.G.M., Coelho, V.H.M., Bertoncello, D., de Walsh, I.A.P.: Qualidade de vida e capacidade para o trabalho de bombeiros. **372**, 231–238 (2015)
4. da Silva, R.D., da Reis, M.S., Leão, D.P., de Amorim, M.L.C.: Avaliação da Qualidade de Vida e Sobrecarga de Cuidadores de Pessoas com Deficiência Intelectual. Rev Bras Ciências da Saúde. **14**(3), 69–76 (2010)
5. https://www.saudebemestar.pt/pt/blog-saude/qualidade-de-vida/. Last accessed 26 Dec 2019
6. Tuomi, K., Ilmarinen, J., Jahkola, A., Katajarinne, L., Tulkki, A.: Índice de capacidade para o trabalho. Tradução de FM Fischer, Helsinki, Finlândia Inst Finlandês Saúde Ocup. (1997)
7. Pereira, A.: Capacidade de Trabalho e Factores Psicossociais do Sector de Higiene Pública com e sem Acidentes de Trabalho, p. 76 (2013)
8. Ilmarinen, J., Tuomi, K., Klockars, M.: Changes in the work ability of active employees over an 11-year period. Scand. J. Work Environ. Heal. **23**(SUPPL. 1), 49–57 (1997)
9. Ilmarinen, J.E.: Aging workers. Occup. Environ. Med. **58**, 546 (2001)
10. Moura, A.L., dos Reis, L.M., Vannuchi, M.T.O., Haddad, M.D.C.L., de Domansky, R.C.: Capacidade para o trabalho de funcionários da prefeitura de um campus universitário público. Rev Eletrônica Enferm. **15**(1), 130–137 (2013)
11. Chobanian, A.V., Bakris, G.L., Black, H.R.: High Blood Pressure: The JNC 7 Report Prevention, Detection, Evaluation, and Treatment of The Seventh Report of the Joint National Committee on The JNC 7 Hypertension Guidelines. (1.9191911201010101e+25), pp. 1–4 (2003)
12. Almeida, A., Santos, M., Mendes, C., Machadinho, M.: Avaliação da Capacidade de Trabalho versus Envelhecimento dos funcionários, num município português de média dimensão. Rev Port Saúde Ocup. vol. 6, pp. 1–40. Dec 2018
13. Silva, C., Pereira, A., Bem-haja, P.: Índice de Capacidade para o Trabalho : Portugal e Países Africanos de Língua Oficial Portuguesa Universidade de Aveiro Instituto Finlandês de Saúde Ocupacional Universidade de Coimbra – Centro de Estudos e Investigação de Saúde UC Sindicato de Enfermeiros. Jan 2011
14. Martinez, M.C., Latorre, M.R.D.O., Fischer, F.M.: Work ability: a literature review. Cien Saude Colet. **15**(SUPPL. 1), 1553–61 (2010)

15. Correia, T., Simões, H., Telo, E., Cotrim, T., Figueiredo, J., Ferreira, A.: Envelhecimento no Trabalho : Capacidade para o trabalho dos Docentes da ESTeSC. Artig Científico, pp. 1–12 (2017)
16. Martinez, M.C., Latorre M.D.R.D.D.O.: Saúde e capacidade para o trabalho de eletricitários do Estado de São Paulo. Cienc e Saude Coletiva. **13**(3), 1061–1073 (2008)
17. Gonzáles, R.M.B., Beck, C.L.C., Donaduzzi, J.C., Stekel, L.M.C.: O estado de alerta: um exploratório com o corpo de bombeiros. Esc Anna Nery. **10**(3), 370–377 (2006)
18. Tuomilehto, J.: Impact of age on cardiovascular risk: implications for cardiovascular disease management. Atheroscler Suppl. **5**(2), 9–17 (2004)
19. Sluiter, J.K.: High-demand jobs: age-related diversity in work ability? Appl. Ergon. **37**(4), 429–440 (2006)

Effectiveness of an Oral Health Program Among Brazilian Oil Workers

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Abstract The aim of this study was to assess the effectiveness of the implementation of an oral health program among Brazilian oil workers, Bahia. The program consists in an annual consultation, with and an occupational dentist and oral health technicians, performing oral examination, in addition to having access to plaque and gingival indices obtained in the exam. The Oral Hygiene Index (OHI) was used, as well as the "Quality of oral hygiene", "Periodontal disease", "Systemic Arterial Hypertension" (SAH) and "Diabetes Mellitus" (DM) questionnaires. The reduction of periodontal disease was associated with the improvement of oral hygiene quality, with a positive impact in the reduction of the probability to develop high blood pressure and DM. The oral health promotion programme was effective in keeping or maintaining good oral health among workers, also resulting in savings to the company.

Keywords Periodontal disease · Oral health program · Oil industry

1 Introduction

The World Health Organization [1] defines strategies for oral disease prevention and health promotion, detailed in four different objectives: (i) reduction of the burden and disability of oral diseases, particularly in poor and marginalized populations; (ii) promotion of healthy lifestyles and reduction of risk factors for oral health arising from environmental, economic, social and behavioral causes; (iii) development of oral health systems that equitably improve oral health outcomes, responding to people's legitimate demands and are financially fair; and

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(iv) frame oral health policies, based on the integration of oral health into national and community health programs, and promote oral health as an effective dimension to society's development policy.

The relative high risk of oral disease is related to socio-cultural determinants such as poor living conditions, low education level, lack of traditions, beliefs and culture in support of oral health. In addition, oral disease control depends on the availability and accessibility of oral health systems, but the reduction of oral disease risks is only possible if services are oriented towards primary health care and prevention. Specifically regarding the worker, severe oral health conditions and unmet dental care needs can interfere with the individual's workday, either through absenteeism or presentism. Stimulating self-care through plaque control, either by assisted brushing or by the dental prevention procedure, is an important measure in health promotion and disease prevention [2].

The implementation of a Workers Oral Health Program, based on the principles of health promotion and prevention, aiming at reducing oral illness and, consequently, improving the quality of life, is of fundamental importance in the industry context. In this sense, this study aimed to analyze the association between the Quality of Oral Hygiene (QOH), Periodontal Disease (PD), hypertension and diabetes in workers under intervention of the Workers Oral Health Program of the studied oil company.

2 Materials and Methods

The study was performed at the occupational health service of the oil industry, Bahia, Brazil, in 2018. 715 workers were enrolled in the Workers Oral Health Program and were attended by an occupational dentist and oral health technicians, in consultation with an average duration of 45 min, in which they received information about the plaque and the damage that it can causes, oral examination with the aid of intraoral camera, performed plaque development assessment, assisted brushing and dental floss with the aid of audio-visual material, receiving home-use pads as an aid in brushing, in addition to having access to plaque and gingival indices obtained in the exam. To classify the Oral Hygiene Index (OHI), the Greene and Vermillion Simplified Oral Hygiene Index protocol [3], referred by Chaves [4], as well as the probing technique for PD diagnosis, were used. The use of OHI as a tool for assessing the quality of oral hygiene of the worker, besides allowing a more directed orientation to each individual, made possible the data analysis and its association with other health indicators. To collect information a questionnaire covering the "Quality of oral hygiene", "Periodontal disease", "Systemic Arterial Hypertension (SAH)" and "Diabetes Mellitus" (DM), was used.

Data analysis was performed using SPSS version 25 for Windows (United States, New York, IBM Corporation). Chi-square (χ^2) test was used to test associations between nominal variables. Correlation analysis between variables was performed using *Pearson's* correlation (r^2) coefficient.

The study was approved by the Research Ethics Committee of the Bahiana School of Medicine and Public Health of Brazil, registered with CAAE 84318218.2.0000.5544.

3 Results and Discussion

According to Table 1, men (91.3%), aged between 50–59 years (46.2%), married (57.1%) and with complete middle level of education (64.3%), prevailed in this study.

Table 1 Sample characterization

Variables	Sex		*p*
Age	Male	Female	
<29	25 (3.8)	5 (8.1)	0.001
30–39	157 (24.0)	28 (45.2)	
40–49	138 (21.1)	13 (21.0)	
50–59	302 (46.2)	15 (24.2)	
>60	31 (4.7)	1 (1.6)	
Marital Status			
Single	237 (6.3)	30 (48.4)	0.025
Stable union	20 (3.1)	1 (1.6)	
Married	373 (57.1)	25 (40.3)	
Divorced	21 (3.2)	6 (9.7)	
Other	2 (0.3)	0 (0.0)	
Education			
Incomplete middle level	56 (9.9)	1 (1.7)	0.191
Complete middle level	362 (64.3)	39 (66.1)	
Incomplete high level	2 (0.4)	0 (0.0)	
Complete high level	111 (19.7)	13 (22.0)	
Complete high level with post-graduate studies	32 (5.7)	6 (10.2)	
OHI			0.005
Bad oral hygiene (OHI >3.0).	5 (0.8)	0 (0.0)	
Poor oral hygiene (OHI 2.1 to 3.0)	56 (8.6)	0 (0.0)	
Regular oral hygiene (OHI 1.1 to 2.0)	239 (36.6)	14 (22.6)	
Proper oral hygiene (OHI 0.0 to 1.0)	148 (22.7)	23 (35.5)	
Adequate oral hygiene with basic semi-annual therapy	205 (31.4)	26 (41.9)	

(continued)

Table 1 (continued)

Variables	Sex		p
Age	Male	Female	
PDI			0.183
0—Untreated periodontitis, with tooth mobility, associated with risk factors (smoking and/or CNCDs)	4 (0.6)	0 (0.0)	
1—Untreated periodontitis, with tooth mobility, not associated with risk factors (smoking and/or CNCDs)	3 (0.5)	0 (0.0)	
2—Periodontitis without treatment, without tooth mobility, associated or not with risk factors (smoking and/or CNCDs)	11 (1.7)	0 (0.0)	
3—Treated periodontitis, associated or not with risk factors	7 (1.1)	3 (4.8)	
4—Same previous condition associated with periodic maintenance consultation	1 (0.2)	0 (0.0)	
5—Does not have periodontal disease	627 (96.0)	59 (95.2)	

Notes CNCDs—Chronic Non-communicable Diseases; OHI—Oral hygiene index; PDI—Periodontal disease index

The results reveal that male workers have worst QOH (p = 0.005), a result previously identified by Al-Ansari and Honkala [5]. The majority of workers have a proper (56.1%) or regular QOH (35.4%). Relating the PDI, no significant differences were found between male and female workers (p = 0.183). In general, 95.9% of the workers do not present periodontal disease. Despite this, 2.5% of the periodontal disease diagnostics do not have treatment and have higher probability to be associated with CNCDs and smoking. Table 2 aims to present the results of the association between PDI and other factors, such as the quality of workers oral hygiene and the arterial hypertension and DM prevalence among workers. The number and percentage (between parentheses) of workers are presented, as well as the value of chi-square association and *Pearson* correlation (last line of each association).

The results in Table 2 reveal a significant association (p = 0.001) between the QOH and the PDI. Based in this outcome it is possible to state that the realization of an adequate oral hygiene with the performance of basic semi-annual therapy is associated with a lower probability to develop PD. Previous studies [6–8], have also reported that a poor oral hygiene results in a high risk of periodontitis by two- to five-fold.

Another important result is the identified association between arterial hypertension and the PD (p = 0.003). HBP can lead to changes in microcirculation, able to cause ischemia in the periodontium, which favours periodontal disease [9, 10]. An association between the reduction of PD and the cumulative reduction of DM was also found (p = 0.003). This result is in accordance with past studies [11, 12] reporting that the treatment of periodontal disease is associated with diabetes reductions of approximately 0.4%.

Table 2 Association between periodontal disease and oral hygiene, high blood pressure and diabetes mellitus

		PDI					
		0	1	2	3	4	5
QOH	Bad oral hygiene (OHI >3.0)	0 (0.0)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	4 (0.6)
	Poor oral Hygiene (OHI 2.1 to 3.0)	4 (100)	1 (33.3)	6 (54.5)	1 (10.0)	0 (0.0)	44 (6.4)
	Regular oral hygiene (OHI 1.1 to 2.0)	0 (0.0)	2 (66.7)	4 (36.4)	3 (30.0)	0 (0.0)	244 (35.6)
	Proper oral hygiene (OHI 0.0 to 1.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (40.0)	0 (0.0)	166 (24.2)
	Adequate oral hygiene with basic semi-annual therapy	0 (0.0)	0 (0.0)	0 (0.0)	2 (20.0)	1 (100)	228 (33.2)
		χ^2 = 106.1 (p = 0.001); r^2 = 0.226 (p = 0.001)					
HBP	SAH with associated clinical conditions (ACD or CKD)	0 (0.0)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	6 (0.9)
	SAH with presence of target organ injury or DM	0 (0.0)	0 (00)	0 (0.0)	1 (10.0)	0 (0.0)	7 (1.0)
	SAH with 3 or more risk factors	0 (0.0)	1 (33.3)	1 (9.1)	0 (0.0)	0 (0.0)	12 (1.7)
	SAH with 1 to 2 risk factors	2 (50.0)	1 (33.3)	1 (9.1)	4 (40.0)	1 (100)	103 (15.0)
	SAH without risk factor	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	8 (1.2)
	Non hypertensive	2 (50.0)	1 (33.3)	8 (72.7)	5 (50.0)	0 (0.0)	550 (80.2)
		χ^2 = 49.4 (p = 0.003); r^2 = 0.127 (p = 0.001)					
DM	Glycated Hb >9% or Fasting blood glucose >200 mg/dl, maintaining these results for the last 2 years	0 (0.0)	1 (33.3)	1 (9.1)	1 (10.0)	0 (0.0)	10 (1.5)
	Glycated Hb >9% or Fasting blood glucose >200 mg/dl	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.3)
	Hb glycated between 7 and 9% or Fasting glycemia between 130 and 200 mg/l	0 (0.0)	1 (33.3)	2 (18.2)	0 (0.0)	0 (0.0)	32 (4.7)
	Glycated Hb < 7% or Fasting blood glucose <130 mg/dl	1 (25.0)	0 (0.0)	0 (0.0)	1 (10.0)	0 (0.0)	10 (1.5)
	Glycated Hb < 7% or Fasting blood glucose <130 mg/dl, maintaining these results for the last 2 years	0 (0.0)	0 (0.0)	1 (9.1)	1 (10.0)	1 (100)	11 (1.6)
	Non diabetic	3 (75.0)	1 (33.3)	7 (63.6)	7 (70.0)	0 (0.0)	621 (90.5)
		χ^2 = 110.04 (p = 0.001); r^2 = 0.181 (p = 0.001)					

Notes ACD—atherosclerotic cardiovascular disease; CKD—Chronic Kidney Disease; SAH—Systemic arterial hypertension; DM—Diabetes Mellitus

4 Conclusions

The results showed that the education actions carried out in the scope of the Workers Oral Health Program allow the involvement of the individuals in relation to the self-care of their oral health condition, contributing to the evident visualization of the amount of bacterial plaque still adhered to the teeth after poor oral hygiene, visualizing existing lesions through the intraoral chamber and performing basic therapy within the oil company. These actions encourage workers to play their role in promoting their own health, also resulting in reduced absenteeism, with evident economic implications.

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References

1. World Health Organization.: The World Oral Health Report 2003 [Internet]. Vol. 31 Suppl 1, Community dentistry and oral epidemiology, Geneva (2003)
2. Gomes, V.E., Da, Silva D.D.: A importância do controle de placa dental na clínica odontológica. Arq em Odontol **46**(1), 22–27 (2010). [The importance of dental plaque control in the dental clinic]
3. Greene, J.C., Vermillion, J.R.: The simplified oral hygiene index. J. Am. Dent. Assoc. **68**, 7–13 (1964)
4. Chaves, M.M.: Odontologia social [Social dentistry]. 3ª ed. São Paulo, Artes Médicas, pp. 429–443 (1986)
5. Al-Ansari, J.M., Honkala, S.: Gender differences in oral health knowledge and behavior of the health science college students in Kuwait. J. Allied Health **36**(1), 41–46 (2007)
6. Zimmermann, H., Zimmermann, N., Hagenfeld, D., Veile, A., Kim, T.-S., Becher, H.: Is frequency of tooth brushing a risk factor for periodontitis? A systematic review and meta-analysis. Community Dent. Oral Epidemiol. **43**(2), 116–127 (2015)
7. Lertpimonchai, A., Rattanasiri, S., Arj-Ong Vallibhakara, S., Attia, J., Thakkinstian, A.: The association between oral hygiene and periodontitis: a systematic review and meta-analysis. Int. Dent. J. **67**(6), 332–343 (2017)
8. Zaitsu, T., Kanazawa, T., Shizuma, Y., Oshiro, A., Takehara, S., Ueno, M., et al.: Relationships between occupational and behavioral parameters and oral health status. Ind Health **55**(4), 381–390 (2017)
9. Leong, X., Ng, C., Badiah, B., Das, S.: Association between Hypertension and Periodontitis: possible mechanisms. Sci. World J. **2014**, 1–11 (2014)
10. Macedo Paizan, M.L., Vilela-Martin, J.F.: Is there an association between periodontitis and hypertension? Curr. Cardiol. Rev. **10**(4), 355–361 (2014)
11. Preshaw, P.M., Alba, A.L., Herrera, D., Jepsen, S., Konstantinidis, A., Makrilakis, K., et al.: Periodontitis and diabetes: a two-way relationship. Diabetologia **55**(1), 21–31 (2012)
12. Daniel, R., Gokulanathan, S., Shanmugasundaram, N., Lakshmigandhan, M., Kavin, T.: Diabetes and periodontal disease. J Pharm Bioallied Sci. **4**(Suppl 2), S280–S282 (2012)

Health Risk Assessment in Oil Industry in Bahia, Brazil: The Worker's Health Risk Index (*WHRI*)

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Abstract The objective of this study was to assess the worker's health (WH) risk, focused on sustainable development in a work context and based on the development and application of the Worker's Health Risk Index (*WHRI*) in the oil extraction and production industry in Bahia, Brazil. The sample, obtained by quota sampling, comprised 965 participants. The development stage integrates the Interdisciplinary Workers Health Approach Instrument (IWHAI) application to collect worker's data, the analysis of the relationships between the indicators, the risk ranges definition, the *WHRI* formulas elaboration, the *WHRI* final application and its discriminant validity. Three risk ranges were defined: "Low", "Moderate" and "High". *WHRI* revealed the ability to identify differences between the population studied, according to sex, age group and education level. The results indicate that 74% of the participants are in the "Low", 21% in the "Moderate" and 5% in the "High" risk ranges. High-risk workers are also those with diabetes mellitus, triglycerides, altered glycemia and hypertension, poor oral hygiene and periodontal condition, smoking, less physically active (all with $p < 0.05$), and higher levels of abstentionism. *WHRI* major contribution is to make available a useful tool for the identification of WH risk, contributing to define clearer health promotion, prevention and intervention policies in the context of WH.

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1 Introduction

Risk prevention and the promotion of safer and healthier conditions in the workplace are essential not only to improve the quality of employment and working conditions, but also to promote competitiveness [1]. Healthy workers have a direct and quantifiable positive impact on productivity, contributing to improve the sustainability of social security systems [2, 3]. Risk stratification of health system users is a central element of the health management of a population. An important model for the organization of care regulation is the Risk Pyramid Model (RPM), which operationalizes the risk stratification of non-acute chronic conditions and defining intervention strategies for self-care and in professional care. Although RPM is a relevant model for stratifying populations in risk ranges, their theoretical frameworks do not describe the methodology that determines their classes.

In line with the need for risk stratification and with the intention of covering a lack of availability of health and sustainability indicators within the work context, this study proposes the Worker's Health Risk Index (*WHRI*), which aims to assess the Worker's Health (WH) risk, focusing on sustainable development in the workplace. This approach assumes that the WH results from a set of associations between environment, human health and working relationships, which, interrelated, contribute to the general health status of the working population. For this reason, and in an interdisciplinary perspective, the development of an index such as *WHRI* is considered relevant, enabling the prevention and integral promotion of health in the collective work environment.

2 Materials and Methods

2.1 Study Design

The research is based on a strong methodological component, carried out in the period of August to October 2018, in the worker's occupational health service in the oil extraction and production industry in Bahia, Brazil. The study involved 10 specialists, all active in the WH field, with a minimum of five years of interdisciplinary experience, and three data science experts. Data were collected during the annual occupational assessment of the subjects, in appropriate offices, by professionals of medicine, nursing, nutrition, dentistry and physical education, with large experience in the specific area of work. All calls were performed in an integrated, single shift and lasted an average of 40 min with each professional.

The Interdisciplinary Worker's Health Approach Instrument (IWHAI) [4], previously validated, was used for data collection purposes. Data were treated to standardize variable names, as well as a randomly generated code was created to ensure anonymity of study participants. To assess the *WHRI*'s ability to identify differences/associations between participants by sex, age group and educational level, the Chi-square test was applied ($\alpha = 5\%$). In all stages of the study, the recommendations and guidelines of Resolution 466/2012 of the Brazilian Ministry of Health on ethical aspects regulating research with human beings were followed. The study was approved by the Research Ethics Committee of the Bahiana School of Medicine and Public Health and CAAE no. 84318218.2.0000.5544. Before participating in the study, all subjects gave their informed consent for inclusion.

2.2 Sample

The *WHRI* was applied to a sample of 965 workers, where men (91.6%), aged 50–59 years (43.6%) and with a complete secondary level (60.4%), prevailed. The sample does not differ from the population in terms of the distribution of the percentages by sex ($p > 0.05$) and age group ($p > 0.05$), contributing to a more robust analysis, and also allowing to infer the results found for the population (see Table 1).

2.3 WHRI *Indicators Selection*

Based on the literature review, 6 dimensions, 44 indicators and 220 sub-indices, integrating the IWHAI [4], were included. The "Personal factor" dimension, corresponding to the "Age group" indicator and the respective sub-indices, were added to the *IWHAI*, and the calculations were performed by the data scientists. For the definition of the variables, aspects related to social determinants were considered, i.e., health [5], global disease burden [6, 7], environmental aspects [8], SDGs [9] and, in particular, working conditions affecting the health of the individual.

Table 1 Population and sample characterization

		Population N (%)	Sample n (%)	p
Sex	Male	1117 (87.6)	884 (91.6)	> 0.05
	Female	158 (12.4)	81 (8.4)	
Age	≤ 29	50 (3.9)	44 (4.6)	
	30 a 39	350 (27.5)	261 (27.0)	
	40 a 49	245 (19.2)	209 (21.7)	
	50 a 59	556 (43.6)	410 (42.5)	
	≥ 60	74 (5.8)	41 (4.2)	
	Total	1275	965	

WHRI was coded in closed responses with an interval scale of 0 to 4, where zero represents non-existent or inadequate risk control and four represents optimal risk control, with the following graduation: 0—non-existent or inadequate; 1—tolerable; 2—reasonable; 3—good and 4—excellent. The 3 data science experts defined the parameters' values to be applied in all *WHRI* development steps, as detailed in Table 2.

As Table 2 shows, the first parameter refers to the Dimension Weight (*W*), comprising an integer number, ranging from 0 to 5. The highest value, i.e., $W = 5$, characterizes the dimension whose indicators have a major impact on the interdisciplinary assessment, corresponding to the medicine dimension. The second parameter corresponds to the criticality for each indicator, which was defined by the Critical Sub-index (*Ci*), ranging from 0 to 2. The third parameter is the Associated Indicator (*Ai*), establishing the association between indicators. As an example, there is Feeling of pain indicator, which has *Ci* at level 2, so the indicator will be considered critical whenever one of the sub-indices 0, 1 or 2 is chosen, with no difference between these scores. Feeling of pain is associated with Musculoskeletal pathology and Ergonomic risks—physical aspects indicators, which means that they are influenced by them, which can be either positive or negative.

2.4 WHRI *Calculations*

The development of the *WHRI* calculation was mainly based in the model of calculation of the potential risk, by Leite and Dourado [10] and Navarro [11]. The Multidisciplinary Risk (*Mr*) is the value calculated from a weighted average of the sub-indices filled in the indicators of each dimension, added by a factor calculated from the number of risk associations that each indicator had with other dimensions, or with the dimension itself. The worker will have a *Mr* score for 5 dimensions, i.e., medicine, nursing, physical education, nutrition and dentistry and to calculate it, all *WHRI* indicators must be filled. The *Mr* calculation is shown in Eq. 1.

$$Mr = \left\{ \frac{\left[\frac{\log(W+1)}{(W+Q)} \right]}{(W+I)} \right\} + \left\{ R + \left[A \times \left(\frac{0.05}{T} \right) \right] \right\} \tag{1}$$

where W is the dimension weight, Q is the number of dimensions integrating disciplinary care, I is the number of indicators by dimension, R is the reference value, detailed below, A is the number of indicators with sub-index ranging from 0 to 2, i.e., *Ai,* associated with some dimension indicator, considering all the dimensions assessed for a particular individual and T is the number of total associations between indicators of all dimensions. 0.05 is a constant responsible for a bigger data detail of the negative weights of the associated indicators. $R = 0.95$, when there is at least one indicator in the dimension whose sub-index is less than or

Table 2 *WHRI* dimensions, indicators and associated indicators

W	Code	Indicator	*Ci*	*Ai*						
				I01	I02	I03	I04	I05	I06	I07
(0)	G01	Age group								
A(1)	O02	Oral hygiene quality								
	O03	Periodontal condition	0							
	O04	Periodontal disease	1	O02	M06					
	O05	Caries	0	N02						
	O06	Oral lesion on soft or hard tissues	0	M06	N06					
	O07	Bruxism		M09						
B (2)	N01	Energy balance intake		P01						
	N02	Simple carbohydrate intake	0							
	N03	Saturated lipids intake	0							
	N04	Sodium mineral intake	0							
	N05	Fibre intake								
	N06	Alcohol use	0	E05	E06					
	N07	Level of food knowledge								
	N08	Body weight condition								
	N09	Altered triglycerides	0	N06						
C (3)	P01	Physical activity level		E06	E07					
	P02	Contemplation for physical activity	1							
	P03	Feeling of pain	2	M07	E02					
	P04	Cardiorespiratory fitness								
	P05	Abdominal strength level								
	P06	Flexibility level								
	P07	Manual gripping force								
D (4)	E01	Environmental hazards exposure	1							
	E02	Ergonomic risks—physical	1							
	E03	Ergonomic risks—organizational								
	E04	Work environment health conditions	0							
	E05	Family relationships								
	E06	Social aspects—leisure								
	E07	Self-care level	1	E05						
	E08	Pests and vectors		E04						
	E09	Drinking water Quality		E04						
	E10	Air quality		E04						
	E11	Work accident		E01	E02					
	E12	Work-related absenteeism		P03						

(continued)

Table 2 (continued)

W	Code	Indicator	*Ci*	*Ai*						
				I01	I02	I03	I04	I05	I06	I07
E(5)	M01	Dyslipidemia	0	N03	N09					
	M02	Diabetes mellitus	2	N02	P01	E05	E07	M04	M06	O06
	M03	Altered glycemia	1	N02	P01	E05	E07			
	M04	Arterial hypertension	0	N04	P01	E05	E07			
	M05	Altered blood pressure	1	N04	P01	E05	E07			
	M06	Use of tobacco	1							
	M07	Musculoskeletal pathology	0							
	M08	Psychiatric pathology	1							
	M09	Stress level and symptoms	0	N06						

Note W—Dimension weight; *Ci*—Critical sub-index; *Ai*—Associated indicator; A—Dentistry; B—Nutrition; C—Physical education; D—Nursing; E—Medicine

equal to the value defined as critical (see Table 2, critical sub-index (*Ci*)), 0.95 is a constant that limits the maximum that the *Mr* can reach before the *Ai*. In all other cases, $R = 0.95 - M/4.3$, where *M* is the sub-indices arithmetic mean, and 4.3 is a constant responsible for increasing the *WHRI*'s accuracy, increasing its probability of identity.

The *WHRI* is calculated from the *Mr* mean (Eq. 1) of the worker, according to Eq. 2. Each worker will have a specific *WHRI* score, and the same result will not be possible for more than one individual.

$$WHRI = \frac{\left\{0.95 - \left(\frac{Is}{3.3}\right)\right\} + \sum Mr}{Q + 1} \quad (2)$$

where *Is* is the indicator corresponding to the subject's age group (see Table 3), *Mr* is the multidisciplinary risk and *Q* is the number of dimensions integrating disciplinary care, 0.95 is a constant that limits the maximum that the *Mr* can reach before the *Ai* and the difference between 4.3, constant from Eq. 1 and 1, i.e., equal to 3.3, is another constant responsible for making the sum of *Mr* proportional to the calculation of the age dimension.

Table 3 Indicator assigned to the subject's age group

Age group	*Is*
$As \geq 60$	0
$50 \leq As < 60$	1
$40 \leq As < 50$	2
$30 \leq As < 40$	3
$As < 30$	4

Note As—age of the subject; *Is*—indicator corresponding to the subject's age group

For the calculation of the value of *Mr* it is necessary to extract the values of *W*, *I*, *M*, *A*, *R, Q*, and *T* of each dimension, already defined in Eq. 1. To complete the *WHRI* calculation it is necessary to extract the values of *Is*, *Q* and $\sum Mr$, as defined in Eq. 2. In order to transform the data generated from the *WHRI* calculations into information supporting decision making in the WH field, specialists and data experts met to define three distinct risk ranges: Low risk ($WHRI < 0.530$); Moderate risk ($0.530 \leq WHRI < 0.662$); and High risk ($WHRI \geq 0.662$).

As a theoretical basis for the definition of the risk range, models by the Leeds Department of Health [12] and Porter and collaborators [13], that stratify the population by risk levels, were used. The following classifications were considered: Low-risk values vary from 0.007 to a defined value of 0.529. Individuals who have these *WHRI* values are considered to be at low WH risk, particularly behavioural risks [14], and with needs for interventions related to health promotion actions [15]; Moderate-risk values vary between the lower limits of 0.530 and the higher limits of 0.661. Individuals with these *WHRI* values are considered to be at moderate WH risk, specifically in terms of biopsychosocial and environmental risks [16], and with needs for interventions related to health prevention actions [17]; High-risk values are above the acceptability limit of 0.662. Individuals who present these *WHRI* values are considered to be at high WH risk and need interventions related to complex health care actions [18].

2.5 WHRI *Validity*

Because *WHRI* was based in *IWHAI*, already validated and published [4], *WHRI* is considered as validated. At this stage, the aim was to the test the discriminant validity by assessing the *WHRI* significant differences of workers' groups according to an fundamental shared characteristic, i.e., risk ranges. *Kruskal–Wallis* test was used for comparing the sub-indices medians of the three risk ranges, also allowing to verify if the WHRI is able to identify differences between the risk ranges.

3 Results and Discussion

The *WHRI* risk range distribution was compared by sex, age group and education level of the sample, according to Table 4.

5.1% of the workers were classified as high-risk, 20.6% as moderate-risk and 74.3% as low-risk. The results (Table 4) indicate a heterogeneous distribution of workers across the three risk ranges. In the high-risk range there are predominantly male workers ($p < 0.05$), aged 50 or older ($p < 0.05$) and with complete or incomplete intermediate education levels ($p < 0.05$). These risk factors were also identified by Niccoli and Partridge [19] and Dhingra and Vasan [20]. In line with these results, an education level below the university degree, is also a risk factor ($p < 0.01$).

Table 4 *WHRI* risk range comparison by sample sociodemographic characteristics

Variables		Low-risk	Moderate-risk	High-risk	p
		n (%)	n (%)	n (%)	
Sex	Male	644 (72.9)	191 (21.6)	49 (5.5)	0.002
	Female	73 (90.1)	8 (9.9)	0 (0.0)	
Age	≤ 29	44 (100)	0 (0.0)	0 (0.0)	0.000
	30 a 39	247 (94.6)	13 (5.0)	1 (0.0)	
	40 a 49	173 (82.8)	33 (15.8)	3 (1.4)	
	50 a 59	233 (56.8)	143 (34.9)	34 (8.3)	
	$\geq$ 60	20 (48.8)	10 (24.4)	11 (26.8)	
Education	Incomplete intermediate level	29 (51.8)	19 (33.9)	8 (14.3)	0.002
	Complete intermediate level	438 (75.3)	116 (19.9)	28 (4.8)	
	Incomplete higher level	28 (84.8)	4 (12.1)	1 (3.0)	
	Complete higher level	124 (78.5)	28 (17.7)	6 (3.8)	
	Complete higher level with postgraduate degree	32 (84.2)	6 (15.8)	0 (0.0)	

Table 5 presents the prevalence of the sub-indices of indicators by risk range. To each indicator, the most prevalent sub-index by risk range and the percentage of workers in that condition is presented.

According to Table 5, most of the indicators, i.e., all those indicated in bold, identify significant differences between the three risk ranges. In the dimension of medicine, nursing, physical and dental activity, the most significant differences are observed ($p < 0.05$), suggesting that workers with higher levels of diabetes mellitus altered triglycerides, glycemia, blood pressure and use of tobacco, are found in the high-risk range. Workers in the high-risk range are also those with poorer oral hygiene and periodontal condition, and are the least physically active (all with $p < 0.05$). For these reasons, these are also the workers with the highest levels of workplace absenteeism ($p < 0.05$). In Table 5, it is possible to identify which indicators are simultaneously poorest by risk range. In the high-risk range are workers with worse levels on critical health indicators, particularly those related to the medical field, such as glycemia, blood pressure and diabetes, which, associated with sedentary lifestyles and consumption of harmful substances, such as tobacco and alcohol, lead to the development of chronic conditions severely affecting their health and productivity at work, as already mentioned by Farhud [21] in a previous study. Associated with the consumption of tobacco, alcohol, diabetes, and foods rich in sugar are also severe periodontal conditions, as already identified by Llambés and colleagues [22].

Table 5 Sub-indices prevalence (%) by risk range

	Indicator	Risk Ranges			*p*
		Low	Medium	High	
Dentistry	Oral hygiene quality	4 (36.9)	2 (44.7)	2 (61.2)	**0.001**
	Periodontal condition	4 (41.2)	1 (41.2)	1 (57.1)	**0.001**
	Periodontal disease	3 (55.6)	2 (50.0)	2 (42.9)	0.126
	Caries	1 (46.1)	1 (63.6)	1 (60.0)	**0.001**
	Oral lesion on soft or hard tissues	4 (100)	4 (100)	1 (100)	0.480
	Bruxism	2 (54.2)	3 (47.3)	2 (60.0)	0.335
Nutrition	Energy balance intake	3 (54.0)	2 (48.7)	2 (53.1)	**0.001**
	Simple carbohydrate intake	3 (78.1)	3 (68.3)	3 (65.3)	**0.001**
	Saturated lipids intake	3 (93.6)	3 (91.0)	3 (87.8)	0.201
	Sodium mineral intake	3 (98.5)	3 (98.0)	3 (100)	0.902
	Fibre intake	3 (69.8)	3 (57.3)	3 (61.2)	**0.002**
	Alcohol use	3 (57.9)	3 (51.3)	3 (38.8)	**0.003**
	Level of food knowledge	3 (59.5)	2 (56.3)	2 (57.1)	**0.001**
	Body weight condition	2 (47.3)	2 (45.7)	2 (49.0)	**0.002**
	Altered triglycerides	3 (67.9)	3 (43.4)	1 (40.8)	**0.001**
Physical education	Physical activity level	3 (44.8)	0 (40.2)	0 (65.3)	**0.001**
	Contemplation stage for physical activity	3 (73.9)	3 (58.3)	1 (32.7)	**0.001**
	Feeling of pain	4 (93.4)	4 (67.9)	4 (79.6)	**0.002**
	Cardiorespiratory fitness	3 (60.1)	3 (63.1)	3 (77.1)	**0.001**
	Abdominal strength level	4 (35.6)	0 (33.5)	0 (28.1)	**0.001**
	Flexibility level	0 (27.9)	0 (43.7)	0 (46.2)	**0.001**
	Manual gripping force	3 (66.7)	3 (65.5)	3 (63.0)	**0.003**
Nursing	Ergonomic risks—physical aspects	3 (81.7)	3 (68.9)	3 (63.3)	**0.001**
	Ergonomic risks organizational aspects	3 (94.9)	3 (94.9)	3 (91.8)	0.956
	Work environment health conditions	3 (85.1)	3 (81.1)	3 (89.8)	0.259
	Family relationships	3 (98.2)	3 (96.4)	3 (87.8)	**0.001**
	Social aspects—leisure	3 (97.5)	3 (96.4)	3 (100)	**0.019**
	Self-care level	3 (54.0)	2 (55.1)	2 (55.1)	**0.001**
	Pests and vectors	2 (52.2)	1 (55.8)	1 (62.5)	**0.031**
	Drinking water Quality	0 (52.0)	0 (54.8)	0 (60.4)	0.733
	Air quality	3 (862.5)	3 (55.3)	3 (55.1)	0.147
	Work accident	4 (99.6)	4 (100)	4 (100)	0.595
	Work-related absenteeism	4 (48.7)	2 (32.7)	2 (32.7)	**0.001**

(continued)

Table 5 (continued)

	Indicator	Risk Ranges			*p*
		Low	Medium	High	
Medicine	Dyslipidemia	3 (37.2)	4 (33.7)	4 (30.6)	0.082
	Diabetes mellitus	4 (46.7)	2 (50.0)	2 (33.3)	**0.002**
	Altered glycemia	4 (80.9)	4 (72.4)	4 (80.0)	**0.002**
	Arterial hypertension	3 (84.6)	3 (74.3)	3 (37.5)	**0.001**
	Altered blood pressure	4 (50.7)	3 (37.2)	2 (49.0)	**0.001**
	Use of tobacco	4 (75.0)	4 (44.5)	2 (47.1)	**0.001**
	Musculoskeletal pathology	4 (49.3)	2 (39.4)	2 (56.3)	**0.001**
	Psychiatric pathology	4 (47.9)	4 (60.0)	3 (52.1)	0.165
	Stress level and symptoms	4 (91.9)	4 (85.7)	4 (87.5)	**0.021**

Note 0—non-existent or inadequate; 1—tolerable; 2—reasonable; 3—good and 4—excellent

4 Conclusions

WHRI application in the WH context allowed its validity in identifying the share of workers in the three "low", "moderate" and "high" risk ranges. The *WHRI* robustness is visible in the ability to identify differences among worker's sociodemographic characteristics ($p < 0.001$), helping to define health policies in the workplace that promote overall WH, also contributing to the increase of worker's productivity. It was verified that the sex, age and education influence the WH risk, being higher in men, over 50 years old and with low educational level ($p < 0.001$). The fact that 74% of workers are in the "low" risk range, does not mean that they should be considered as free to develop disease, and, consequently, it is crucial to monitor WH. This result is of fundamental importance for the oil industry studied, as oil production in old fields such as Bahia, Brazil, is declining, leading to an economic scenario of business resource constraints.

The application of a tool as *WHRI* enables the definition of risk management strategies aimed at the better use of economic resources to match care resources in different situations. In future studies, it would be important to analyze the association of *WHRI* with health assessment results, and the correlations between risk ranges and worker's conditions in the workplace.

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References

1. Dinis, M.A.P., Sousa, H.F.P., de Moura, A., Viterbo, L.M.F., Pinto, R.J.: Health behaviors as a mediator of the association between interpersonal relationships and physical health in a workplace context. Int. J. Environ. Res. Public Health **16**, 2392 (2019)

2. European Comission: Communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions. In: København, K. (ed.) Taking stock of the Europe 2020 strategy for smart, sustainable and inclusive growth. Brussels, 19.3.20. European Environment Agency (2014)
3. World Health Organisation: Health workforce requirements for universal health coverage and the Sustainable Development Goals. Human Resources for Health Observer Series. World Health Organization, Geneve (2016)
4. Viterbo, L.M.F., Dinis, M.A.P., Costa, A.S., Vidal, D.G.: Development and validation of an Interdisciplinary Worker's Health Approach Instrument (IWHAI). Int. J. Environ. Res. Public Health **16**, 1–17 (2019)
5. Graham, H., White, P.C.L.: Social determinants and lifestyles: integrating environmental and public health perspectives. Public Health **141**, 270–278 (2016)
6. Forouzanfar, M.H., et al.: Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet **388**, 1659–1724 (2016)
7. Malta, D.C., et al.: Fatores de risco relacionados à carga global de doença do Brasil e Unidades Federadas, 2015. Rev. Bras. Epidemiol. **20**, 217–232 (2017)
8. Bini, C., Bech, J.: PHEs, Environment and Human Health. In: Potentially Harmful Elements in the Environment and the Impact on Human Health. Springer, Cham (2014)
9. Leadership council of the sustainable development solutions network indicators and a monitoring framework sustainable development goals: launching a data revolution for the SDGs (2015). Accessed on 28 June 2019
10. Leite, H., Dourado, J.: Potential risk: A new approach. In Public health–methodology, environmental and systems issues. In: Maddock, M. (ed) Public Health—Methodology, Environmental and Systems Issues, pp. 1–26. IntechOpen, London (2012)
11. Navarro, M.V.T.: Avaliando o risco potencial. Risco, radiodiagnóstico e vigilância sanitária. EDUFBA, Ondina (2009)
12. Department of Health: Supporting people with long term conditions. In: An NHS and Social Care Model to support local innovation and integration. Long Term Conditions Team Primary Care/Department of Health, Leeds (2005)
13. Porter, M., Kellogg, M.: Kaiser Permanente: an integrated health care experience. Rev. Innovación Sanit. y Atención Integr. **1**, 1–8 (2008)
14. Institute of Medicine (US) Committee on Health and Behavior: Research, Practice, and Policy: The Interplay of Biological, Behavioral, and Societal Influences. National Academies Press, Washington, D.C. (2001)
15. Meng, L., et al.: Strategies for worksite health interventions to employees with elevated risk of chronic diseases. Saf. Health Work. **8**, 117–129 (2017)
16. Dinis, M.A.P.: Environment and human health. J. Environ. Pollut. Hum. Heal. **4**, 52–59 (2016)
17. World Health Organization (WHO): World Health Statistics 2016: Monitoring health for the SDGs, sustainable development goals (2016)
18. Kompier, M.A.J., Kristensen, T.S.: Organizational work stress interventions in a theoretical, methodological and practical context. Occup. Environ. Med. **62**, 205–210 (2005)
19. Niccoli, T., Partridge, L.: Ageing as a risk factor for disease. Curr. Biol. **22**, R741–R752 (2012)
20. Dhingra, R., Vasan, R.S.: Age as a risk factor. Med. Clin. North Am. **96**, 87–91 (2012)
21. Farhud, D.D.: Impact of lifestyle on health. Iran. J. Public Health **44**, 1442–1444 (2015)
22. Llambés, F., Arias-Herrera, S., Caffesse, R.: Relationship between diabetes and periodontal infection. World J. Diabetes **6**, 927–935 (2015)

Contribution Ergonomic Assessment of Musculoskeletal Hazards in Waste Bag Removal from Containers

Lincoln da Silva, Franciele Forcelini, Thiago Varnier, Giselle S. A. D. Merino and Eugenio A. D. Merino

Abstract Waste collection is carried out manually in a large number of countries, especially developing countries. However, due to the risks inherent in lifting loads and the characteristics of the collection activity, musculoskeletal disorders (MSDs) recur among waste collectors. Therefore, this research aimed to evaluate the MSDs inherent to the activity of lifting waste bags from waste containers. The sample consisted of 3 male workers, representing anthropometric percentiles 5th, 50th, and 95th. To enable the research were used: sociodemographic questionnaire, bioimpedance, motion capture and surface EMG. The 5th percentile, showing a falling trend in MF values for the Upper Left Trapezium, 50th percentile showed no falling trend in FM values and the 95th showed a falling trend in MF values for the Upper Left Trapezium. Regarding the movement analysis, the activity was performed on anterior flexion and trunk rotation. While there was shoulder flexion above 90°. The methods and tools used were adequate and complementary to each other, so it can be concluded that the waste bags removal from containers offers musculoskeletal risks related to the lower back and shoulders. These workers are affected by musculoskeletal fatigue and may suffer MSDs, resulting in the worker removal and increased expenses for rehabilitation and reintroduction in the activity.

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Keywords Ergonomics · Waste collection · Musculoskeletal disorders

1 Introduction

Global waste generation is growing sharply due to population and economic growth [5]. In this context, waste collection has generated musculoskeletal disorders (MSDs) risks to workers [3, 19, 24]. This happens due to the biomechanical requirement, related to the loads lifting and the lack of time to recover the muscular physiological state [20].

These problems predominate in developing countries due to the bad working conditions of the waste collectors [9]. They are required to exceed their physical and cognitive limits by lifting large loads in short periods that do not consider the need for recovery. Lifting loads [11, 21], working with arms above the shoulder line [6, 10, 26] and repeatability are occupational risk factors that can lead to MSDs in waste collectors, associated with the removal of waste bags from waste containers.

Due to the importance of this work, the understanding of the physical consequences that may culminate in the worker illness constitute an important research issue. Therefore, this research aimed to evaluate the risks of MSDs inherent to the activity of lifting waste bags from waste containers.

2 Materials and Methods

The sample consisted of 3 male workers, representing anthropometric percentiles 5th, 50th, and 95th, who met the study inclusion criteria (worked for more than 12 months in the general services function and performed the activity for more than 4 h a day) and agreed to participate, signing the Informed Consent Form, according to items IV.3 of Resolution 466/12 of the National Health Council. The waste container and the layout used for data collection is shown in Fig. 1.

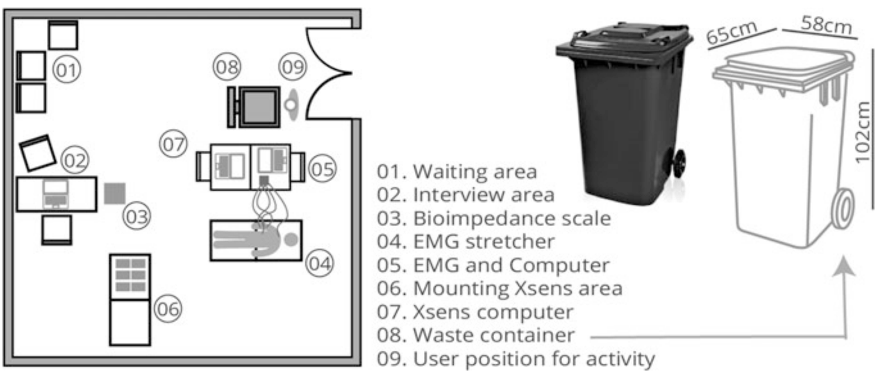

Fig. 1 Data collection layout and waste container

The research included three stages: problem investigation; data collection and data analysis. The data collection procedure was composed of eight steps: (1) environment preparation (2) signature of terms and survey; (3) bioimpedance scale; (4) electrode positioning (EMG); (5) motion capture mount (Xsens); (6) subject position for task (lifting waste bags (weighed 15 kg) from waste containers; (7) activity data recording (EMG and Xsens) and; (8) EMG electrodes and Xsens removal.

2.1 Technical Procedures

To enable the research were used: sociodemographic questionnaire, bioimpedance, motion capture and surface electromyography (EMG), as described below. EMG and motion capture were performed together synchronously [17] in the moment of the waste bag (15 kg) removal from the waste container.

(i) **Sociodemographic questionnaire**. The questionnaire comprised information requirements regarding age, body mass, height, gender.

(ii) **Electrical Bioimpedance (BIA)**. For this, the instrument used was a portable bioelectrical impedance scale OMRON® HBF-514C. This equipment has four electrodes bilaterally. The current used is 500 μA at a frequency of 50 kHz.

(iii) **Motion capture.** Motion capture by inertial sensors was used to analyze joint amplitudes and execution time of the waste bag removal task. The collection was performed with equipment composed of 17 inertial sensors attached to different parts of the body (Xsens MVN BiomechTM, Enschede, The Netherlands) that track the segments, orientation, position, movement and center of mass. The system operates in real time and is captured at a frequency of 120 Hz.

(iv) **Electromyography (EMG)**. EMG, as a method capable of demonstrating physiological characteristics of muscles during the task execution [15], was used to verify muscle fatigue in the waste bags removal from containers, with focus on the shoulder girdle and lower back. MF (Median Frequency) was explored to verify fatigue. The skin was prepared by trichotomy and abrasion with gauze, previously in the place to be evaluated, followed by sanitization with alcohol 70% in order to reduce the interference in the myoelectric signal uptake. The acquisition of EMG signals was performed with a Miotool 400 4-channel electromyograph Miotec. The system works with Miograph 2.0 USB software, where data is transmitted to a portable computer. The myoelectric signals were collected with a sampling rate of 2000 Hz for each channel, 5 Hz high pass filter, 500 Hz low pass filter and 60 Hz notch filter. For EMG signal recording, were used pre-gelled Ag/AgCl surface electrodes (Meditrace®), in bipolar configuration, with 1 cm diameter capture area and 2 cm inter-electrode distance. The electrodes were positioned in the following muscles: Upper Right Trapezius (URT), Upper Left Trapezius (ULT), Right Multifidus (RM) and Left Multifidus (LM), according to SENIAM standards [7]. The reference electrode was placed over the right arm olecranon bone. The standards for proper registration of EMG signals recommended by the International Society of Electrophysiology and Kinesiology (ISEK) [16] were strictly observed.

3 Results

The participants represent general service workers, which constantly execute the activity of waste bag removal from waste containers. They undergo regular health assessments, which prove that they are in good condition, being able to develop their activities. In addition, at the time of the survey, the workers did not have any abnormal health conditions (such as flu states) that prevented them from performing their daily activities. Their anthropometric and bioimpedance data can be seen in Fig. 2.

Regarding the electromyographic translation of muscle activity during the removal of waste bags from containers, Figs. 3, 4 and 5 show the evolution of MF as a function of time. Figure 3, related to the 5th percentile, demonstrates a falling trend in MF values for the ULT. However, the other muscles did not decrease in FM values. Figure 4, related to the 50th percentile, showed no falling trend in FM values. Figure 5, related to the 95th percentile, showed a falling trend in MF values for ULT and RM. The URT FM values had a linear behavior close to the falling trend.

5th Percentile · Up to 159.5 cm	50th Percentile · From 170 to 180 cm	95th Percentile · Over 181 cm
Age: 30 years	Age: 21 years	Age: 20 years
Height: 153cm · Weight: 61.3Kg	Height: 173 cm · Weight: 62.5Kg	Height: 181 cm · Weight: 61.9 Kg
Body Fat: 27% · Muscles: 36.9%	Body Fat: 12.7% · Muscles: 44.8%	Body Fat: 9% · Muscles: 46.8%
Body Mass Index: 26.2	Body Mass Index: 20.9	Body Mass Index: 20

Fig. 2 Anthropometric and bioimpedance data

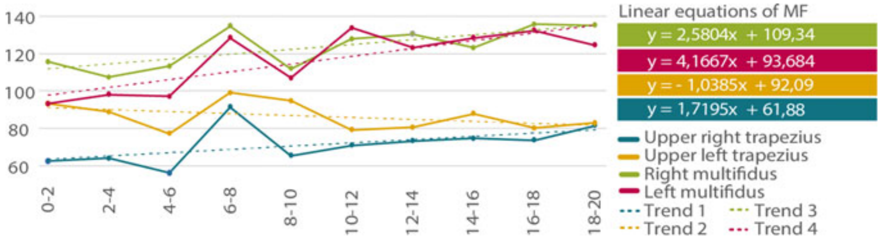

Fig. 3 Median Frequency (Hz)—5th percentile

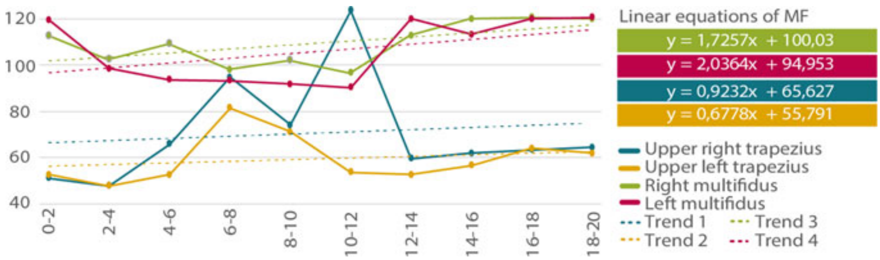

Fig. 4 Median Frequency (Hz)—50th percentile

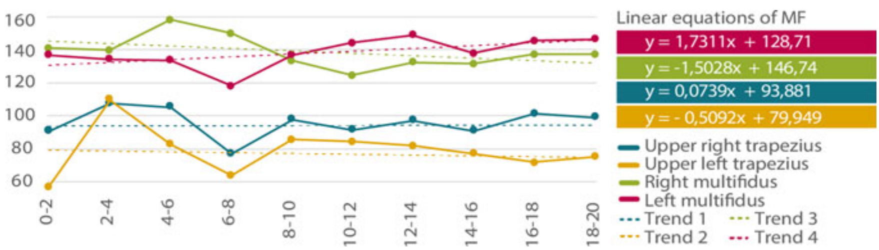

Fig. 5 Median Frequency (Hz)—95th percentile

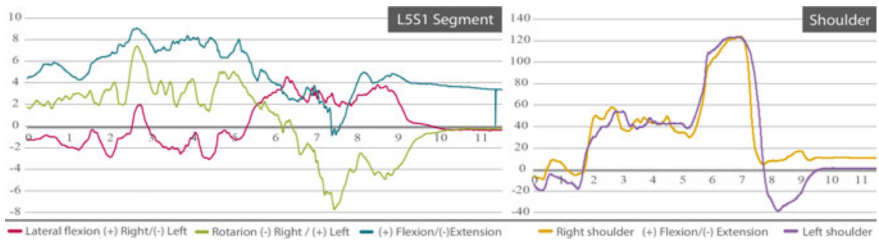

Fig. 6 Motion capture data—5th percentile

Regarding the movement analysis (see Figs. 6, 7, 8), the segment L5-S1 anterior flexion was more evident in the 5th percentile and rotation is present in all percentiles during the task. In relation to the shoulder flexion and extension movement, a similar behavior is observed in all percentiles. First, when tying the bag with flexion of approximately 60° followed by an elevation to 120° when removing the bag from the container. However, the 95th percentile obtained values below 120° at the peak of bag removal movement.

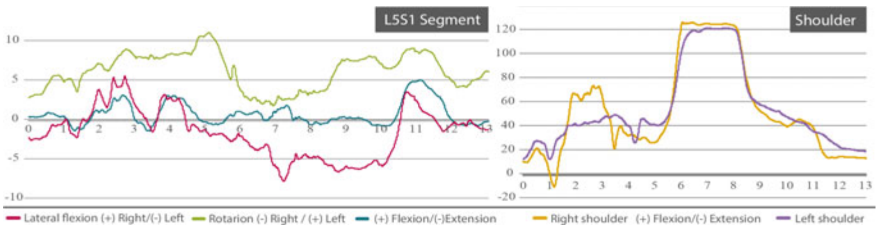

Fig. 7 Motion capture data—50th percentile

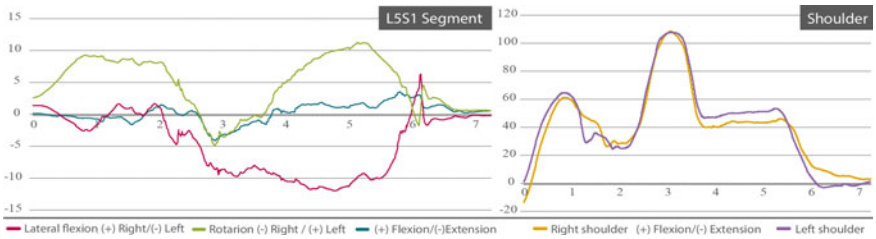

Fig. 8 Motion capture data—95th percentile

4 Discussion

Anthropometric analysis showed a directly proportional relationship between age, weight, fat percentage and BMI. The 5th percentile can be classified as overweight [27].

In relation to EMG, it is relevant to mention that this research has an applied character and the collection of myoelectric data was performed at the moment of waste bag removal from waste containers. Thus, data on muscle contractions in the frequency domains was analyzed in order to understand fatigue situations.

As for the production of force and work, it can be influenced by neuromuscular fatigue [4]. MF values generated by the power spectrum are dependent on the physiological processes related to the synchronization and firing frequency of the motor units. Therefore, these values are better indicated to analyze fatigue because they present greater sensitivity to muscle biochemical processes [1, 8].

Surface electromyography showed a muscle fatigue trend by decreasing MF values in the ULT muscles of the 5th and 95th percentiles and the RM, in the 95th percentile. In situations of high muscle demand, there may be a reduction in blood supply to the interior of the muscle, resulting in decreased nutrient and oxygen intake and triggering musculoskeletal fatigue [12].

Regarding the movement analysis, the anterior trunk flexion activity was observed, especially in the 5th percentile. Working in this position is a risk factor for lower back pain [18]. The tasks were also performed with lumbar rotation, and the higher the degree of lumbar rotation and anterior flexion, the greater the musculoskeletal risk for the development of MSDs [2, 14].

Regarding shoulder flexion, it can be evidenced tasks with angles $\geq 60°$ at the time of bag closure and preparation for pulling and >120° at the peak of lifting for waste bag removal from the container. The amount of time that the shoulders remained at $\geq 60°$ of flexion may mitigate the risk of musculoskeletal injuries, which may be increased in working situations with flexion >90° [23] due to the reduced blood flow and its impact on the shoulder muscles and osteoligamentous structures [13, 22, 25].

These musculoskeletal risk situations pointed out in the study may lead the worker to loss of his physical health and generate increased absenteeism. Complaints of lower back problems and muscle injuries are common in this group [3, 19].

5 Conclusion

The methods and tools used were adequate and complementary to each other, so it can be concluded that the waste bags removal from containers offers musculoskeletal risks related to the lower back and shoulders. These workers are affected by musculoskeletal fatigue and may suffer MSDs, resulting in the worker removal and increased expenses for rehabilitation and reintroduction in the activity.

Protecting the workers in this sector is fundamental, so it is recommended that the containers characteristics and the activity of bag waste removal be reviewed for further product improvement and ergonomic adaptation aiming at improving the task and reducing musculoskeletal risks.

Future studies are intended to enlarge de sample of the research, as well as generate requirements for the development of a waste container that reduces the effort to remove the garbage as well as the risk of MSDs.

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References

1. Basmajian, J.V., Deluca, C.J.: Muscle Alive: Their Function Revealed by Electromyography. Willians & Wilkins, Baltimore (1985)
2. Beeck, R.O.D., Hermans, V.: Research on Work-related Low Back Disorders. European Agency for Safety and Health at Work, Bilbao, Spain (2000)

3. Choi, H.W., et al.: Characteristics of occupational musculoskeletal disorders of five sectors in service industry between 2004 and 2013. Ann. Occup. Environ. Med. **29**(41), 1–9 (2017)
4. Dimitrova, N.A., Dimitrov, G.V.: Interpretation of EMG changes with fatigue: facts, pitfalls, and fallacies. J. Electromyogr. Kinesiol. **13**, 13–36 (2003)
5. Emmatty, F.J., Panicker, V.V.: Ergonomic interventions among waste collection workers: a systematic review. Int. J. Ind. Ergon. **72**, 158–172 (2019)
6. Harkness, E.F., et al.: Mechanical and psychosocial factors predict new onset shoulder pain: a prospective cohort study of newly employed workers. Occup. Environ. Med. **60**(11), 850–857 (2003)
7. Hermens, H.J. et al.: The SENIAM Project: Surface Electromyography for Non-invasive Assessment of Muscle, pp. 22–25. ISEK Congress Austria (2002)
8. Hunter, A.M., Stclair, G.A., Lambert, M., Noakes, T.D.: Electromyographic (EMG) normalization method for cycle fatigue protocols. Med. Sci. Sports Exerc. **34**, 857–861 (2002)
9. Kandasamy, S.P., et al.: Municipal solid waste management at Chennai in southern India—an occupational health perspective. Int. J. Health Promot. Educ. **51**(1), 50–61 (2013)
10. Koester, M.C., George, M.S., Kuhn, J.E.: Shoulder impingement syndrome. Am. J. Med. **118**, 452–455 (2005)
11. Kuijer, P.P.F.M., Sluiter, J.K.: Health and safety in waste collection: towards evidence-based worker health surveillance. Am. J. Ind. Med. **1064**(53), 1040–1064 (2010)
12. Larivière, C., Gravel, D., Arsenault, A., Gagnon, D., Loisel, P.: Muscle recovery from a short fatigue test and consequence on the reliability of EMG indices of fatigue. Eur. J. Appl. Physiol. **89**, 171–176 (2003)
13. Leclerc, A., Chastang, J.F., Niedhammer, I., Landre, M.F., Roquelaure, Y.: Incidence of shoulder pain in repetitive work. Occup. Environ. Med. **6**, 39–44 (2004)
14. Lotters, F., Burdorf, A., Kuiper, J., Miedema, H.: Model for the work-relatedness of low-back pain. Scand. J. Work Environ. Health **29**(6), 431–440 (2003)
15. Marras, W.S.: Industrial electromyography (EMG). Int. J. Ind. Ergon. **6**(1), 89–93 (1990)
16. Merletti, R.: Standards for reporting EMG data. J. Electromyogr. Kinesiol. **7**, 1–2 (2000)
17. Merino, G., et al.: Ergonomic evaluation of the musculoskeletal risks in a banana harvesting activity through qualitative and quantitative measures, with emphasis on motion capture (Xsens) and EMG. Int. J. Ind. Ergon. **69**, 80–89 (2019)
18. Miller, B.J., Fathallah, F.A. The effects of a stooped work task on the muscle activity and kinematics of the lower back. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, pp. 1284–1288, SAGE Publications, Sage CA, Los Angeles, CA (2006)
19. Mol, M.P.G., et al.: Urban waste collectors in Belo Horizonte, Brazil: their perceptions of occupational health risk. Qual. Health Res. **29**(3), 371–381 (2019)
20. NIOSH (National Institute of Occupational Safety and Health).: Work Practices Guide for Manual Lifting (NIOSH No. 81–122). US Department of Health and Human Services, National Institute for Occupational Safety and Health, Cincinnati, OH (1981)
21. Poole, C.J.M., Basu, S.: Systematic review: occupational illness in the waste and recycling sector. Occup. Med. **67**(8), 626–636 (2017)
22. Pope, D.P., Silman, A.J., Cherry, N.M., Pritchard, C., Macfarlane, G.J.: Association of occupational physical demands and psychosocial working environment with disabling shoulder pain. Am. Rheum. Dis. **60**, 852–858 (2001)
23. Punnett, L., et al.: Shoulder disorders and postural stress in automobile assembly work. Scand. J. Work Environ. Health. **26**(4), 283–291 (2000)
24. Rushton, L.: Health hazards and waste management. Br. Med. Bull. **68**(1), 183–197 (2003)
25. Stenlund, B., Lindbeck, L., Karlsson, D.: Significance of house painters' work techniques on shoulder muscle strain during overhead work. Ergonomics **45**, 455–468 (2002)
26. Vecchio, P., et al.: Shoulder pain in a community-based rheumatology clinic. British J. Rheumatol. **34**(5), 440–442 (1995)
27. World Health Organization.: Obesity: preventing and managing the global epidemic. Report of a WHO consultation on obesity, WHO, Geneva (1998)

Local Information System on Occupational Accidents: Subsidies for the Development of Public Policies on Occupational Health

Luiz Gonzaga Chiavegato Filho, Danilo de Brito Garcia and Marta Santos

Abstract The informal labour market growth, the occupational accidents under-reporting and the recent changes in the Brazilian labour legislation are topics that disrupt the construction of official data on the health and safety of the working population. These conditions reinforce the development of local and independent systems for collecting data on occupational accidents, as shown by the experience reported here, with the autonomy to overcome possible obstacles and to improve the information quality. Therefore, the results presented here are regarding to the second year of the system implementation in the city of São João del-Rei, Brazil. There were 257 cases of occupational accidents reported, being 69.3% classified as minor; 22.2% as moderated and 7.8% as serious. There were no records of fatal cases. The overall incidence was 11.47‰. The occupation with the highest number of notifications was, for the second year in a row, that of woodworkers, with 58 cases. The upper limbs were the most affected body parts, in approximately 70% of the occurrences. The diagnosis of cut-laceration injury occurred with the same frequency. Considering these data, we intend to develop assistance practices related to workers' health, emphasizing surveillance, and meeting the principles of the assistance integrality and interprofessionality in the forms of work the health professionals have.

Keywords Accidents at work · Health and safety at work · Monitoring

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1 Introduction

According to Brazilian law, occupational accidents are defined as cases of bodily injury, intoxication, and trauma that occurred in the course of the work activity, causing death, permanent or temporary loss or reduction of the ability to work. This definition covers work and occupational diseases and typical and commuting accidents. These work-related disorders are distinguished by their complexity and their numerous and interacting social, psychological, physiological and technical determinations. These circumstances characterize them as important public health problem, given the high human, social and financial costs [1, 2].

As reported by the Occupational Safety and Health Observatory[1] (OSST), throughout Brazil, between 2012 and 2018, about 4.5 million accidents were reported, of which 16,555 resulted in death. The costs for public coffers are estimated at around R$ 26 billion, considering only new cases in the mentioned period [3].

The OSST gathers, improves and facilitates access to data on occupational health and safety conditions all over Brazil, facilitating reflection and analysis. All the same, information is limited, due to the growth of the informal labour market and the underreporting of occurrences, conditions that may be aggravated as a result of the changes suffered by the Brazilian labour law[2] in 2017 [4–8].

The informality of the labour market in Brazil reached 40.6%[3] of the PEA (economically active population) in 2018. As the occupational accidents that occurred in informal labour relations are not registered, there are no official statistics on the health and safety conditions of these workers. Such precariousness makes it difficult to conduct empirical studies to understand this reality [5, 6, 8].

In 2018, the OSST estimates showed that, in Brazil, the underreporting of occupational accidents achieved 24.7%. In the State of Minas Gerais, it was estimated that underreporting represented 27.5% of the cases and, specifically in São João del-Rei, where this project is developed, the number is 56.3%. The battle against underreporting is a worldwide challenge and gets even more complicated when the registrations are made with social security and insurance purposes [3, 5, 6, 9].

The presented scenario highlights the importance of developing local and independent data systems on work accidents, with the autonomy to circumvent these barriers and improve information quality. For these reasons, in mid-2017, the Department of Psychology of the Federal University of São João del-Rei[4] (UFSJ), in partnership with the local mayoralty, developed this experience, with the purpose of, initially, improving the quality of information, and then to strengthen integrality and interprofessionality in workers' health care practices. The first is one of the

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[1]The OSST is a tool developed by the Labor Prosecutor's Office (MPT) and the International Labor Organization (ILO).

[2]http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2017/lei/l13467.htm.

[3]https://www.ibge.gov.br/estatisticas-novoportal/sociais/trabalho/9173-pesquisa-nacional-por-amostra-de-domicilios-continua-trimestral.html?=&t=resultados.

[4]Brazilian city located in the countryside of the state of Minas Gerais.

basic principles of the Brazilian Unified Health System. The second is a foundation for the organization of health workers, as it favours collaborative and interdisciplinary work [10–13, 17].

The mentioned program is two years old and in its first stage. The projection is that by 2020 the second stage will begin. In this article, we intend to report the results found in the second-year functioning of this System. In this period, it was possible to compare official epidemiological data to the data found in the first year of the research (07/01/2017 to 06/30/2018) already reported. The intention here is to improve the information quality, on occupational accidents, and to confirm some specificities about health and safety, in the municipality, with the expectance of developing public policies on worker health [6].

Based on the foundations of the Work Psychology and Ergonomics of Activity, the progress to the second stage, over the next year, will be key to the monitoring system improvement, giving visibility to the multiple dimensions of work-health relations, contributing to training health professionals and for changes in work situations [14–16].

2 Material and Methods

2.1 The Location, Participants and Responsible Team

The local monitoring system on work accidents is available for the full range of workers in São João del-Rei and surrounding areas, regardless of the nature and type of employment, provided they are attended at one of the three urgency and emergency units or in one of the 18 primary care units in the municipality.

According to the latest Brazilian Institute of Geography and Statistics[5] (IBGE) census data, in 2019, the population of São João del-Rei is estimated in 90,082 people, roughly, and the number of employed people is 22,415, representing only 24.8% of the total population. The number of people with occupation was the one used as the basis for calculating the general incidence.

A researcher and professor of work psychology at UFSJ, who is the project coordinator, a psychologist from the Local Public Health Department and an intern from the Psychology course at UFSJ, compose the team in charge of the project.

2.2 Tools

The RELAAT (Occupational Injuries Assistance's Report) was the tool used for data collection. Its elaboration was based on a similar experience held in a different

[5]https://cidades.ibge.gov.br/brasil/mg/sao-joao-del-rei/panorama.

municipality with the purpose of simplifying the information recording. The notification is mandatory[6] but it has no security or social security purposes, so that there is no legal implication or compromise that could affect the injured worker. The data related to the occurrences are recorded in five categories: care, patient, accident or illness, medical notes, the time interruption length, and the referrals [5].

In Brazil, the time interruption length tends to indicate the severity of the work accidents, so they are classified as minor, moderated, serious or fatal. In the 'minor' cases, the return to work should happen at the latest in 3 days; 'moderated', return between 3 and 30 days; and 'serious', work incapacity greater than 30 days [17].

2.3 Procedures and Data Analysis

In the three local urgency and emergency units, occupational accident reports have been made since May 2017. While in the 18 primary care units (UAPs) since December 2018. The data presented here refer to a period of one year, from 07/01/2018 to 06/30/2019.

After the nursing technicians, of the respective unit, have filled the form, the doctors have to complement it. All health professionals involved received instructions about the way the information should be included in the RELAAT. Periodically, the team in charge of the project provided feedback to these professionals, with the return of the information collected and with an assessment of the notification quality.

The database consists of Excel spreadsheets, saved in cloud storage, and compiled by programming in Excel VBA. Statistical analyses were performed by using Program R [18].

3 Results

In the period under analysis, 257 cases of work accidents were reported in the Health Units of São João del-Rei. The general incidence rate was estimated at 11.47 per thousand workers, of which 236 (91.8%) people were victims of typical accidents, 18 (7.0%) were victims of commuting accidents and 3 (1.2%) cases were reported as being occupational diseases. Of these total occurrences, 178 (69.3%) occupational accidents were classified as minor; 57 (22.2%), as moderated; and 20 (7.8%) as serious. There were no fatal case records (Table 1). It is important to emphasize that, most of the notifications presented variables, which could not be evaluated since they were not properly filled. This condition explains any differences between the results presented and the total number of notifications.

[6]Municipal Decree 6.808, from December, 20, 2016.

Table 1 Distribution according to the work accidents classification[a]

	Minor (n = 178)	Moderated (n = 57)	Serious (n = 20)	Total (n = 257)
Age categories				
18–24	35	11	2	49
25–34	49	17	2	68
35–44	46	14	5	65
45–54	31	7	7	46
>54	12	6	3	21
Schooling[b]				
B	90	27	9	126
I	71	24	7	103
H	8	0	0	8
Period of employment				
Up to 1 year	48	17	5	71
1–3 years	36	11	2	49
3–5 years	10	6	1	17
>5 years	28	9	6	43
Occupation				
Woodworker	35	15	7	58
Constr. worker[c]	24	3	2	29
General services	8	5	0	13
Butcher	8	3	0	11
Nursing	9	1	0	10
Others	94	30	11	136
Work relation type				
Formal worker	101	38	11	152
Self-employed	52	10	4	66
Others	10	3	2	15

[a]The total sum per columns or rows might not match due to missing information; [b]B-Basic [$\leq$9 years of formal study]; I-Intermediate [from 9 to 12]; and H-High [>12]; [c]Construction worker

Regarding sociodemographic characteristics, the average age (weighted) of injured workers was 36.93 years old (standard deviation 12.7) and ranged from 17 to 68 years old. The age was then categorized into five groups. It is noted that slightly more than half (51.8%) of people were between 25 and 44 years old. Gender was reported in 32 notifications as female (12.45%) and in 225 as male (87.55%), and among women, the most described occupations were nursing, with 22.6%, and the cook, with 19.4%. Schooling was grouped into basic education ($\leq$9 years of schooling), with 126 cases (49%); intermediate (between 9 and 12 years), with 103 cases (40.1%); and High (>12 years), with 8 cases (3.1%).

In the distribution of workers injured by each occupation, it is noted that the incidence is higher among the wood furniture-manufacturing sector workers, with

58 (22.5%) reported cases. By all of these workers are the following occupations: the woodworker, the carpenter, the sawyer, the saw operator, and furniture finisher. As all of them belong to the same sector, we decided, at that moment, to gather them together and to name them generically as "woodworkers".

All of the injured "woodworkers" were male. There were 56 (96.6%) cases of typical accidents and 2 (3.4%) cases of commuting accidents, 35 (61.4%) were minor accidents, 15 (26.32%) moderated, 7 (12, 3%) serious. Although the 25-34 age group (28.8%) prevails, there were individuals in all groups. The average age was 37.1 years old with a confidence interval of 6.1 years, in other words, the age of 37.1 ± 6.1 (confidence interval of 95% to probability). Among the main immediate causes of accidents are 'machines/equipment', with 39 (68.4%) cases and then falling objects, with 8 (14%) cases. The most frequent diagnosis was a cut-laceration injury, with 50 (86.2%) cases. In 25 (43.2%) records, 'woodworkers' reported as being self-employed or informally employed.

The "construction workers" were the second most reported occupation, with 29 (11.3%) occurrences, 28 (96.6%) were typical and 1 (3.4%) was an occupational disease. The main causes were machinery and equipment, with 16 (57.1%) cases, falling from height with 6 (21.4%), and falling objects with 4 (14.3%). In 19 (65.5%) notifications, 'construction workers' reported as being self-employed or informally employed.

Regarding the working relation type, just over half (58.37%) of the work accidents happened to formally registered workers, while 25.7% defined themselves as self-employed workers, that is, they worked on their own or in the informal sector. With respect to the period of employment, approximately 30% of the cases occurred in the first year of work. Within this group, the woodworkers stand out again, with 21.74%; the construction workers, with 17.39%; and then the general assistant, with 10.14%.

Regarding serious accidents, there were 20 notifications in total, being 18 (90%) cases with male workers and 2 (10%) with female workers; notifications occurred in all age groups, but the age group between 45 and 54 years (36.8%) and then between 35 and 44 years (26.3%) prevailed; most had basic schooling (45%) and all the others had intermediate (35%) (it was not possible to verify 20% of cases); and, regarding occupations, there were 7 (38.9%) woodworkers, 2 (11.1%) construction workers and 2 (11.1%) cooks. The other notifications were all with different occupations.

Among the body parts, that were most affected in work accidents, are the upper limbs, found in 70.8% of cases, then lower limbs and head with 16.73% and 15.17%, respectively. Regarding the nature of the injury, cuts prevailed, with 178 (69.2%) cases, followed by fractures, contusions, and injuries with 5% each. Among the main immediate causes reported are machines and equipment, with 167 (52.9%) reports; falling objects, with 43 (16.8%); falling from high, with 11 (4.28%) and biological agents, with 9 (3.5%).

4 Discussion

Once more, the woodworkers emerge as the most incident occupation, a condition, so far, roughly ignored by the official agencies. According to official data, between 2012 and 2018, the economic sectors that most reported accidents in São João del-Rei were the hospital care activity (23%), the retail merchandise trade of goods in general (6%) and the building construction (4%). The wood furniture-manufacturing workers (woodworkers) appear with only 15 (2%) cases over this period [3, 6].

In 2018, according to Dataviva[7] (an information visualization engine created by the Strategic Priorities Office of the government of Minas Gerais), there were approximately 411 'woodworkers' in the São João del-Rei microregion, which gives an incidence rate of 139.4‰, which is an extremely high value. In this case, the odds ratio would be 20.8 (confidence interval in 95% from 15.3 to 28.4), that is, woodworkers are 20.8 times more likely to suffer accidents when compared to the injured workers of the other categories in this study. The chi-square test for the proportion of the injured 'woodworkers' group was significant (p-value < 0.01), in other words, there is strong evidence that workers performing this type of activity suffer more work accidents than any other occupation that also had work accidents reported.

These results are consistent with studies from other countries showing that there is a high incidence of occupational accidents in the wood furniture-manufacturing sector. In 2011, according to estimates by the Bureau of Labour Statistics (BLS), wood product manufacturing workers achieved the second-highest incidence of the total recordable cases [19, 20].

There are not many studies on occupational accidents related to the wood furniture-manufacturing sector. However, some research indicates that depending on the work environment, the main risk factors are: degraded environmental working conditions (noise, low light, dust, etc.), the nature of work (repetitive, shift work, fatigue, physical workload); machines with inadequate conditions of use; the absence of training; the psychosocial risks and the security climate (security system, management commitment). The same studies also highlight that ergonomics help and work organization improvement could avoid or minimize such risk factors [21, 22].

These findings are compatible with what we have found in our study, since among the main reported causes of occupational accidents with 'woodworkers' are machinery and equipment (68.4%) and falling objects (16.8%). Besides that, almost half (43.2%) of these professionals consider themselves self-employed or informally employed.

The total number of injured workers who reported being self-employed or informally employed (25.7%) and, particularly among woodworkers (43.2%) and

[7] http://dataviva.info/pt/location/4mg000212/wages.

construction workers (65.5%), show how informality and underreporting are still barriers that need to be overcome on behalf of the health quality and safety information [3–9].

The epidemiological data presented should be considered essential clues for investigations, interventions, and practices in occupational health in order to strengthen the work activity point of view and transform the real situations of work [10–16].

5 Conclusion

Despite limitations, especially in relation to causality, this cross-sectional study has highlighted the importance of a local occupational accident information system to improve the quality of information and to overcome the barriers of underreporting and informality in the labour market. In addition, it ratified the information obtained in the first-year operation of the system.

Right now, based on this survey, it is essential to evolve to the second stage of the project, aiming to build actions and practices related to worker health, ensuring full attention to the worker and interprofessionality among the health professionals involved. The integrality presupposes, among other aspects, the convergence of a multidisciplinary team knowledge in the provision of health services, while interprofessionality, as a foundation for the organization of work in health, favours the development of collaborative work and strengthens integrality.

The challenge, therefore, is to go beyond describing and analysing work situations in order to develop and consolidate the work activity viewpoint as a tool for transformations of workplaces into sustainable and healthy places.

References

1. Federal, S.: Doença ocupacional, 112 p. Coordenação de Edições Técnicas, Brasília (2016)
2. Almeida, I.M., Vilela, R.A.G., Silva, A.J.N., Beltran, S.L.: Modelo de Análise e Prevenção de Acidentes-MAPA: ferramenta para a vigilância em Saúde do trabalhador. Ciência & Saúde Coletiva **19**(12), 4679–4688 (2014)
3. OSST homepage.: https://smartlabbr.org/sst. Last accessed 27 Oct 2019
4. Gomez, C.M., Vasconcellos, L.C.F., Machado, J.M.H.: Saúde do trabalhador: aspectos históricos, avanços e desafios no Sistema Único de Saúde. Ciência & Saúde Coletiva **23**(6), 1963–1970 (2018)
5. Cordeiro, R., Vilela, R.A.G., Medeiros, M.A.T., Gonçalves, C.G.O., Bragantini, C.A., Varolla, A.J., Celso, S.: O sistema de vigilância de acidentes do trabalho de Piracicaba, São Paulo, Brasil. Cadernos de Saúde Pública **21**(5), 1574–1583 (2005)
6. Chiavegato Filho, L.G., Garcia, D.B., Santos, M.: Local surveillance of occupational accidents and diseases: a device to support workers health public services. In: Cotrim, T.P., Serranheira, P., Sousa, P., Hignett, S., Albolino, S., Tartaglia, R. (eds.). Advances in Intelligent Systems and Computing, vol. 1012, pp. 291–300. Springer International Publishing (2019)

7. Nenonen, S.: Fatal workplace accidents in outsourced operations in the manufacturing industry. Safety Sci. **49**(10), 1394–1403 (2016)
8. Santana, V.S., Loomis, D.: Informal jobs and non-fatal occupational injuries. British Occup. Hyg. Soc. **48**(2), 147–157 (2004)
9. Galdino, A., Santana, V.S., Ferrite, S.: Os Centros de Referência em Saúde do Trabalhador e a notificação de acidentes de trabalho no Brasil. Cadernos de Saúde Pública **28**(1), 145–159 (2012)
10. World Health Organization: Framework for Action on Interprofessional Education & Collaborative Practice. WHO, Geneva (2010)
11. World Health Organization: Integrated Care Models: An Overview. WHO Regional Office for Europe, Copenhegen (2016)
12. Ceccim, R.B.: Conexões e fronteiras da interprofissionalidade: forma e formação. Interface—Comunicação, Saúde, Educação **22**(Supl. 2), 1739–1749 (2018)
13. Stout, N.A.: The public health approach to occupational injury research: From surveillance to prevention. Saf. Sci. **46**(2), 230–233 (2008)
14. Vilela, R.A.G., Querol, M.A.P., Almeida, I.M., Filho, J.M.J.: Workers' health: from diagnosis to formative intervention. In: Vilela, R., Pereira, Q.M., Beltran, H.S., Cerveny, G., Lopes, M. (eds.). Collaborative Development for the Prevention of Occupational Accidents and Diseases. Springer, Cham (2020)
15. Molinié, A.F., Leroyer, A.: Acompanhar as evoluções do trabalho e da saúde: EVREST, um dispositivo comum para usos diferenciados. Laboreal **9**(1), 66–86 (2013)
16. Weill-Fassina, A., Pastré, P.: As competências profissionais e seu desenvolvimento. In: Falzon, P. (ed.) Ergonomia, pp. 175–192. Blucher, São Paulo (2007)
17. Ministério do Trabalho e Emprego.: Guia de Análise: Acidentes de Trabalho. Ministério do Trabalho e Emprego, Brasília, DF (2010)
18. R Core Team: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria (2017). https://www.R-project.org/
19. Beery, L., et al.: Occupational injuries in Ohio wood product manufacturing: a descriptive analysis with emphasis on saw-related injuries and associated causes. Am. J. Ind. Med. **57**(11), 1265–1275 (2014)
20. NIOSH.: Report on workers safety in the manufacturing sector. National Institute of Occupational Safety and Health (NIOSH), Bangi, Malaysia (2009)
21. Holcroft, C.A., Punnet, L.: Work environment risk factors for injuries in wood processing. J Safety Res. **40**(4), 247–255 (2009)
22. Champoux, D., Brun, J.: Occupational health and safety management in small size enterprises: an overview of the situation and avenues for intervention and research. Saf. Sci. **41**(4), 301–318 (2003)

Incidence and Risk Factors of *Toxoplasma gondii* in Workers that Occupationally Handle Animals: A Systematic Review

Maria Manuel Fernandes and Marcelo M. Ribeiro

Abstract *Toxoplasma gondii* is a parasite capable of infecting humans and other warm-blooded animals, which has chronically infected approximately a third of the world population. While mostly asymptomatic in immunocompetent patients, it is considered a serious disease in immunocompromised patients, with potentially fatal consequences. Workers that occupationally handle animals—such as farmers, butchers and veterinarians -, are under higher risk of being infected. Most common risk factors among these workers include contact with soil, improper hygiene, and consumption of undercooked meat and unwashed raw vegetables or fruits. There is also an increase in seropositivity with age. The authors conducted a systematic review of all available studies on the topic on the period between 2014 and June 2019 and included studies that detail *T. gondii* prevalence and risk factors. The information and data was collected from scientific databases—such as PubMed, Science Direct, Scopus and ISI Web of Science. The aim of this systematic review was to assess incidence and risk factors of *Toxoplasma gondii* in workers that are under exposure to animals in their line of work.

Keywords *Toxoplasma gondii* · Workers · Veterinarians · Risk factors · Occupational exposure

1 Introduction

With worldwide distribution, the obligate intracellular parasite *Toxoplasma gondii* has been documented in virtually every species of mammal and even on several species of birds. It is capable of infecting humans and other warm-blooded animals, which makes its associated infection—toxoplasmosis—one of the most common

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[10]. It is estimated that, approximately, a third of the population worldwide is chronically infected with *T. gondii* [5].

Overall prevalence of *T. gondii* is dependent on eating habits, environmental conditions, and presence of and contact with the definitive hosts of this parasite. In developing and tropical countries, prevalence is influenced by environmental conditions and climate, as is generally higher in urban rather than rural areas, and in humid compared with dry climates. In Western Europe, overall prevalence is 30–50%. High prevalence (>80%) is observed in parts of Eastern/Central Europe, Latin America, the Middle East, Africa, and parts of Southeast Asia [19]. In the United States of America the overall seroprevalence among persons >6 years of age is 12.4% [7].

While mostly asymptomatic in immunocompetent patients, Toxoplasmosis is considered a serious disease in immunocompromised patients (such as HIV/AIDS patients, cancer patients, and organ transplant recipients). Because *T. gondii* may remain within the host through its life span—usually in a latent, subclinical infection -, there is a possibility of a spontaneous reactivation, which is more likely to occur in immunocompromised patients and can be fatal. Screening for *T. gondii* in generally only done in pregnant women, however, it is not mandatory in every country, as some have no prenatal program of surveillance [12, 13].

Given its ability to infect multiple animals—and not just cats, *T.gondii*'s definitive host-, it is likely that people that interact with animals on a daily basis, such as veterinarians, farmers, butchers and abattoirs workers, would be more susceptible to be infected.

T. gondii can be acquired through different routes. The most common routes are through ingestion of oocysts from the environment and contact with cat faeces, ingestion of tissue cysts in undercooked meat and under-washed raw vegetables and fruits, and by transplacental transmission [9].

Because it can be acquired through the consumption of food, primarily meat and vegetables—although contamination through water has been reported-, it is considered a food-borne infection. Given that large number of different possible vehicles of infection transmission (meat from small ruminants, pork, beef, and game meat, as well as fresh produce, seafood and dairy products), the process of controlling the incidence of this parasite is a challenge.

The objective of this systematic review is to assess incidence and risk factors of *Toxoplasma gondii* in workers that either handle or are under exposure to animals in their line of work.

2 Methodology

The current study is in accordance with the PRISMA-P statement for systematic review and meta-analysis protocols [17, 22].

For the identification of studies regarding incidence and risk factors of *T. gondii* in workers occupationally exposed to animals, online databases—PubMed, Science Direct, Scopus and ISI Web of Science—were browsed from 2014 until June 2019, for articles and articles in press written in English.

For this purpose, a search using a combination of the following keywords: "*Toxoplasma gondii*", "workers", and "employees" was conducted. In order to avoid missing any articles, after database searching, the reference list of the relevant papers were also screened manually. Were excluded articles that did not detail on the prevalence of *T. gondii*, and failed to specify if the population in study was under occupational exposure to animals.

The articles retrieved from this research were imported to Mendeley. After initial title screening and the removal of duplicated papers—given the small number of articles left that met the criteria-, all the remaining articles selected for full-text analysis (Fig. 1).

Data from relevant studies was compiled into a Microsoft Excel datasheet (Table 1):

- General information: first author, year of publication and country;
- Characteristics of the study: target, number of infected people, total number included in the study, percentage of *T. gondii* prevalence, risk factors.

Risk of bias was evaluated for each individual study analysed making use of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach to evaluate quality of evidence. Data acquired was analysed according to the intended objectives of this review; goals and objectives, evaluated variables, applied methods and equipment, evaluation procedure, and compliance with ethical standards were also under analysis. There was no observed risk of bias.

3 Results

Two thousand six hundred thirty-five articles were found in the initial key-word search before criteria insertion and duplicates removal. Of the 38 remaining articles, were excluded articles that had irrelevant abstracts, did not specify in the people included the study were under occupational exposure to animals, or failed to mention the parasite *T. gondii*. Fourteen articles met the inclusion criteria and were included in this review (Fig. 1).

For each selected study, the data was extracted as described in the methodology section and compiled into a table (Table 1).

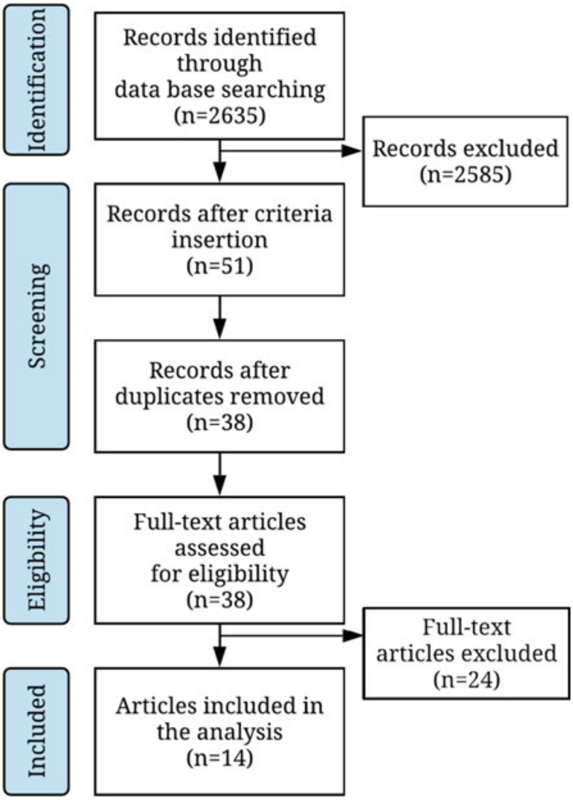

Fig. 1 Flow diagram. Adapted from Moher et al. [16]

Table 1 Data collected from the articles included in this review

Author	Year	Country	No of infected/ total no	% of Infection	Risk factors
Abu [1]	2015	Ghana	Fisherman: 33/35	94.29	Contact with soil Improper hygiene Increase in seropositivity with age Presence of cats
			Farmer: 42/43	97.67	
			Fishmonger: 45/46	97.83	
Alvarado-Esquivel et al. [3]	2014	Mexico	Livestock raiser: 2/51	3.9	Eat/drink while working Consumption of duck meat
			Veterinarian sciences: 10/139	7.2	
Anees et al. [4]	2014	Pakistan	Butchers: 5/50	10	Age $\geq$51 y Contact with the animals in abattoirs

(continued)

Table 1 (continued)

Author	Year	Country	No of infected/ total no	% of Infection	Risk factors
Brandon-Mong et al. [6]	2015	Malaysia	Vets: 7/38	18.4	Field work Animal surgery and cleaning Age ≥ 30 y Work >10 y
			Vet technicians: 15/45	33.3	
			Vet students: 29/194	14.9	
Doni et al. [8]	2015	Turkey	Female farmworkers: 399/684	58.3	Age >35 y Seasonal migratory farm work No of pregnancies
Ekanem [11]	2018	Nigeria	Livestock seller: 77/165	43	Exposure to poultry Work >5 y Contact with raw meat
			Butchers: 102/174	57	
Lassen et al. [14]	2016	Estonia	Vets: 73/158	46.2	n.a (High *T. gondii* prevalence in domestic cats may be a risk factor)
			Animal Caretakers: 279/375	74.4	
			Hunters: 94/144	65.3	
Mardani and Tavalla [15]	2015	Iran	Butchers: 46/110	41.8	Exposure to raw meat Proximity to slaughtered animals Consumption of undercooked meat
Rostami et al. [20]	2016	Iran	Farmers & Shepherds: 46/57	80.7	Age ≥ 50 y Consumption of undercooked meat and unwashed raw vegetables or fruits Using untreated water
Sang-Eun et al. [21]	2014	Korea	Vets: 40/299	13.4	Field work Using untreated water Contact with infected animals Ingestion of raw pork
			Lab Vets: 36/646	5.5	
Siponen et al. [24]	2019	Finland	Vets: 43/294	14.6	Age ≥ 40y Living in the country Tasting beef while cooking Large animal practice
Thiongo et al. [25]	2016	Kenya	Slaughterhouse workers: 34/87	39.1	Contact with chicken meat
Wójcik-Fatla et al. [27]	2018	Poland	Vets: 166/373	44.5	Age ≥ 61
Xing-Jun et al. [28]	2018	China	Pork processing industry employees: 36/200	18	Contact with animals

4 Discussion

Cats (and other members of the Felidae family) are *T. gondii* definitive hosts. Considering that small-practice veterinarians are likely to be in daily contact with various cats, it would be expected that contact with this animal would be considered a big risk factor among veterinarians. However, according to Shuhaiber et al. [23], contact with cats is a relatively low risk factor among veterinarians considering the lifecycle of *T. gondii* in the cat—cats excrete oocysts for only two weeks of their life, and those oocysts require 1–5 days to become infectious. It is common practice in veterinary clinics to clean cat litter within 24 h, which reduced probability of exposure. Higher standards of personal hygiene are also contributing factors to reduced risk.

It is important that veterinary schools continue to educate their students on the risks of this disease and on other standard precautions for zoonotic disease prevention in veterinary personnel as Brandon-Mong et al. [6] still determined as incidence of almost 15% among veterinary students in Malaysia [26].

The information collected for this review confirms this idea, as contact with cats is not considered a risk factor in articles that study *T. gondii* prevalence in veterinarians. It is however considered a risk factor with farmers [1], not necessarily by contact with the animal but by its common use in farms as a form of mice control and by the presence of its faeces in the cultivated fields.

For that reason, it is recommended that cats should not be allowed access to community gardens and any location where food is grown, as well as limit access to domestic cats to the outdoors in general [2].

The use of animal manure to fertilize fields and the use of wastewater for irrigation is also a source of possible contamination, and this is usually carried out without adequate personal protective equipment [29].

There is also an associated risk with contact with animal meat and tissue that affects veterinarians, butchers and slaughterhouse workers (as determined by Anees et al. [4], Brandon-Mong et al. [6], Ekanem et al. [11], Mardani and Tavalla [15] and Thiongo et al. [25]). This is because *T. gondii*'s cysts can be small and can be found randomly distributed among different organs and tissues.

To reduce this risk factor, extra precautions should be taken into account when performing necropsies or handling meat, given that meat, brain tissue, diaphragms and myocardial tissues are preferential location of cysts. Wearing protective gear such as gloves and lab coats or coveralls while handling carcasses, and proper hygiene habits during and after the removal of contaminated items before eating or handling not contaminated items [18].

This is particularly important to avoid possible cross-contamination because not only *T. gondii* but also many other zoonotic pathogens can be transmitted from animals to people directly or indirectly through the environment by hand-to-mouth contact. Transmission can occur directly during examination, treatment, and handling of animals, or indirectly through contact with contaminated objects such as cages, equipment and workplace surfaces [2].

5 Conclusion

The main goal of this review was to assess incidence and risk factors of *T. gondii* in workers that are under exposure to animals in their line of work.

In a general way, all the articles analysed present valid known risk factors given the line of work in question. However, even in similar conditions, not all risk factors hold the same importance in the infection route. This raises the question of how many other factors have to be taken into consideration and studied so we can better understand how to put a stop in the widespread nature of this parasite.

References

1. Abu, E.K., Boampong, J.N., Ayi, I., Ghartey-Kwansah, G., Afoakwah, R., Nsiah, P., Blay, E.: Infection risk factors associated with seropositivity for Toxoplasma gondii in a population-based study in the Central Region, Ghana. Epidemiol. Inf. **143**(9), 1904–1912. https://doi.org/10.1017/S0950268814002957 (2015)
2. Aguirre, A.A., Longcore, T., Barbieri, M., Dabritz, H., Hill, D., Klein, P.N., Sizemore, G.C.: The one health approach to toxoplasmosis: epidemiology, control, and prevention strategies. EcoHealth. https://doi.org/10.1007/s10393-019-01405-7 (2019)
3. Alvarado-Esquivel, C., Pacheco-Vega, S., Hernández-Tinoco, J., Saldaña-Simental, D., Sánchez-Anguiano, L., Salcedo-Jáquez, M., Guido-Arreola, C.: Lack of association between Toxoplasma gondii infection and occupational exposure to animals. Eur. J. Microbiol. Immunol. **4**(4), 184–192 (2014). https://doi.org/10.1556/EUJMI-D-14-00024
4. Anees, A., Maqbool, A., Khan, U.J., Yasmin, G., Zahra, F.: Seroprevalence of antibodies to Toxoplasma gondii in butchers and buffaloes at Lahore, Pakistan. Pakistan J. Zool. **46**(5), 1479–1483. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84907868228&partnerID=40&md5=0f0340c335698c4bc56e091378b07178 (2014)
5. Ben-Harari, R.R., Goodwin, E., Casoy, J.: Adverse event profile of pyrimethamine-based therapy in Toxoplasmosis: a systematic review. Drugs in R&D **17**(4), 523–544. https://doi.org/10.1007/s40268-017-0206-8 (2017)
6. Brandon-Mong, G.-J., Che Mat Seri, N.A.A., Sharma, R.S.-K., Andiappan, H., Tan, T.-C., Lim, Y.A.-L., Nissapatorn, V.: Seroepidemiology of Toxoplasmosis among people having close contact with animals. Frontiers Immunol. **6**, 143. https://doi.org/10.3389/fimmu.2015.00143 (2015)
7. CDC.: Toxoplasmosis. Retrieved from DPDx website https://www.cdc.gov/dpdx/toxoplasmosis/index.html (2017)
8. Doni, N.Y., Simsek, Z., Gurses, G., Zeyrek, F.Y., Demir, C.: Prevalence and associated risk factors of Toxoplasma gondii in female farmworkers of southeastern Turkey. J. Inf. Dev. Countries **9**(1), 87–93. https://doi.org/10.3855/jidc.5824 (2015)
9. Dubey, J.P.: The history of Toxoplasma gondii—the first 100 years. J. Eukaryotic Microbiol. **55**(6), 467–475. https://doi.org/10.1111/j.1550-7408.2008.00345.x (2008)
10. Dubey, J.P.: Toxoplasmosis of Animals and Humans, 2nd edn. C. Press, Ed. https://doi.org/10.1201/9781420092370 (2010)
11. Ekanem, U.S., Moses, A.E., Abraham, E.G., Motilewa, O.O., Umo, A.N., Uwah, A.I., Itina, E.I.: Seroprevalence of anti-Toxoplasma gondii IgG antibody and risk factors among abattoir workers in Uyo, Southern Nigeria. Nigerian J. Clin. Pract. **21**(12), 1662–1669. https://doi.org/10.4103/njcp.njcp_44_18 (2018)

12. European Centre for Disease Prevention and Control.: Congenital Toxoplasmosis—Annual Epidemiological Report for 2015. Retrieved from https://ecdc.europa.eu/sites/portal/files/documents/AER_for_2015-toxoplasmosis.pdf (2018)
13. European Food Safety Authority; European Centre for Disease Prevention and Control.: the European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2017. EFSA J. **16**(12), 5500. https://doi.org/10.2903/j.efsa.2018.5500 (2018)
14. Lassen, B., Janson, M., Viltrop, A., Neare, K., Hütt, P., Golovljova, I., Jokelainen, P.: Serological evidence of exposure to globally relevant zoonotic parasites in the Estonian population. PLoS ONE **11**(10). https://doi.org/10.1371/journal.pone.0164142 (2016)
15. Mardani, M., Tavalla, M.: Seroepidemiology of Toxoplasma gondii IgG and IgM among butchers in southwest of Iran. Asian Pacific J. Trop. Dis. 5(12), 993–995. https://doi.org/10.1016/S2222-1808(15)60970-7 (2015)
16. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G.: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. BMJ. 339. https://doi.org/10.1136/bmj.b2535 (2009)
17. Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., PRISMA-P Group.: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst. Rev. **4**(1), 1. https://doi.org/10.1186/2046-4053-4-1 (2015)
18. Moore, R.M., Davis, Y.M., Kaczmarek, R.G.: An overview of occupational hazards among veterinarians, with particular reference to pregnant women. Am. Ind. Hyg. Assoc. J. **54**(3), 113–120. https://doi.org/10.1080/15298669391354423 (1993)
19. Paris, L.: 106—Toxoplasmosis. Ryan, E.T., Hill, D.R., Solomon, T., Aronson, N.E., T.P.B. T.-H. T.M., E.I.D., Endy, T.E. (eds.). https://doi.org/10.1016/B978-0-323-55512-8.00106-X
20. Rostami, A., Seyyedtabaei, S.J., Aghamolaie, S., Behniafar, H., Lasjerdi, Z., Abdolrasouli, A., Alvarado-Esquivel, C.: Seroprevalence and risk factors associated with toxoplasma gondii infection among rural communities in northern Iran. Revista Do Instituto de Medicina Tropical de Sao Paulo, vol. **58**. https://doi.org/10.1590/S1678-9946201658070 (2016)
21. Sang-Eun, L., Hong, S.-H., Jeong, Y.-I., Lee, J.-H., Yoo, S.-J., Lim, H.-S., Cho, S.-H.: Cross-sectional analysis of the seropositivity and risk factors of Toxoplasma gondii infection among veterinarians, in relation to their public professional activities. Veterinary Parasitol. **203**(1–2), 29–34. https://doi.org/10.1016/j.vetpar.2014.01.001 (2014)
22. Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Stewart, L.A.: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ, vol. 349. https://doi.org/10.1136/bmj.g7647 (2015)
23. Shuhaiber, S., Koren, G., Boskovic, R., Einarson, T.R., Soldin, O.P., Einarson, A.: Seroprevalence of Toxoplasma gondii infection among veterinary staff in Ontario, Canada (2002): implications for teratogenic risk. BMC Inf. Dis. **3**, 8. https://doi.org/10.1186/1471-2334-3-8 (2003)
24. Siponen, A.-M., Kinnunen, P.M., Koort, J., Kallio-Kokko, H., Vapalahti, O., Virtala, A.-M., Jokelainen, P.: Toxoplasma gondii seroprevalence in veterinarians in Finland: Older age, living in the countryside, tasting beef during cooking and not doing small animal practice associated with seropositivity. Zoonoses Pub. Health **66**(2), 207–215. https://doi.org/10.1111/zph.12550 (2019)
25. Thiongo, S.K., Ichagichu, J.M., Ngotho, M., Aboge, G.O., Kagira, J.M., Karanja, S.M., Maina, N.N.: Use of the nested polymerase chain reaction for detection of Toxoplasma gondii in slaughterhouse workers in Thika District, Kenya. South Afr. Med. J. **106**(4), 417–419. https://doi.org/10.7196/SAMJ.2016.v106i4.8777 (2016)
26. Williams, C.J., Scheftel, J.M., Elchos, B.L., Hopkins, S.G., Levine, J.F.: Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel: National Association of State Public Health Veterinarians: Veterinary Infection Control

Committee 2015. J. Am. Vet. Med. Assoc. **247**(11), 1252–1277 (2015). https://doi.org/10.2460/javma.247.11.1252
27. Wójcik-Fatla, A., Sroka, J., Zając, V., Zwoliński, J., Sawczyn-Domańska, A., Kloc, A., Dutkiewicz, J.: Study on Toxoplasma gondii, Leptospira spp., Coxiella burnetii, and Echinococcus granulosus infection in veterinarians from Poland. J. Veterinary Res. (Poland) **62**(4), 477–483. https://doi.org/10.2478/jvetres-2018-0069 (2018)
28 Xing-Jun, Z., Yue, Z., Guo-Jin, Y., Chang-Gui, Z.: Seroepidemiological survey of Toxoplasma gondii infection among employees in a pork food processing enterprise. Zhongguo xue xi chong bing fang zhi za zhi=Chinese journal of schistosomiasis control **30** (6), 694–695. https://doi.org/10.16250/j.32.1374.2018171 (2018)
29. Yongabi Anchang, K., Avery, L., Pertiwiningrum, A.: A commentary on occupational infectious diseases due to agricultural practices in Sub-Saharan Africa. Biomass Bioenergy **70**, 99–111. https://doi.org/10.1016/j.biombioe.2014.02.037 (2014)

Assessment of Urinary 1-hydroxypyrene and 3-hydroxybenzo(a)pyrene in Barbecue Grill Workers

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Abstract Cooks and kitchen workers at restaurants are continuously exposed to cooking fumes released during food processing. There is limited information about kitchen and barbecue grill workers' occupational exposure. This work determined the levels of 1-hydroxypyrene and 3-hydroxybenzo(a)pyrene in the post-shift urines of barbecue grill workers during a regular working period. Levels of both polycyclic aromatic hydrocarbon (PAH) metabolites were extracted by solid-phase extraction and quantified by high-performance liquid chromatography with fluorescence detection. Overall, median concentrations of 1-hydroxypyrene were significantly higher during the period when workers were exposed than in the days out of duty (0.068 *versus* 0.050 µmol/mol creatinine; p = 0.003). Total exposure to 1-hydroxypyrene was well below the benchmark level of 0.5 µmol/mol creatinine proposed by the American Conference of Governmental Industrial Hygienists. The PAH biomarker of exposure to carcinogens, 3-hydroxybenzo(a)pyrene, was only detected during the working period (0.123–2.07 nmol/mol creatinine). Findings achieved in this study suggest that grill workers are occupationally exposed to PAHs and thus are more vulnerable to the potential health risks associated with long-term exposures. However, more studies are needed with other biomarkers of exposure to PAHs to better estimate the occupational exposure of barbecue grill workers.

Keywords Human biomonitoring · Occupational exposure · Urinary monohydroxyl metabolites

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1 Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a large group of ubiquitous organic contaminants formed during the incomplete combustion of organic matter and pyrolysis processes of biomass, petroleum, and coal [1]. Among the hundreds of compounds, US Environmental Protection Agency classified 16 PAHs as priority pollutants with some of them being classified as possible/probable carcinogens to humans [2–4]. Benzo(a)pyrene, known human carcinogen, is often used as an indicator of exposure to carcinogenic PAHs [3]. PAHs have been associated with reproductive, cardio-respiratory, and immune toxic effects in humans [5]. People are exposed to PAHs through the inhalation of polluted air, ingestion of contaminated food and dermal contact. However, there are several factors that influence the mechanisms through which PAHs are absorbed/adsorbed by human body including the age and metabolism of the subject, the routes of exposure, and some environmental characteristics such as temperature, humidity, and solar radiation [6]. Short-term occupational exposure to PAHs may cause eye irritation, inflammation, nausea and vomiting while long-term exposures have been associated with the occurrence of DNA and protein damages, gene mutations, and a higher prevalence of cancer [7].

Some groups of occupationally exposed professionals, namely those working in aluminum production, steel and iron foundries, road paving, roof insulation, wood surface painting, and tar refineries are continuously exposed to PAHs and may suffer from the associated potential health risks [8]. Cooks and barbecue grill-workers are also continuously exposed to the emissions from food cooking activities during their regular work, however limited information is available [9–16]. Their occupational exposure to PAHs occurs mostly through dermal contact and inhalation of exhaust fumes and smoke [7]. Biological monitoring is a fundamental tool in occupational health risk assessment since it allows the determination of total internal exposure regardless of the source. Limited information is available regarding the use of biomonitoring studies in kitchen workers of restaurants and barbecue grill workers [17–24]; no information was found for European workers. Therefore, this work aims to fill the gap regarding barbecue grill workers' occupational exposure through the assessment of two urinary monohydroxyl metabolites (OH-PAHs), 1-hydroxypyrene and 3-hydroxybenzo(a)pyrene during a regular working period.

2 Materials and Methods

2.1 Characterization of Grill Workers and Urine Sampling

This work was conducted in three restaurants situated in different cities from the Oporto metropolitan area (north of Portugal). Barbecue grill workers were invited to participate in this study through a personal structured questionnaire to collect general information on biometric (gender, age, height, weight), health status (diagnosed cardio-respiratory), regular practice of exercise), smoking habits, number of years working as grill workers, duration of a regular work-shift and frequency of days-off [25]. All grill workers signed an informed consent form that was previously approved by the Ethic Committee of University of Porto. Only healthy and non-smoking subjects, who reported a recent diet without the ingestion of smoked, grilled, and barbecued foods were considered in this study.

All participants were invited to collect a spot urine sample at the end of their work-shift during five consecutive working days and in the following days-off. Urine samples were collected in sterilized polycarbonate flasks, coded, and immediately frozen at −20 °C till analysis.

2.2 Urinary OH-PAHs Extraction

Extraction and quantification of urinary 1-hydroxypyrene and 3-hydroxybenzo(a) pyrene were performed according to Oliveira et al. [26]. Briefly, 10 mL of urine was buffered with an acetate buffer solution (pH 5) and incubated during 2 h at 37 °C with 80 µL of β-glucuronidase/arylsulfatase from *Helix pomatia* (EC3.2.1.31/EC3.1.6.1; 5.5/2.6 U/ml; Roche Diagnostics, Indianapolis, USA). The hydrolyzed samples were extracted in Sep-Pak Light Plus C18 cartridges (Waters, Sigma-Aldrich, Steinheim, Germany) with 20.0 mL of methanol/ethyl acetate (1:9). Extracts were evaporated till dryness, redissolved in 500 µL of methanol and filtered through a PTFE 0.2 µm membrane filter before analysis.

2.3 Chromatographic Analysis

The chromatographic analysis was done in a high-performance liquid chromatograph from Shimadzu Corporation (Kyoto, Japan) equipped with a fluorescence detector. The separation of PAH metabolites was done in a C18 column (CC 150/4 Nucleosil 100-5 C18 PAH, 150 × 4.0 mm; 5 µm particle size; Macherey–Nagel, Duren, Germany) at 25 °C. The optimum excitation/emission wavelength pairs for 1-hydroxypyrene and 3-hydroxybenzo(a)pyrene were 242/388 nm and 308/432 nm, respectively. Calibrations were performed with mixed standards of at least 6 different concentrations in methanol. Limits of detection (LOD) and quantification (LOQ) were calculated as the minimum detectable amount of PAH metabolite with a signal-to-noise ratio of 3:1 and 10:1, respectively [27]. 1-hydroxypyrene and 3-hydroxybenzo(a)pyrene LODs were 2.6 and 1.1 ng/L urine, with the corresponding LOQs of 8.5 and 3.5 ng/L urine, respectively.

Concentrations of urinary PAH metabolites were normalized with the creatinine levels determined in the urine of each subject through the Jaffe colorimetric method [28].

The quantification of PAH metabolites in the urine of grill workers was done in triplicate.

2.4 Statistical Treatment

Statistical analysis was done with SPSS (IBM SPSS Statistica 20) and Statistica (v. 7, StatSoft Inc., USA) software. Concentrations of PAH metabolites were presented as median and range since normal distribution was not found by parametric tests. Statistical significance was defined as $p < 0.05$.

3 Results and Discussion

The age of participants ranged between 31 and 35 years, with a body mass index varying between 24 and 30 kg/m^2. Grill workers reported an exposure of more than five years to the emissions released during the preparation and cooking of foods in barbecue restaurants. Overall, all participants reported a period of five to six consecutive days of working followed by day and a half off. Urine samples were organized in two different groups according to the exposure to grill emissions: (i) urines donated during a regular period of work and (ii) urine samples collected during the days out of working.

Median concentrations of creatinine in the urine of participants varied between 1.13 and 2.82 g/L urine which were within the range of acceptable values of 0.3–3.0 g/L urine proposed by the World Health Organization for healthy people [29].

Figure 1 presents the levels of 1-hydroxypyrene in the urine of barbecue grill workers in the exposed and non-exposed period. Overall, median concentrations were predominantly higher during the working period than in the non-exposed days (0.068 *versus* 0.050 µmol/mol creatinine; $p = 0.003$), with maximum levels reaching 0.142 µmol/mol creatinine. 1-hydroxypyrene, the PAH biomarker of exposure, was detected in all the urine samples even in those collected during the resting period (0.033–0.058 µmol/mol creatinine). Grill workers' total exposure to 1-hydroxypyrene was well below the post-shift benchmark level of 0.5 µmol/mol creatinine proposed by the American Conference of Governmental Industrial Hygienists for a period of 8-h of exposure to coal tar pitch volatiles [30].

Median concentrations of 3-hydroxybenzo(a)pyrene, the PAH biomarker of carcinogenicity, ranged between 0.123 and 2.07 nmol/mol creatinine during the exposed days (median of 0.153 nmol/mol creatinine) and from 0.116 to 0.290 nmol/mol creatinine during the resting period (median of 0.127 nmol/mol creatinine; Fig. 2). Urinary 3-hydroxybenzo(a)pyrene was only detected in 20% of

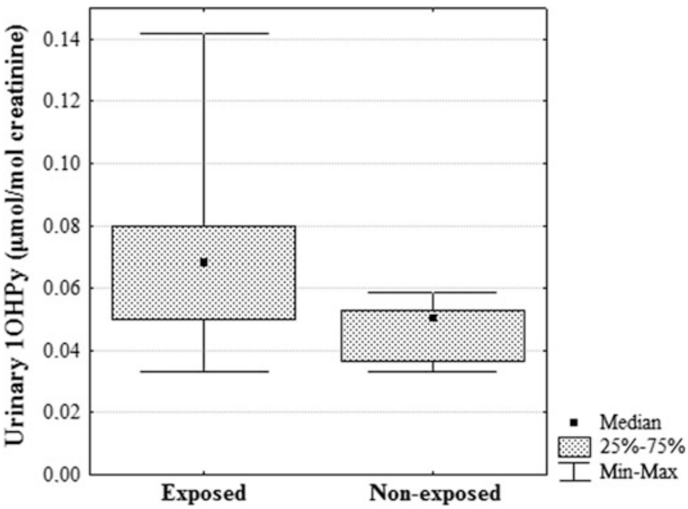

Fig. 1 Urinary concentrations of 1-hydroxypyrene (median; 25–75% and range; µmol/mol creatinine) measured in barbecue grill workers during exposure and non-exposure periods

grill workers' urines during working days; it was not detected during the non-working period. To the knowledge of the authors, there are no recommendations and/or guidelines available for the urinary maximum concentrations of 3-hydroxybenzo(a)pyrene.

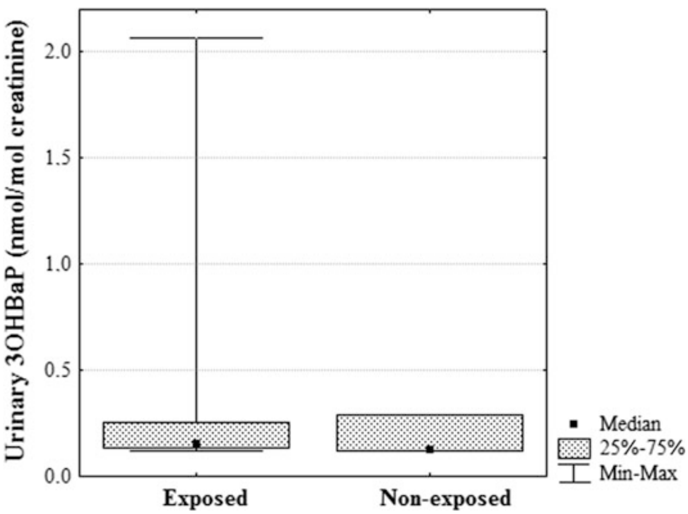

Fig. 2 Urinary concentrations of 3-hydroxybenzo(a)pyrene (median; 25–75% and range; nmol/mol creatinine) determined in grill workers during exposure and non-exposure periods

Levels of 1-hydroxypyrene found in this work were significantly lower than the values reported in cook and kitchen workers from Chinese restaurants exposed to cooking oil fumes [18, 20, 22, 24]; none of these studies included barbecue grill workers. At Portuguese barbecue restaurants, charcoal is extensively used in the preparation of grilled meat, fish, and vegetables. It is known that combustion of charcoal releases large amounts of health-relevant pollutants including carbon monoxide, particulate matter and PAHs [5, 9, 16, 23, 31]. Data available from the literature is mainly related with kitchen workers' occupationally exposed to the emissions of other cooking methods besides barbecuing and grilling such as deep-frying and stir frying, which releases higher amounts of pollutants as a consequence of burning oils [18, 20–22]. Moreover, some authors were able to determine higher levels of oxidative stress biomarkers in kitchen workers comparatively with control groups [18–20, 22].

4 Conclusions

Levels of two urinary PAH metabolites, 1-hydroxypyrene and 3-hydroxybenzo(a) pyrene, were determined in grill workers during a regular week of work. The achieved results proved that grill workers were continuously exposed to pyrene (median total exposure of 0.068 μmol/mol creatinine) and benzo(a)pyrene (0.153 μmol/mol creatinine) during their work at barbecue restaurants. Since PAHs are ubiquitous pollutants that are present as a large mixture of compounds, it is expected that grill workers are chronically exposed to a higher number of PAHs. Therefore, future studies with a higher number of participants and including other biomarkers of exposure to PAHs are needed to validate and explore the findings of this study and to estimate the potential health risks.

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References

1. Abdel-Shafy, H.I., Mansour, M.S.M.: A review on polycyclic aromatic hydrocarbons: Source, environmental impact, effect on human health and remediation. Egyptian J. Petroleum **25**, 107–123 (2016)
2. USEPA.: Guidelines for Carcinogen Risk Assessment, EPA/630/P-03/001F, Risk Assessment Forum. US Environmental Protection Agency, Washington, D.C. (2005)
3. IARC.: Monographs on the Evaluation of the Carcinogenic Risks to Humans: Some Non-Heterocyclic Polycyclic Aromatic Hydrocarbons and Some Related Exposures, pp. 1–853. International Agency for Research on Cancer (2010)

4. IARC.: Monographs on the Evaluation of the Carcinogenic Risks to Humans: Naphthalene. International Agency for Research on Cancer, Lyon, France (2002)
5. Kamal, A., Cincinelli, A., Martellini, T., Malik, R.N.: A review of PAH exposure from the combustion of biomass fuel and their less surveyed effect on the blood parameters. Environ. Sci. Pollut. Res. **22**, 4076–4098 (2015)
6. Oliveira, M., Slezakova, K., Delerue-Matos, C., Pereira, M.C., Morais, S.: Children environmental exposure to particulate matter and polycyclic aromatic hydrocarbons and biomonitoring in school environments: a review on indoor and outdoor exposure levels, major sources and health impacts. Environ. Int. **124**, 180–204 (2019)
7. Gao, P., da Silva, E., Hou, L., Denslow, N.D., Xiang, P., Ma, L.Q.: Human exposure to polycyclic aromatic hydrocarbons: Metabolomics perspective. Environ. Int. **119**, 466–477 (2018)
8. Moustafa, G.A., Xanthopoulou, E., Riza, E., Linos, A.: Skin disease after occupational dermal exposure to coal tar: a review of the scientific literature. Int. J. Dermatol. **54**, 868–879 (2015)
9. Taner, S., Pekey, B., Pekey, H.: Fine particulate matter in the indoor air of barbeque restaurants: elemental compositions, sources and health risks. Sci. Total Environ. **454**, 79–87 (2013)
10. Huang, H.L., Lee, W.M.G., Wu, F.S.: Emissions of air pollutants from indoor charcoal barbecue. J. Hazard. Mater. **302**, 198–207 (2016)
11. Kim, H.J., Chung, Y.K., Kwak, K.M., Ahn, S.J., Kim, Y.H., Ju, Y.S., Kwon, Y.J., Kim, E.A.: Carbon monoxide poisoning-induced cardiomyopathy from charcoal at a barbecue restaurant: a case report. Ann. Occup. Environ. Med. **27**, 8 (2015)
12. Kuo, C.Y., Chang, S.H., Chien, Y.C., Chiang, F.Y., Wei, Y.C.: Exposure to carcinogenic PAHs for the vendors of broiled food. J. Expo. Sci. Environ. Epidemiol. **16**, 410–416 (2006)
13. Li, Y.C., Shu, M., Ho, S.S.H., Wang, C., Cao, J.J., Wang, G.H., Wang, X.X., Wang, K., Zhao, X.Q.: Characteristics of PM2.5 emitted from different cooking activities in China. Atmos. Res. **166**, 83–91 (2015)
14. Song, Y.F., Sun, L., Wang, X.F., Zhang, Y.T., Wang, H., Li, R., Xue, L.K., Chen, J.M., Wang, W.X.: Pollution characteristics of particulate matters emitted from outdoor barbecue cooking in urban Jinan in eastern China. Front. Env. Sci. Eng. **12**, 8 (2018)
15. Wu, C.C., Bao, L.J., Guo, Y., Li, S.M., Zeng, E.Y.: Barbecue fumes: an overlooked source of health hazards in outdoor settings? Environ. Sci. Technol. **49**, 10607–10615 (2015)
16. Oliveira, M., Capelas, S., Delerue-Matos, C., Pereira, I.B., Morais, S.: Barbecue grill workers occupational exposure to particulate-bound polycyclic aromatic hydrocarbons. In: Arezes, P. M., Baptista, J.S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Miguel, A. S., Perestrelo, G. (eds.) Occupational and Environmental Safety and Health, pp. 201–209. Springer International Publishing, Cham (2019)
17. Acharya, N., Gautam, B., Subbiah, S., Rogge, M.M., Anderson, T.A., Gao, W.M.: Polycyclic aromatic hydrocarbons in breast milk of obese vs normal women: Infant exposure and risk assessment. Sci. Total Environ. **668**, 658–667 (2019)
18. Ke, Y.B., Huang, L.H., Xia, J.J., Xu, X.Y., Liu, H.H., Li, Y.R.: Comparative study of oxidative stress biomarkers in urine of cooks exposed to three types of cooking-related particles. Toxicol. Lett. **255**, 36–42 (2016)
19. Ke, Y.B., Cheng, J.Q., Zhang, Z.C., Zhang, R.L., Zhang, Z.Z., Shuai, Z.H., Wu, T.C.: Increased levels of oxidative DNA damage attributable to cooking-oil fumes exposure among cooks. Inhal. Toxicol. **21**, 682 (2009)
20. Lai, C.H., Jaakkola, J.J.K., Chuang, C.Y., Liou, S.H., Lung, S.C., Loh, C.H., Yu, D.S., Strickland, P.T.: Exposure to cooking oil fumes and oxidative damages: a longitudinal study in Chinese military cooks. J. Expo. Sci. Environ. Epidemiol. **23**, 94–100 (2013)
21. Pan, C.H., Chan, C.C., Wu, K.Y.: Effects on Chinese restaurant workers of exposure to cooking oil fumes: a cautionary note on urinary 8-hydroxy-2′-deoxyguanosine. Cancer Epidemiol. Biomark. Prev. **18**, 687–687 (2009)
22. Pan, C.H., Chan, C.C., Huang, Y.L., Wu, K.Y.: Urinary 1-hydroxypyrene and malondialdehyde in male workers in Chinese restaurants. Occup. Environ. Med. **65**, 732–735 (2008)

23. Singh, A., Nair, K.C., Kamal, R., Bihari, V., Gupta, M.K., Mudiam, M.K.R., Satyanarayana, G.N.V., Raj, A., Haq, I., Shukla, N.K., Khan, A.H., Srivastava, A.K.: Assessing hazardous risks of indoor airborne polycyclic aromatic hydrocarbons in the kitchen and its association with lung functions and urinary PAH metabolites in kitchen workers. Clin. Chim. Acta **468**, 231–232 (2017)
24. Wang, J.J., Luo, X.L., Xu, B., Wei, J., Zhang, Z.Z., Zhu, H.L.: Elevated oxidative damage in kitchen workers in chinese restaurants. J. Occup. Health **53**, 327–333 (2011)
25. WHO.: World Health Survey B—Individual Questionnaire. Evidence and Information Policy (2002)
26. Oliveira, M., Slezakova, K., Alves, M.J., Fernandes, A., Teixeira, J.P., Delerue-Matos, C., Pereira, M.D., Morais, S.: Firefighters' exposure biomonitoring: impact of firefighting activities on levels of urinary monohydroxyl metabolites. Int. J. Hyg. Environ. Health **219**, 857–866 (2016)
27. Miller, J.C., Miller, M.J.N.: Statistics for Analytical Chemistry. Pearson Education Ltd, Harlow (2000)
28. Kanagasabapathy, S.K.A.S.: Guidelines on standard operating procedures for clinical Chemistry, pp. 25–28. World Health Organization. Regional Office for South-East Asia, New Delhi (2000)
29. WHO.: Biological Monitoring of Chemical Exposure in Workplace-Guidelines. World Health Organization, Geneva (1996)
30. ACGIH.: Documentation for a Recommended BEI of Polycyclic AromaticHydrocarbons. In: American Conference of Governmental Industrial Hygienists, Cincinatti, Ohio, USA (2010)
31. Dai, W.T., Zhong, H.B., Li, L.J., Cao, J.J., Huang, Y., Shen, M.X., Wang, L.Q., Dong, J.G., Tie, X.X., Ho, S.S.H., Ho, K.F.: Characterization and health risk assessment of airborne pollutants in commercial restaurants in northwestern China: under a low ventilation condition in wintertime. Sci. Total Environ. **633**, 308–316 (2018)

The Relevance of Hand-Mouth Contact in Occupational Exposure to Metals

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Abstract In occupational settings the ingestion route is normally not considered significant when compared with the other exposure routes, such as inhalation or dermal contact. However, work-related ingestion of hazardous substances may be a reality and hand-to-mouth contact can have an important role. The work aimed to claim attention for the relevance of hand-mouth contact in the case of occupational exposure to metals and for the need to contemplate exposure by ingestion route when defining measures to prevent exposure. An extensive search was performed to identify scientific papers reporting data of hands contamination in occupational settings where exposure to metals could happen. Eight studies were retained and included in a more detailed analysis concerning exposure scenario, main findings and actions taken to control exposure by hand-mouth contact. It was possible to conclude that occupational health interventions should focus more on understanding how inadvertent ingestion can happen and the role of the hand-mouth contact in the total exposure. This is of particular relevance for adopting the most relevant and suitable risk management measures.

Keywords Occupational exposure · Metals · Exposure assessment · Hand-to-mouth contact · Ingestion route

1 Introduction

In occupational settings the most relevant exposure route is inhalation followed by dermal contact and, normally consider less relevant, the ingestion route. Even regarding of potential toxicity, inhalation is frequently mention as the most

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important exposure route and, in contrast, the ingestion route is normally not considered significant when compared with the other exposure routes [1]. This is possibly due to several reasons such as: the common rational that ingestion of hazardous substances can only occur by intentional means or acts of gross negligence, then it can be avoided; the recognition that many materials are only very poorly absorbed from the gut (i.e. they have low bioavailability) and, in this way, are improbable to produce toxic effects when ingested in small quantities and also because these substances can be metabolized in the liver and eliminated before producing any toxic effect; and, also, the assumption that where a worker is exposed by inhalation, dermal contact and ingestion, the total burden of the substance taken into the body by ingestion is probably smaller than by the other routes [2].

However, work-related ingestion of hazardous substances may be a reality and can occur by different ways, such as: clearance of inhaled aerosols deposited within the ciliated airways of the lung; ingestion of contaminated food or beverages; transfer of contamination by hand-to-mouth or object-to-mouth contact and by direct deposition of contaminants around the mouth and into the oral cavity [2]. In addition, this can be due to direct deposition into the skin, handling of equipment or touching surfaces already contaminated [3].

In principle, exposure by ingestion can be controlled by good hygiene practices such as segregating working and eating facilities, adequate cleaning of workplace surfaces and hands washing prior to eating [3, 4].

In occupational settings, metals are the substances where previous reports have already described that hand-mouth contact is of relevance for total exposure burden. For instance, several studies developed in electroplating setting have demonstrated poor correlation between airborne levels and urinary nickel levels [5, 6] and suggested that this might be partly due to dermal uptake but also due to contaminated hands and poor hygienic behavior [5]. Additionally, is relevant to consider that in cases where contact with a material is intermittent, but there is the chance that the transferred substance can remain on the skin after contact—the case of metals—hand-to-mouth transfers (and subsequent ingestion) are more important than dermal absorption and the attention on this exposure route is justified [7]. Moreover, in many occupational settings, worker hands typically receive the highest level of dermal contamination and are most important in terms of transfer of contamination to the mouth. Thus, it is possible to understand why ingestion exposure is resulting mainly from hand-to-mouth contact [2].

The aim of this paper is to claim attention for the relevance of hand-mouth contact in the case of occupational exposure to metals and for the need to contemplate exposure by ingestion route when defining measures to prevent exposure.

2 Materials and Methods

An extensive search was performed to identify scientific papers available in PubMed and Web of Science published after 2010, reporting data of hands contamination in occupational settings where exposure to metals could happen. It was decided after 2010 to allow to understand if the most recent research work has consider the hand-mouth contact in occupational exposure to metals. Only articles written in English were considered. The search was done using the following key-words in combination: dermal exposure, metals and occupational.

3 Results

Of the 180 papers find and evaluated in total, 172 were excluded from the present review because they did not fulfill the inclusion criteria, particularly the papers do not provide data of hands contamination. Eight studies were retained and included in a more detailed analysis concerning exposure scenario, main findings and actions taken to control exposure by hand-mouth contact (Table 1). Three studies were dedicated to occupational settings where exposure to nickel and nickel compounds could happen; only one study was dedicated to other substances such as aluminum oxide, to beryllium, to cobalt and platinum. Two studies were focused on occupational settings where exposure to more than one metal could occur.

Table 1 Papers considered for further analysis (n = 8)

Occupational setting	Metal	Hand-mouth contact role in total exposure demonstrated	Actions taken to control exposure	Reference
Nickel production and primary nickel user industries	Nickel	There is potential for inadvertent ingestion of nickel and nickel compounds	Use of PPE and automatic, remote materials handling processes	Hughson et al. [8]
Metal refinery	Nickel	The presence of high levels on the hands also increases the risk of ingestion of nickel through a hand-to-mouth contact	Selection of adequate protective gloves, improvement of hand wash facilities, changes in operating procedures for cleaning of areas and surfaces, the use of a colorimetric test to be used as spot-checks on cleaned surfaces and more frequent training	Plessis et al. [4]

(continued)

Table 1 (continued)

Occupational setting	Metal	Hand-mouth contact role in total exposure demonstrated	Actions taken to control exposure	Reference
Use of engineered nanoparticles in chemical mechanical planarization	Aluminum oxide	Workers had the potential for incidental contact with slurry containing nanoparticles, process wastewaters, dried residues on workplace surfaces or equipment	Actions to avoid or minimize aerosolization and skin contact were identified as needed	Shepard and Brenner [9]
Manufacture and finishing of beryllium materials	Beryllium	Dermal exposures should be considered in addition to inhalation exposures	Reinforce skin protection and surface cleaning	Armstrong et al. [10]
Companies that worked with metals	Several metals	Evidence that exposure level on the hands is a determinant of inadvertent ingestion exposure	Use of respiratory protection equipment because can act as a barrier to hand-to-mouth contact	Gorman et al. [11]
Hard metal production company	Cobalt	Data suggest that uptake via hand-to-mouth can affect the total uptake at the same order of magnitude as exposure by inhalation	Actions to prevent skin contamination were identified as needed	Klasson et al. [12]
Electroplating	Chromium and nickel	The positive correlations between hand contamination and biomonitoring results confirm that dermal exposure is significant in terms of contribution to overall systemic dose	Improve controls in line with principles of the hierarchy of control	Beattie et al. [13]
Precious metals refineries	Platinum	Skin exposure could, to a lesser degree than respiratory exposure, contribute to urinary excretion	Use of disposable coveralls by directly exposed workers	Linde et al. [14]

4 Discussion

The eight studies considered in this review provide the evidence that metals contamination level on the hands is a determinant of inadvertent ingestion exposure by the hand-mouth contact. Indeed, in the papers analyzed the conclusions were that unintentional ingestion consists mainly of hand-to-mouth contact, and is therefore closely related to dermal exposure. This aspect explain the findings obtained in several papers [11–13] of low metal air levels with relatively high concentrations in biomonitoring data.

Considering the above it would be of interest to combine the assessment of the frequency of hand-to-mouth contact through video analyses or even by direct observation of worker behavior during the development of the tasks and biomonitoring. This last exposure assessment tool would provide an integrated assessment of total worker exposure, and likely an indication of exposure over time [15]. Then, if we observe hand-to-mouth contact and if the biomonitoring data demonstrated that the total exposure exceeds the level that would be anticipated to result from inhalation exposure route alone, then the contribution of the hand-to-mouth contact to the total exposure can be determined.

Another aspect that is relevant to mention is that hand-to-mouth contact include contacts involving both gloved and bare hands. In one of the studies analyzed [11] the researchers observed that, among the workers who wore gloves, the gloves were typically not worn continuously and that hand-mouth contact was less frequent when the hands were covered with gloves. Therefore, in addition to adequate workplace (equipment and surfaces) cleaning practices also the use of protection equipment—gloves and also respiratory protection equipment—can contribute to reduce exposure by unintentional ingestion since contributes to avoid hands contamination and hand-mouth contact.

Some authors also mentioned the importance of worker behavior for ingestion exposure route and, particularly, for hand-to-mouth contact [2, 11, 16]. The authors suggest that understanding the behavioral influences guiding ingestion exposure will allow targeting interventions to reduce risks from this route. Additionally, this will permit recognizing the reasons of exposure differences between workers doing the same tasks with similar risk management measures. In this context, and to accomplish changes on workers behavior during task performance, particularly concerning hand-mouth contact, it would be relevant to give feedback on measured exposure levels together with videos collected and instructions towards basic hygienic measures. In previous research work, this kind of intervention has already obtained positive results concerning workers behavior and exposure reduction [17].

5 Conclusions

This review claimed attention for the importance of hand-mouth contact in occupational settings where exposure to metals can occur. Additionally, and considering the small numbers of papers dedicated to this aspect, research work and occupational health interventions should focus more on understanding how inadvertent ingestion can happen and the role of the hand-mouth contact in the total exposure. The development of measurements tools for inadvertent ingestion exposure should be developed and applied in monitoring campaigns [18]. This is of particular relevance for adopting the most relevant and suitable risk management measures.

References

1. Semple, S.: Dermal exposure to chemicals in the workplace: Just how important is skin absorption? Occup. Environ. Med. **61**, 376–382 (2004). https://doi.org/10.1136/oem.2003.01064
2. Cherrie, J., Semple, S., Christopher, Y., Saleem, A., Hughson, G., Philips, A.: How important is inadvertent ingestion of hazardous substances at work? Ann. Occup. Hyg. **50**(7), 693–704 (2006)
3. Viegas, S., Cebola de Oliveira, A., Carolino, E., Pádua, M.: Occupational exposure to cytotoxic drugs: the importance of surface cleaning to prevent or minimize exposure. Arh. Hig. Rada Toksikol **69**, 238–249 (2018)
4. Plessis, J., Eloff, F., Badenhorst, C., Olivier, J., Laubscher, P., Van Aarde, M., Franken, A.: Assessment of dermal exposure and skin condition of workers exposed to Nickel at a south african base metal refinery. Ann. Occup. Hyg. **54**(1), 23–30 (2010)
5. Cattani, M., Cena, K., Edwards, J., et al.: Potential dermal and inhalation exposure to chlorpyrifos in Australian pesticide workers. Ann. Occup. Hyg. **45**, 299–308 (2001)
6. Kiilunen, M., Aitio, A., Tossavainen, A.: Occupational exposure to Nickel salts in electrolytic plating. Ann. Occup. Hyg. **41**, 189–200 (1997)
7. Dubé, E.M., Petito Boyce, C., Beck, B.D., et al.: Assessment of potential human health risks from arsenic in CCA-treated wood. Human Ecol. Risk Assess. **10**, 1019–1067 (2004)
8. Hughson, G.W., Galea, K.S., Heim, K.E.: Characterization and assessment of dermal and inhalable nickel exposures in Nickel production and primary user industries. Ann. Occup. Hyg. **54**(1), 8–22 (2010)
9. Shepard, M., Brenner, S.: Cutaneous exposure scenarios for engineered nanoparticles used in semiconductor fabrication: a preliminary investigation of workplace surface contamination. Int. J. Occup. Environ. Health **20**(3), 247–257 (2014)
10. Armstrong, J., Day, G., Park, J., Stefania, A., Stanton, M., Deubner, D., Kent, M., Schuler, C., Virjil, M.: Migration of Beryllium via multiple exposure pathways among work processes in four different facilities. Occup. Environ. Hyg. **11**(12), 781–792 (2014). https://doi.org/10.1080/15459624.2014.919392
11. Gorman, M., MacCalman, L., Semple, S., van Tongeren, M.: Field measurements of inadvertent ingestion exposure to metals. Ann. Work Exp. Health **61**(9), 1097–1107 (2017). https://doi.org/10.1093/annweh/wxx071
12. Klasson, M., Lindberg, M., Bryngelsson, I., Arvidsson, H., Pettersson, C., Husby, B., Westberg, H.: Biological monitoring of dermal and air exposure to cobalt at a Swedish hard metal production plant: does dermal exposure contribute to uptake? Contact Dermatitis **77**, 201–207 (2017)

13. Beattie, H., Keen, C., Coldwell, M., Tan, E., Morton, J., McAlinden, J., Smith, P.: The use of bio-monitoring to assess exposure in the electroplating industry. J. Eposure Sci. Environ. Epidemiol. **27**, 47–55 (2017)
14. Linde, S., Franken, A., du Plessis, J.: Urinary excretion of platinum (Pt) following skin and respiratory exposure to soluble Pt at South African precious metals refineries. Int. J. Hyg. Environ. Health **221**, 868–875 (2018)
15. Deubner, D.C., Lowney, Y., Paustenbach, D., Warmerdam, J.: Contribution of incidental exposure pathways to total beryllium exposures. Appl. Occup. Environ. Hyg. **16**(5), 568–578 (2001)
16. Gorman, M., Davis, A., van Tongeren, M., et al.: Inadvertent ingestion exposure: hand- and object-to-mouth behavior among workers. J. Expo Sci. Environ. Epidemiol. **26**, 9–16 (2016)
17. Basinas, I., Sigsgaard, T., Bønløkke, J., Andersen, N., Omland, Ø., Kromhout, H., Schlünssen, V.: Feedback on measured dust concentrations reduces exposure levels among farmers. Ann. Occup. Hyg. **60**(7), 812–824 (2016). https://doi.org/10.1093/annhyg/mew032
18. Viegas, S.: The relevance of surfaces contamination assessment in occupational hygiene interventions in case of exposure to chemicals. In: Arezes, P.M., et al. (eds.) Occupational Safety and Hygiene VI, pp. 41–45. CRC Press, Taylor and Francis Group, Leiden. ISBN 978-1-138-54203-7 (2018)

Long-Haul Logistic Truck Drivers' Physiological Fatigue on Low Back and Shoulder: A Primary Exploration

T. Sa-ngiamsak, N. Phatrabuddha, T. Yingratanasuk and A. Thetkathuek

Abstract Logistics sector plays a key role in running economy and trade. Long-haul trucks' drivers need to perform the prolonged driving task with multiple risks of musculoskeletal disorders hazards. This study aimed to primarily explore physiological fatigue focusing on low back and shoulder of a group of ten long-haul logistic truck drivers. Muscle strength measurements via maximum voluntary contraction were employed as a basic quantitative indicts. The investigation was conducted before and after the long-distance real driving tasks covering the area between the special eastern economic corridor zone and Bangkok, Thailand (usually taking around 10–12 h for a round service). By comparing the results before and after, both low back and shoulder muscle strength tests showed statistically significant decreases of the maximum voluntary contraction ($p < 0.05$). Meanwhile, differential decrease percentage among low back and shoulder demonstrated no statistically significant difference ($p = 0.646$). All results suggested that relevant countermeasures needed to be taken in to accounts in order to minimize the involving risk factors. And this also confirmed that fitness test using muscle strength measurements helps primarily explore the physiological fatigue but to acquire the particular amount of fatigue occurring on related muscles, deeper information is still needed. By this, and with this particular task, electromyography investigation method still remains superior.

Keywords Long-distant truck drivers · Muscle fatigue · Muscle strength test

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1 Introduction

Distribution of goods and/or raw materials is essential in running economy and trade. Since so many products can be easily accessed online nowadays, this leads to the booming of E-commerce that involves handing over the delivery tasks to the logistics sector at the end. The report from World Bank logistics index showed that there was a surge of 13 spots on logistics performance index ranking for Thailand, rising from 45th in 2016 to 32nd out of 160 countries in 2018, second only to Singapore in ASEAN, and seventh in Asia [1].

The physical movements of those goods and/or raw materials require efficient logistics systems. Long-distance road transportation is one of the key links to this success in delivering to the customers or handing over the regional distribution. Long-haul logistic truck drivers have to perform the task for several hours on the road with traffic conditions. There are many risk factors such as sustained or repetitive movement, vibration, stress, prolonged operating period, total service, age and pain history that contribute to fatigue development which could have caused Musculoskeletal Disorders (MSDs) in the long run [2]. By considering this, the long-haul logistic transportation characteristics seem to contain most of those risk factors. To identify this problem as early as possible is very important to the engagement of efficient countermeasures. Although, there are many ways to quantitatively assess muscle fatigue in which the well-recognized methods are: (1) Lactic acid assessment by verifying through a gradual increase in lactic acid concentration as a consequence of the metabolic product [3], (2) Electromyography (EMG) signals evaluation by verifying through either invasive which mostly utilized as diagnostic tool [4] or non-invasive technique that popularly applied in sport or ergonomic [4, 5] and (3) Muscular performance tested by using muscle strength measurements is one of the physical fitness test procedures that has a strong correlation to muscle fatigue [6]. From all three, the last one seems to be the easiest and most inexpensive method by which it seems to require the least skill to implement. This study aimed to explore physical fatigue on low back and shoulder of long-haul logistic truck drivers to investigate the appearance of muscle fatigue and its situation in percentage as well as the value of this method in primary assessment.

2 Materials and Methods

2.1 Subjects

A group of ten long-haul logistic truck drivers, all were men, participated in this study with age and Body Mass Index (BMI) ranging between 33.4–46.7 years (mean age: 39.73 ± 4.8 years) and 18.9–30.7 (mean BMI: 23.69 ± 3.79) respectively. Working experience in this job was from 0.3 to 3 years (mean: 1.68 ± 0.94 years) with averaged working hours per week 40–84 h (mean: 59.8 ± 15 h). Up to 80% of the participants were right-handed and 20% were the left-handed.

2.2 Instrument

Information obtained from this study was conducted via physical fitness test. Two body parts including low back and shoulder were examined muscle strength. Back dynamometer form Lafayette instrument company, model no. 32526, serial No. 1-800-428-7545, was used for lowback strength measurement and the experimental set of stool and a spring balance that was applied from the back dynamometer were used for the shoulder strength test.

2.3 Research Protocol

This research was designed as an experimental study to explore muscle fatigue developing before and after a long-haul drive of ten logistic truck drivers who were working at one selected logistic company. Their jobs were distributing goods between a logistic hub located in the special eastern economic corridor zone and Bangkok, the capital of Thailand. This route was considers a long-distant drive, since it takes approximately 10–12 h for a round service trip with traffic conditions.

All participants were explained research objectives and asked to sign an informed of consent if they agreed to participate in the study. Before the start of a long-haul drive, they were directly questioned and explained in details one by one by the researchers for questionnaire that they were not fully clear.

After the questionnaire, each was asked to perform the physical fitness test via muscle strength before and after the long-haul real service drive. The pre-test and post-test of muscle strength, started with low back muscle strength which was achieved via pulling the back dynamometer for 3 times, measuring for the highest maximum voluntary contraction (MVC) [7]. This process, the participants were asked to keep their legs straight, only upper limb that pulled as demonstrated in Fig. 1, then left them to take a rest for 10 min before moving to the shoulder (Upper trapezius) strength measurement which involved the pulling of spring balance, utilized from the back dynamometer for 3 times, measuring for the highest MVC. This process, the participants needed to maintain their trunk straight and raised only the tested shoulder up as shown in Fig. 1.

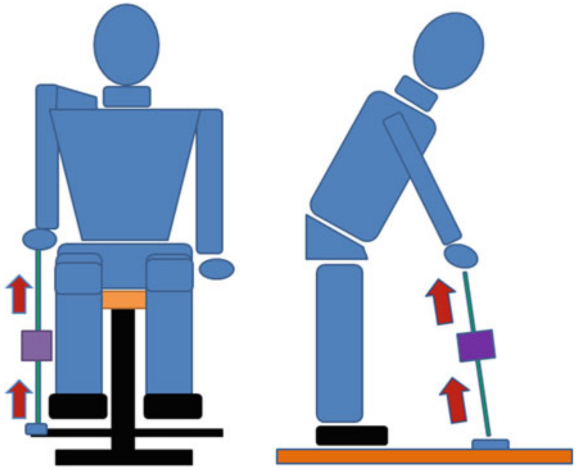

Fig. 1 Physical fitness tests of muscle strength on shoulder (left-hand side) and low back (right-hand side) before and after the long-haul real daily drive

2.4 Research Ethics

The study protocol and all the collecting tools were examined and approved by the Institutional Review Board committee of Burapha University, Thailand (IRB No. Sci 025/2560). Each subject who agreed in the research participation signed an informed of consent. All participants were given the full right to decline or withdraw out of the research project at any time if they wanted.

2.5 Statistical Analysis

All of the collected data were stored, verified and encoded in a computer. The SPSS/PC version 22 software was utilized in data statistical analysis. Mean and standard deviation were used to describe the demographic features. After normality test for data distribution, the paired samples t-test statistics and Wilcoxon signed-rank test were used for normal and non-normal distribution data respectively to analyze either the difference among before and after long-haul drive and percentage decrease of MVC between Low back and Shoulder. Significance was set at 95% confidence level.

3 Results

Following the research protocol, all subjects completed both low back and shoulder physiological fatigue test with the results analyzed statistically as following details.

3.1 Low Back Fatigue Test

The physical fitness test of low back muscle strength revealed that an averaged MVC of the before long-haul drive was 124 ± 33.97 kg, with 90 and 180 kg for the minimum and maximum values respectively. Meanwhile, the amount of 106 ± 28.75 kg was obtained from the after long-haul drive test, with 75 and 160 kg for the minimum and maximum values respectively. All can be graphically demonstrated as in Fig. 2. After the statistical analysis, a significant difference ($p < 0.05$) on low back MVC between before and after the long-haul drive was noticed as details shown in Table 1.

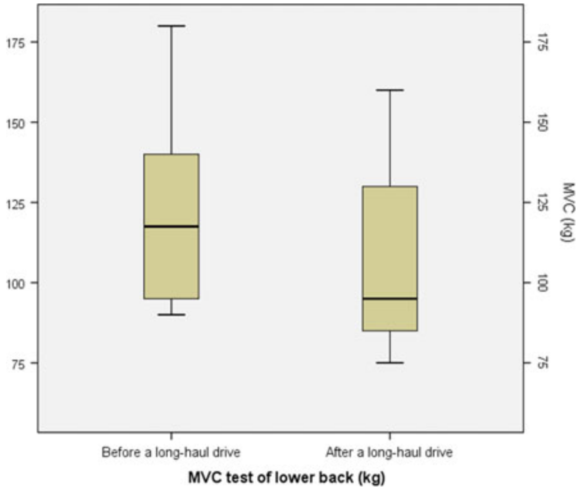

Fig. 2 Mean, maximum and minimum values of MVC of the before and after a long-haul drive on the low back strength test

Table 1 Physiological fatigue test statistics analysis

Physiological fatigue test	Statistic-analysis	Statistic-test	Sig. (*p*-value)
Low back MVC [Before and after]	Paired samples t-test	t = 5.014	$p = 0.001$*
Shoulder MVC [Before and after]	Wilcoxon signed-rank test	z = −2.682	$p = 0.007$*
% decrease of MVC [Low back and shoulder MVC]	Paired samples t-test	t = −0.475	$p = 0.646$

*Sig. level at *p*-value < 0.05

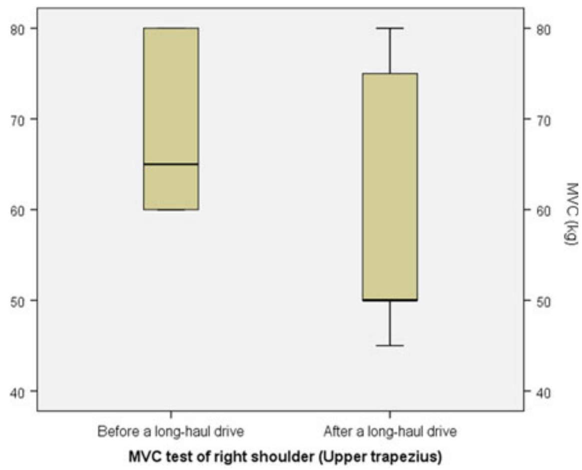

Fig. 3 Mean, maximum and minimum values of MVC of the before and after a long-haul drive on the shoulder (upper trapezius) strength test

3.2 Shoulder (Upper Trapezius) Fatigue Test

The physical fitness test of shoulder (upper trapezius) muscle strength revealed that an averaged MVC of the before long-haul drive was 68.5 ± 8.52 kg with 60 and 80 kg for the minimum and maximum values respectively. Meanwhile, the amount of 58 ± 13.58 kg was obtained from the after long-haul drive test, with 45 and 80 kg for the minimum and maximum values respectively. All can be graphically demonstrated as in Fig. 3. After the statistical analysis, it was observed a significant difference ($p < 0.05$) on shoulder MVC between before and after the long-haul drive as details shown in Table 1.

3.3 Differential Percentage of MVC Between Before and After a Long-Haul Drive

Differential percentage of MVC on low back strength test between before and after a long-haul drive decreased by 14.26 ± 6.89% with 5.56% and 25% for the minimum and maximum values respectively. Meanwhile, the shoulder (upper trapezius) strength test showed a decrease in differential percentage of MVC by 16.10 ± 10.66% with 0% and 30.77% for the minimum and maximum values respectively. All can be graphically demonstrated as in Fig. 4. And considering the statistical analysis, no significant difference ($p < 0.05$) was found for the differential percentages of MVC between before and after a long-haul drive from both tests as details shown in Table 1.

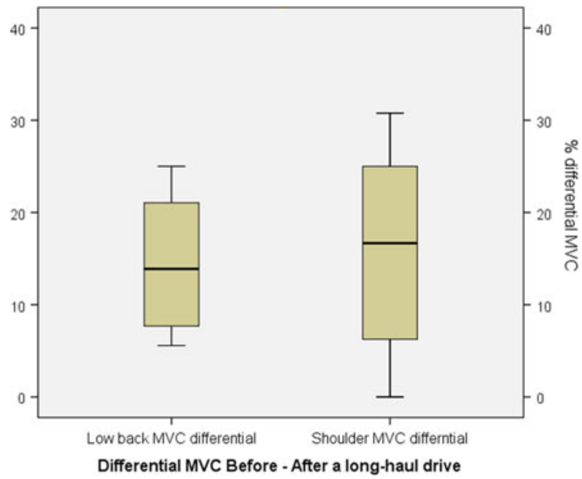

Fig. 4 Mean, maximum and minimum values of differential percentage of MVC between before and after a long-haul drive of low back and shoulder

4 Discussion

The aim of this study was to primarily explore physiological fatigue of low back and shoulder (upper trapezius) among long-haul logistic truck drivers using muscle strength measurements as basic quantitative indicts. All the long haul logistic trucks operated on the roads with traffic conditions for several hours a day, by which the drivers have to work with several fatigue contributors including: vibration, stress, prolonged muscle loading, sustained or repetitive movement, long operating hours [2]. Physical manifestations, observing via declination of force, person's ability to exert force and exercise capability, indicate the development of muscle fatigue [8–14]. Several causes, including: insufficient oxygen and nutritive substances supplied through blood circulation as well as changes in efficiency of the nervous system, result to metabolic, structural and energetic changes in muscles and hence the development of fatigue [3]. As a consequence, contractile proteins that are responsible to generate all the physical manifestation such as force, person's ability to exert force and exercise capability turn to become impaired [15].

The performance test of low back muscle and shoulder strength which only right side was chosen for the tests in this study showed significant differences on decreasing MVC values compared between before and after the long-haul drive. This can be explained as a result from an accumulative fatigue developing during the long-distance drive since MVC represents exert force which declined after the task. This was in line with a study conducted by Leinonen (2005) and the team that studied back and neck extensor loading in urban bus drivers with 7 h driving period. From the study, MVC, one of many muscle fatigue verifying indicts, revealed decreasing values after the drive compared to the before [16]. The study from Marina (2011) and the team also showed the same accordance. The decrease of MVC was observed during the 24 h motorcycle endurance race but in this case it was focused on hands with examination conducted via handgrip strength [17].

There was a slightly difference on differential percentage of MVC between before and after a long-haul drive, by which 14.2% and 16.10% were found for the low back and shoulder respectively. This small difference showed non-significance in statistics analysis. This could be explainable in the way that the fatigue had developed in both body parts with more or less the same rate. Anyways, according to the report from INRIX Global Traffic Scorecard; Bangkok that is the capital of Thailand and also the central of the nation's trade and economy was ranked the 12th most congested city in the world in the year 2017 [18]. This fact might have been responsible for this obvious fatigue manifestation and the higher percentage difference of shoulder might reflect the traffic conditions in study area. By this, the drivers might have to maneuver the steering wheel much more often and with the higher degree of stress.

5 Conclusion

The results of this study demonstrated that long-haul truck drivers suffered with physiological fatigue on upper limb in which low back and shoulder were selected for this study. Countermeasures such as controls of ergonomics, vibration and management were urgently recommended to compromise the problem. The use of physical fitness test of muscle strength can help investigate muscle fatigue existence as the primary method. To efficiently control the risks, more in depth method is still needed to acquire as much amount of information about fatigue as possible. By this, and with this particular task, EMG investigation still remains needed for the full investigation.

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References

1. World Bank. (2018). The logistics performance index (LPI). https://tfig.unece.org/contents/logistic-performance-index.htm
2. Sa-Ngiamsak, T., Phatrabuddha, N., Yingratanasuk, T.: Neuromuscular fatigue assessment in operators performing occupational-transportation/transshipment tasks: a short systematic review. Paper presented at the Occupational Safety and Hygiene VI—Selected contributions from the International Symposium Occupational Safety and Hygiene, SHO 2018 (2018)
3. Cifrek, M., Medved, V., Tonkovic, S., Ostojic, S.: Surface EMG based muscle fatigue evaluation in biomechanics. Clin. Biomech. **24**, 327–340 (2009)
4. Drost, G., Stegeman, D.F., Engelen, B.G.M., Zwarts, M.J.: Clinical applications of high-density surface EMG: a systematic review. J. Electromyogr. Kinesiol. **16**, 586–602 (2006)
5. Merletti, R., Holobar, A., Farina, D.: Analysis of motor units with high-density surface electromyography. J. Electromyogr. Kinesiol. **18**, 879–890 (2008)

6. Corin, G., Strutton, O.H., McGregor, A.H.: Establishment of a protocol to test fatigue of trunk muscles. Br. J. Sports. Med. **39**, 731–735 (2005). https://doi.org/10.1136/bjsm.2004.015537
7. Sa-ngiamsak, T.: Exploring study protocols examining muscle fatigue among transportation and transshipment operators: a systematic review. Int. J. Occup. Environ. Saf. **3**(1), 11 (2019)
8. Davis, M.P., Walsh, D.: Mechanisms of fatigue. J. Support. Oncol. **8**, 164–174 (2010)
9. Allen, D.G., Westerblad, H.: Role of phosphate and calcium stores in muscle fatigue. J. Physiol. **536**, 657–665 (2001)
10. Edwards, R.H.T.: Human Muscle Function and Fatigue. Pitman Medical, London (1981)
11. Heimer, S.: Fatigue (1987) (in Croatian).
12. Lorist, M.M., Kernell, D., Meijman, T.F., Zijdewind, I.: Motor fatigue and cognitive task performance in humans. J. Physiol. **545**, 313–319 (2002)
13. Sa-Ngiamsak, T.: Assessment of muscle fatigue in work related musculoskeletal disorders by high-density surface electromyography. Docteral Degree. University of Porto, Porto, Portugal (2016)
14. Vollestad, N.K.: Measurement of human muscle fatigue. J. Neurosci. Methods **74**(2), 219–227 (1997)
15. Enoka, R.M., Duchateau, J.: Muscle fatigue: what, why and how it influences muscle function. J. Physiol. **586**(1), 11–23 (2008)
16. Leinonen, V., Kankaanpää, M., Vanharanta, H., Airaksinen, O., Hänninen, O.: Back and neck extensor loading and back pain provocation in urban bus drivers with and without low back pain. Pathophysiology **12**(4), 249–255 (2005)
17. Marina, M., Porta, J., Vallejo, L., Angulo, R.: Monitoring hand flexor fatigue in a 24-h motorcycle endurance race. J. Electromyogr. Kinesiol. **21**(2), 255–261 (2011). https://doi.org/10.1016/j.jelekin.2010.11.008
18. Fernquest, J.: Bangkok traffic jams among world's worst. Bangkok Post. Retrieved from https://www.bangkokpost.com/learning/advanced/1201724/bangkok-traffic-jams-among-worlds-worst (2017)

Ergonomics and Biomechanics

Human-Centered Approach for the Design of a Collaborative Robotics Workstation

Ana Colim, Paula Carneiro, Nélson Costa, Carlos Faria, Luís Rocha, Nuno Sousa, Márcio Silva, Ana Cristina Braga, Estela Bicho, Sérgio Monteiro and Pedro M. Arezes

Abstract Collaborative robotic solutions, where human workers and robots share their skills, are emerging in the industrial context. In order to achieve an appropriate level of Human-Robot Collaboration (HRC), the workstations' design has to be human-centered and adaptive to the workers' characteristics/limitations, considering ergonomic criteria. This study corresponds to the first phase of a research project to apply HRC to minimize the musculoskeletal risk associated with a manual assembly task (industrial furniture manufacturing). A new workstation was designed and an ergonomic approach was developed to assess the main risk factors, as well as to optimize the future task allocation between human workers and robots. A questionnaire about working conditions and musculoskeletal symptomology was applied to a selected group of 8 workers. Rapid Upper Limb Assessment and Strain Index were applied (across 38 postures) to assess musculoskeletal risk related to the assembly tasks. In this study, we propose an ergonomic approach to orient the design and task allocation of HRC work systems. This approach allowed the identification of workers' complaints and risk factors that can be mitigated with future implementations of HRC.

Keywords Adaptive human-centered design · Ergonomics · HRC

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1 Introduction

In the emerging context of Industry 4.0, companies have been looking into technological solutions and process automation. In the manufacturing industry, human factors must be a focal point when designing these new work systems [1]. Supporting this statement, the European Factories of the Future Research Association (EFFRA) Roadmap 2020 defines as a prerequisite the human-centricity for the factories of the future, foreseeing the development of human competences in synergy with technological progress [2]. This human-centered design can support the increase of flexibility, agility, and competitiveness in the face of new social challenges [3]. Pacaux-Lemoine et al. [4] argue that even with the lack of research about this topic, Ergonomics & Human Factors (E&HF) research groups are looking into the industrial engineering domain to explore more human-centered manufacturing control system designs.

The third industrial revolution has established robotic systems as a core tool towards the design of automation solutions for manufacturing companies, namely in handling, palletizing, and assembly tasks [5]. Robots are often viewed as an instrument to potentiate companies' competitiveness [6]. Lindström and Winroth [7] highlight that, in the manufacturing context, these novel systems can be designed according to different approaches, such as:

(i) Techno-centered approach, focusing on the optimization of the shop floor production, with inflexible work systems based on automatic and predefined operations;
(ii) Human-centered approach, allocating more strenuous tasks to the automation/robotics, and assigning to the human workers the tasks more suitable for them.

In the industry of the future, with more prevalent and more complex automation of production processes, the role of the human operator becomes even more relevant. By combining the technical efficiency with the flexibility of humans, it is possible to optimize task allocation and increase the robustness of manufacturing systems [7]. The E&HF scientific area plays an important role to support human-robot task allocation, as well as in the design and implementation of these new work systems. The new industrial workstations should be adapted to explore and take advantage of human workers' skills while ensuring their wellbeing and safety.

HRC is an appealing prospect to the industry in general due to the high degree of adaptability and flexibility [8]. Of those, flexible robotic solutions with intuitive and natural human-machine interfaces and capable of intelligent decision making—COBOTs—are key players. COBOTs or Collaborative Robots are a sub-type of robots specially tailored to work in close proximity to humans or other robots. Although the concept is not new, recent breakthroughs in robotic sensorization and in the integration of safety-rated technology with industrial robots have permitted the certification of the first systems that can operate alongside humans [9]. In times when the topic of the human labor replacement by robots generates so much controversy [10], the design of new workstations where robots collaborate with the operator is an encouraging vision. In this domain, the human-centered design of the workstation with HRC must be adaptive, including various criteria, such as age, disability, and inexperience-related restrictions of the workers in order to increase their working capabilities [3].

This study corresponds to the first phase of a research project that intends to apply collaborative robotics in order to minimize the musculoskeletal risk associated with a manual assembly task. An ergonomic approach is developed to assess the main risk factors and to optimize future task allocation between human workers and robots. Therefore, the current study is focused on the ergonomic approach for the design of a new workstation with a collaborative robot.

2 Methodology

The industrial section is composed of 60 female workers, responsible for assembling medium density fiberboard (MDF) frames. In a previous phase of the research project, we verified that these workers presented different musculoskeletal problems related to their exposure to different risk factors, such as repetitive movements, hand-force application, and awkward postures. Based on this evidence, it was developed a new workstation to accommodate workers with musculoskeletal complaints. In this workstation—named "pre-assembly"—the process consists of gluing blocks in pre-determined positions on MDF stripes, as represented in Fig. 1. These will be later transformed in a subsequent workstation—named "final assembly"—into the final frames.

As schematically presented in Fig. 2, the tasks are as follows: (1) Reach for the stripes from pallet 1 and place them in the assembly workbench; (2) Pick the blocks from a box; (3) Reach for the glue gun; (4) Apply glue to the blocks; (5) Put down the glue gun; (6) Glue the blocks to the stripes; (7) Dislodge, rotate and place back the stripes to the workbench; (8) Dislodge the stripes; (9) Transfer the stripes to the pallet 2; (10) Resupply the glue gun.

A group of 8 workers was selected to test the new workstation (Figs. 2 and 3). This selection was applied by the company's practitioners, based on the prevalence of musculoskeletal complaints in this group, in order to test a workstation adapted to the workers' limitations. Foreseeing the implementation of a collaborative robot to support the assembly work, an ergonomic assessment was developed.

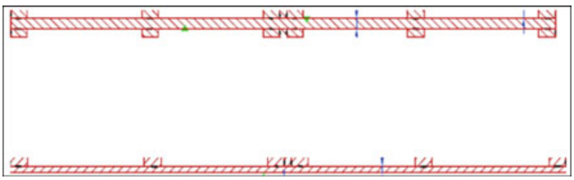

Fig. 1 Example of a subproduct of the workstation studied (MDF preforms)

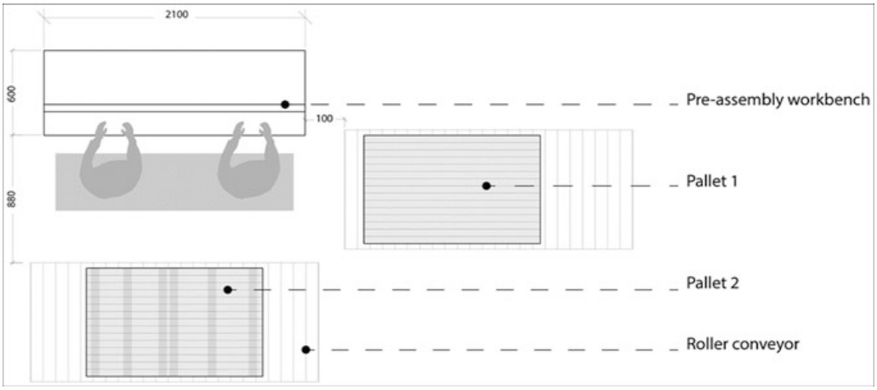

Fig. 2 Workstation organization (dimensions in mm)

Fig. 3 Examples of adopted postures

Primarily, a questionnaire was applied to the workers (n = 8). Demographic data, workers' perceptions about the working conditions and musculoskeletal symptomology were collected. The part of the questionnaire regarding the prevalence of musculoskeletal complaints was based on the Portuguese version of the Nordic Musculoskeletal Questionnaire (NMQ) [11]. The NMQ allows the identification of self-reported musculoskeletal symptomatology across 9 body regions (neck, shoulders, elbows, wrist, thoracic, lumbar, thighs/hips, knees, ankles/feet). For each of the body regions, the respondents have to indicate if felt pain/discomfort in the last 12 months and in the last 7 days. Relatively to the working conditions, the questions were based on the Ergonomic Workplace Analysis (EWA) method [12]. These questions were applied in order to achieve a comprehensive assessment of the workstation, across 14 topics (T), namely: (T1) workspace; (T2) general physical activity; (T3) lifting tasks; (T4) work postures and movements; (T5) risk of accident; (T6) work content; (T7) restrictiveness; (T8) workers' communication; (T9) decision-making; (T10) work repetitiveness; (T11) level of required attention; (T12) lighting; (T13) thermal conditions; and (T14) noise. These topics were assessed by a scale with a four-level rating scale: "very bad" (− −); "bad" (−);

"good" (+); "very good" (+ +) [12]. Questions related to the physical exertion self-reported for the assembly tasks were evaluated by Category Ratio-10 (CR-10) [13].

Posteriorly, the ergonomic assessment included the WMSD risk assessment by Rapid Upper Limb Assessment (RULA) [14], and Strain Index (SI) [15]. RULA method was used for assessing WMSD risk for the upper limbs, considering also the neck, trunk and lower extremities position during work activity. Its application involves the assessment of the postures adopted by the worker during task performance, as well as the forces exerted, the repetitiveness of movements and external loads (such as handling loads) [14]. The SI evaluates the musculoskeletal risk for the distal upper extremity disorders, considering 6 variables: the intensity of exertion, duration of exertion per cycle, efforts per minute, hand/wrist posture, speed of exertion, and duration of task per day [15].

The software IBM® SPSS® Statistics, version 26.0, was applied to analyze the results. A descriptive analysis of the data was conducted to calculate the mean values of quantitative variables (e.g. age). The workers' assessment in EWA and the prevalence of the musculoskeletal symptoms were expressed in a relative percentage, evidencing the values' distribution. The McNemar test—a specific test of the Chi-square for paired samples—was used in order to test the concordance between the musculoskeletal pain prevalence between the two periods considered in the NMQ (last 12 months and last 7 days). Finally, the ratings of exertion perceived by workers and the final ratings of RULA and SI were expressed using the mean as a measure of central tendency. The different ratings of RULA and SI were obtained by the analyst considering different postures for each task (a total of 3–6 postures most frequent for each task depending on the postural variability).

3 Results

3.1 Participants Characterization and Questionnaire Results

The sample of 8 female workers who tested the workstation present a mean age of 49.9 ($\pm$7.7) years old and they have an average work experience of 10.9 ($\pm$0.4) years at the assembly section (Table 1). All workers are right-handed and reported one or more musculoskeletal disorders, namely: carpal tunnel syndrome (n = 5), disc herniation (n = 1), tendinitis (n = 2). Relatively to the NMQ results (Fig. 4) the McNemar test proved that exists a perfect concordance (p = 1.000) between the workers' perceptions for the last 12 months and the last 7 days across the body regions considered. Therefore, the NMQ results presented in Fig. 4 are related to the prevalence of musculoskeletal discomfort/pain along the last 12 months (the more extended period of time). In addition, EWA results based on the workers' perceptions are presented in Fig. 5.

Table 1 Summary of the CR-10, RULA and SI results

Task	CR-10 (8 workers)	RULA (analyst assessment)		SI (analyst assessment)	
	Rating mean (SD)	Rating mean (SD)	Risk Level	Rating mean (SD)	Risk Level
Task 1	2.6 (0.5)	3.2 (0.4)	II	0.3 (0.1)	I
Task 2	2.1 (1.0)	3.6 (0.9)	II	1.5 (0.6)	I
Task 3	2.6 (1.4)	3.0 (n.a.)	II	1.2 (0.5)	I
Task 4	**4.1** (1.6)	3.0 (n.a.)	II	**5.1** (1.5)	III
Task 5	2.6 (1.4)	3.0 (n.a.)	II	1.2 (0.5)	I
Task 6	2.0 (0.9)	**4.4** (0.5)	II	1.0 (0.7)	I
Task 7	3.3 (0.7)	3.0 (n.a.)	II	0.6 (n.a.)	I
Task 8	2.1 (1.2)	3.2 (0.4)	II	0.1 (n.a.)	I
Task 9	1.8 (0.9)	**4.4** (1.3)	II	0.1 (n.a.)	I
Task 10	1.0 (n.a.)	3.0 (n.a.)	II	0.2 (0.1)	I

Legend: n.a.—not applicable

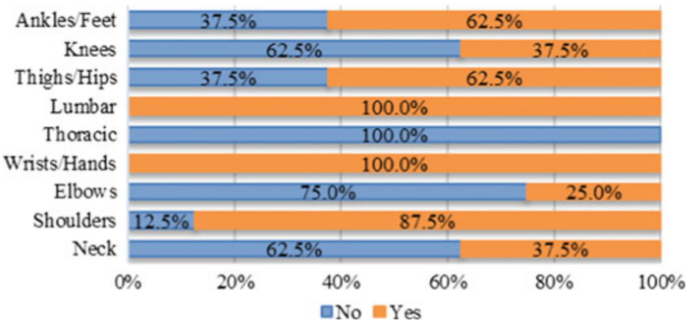

Fig. 4 Prevalence of musculoskeletal pain/discomfort across the different body regions

3.2 *Results of Exertion Perceived and WMSD Assessment*

The workers' perceived exertion to the 10 assembly tasks is presented in Table 1. The final mean ratings of the RULA and SI assessments are also presented. Figure 5 presents examples of postures adopted during the tasks with higher risk levels (according to the RULA and SI assessments).

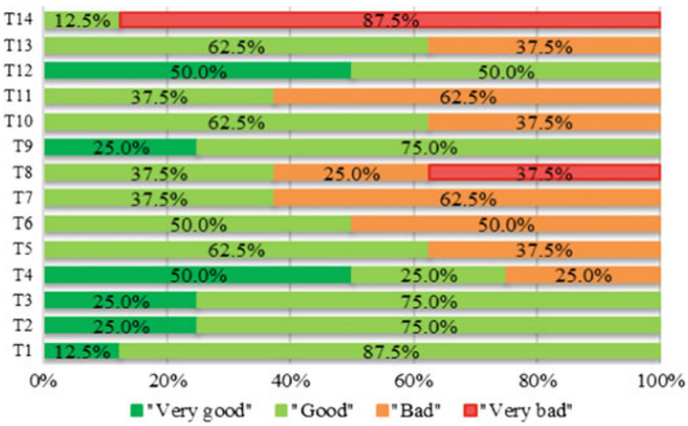

Fig. 5 EWA results—workers' assessment

4 Discussion

The NMQ results (Fig. 4) demonstrated that the body regions with a higher incidence of musculoskeletal problems are the lumbar region and the wrists/hands. The awkward postures and repetition of actions are important risk factors for these body regions and these factors are present in the workstation studied. Additionally, according to the workers' perceptions (Fig. 5), the most critical factors are noise (T14, with a more negative distribution of the answers); workers' communication (T8); restrictiveness (T7); and level of required attention (T11). Therefore, and even after the workstation redesign, the workers still complain about musculoskeletal discomfort, which indicates that this workstation could/should be further improved.

The main results of the RULA assessment indicate that Tasks 6 and 9 imply a higher musculoskeletal risk when compared to the other tasks. In Task 6 the upper limbs are more affected because of the posture adopted when gluing the blocks to the stripes. Figure 3 depicts the shape and size of the blocks handled, which leads to the frequent ulnar deviation and extension of the hand-wrist system. In Task 9, transferring the stripes transfer to the pallet affects primarily the neck and trunk sections. This is caused by the neck extension, the flexion, and inclination of the trunk, and by the bodyweight which is unevenly balanced. These findings reinforce the idea that the workstation should be redesigned for this task. The implementation of a lifting table should be considered as well as the elimination of the lateral roller conveyor. The actual design significantly compromises the workers' posture when transferring the subproducts to the pallet.

The fact that the majority of the workers present musculoskeletal disorders affecting the wrists (carpal tunnel syndrome) increases the concern about the risk assessment, which also includes methods more focused on the hand-wrist system, such as SI. The SI results pointed out to a higher musculoskeletal risk associated with Task 4 (apply glue), mainly due to the intensity exertion perceived by the 8 workers. According to the RULA, the higher risk rating was assigned to Task 6 (fix blocks), essentially for the upper body. These differences between the conclusions of different methods are related to the fact that they are measuring distinct variables. In addition to biomechanically unfavorable postures for the hand-wrist system, this task involves glue gun handling, increasing the musculoskeletal risk mainly due to the intensity of exertion associated (as evidenced by the mean values of CR-10 ratings reported by the workers).

Based on the current study, the implementation of a COBOT in this workstation could improve the ergonomic conditions. For instance, this technology could support the assembly tasks performed, eliminating the most critical tasks (such as Task 4—apply glue). The contributions of the E&HF scientific area must be considered in order to implement adaptive human-centered work systems. COBOTs allow a dynamic and seamless transition of task allocation between human workers and robots, providing inclusiveness and job satisfaction while meeting the production goals [3]. The workers' perception of load and health disorders are important indicators of the workload [12, 13] and based on this assumption, the workers' opinions must be included along with future work.

5 Conclusions

For the factories of the future, the adaptive human-centered design can potentiate the implementation of innovative technologies, such as the COBOTs. This implementation must consider inputs from E&HF in order to optimize the task allocation in HRC workstations. The results of this study showed that the introduction of a COBOT could improve this specific workstation, by subtracting the most critical tasks from workers, as well as to accommodate the workers with musculoskeletal disorders. Therefore, the current ergonomic assessment supports the future work associated with the COBOT implementation.

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References

1. Leso, V., Fontana, L., Iavicoli, I.: The occupational health and safety dimension of Industry 4.0. La Medicina Del Lavoro **109**(5), 327–338 (2018)
2. EFFRA—European Factories of the Future Research Association: Factories 4.0 and Beyond. https://www.effra.eu/sites/default/files/factories40_beyond_v31_public.pdf (2016). Last accessed 2019/08/05

3. Romero, D., Noran, O., Stahre, J., Bernus, P., Fast-Berglund, Å.: Towards a human-centred reference architecture for next generation balanced automation systems: Human-automation symbiosis. In: Umeda, S., Nakano, M., Mizuyama, H., Hibino, H., Kiritsis, D., von Cieminski, G. (eds.) Advances in Production Management Systems: Innovative Production Management Towards Sustainable Growth, vol. 460, pp. 556–566. Springer, Heidelberg (2015)
4. Pacaux-Lemoine, M.P., Trentesaux, D., Rey, G.Z., Millot, P.: Designing intelligent manufacturing systems through Human-Machine Cooperation principles: a human-centered approach. Comput. Ind. Eng. **111**, 581–595 (2017)
5. Heydaryan, S., Bedolla, J.S., Belingardi, G.: Safety design and development of a human-robot collaboration assembly process in the automotive industry. Appl. Sci. **8**, 2–22 (2018)
6. Salim, R., Johansson, J.: Automation decisions in investment projects: a study in Swedish wood products industry. Proc. Manuf. **25**, 255–262 (2018)
7. Lindström, V., Winroth, M.: Aligning manufacturing strategy and levels of automation: a case study. J. Eng. Technol. Manage. **27**, 148–159 (2010)
8. Lu, Y.: Industry 4.0: a survey on technologies, applications and open research issues. J. Ind. Inf. Integr. **6**, 1–10 (2017)
9. Bischoff, R., Kurth, J., Schreiber, G., Koeppe, R., Albu-Schäffer, A., Beyer, A., Eiberger, O., Haddadin, S., Stemmer, A., Grunwald, G., Hirzinger, G.: The KUKA-DLR lightweight robot arm—a new reference platform for robotics research and manufacturing. In: Joint 41st International Symposium on Robotics and 6th German Conference on Robotics 2010, ISR/ROBOTIK 2010, vol. 2, pp. 741–48 (2010)
10. Weiss, A., Huber, A., Minichberger, J., Ikeda, M.: First application of robot teaching in an existing industry 4.0 environment: does it really work? Societies **6**(3), 20 (2016)
11. Mesquita, C., Ribeiro, J., Moreira, P.: Portuguese version of the standardized Nordic musculoskeletal questionnaire: cross cultural and reliability. J. Public Health **18**(5), 461–466 (2010)
12. Ahonen, M., Launis, M., Kuorinka, T.: Ergonomic Workplace Analysis. Finnish Institute of Occupational Health. Ergonomics Section, Helsinki (1989)
13. Borg, G.: Psychophysical scaling with applications in physical work and the perception of exertion. Scand. J. Work Environ. Health **16**(suppl 1), 55–58 (1990)
14. McAtamney, L., Corlett, E.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1990)
15. Moore, J.S., Garg, A.: The strain index: a proposed method to analyze jobs for risk of distal upper extremity disorders. Am. Ind. Hyg. Assoc. J. **56**(5), 443–458 (1995)

Ergonomic Analysis in the Stamping Industry in Manufacturing and Comparison of Results with Nordic Questionnaire

Ana Sophia Rosado, Joana C. C. Guedes, J. Santos Baptista, J. Duarte, Alexandre Araújo and Mário A. P. Vaz

Abstract This study was carried out in a manufacturing industry, more precisely in the sector of stamping with two distinct processes. The objective was to analyze the risk of musculoskeletal injury since the activity demands repetitive movements, loading of pieces and use of force. For the ergonomic analysis, the cycle time, and the number of movements per cycle was measured, an analysis of the workstation and machinery, postural assessment and risks with OWAS, RULA, OCRA and NIOSH methods was performed. The Nordic Questionnaire was also applied to 100% of the workers, and the results were compared with those from the ergonomic analysis methods. It was possible to verify that the results are high-risk, especially due to repetitive activity and the manipulated weight. The Nordic Questionnaire ratified the result of the RULA method, regarding the regions of the body more harmed by the task. These methods are complementary and indicate the reason for the severity of the activity. It is important to improve the work conditions, including more pauses to rest and adopted machines to reduce inappropriate postural movements.

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Keywords Manufacturing industry · Ergonomic analysis · Risks · Validate the results

1 Introduction

The manufacturing industry, operating with a mass production model is very important under the commercial perspective. It has positive aspects regarding productivity and reduction of the value of the product. However, under the ergonomic aspect, this way of production is extremely harmful to workers health, due to repetition of movements, muscular fatigue and stress [3].

Studies have shown that this production model presents a high occurrence of occupational diseases, mainly in the upper limbs and lumbar spine, with repetitive activities and strength requirements [11]. The frequency of movements, requiring a unique muscular group, may lead to fatigue [17]. The wide range of movements allowed by the upper limbs, notably by the shoulders, but also elbow and wrist, can be harmful to physical hygiene [13]. Regarding the back, a study by Shanmugam et al. [16] found that the posture of the curved trunk causes severe damage to the lumbar spine. The other joints, mainly lower limbs are not as demanding in the manufacturing industry. However, it should be remembered that the orthostatic posture has potentially negative health implications, including discomfort in the lumbar region and lower limbs, and may influence cognitive function [2]. A very high workload leads to a predisposition of diseases and the improvement in the organization of tasks contributes to higher income [4]. So, it can be said that is important to evaluate the work postures and provide a healthy environment for the worker. The evaluation can be done using sophisticated methods, but also there are some simple approaches to apply, which are effective in finding risky activities.

The objective of this study was to analyze a manufacturing industry, that demand repetitive work of upper limbs, parts loading and orthostatic posture, and evaluate if the workers were exposed to risks that can cause musculoskeletal injuries.

2 Materials and Methods

The company works 24 h a day, in three shifts (1º: from 06:00 to 14:00 h; 2º: from 14:00 to 22:00 h; 3º: from 22:00 to 06:00 h), with two pauses (00:10 and 00:30 h). The data were all collected at the company during the 1th and 2nd shifts, during three weeks, including layout dimensions, verification of the activity, analysis of movements performed, measurement of body angles using a goniometer, counting the cycle time and the number of movements carried out by cycle. The measurements were made several times, with different workers and were considered the most serious to the musculoskeletal structure to the worker.

2.1 Production

Three machines were analyzed in the sector: the machine 1 stamp three models of parts; the machines 2 and 3 make the final touch of the parts. Important to emphasize that the weight, the dimensions and the handle of the pieces are different.

The production of machine 1 is:

- The 13.30 kg piece: 6 pieces every 1.0 min.
- The 4.70 kg and 5.60 kg pieces: 12 pieces every 1.0 min.

The production of machine 2 is:

- The 5.60 kg piece: one piece every 48.30 s.

The production of machine 3 is:

- The 4.70 kg and 13.30 kg pieces: one piece every 58.30 s.

Figure 1 represents the machine 1, its treadmill and containers where the workers execute the activity and lay down the pieces after the stamping process. Figure 2 represents the machine 2, which is the same as machine 3, the worktable and the containers to accommodate the final pieces.

Fig. 1 Machine 1

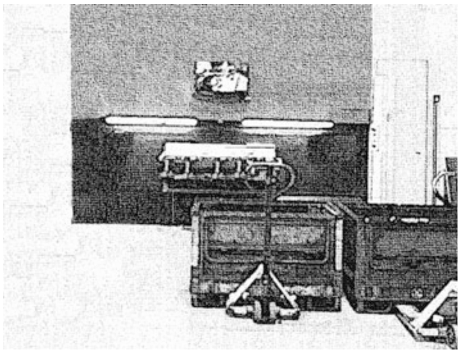

Fig. 2 Machines 2 and 3

2.2 Activity

The activity, briefly, consists of:

- On machine 1: The worker pulls the piece off the treadmill after the stamping process and puts it on the container; after, he removes small pieces of wood from a small box and puts them in the container, in order to prevent them from fitting in.
- On machines 2 and 3, the worker removes the workpieces from the container and puts them on the machine table that will make the final process. After the process, the worker removes the final piece from the table and packs it into the final container.

It is also important to emphasize the orthostatic position throughout the entire work shift. In machines 2 and 3 workers have space to move between the machine table and the containers. However, in machine 1 the workers stay in an orthostatic and static position.

Postures and measurements (body angles, cycle periods, number of movements per cycle) were measured in the first and second shifts. It was applied the Nordic Questionnaire to all workers in the analyzed sector (in the three work shifts) to better understand the work practices.

2.3 Population

There are 28 workers in the sector, 39% female and 61% male. It is important to emphasize that on machine 1 there are 8 workers, all men. On machine 2 there are approximately 6 workers and on machine 3 14 workers.

The workers are aged between 20 and 60 and almost every one of them has a normal weight according to the body mass index (BMI) (mean $\pm$ SD; age = 32.35 $\pm$ 11.34 years, body mass index = 24.07 $\pm$ 3.24 kg/m^2).

All the workers in the sector had started the activities approximately two months before the research began and, amongst them, 25% have never exercised a demanding activity leading to physical exertion and with repetition of movements.

The postural analysis and the body angle were measured using a goniometer. A total of 8 workers in the three machines were assessed. The Nordic Questionnaire was applied to 28 workers.

2.4 Analysis Methods

For the analysis, three machines were observed in all existing production situations. The workplace was observed, and the machinery was measured. Each activity has several tasks, each one being analyzed and assessed. The worker under analysis was observed at the beginning and at the end of the shift to verify all the movements and the most serious task. The measurement of all body angles was performed with the use of a goniometer; counting cycle times and number of movements per cycle. To verify the risk of the tasks, the following ergonomic analysis methods were used: OWAS [10], RULA [12], OCRA [7] and NIOSH [6], which confer a quantitative risk result according to the severity imposed by each one. These methods allow to verify the harmful tasks and if analyzed together the reasons for the risks can be detected. The Nordic Questionnaire is another method to investigate the painful symptomatology supported by the workers. Kuorinka et al. [9] developed the Nordic Musculoskeletal Questionnaire (NMQ), which presents a proposal to standardize the measurement of musculoskeletal symptoms reporting and enables the comparison of the results between the various investigations [5].

3 Results

It can be noted that in all assessments, the task of put the pieces in the final container is the most harmful, as it requires shoulder abduction (often above 90°), simultaneous rotation and flexion of the back (the worker can flex the back in up to 90°), neck extension, radial and ulnar deviation of the wrist (handle of the workpiece). However, the orthostatic position cannot be forgotten. Important to emphasize that in machine 1 the worker also remains in a static position, extremely harmful to the musculoskeletal system. The results of the methods, with the exception of the OWAS method, considered as a risky task are presented in Table 1. The spaces without values (“−”) result from the impossibility of implementing the ergonomic analysis method.

It was only possible to calculate the NIOSH in machine 1 because in the others there is displacement between the container and the stamping worktable. The risk of this machine was high.

The result of the Nordic Questionnaire showed that shoulder and lumbar spine are the most painful body parts. The results of the questionnaire corroborate the results of the ergonomic analysis methods, notably the RULA method.

Figures 3 and 4 demonstrate the risk in different parts of the body, which allowed to have the final result shown in Table 1.

Table 1 Results of ergonomic analysis methods

Machine	1	2	3
OWAS	3	2	2
RULA	7	7	7
OCRA	15	18	22
NIOSH	3.66	“–”	“–”

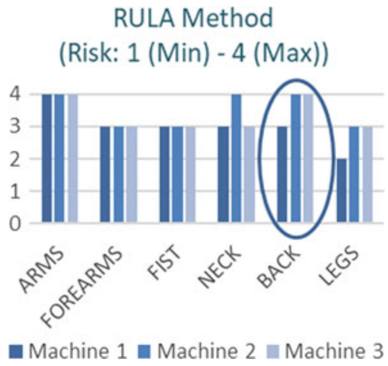

Fig. 3 RULA method result

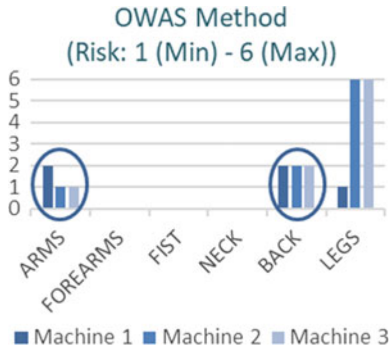

Fig. 4 OWAS method result

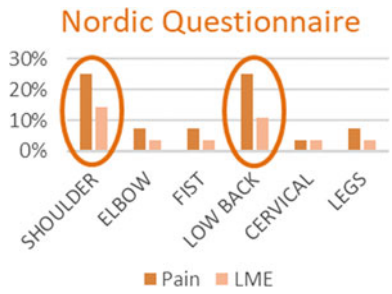

Fig. 5 Nordic questionnaire result

Figures 5 and 6 illustrate which body part is most painful according to the answers of the Nordic Questionnaire, as well as the percentual of supportable pain and extreme pain for the most painful body part.

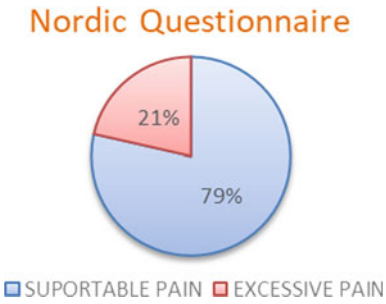

Fig. 6 Nordic questionnaire —pain

4 Discussion

Regarding the methods with the highest emphasis on the worker's posture, the overall result of the method RULA was of maximum risk for the three machines; the result was aggravated by the repetition of movements per minute and also by the weight of the pieces handled in the sector. The OWAS method, as previous studies have already proven, tends to minimize the risk in relation to the RULA [1, 8].

The OCRA method, corroborating the result, considered the activity at unacceptable risk in the three machines, as much as the result of the adapted NIOSH equation for machine 1. These results indicate that the activities should be re-assessed.

It should be clarified that the final container is packaged in a fixed bracket of 15 cm high. When the container is empty, to lay on the pieces, it requires forced postures of the worker.

The severity imposed, according to the methods, occurred due to:

(a) OWAS: shoulders (abduction); back (rotation and flexion). (b) RULA: wide angulation of the shoulders (abduction); back (flexion and rotation); wrist (radial and ulnar deviation on the handle of the pieces) [14]; neck (extension). The scoring has been aggravated due to the weight of the pieces and the number of repetitions per minute. (c) OCRA: small recovery period (intra-journey interval) and frequency (repetition of movements), associated with forced postures of the shoulders and wrists [15]. (d) NIOSH: Heavy load lifting and back rotation.

The lower limbs have not been instrumental to the risk by RULA method, such as the OWAS method for machine 1. However, on machine 1 the worker remains in an orthostatic and static position. The OWAS method considered high risk the activity in machines 2 and 3 for the legs. It is known that orthostatic and static position can cause discomfort and pain in the lower limbs and back, as well as severe circulation injures. Therefore, is important to ensure adequate rest. These positions are forced and consequently harmful to the musculoskeletal system, especially because they are adopted over 8 h a day.

The Nordic Questionnaire result shows that 50% for the workers suffer pain, especially in shoulders and lumbar spine, which are extremely required in the activity. Despite the pain, 21% related that the pain unfeasible the activities of daily life and work. It is important to emphasize that they get better on weekends. Corroborating the outcome of the questionnaire, the analysis by the RULA method makes it clear that the most painful structures are the arms, due to the angulations and repetitive movements of the shoulders, and the low back, by the forced postures of the lumbar spine.

Due to the high risk found by the analysis, it is important to think about improving the working conditions. Some improvements possible to be adopted are: introduce one more pause (00:10 h) to rest; re-study the support that accommodates the container; good practice training; increase the awareness about the bad posture risk.

The sample was representative and allowed to evaluate the risks which workers are exposed. However, the short time for the analysis prevented the evaluation with a larger sample. Future studies should consider a larger sample. Also, the research was made in wintertime, and could not be evaluated if the workers are eventually exposed to thermal stress, which certainly influences the activity performance and bodily functions. The analysis using more than one method allowed to compare the results and conclude the critical situations and the most painful body part.

5 Conclusions

The activities are especially demanding of the upper limbs, considering the intense repetition of movements throughout the daily work journey. The severity of the activity is evidenced by the results of the ergonomic analysis methods. The consequences of the activity are evidenced by the results of the Nordic Questionnaire, which result was of painful symptomatology in the shoulders and lumbar spine despite the workers have been performing the activity for a few months. Evidently, just a few months is not enough to establish a musculoskeletal injury. However, many workers reported pain, which is an indication that the activity deserves attention. The ergonomic analysis methods have a different focus on analysis and are complementary. Therefore, the importance of using them simultaneously. The present study also makes clear the importance of applying the Nordic Questionnaire to compare the results. In the present study, it was demonstrated that the Nordic Questionnaire ratified the evaluation of RULA. Despite the small sampling, the results, especially by RULA, OCRA and NIOSH methods, were extremely concordant, which allows believing the results of the evaluations. Of all analyzed tasks, the methods allowed to conclude that the most harmful is the placement of the pieces in the final container because it requires greater body angulation. The containers and brackets in which they are accommodated must be re-studied in order to be a suitable height for the workers. Reducing body demand would help to reduce pain, discomfort and eventual future injuries.

References

1. Al Madani, D., Dababneh, A.: Rapid entire body assessment: a literature review. Am. J. Eng. Appl. Sci. **9**(1), 107–118 (2016). Retrieved from https://pdfs.semanticscholar.org/52a2/ced2f754da589683aedd53fdbadca3136716.pdf
2. Baker, R., Coenen, P., Howie, E., Lee, J., Williamson, A., Straker, L.: Musculoskeletal and cognitive effects of a movement intervention during prolonged standing for office work. Human Factors **60**(7), 947–961 (2018). Retrieved from https://journals.sagepub.com/doi/full/10.1177/0018720818783945
3. Couto, H.A.: Body and Brain Ergonomics at Work: Principles and Practical Application. ERGO, Belo Horizonte (2014)
4. da Silva, J.C.P., Paschoarelli, L.C.: The Historical Evolution of Ergonomics in the World and its Pioneers (2010). Retrieved from http://books.scielo.org/id/b5b72/pdf/silva-9788579831201.pdf
5. Ferreira, A.B.: Prevalence of Symptoms of Work-Related Musculoskeletal Injuries: Contributions to Worker-Centered Intervention. Évora/Lisboa (2011). Retrieved from https://repositorio.ipl.pt/bitstream/10400.21/1589/1/Prevalência%20of%20symptoms%20of%20musculoskeletal%20injuries%20related%20to%20work.pdf
6. International Standard Organization: ISO 11228-1:2003 Ergonomics—Manual Handling—Part 1: Lifting and carrying (2003)
7. International Standard Organization: ISO 11228-3:2007 Ergonomics—Manual Handling—Part 3: Handling of Low Loads at High Frequency (2007)
8. Kee, D., Karwowsk, W.: A comparison of three observational techniques for assessing postural loads in industry. Int. J. Occup. Saf. Ergon. (JOSE) (2007). Retrieved from https://www.tandfonline.com/doi/abs/10.1080/10803548.2007.11076704
9. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., Jørgensen, K.: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. **18**(3), 233–237 (1987)
10. Louhevaara, V., Suurnäkki, T.: OWAS (Ovako Working Posture Analysing System). Finish Institute for Occupational Health, Helsinki. Institute of Occupational Health. Centre for Occupational Safety, Helsinky (1992)
11. Maitland, C., Manuals, T., Siz, S., Silva, S.: The Maitland Concept Associated with Kinesiotherapy as a Method of Treatment of Shoulder Impingement Syndrome, pp. 1–12 (2002)
12. McAtamney, L., Corlett, N.: Rapid upper limb assessment (RULA). In: Handbook of Human Factors and Ergonomics Methods, pp. 86–96. CRC Press (2004)
13. McDonald, A.C., Mulla, D.M., Keir, P.J.: Muscular and kinematic adaptations to fatiguing repetitive upper extremity work. Appl. Ergon. **75**, 250–256 (2019). Retrieved from https://doi.org/10.1016/j.apergo.2018.11.001
14. O'Young, B., Young, M.A., Stiens, S.A.: Secrets in Physical and Rehabilitation Medician (Artmed, Ed.), Porto Alegre (2000)
15. Pelet, D.: Kinesiology of the Wrist and Hand (2013). Retrieved from https://pt.scribd.com/doc/170132591/cinesiologia-punho-e-mao-aula-para-os-alunos
16. Shanmugam, M., Nehru, S., Shanmugam, S.: A wearable embedded device for chronic low back patients to track lumbar spine position. Biomed. Res. (0970-938X) (2018)
17. Vøllestad, N.K.: Measurement of human muscle fatigue. J. Neurosci. Methods **74**(2), 219–227 (1997)

Working Journey of Drivers of a Continuous and Eventual Freighting Company and Their Interventions: A Case Study

Andreia Cavalcanit de Oliveira, Thais de Almeida Rodrigues and Angelica Cavalcanti Teixeira

Abstract The article presents a case of study conducted in a company that operates in the field of employees and students transportation and aims to highlight the irregularities in the drivers working hours and their consequences for the professional and personal life of these workers. The methodology employed is based on the Ergonomic Work Analysis (EWA), through a process of demand instruction and social construction. An activity analysis was conducted through observational and interactive methods and techniques involving different sectors of the company, which allowed the choice, based on different criteria, of the characteristic situation studied. The results obtained with the distribution of these workers' schedules are allowed by the company, but given the specificity of the company, there are gaps between working hours, which are almost always completed by unscheduled trips, or that causes that there is a regularity in the working hours, as well as a work overload for the drivers of the analyzed company. The non-workload of these professionals is important for those who can achieve a satisfactory service for the population who directly or indirectly uses these transportation services. In this sense, it is essential to adopt practices that encourage the most frequent dialogues among all sectors of the case study, in addition to implementing simple measures such as redefining and organizing events, considering the variables that may arise in the company. in order to minimize the overhead that some worker may have on a particular work day.

Keywords Ergonomics · EWA · Driver · Chartering

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1 Introduction

The growth of Brazilian cities has been happening in an explosive and disorderly manner, resulting in public transport which concerns the entanglement of bus lines that operate with high cost and time wastes [2].

Faced with this problem evidenced in the daily life of Brazilian workers, the charter passenger transportation appears as an alternative presenting itself as a collective but individual transport service, mixing the benefits of public and private modalities. Its efficiency reflects people's daily lives providing an improvement in the quality of life, besides stimulating the development in the various Brazilian regions.

According to the National Transport Confederation [4], in recent years, this type of service has grown in Brazil, as it expands travel alternatives, thus serving a diverse group of passengers and their peculiarities In this context, Santos and Pinto [7] highlight some advantages of employee transportation through the charter system, which are: convenience, speed, increased productivity, decreased absenteeism, invulnerability to strikes in the public transport system.

The Brazilian Occupational Classification of the Ministry of Labor briefly describes the urban and road bus driver as a skilled professional who drives and inspects urban and road commuter vehicles (buses and trolley buses), checks the itinerary., controls passengers' boarding and disembarking, advising them on the fare, itineraries, embarkation and disembarkation points and procedures inside the vehicle. Thus performing procedures aimed at ensuring the safety and comfort of passengers [3].

Pereira [5], also emphasizes that the driver's activity is characterized by a set of regulations performed by the worker, which are structured throughout the experience, with a view to achieving the task's objectives and preserving their health. Thus, being the driver is considered a protagonist in the execution of this type of service.

The ergonomic analysis in this work environment will allow the observation of the current difficulties of these professionals, providing information that can be applied in the elaboration of proposals that can contribute to a positive transformation at work and that has repercussions in terms of comfort, health, safety and efficiency.

Zanelato and Oliveira (2004, apud Silva and Günther 1999) argue that the simple description of the bus driver's activities does not demonstrate the real work context of this professional. Literature Studies found that the most recurring approach is anthropometric ergonomic analysis of public urban transport drivers, so, there is a literary gap for the analysis of cognitive ergonomics of these professionals, especially in this segment of continuous and eventual charter. Therefore, this article aims to highlight the irregularities in working hours of drivers in this segment and their consequences for the professional and personal life of these workers.

2 Methods

The research is a case study based on qualitative and exploratory research, through Ergonomic Work Analysis (EWA), proposed by Wisner, 1987; Vidal, 2011 and Guérin, 2001. Data were collected through interactional and observational methods such as elaboration of semi-structured questionnaires, expanded listening, conversational action and on-site observations. Audiovisual recordings were also made for better understanding the activity.

The study demand is defined as a provoked demand, where possible problems are researched in order to identify situations that may become real situations, coming from and/or authorized by the organization [6].

Firstly, theoretical research was conducted on possible "daily situations" situations faced daily by bus and urban bus drivers through scientific articles, dissertations, theses and reports. Then, hypotheses of experience were formulated referring to situations already experienced and observed by the study team and/or reported by some of these professionals.

The aforementioned stages allowed a greater familiarity with the activity studied both for the elaboration of the research instruments and for the necessary contribution to conversational actions in decisive moments of demand construction in the focus situation (Saldanha 2004). The social construction was based on the structuring of a participative, technical and managerial action which is developed from the demand construction stage in an ergonomic intervention. It is made up of groups of people who are involved, directly or indirectly, in a particular work situation, participating in the survey, validations and restitutions of information, in order to allow knowledge about the activity analyzed and the implementation of improvements [8; Saldanha, 2004].

The global analysis allowed us to identify the general operation of the company, to know its population, to confirm some hypotheses of demand raised by the theoretical study and the living situations and the emergence of new demands, these called institutional demands.

This stage was carried out in systematic visits from June to October, 2018. In addition to the General Directorate, People Management and team of mechanics, five drivers who work in the transportation of factory employees and students were interviewed.

Vidal [8] says that the effective functioning of an ergonomic action requires a participatory, technical and managerial structure of action. For this, it is important to involve the research group with distinct groups that constitute the company. The process of social construction of the research was progressively being built with the visits made in the organization. Initially, contact was sought with our privileged interlocutor (business consultant) in order to establish a bridge of arrival to the company. This interlocutor later joined our ergonomic action group.

The restitution of the information collected and validation of the demands raised were performed from meetings held with the research team, as well as business consultant, people manager, general manager and drivers.

3 Results and Discussion

3.1 Company Characterization and Work Population

This research was conducted in a company that operates in the services segment, specifically in transportation of employees, students and tourist charter. Located in a traditional neighborhood in the west of the city of João Pessoa, capital of Paraíba state, its wide area covers the metropolitan region of João Pessoa and Brazilian states.

With over 20 years of experience, the organization was one of the pioneers in the transportation of employees in Paraíba, as well as the first to have wheelchair accessible bus. Its staff currently consists of 32 employees, distributed among drivers, administrative assistant, secretaries, general service assistants and garage staff. Drivers are distributed by bus type and performance, as shown in Table 1.

Although its performance also encompasses tourism charter, this article focuses on drivers working in the chartering of company employees and students, as they present similarities in the problems highlighted, ranging from the organization of work to personal aspects, in addition to the similarity between your activities. Table 2 presents the problems reported by the drivers interviewed during the survey.

3.2 Bus Driver Activity

The activity of public transportation, according to Battiston et al. [1], covers both micro and macros aspects. When it comes to the vehicle (bus) and the workplace, the macros address a broader structure, such as traffic and its interactions with other vehicles, cyclists and pedestrians, pollution and with weather conditions, for example. These aspects, in short, correspond to the actual driver activity.

Table 1 Performance/Population (drivers)

Bus type division	Number of vehicles	Number of drivers	Performance
Tourism (road)	5	5 (criteria of choice according to direction)	Intercity and interstate trips Special trips
Chartering (local bus station)	10	10	Employee transport Special trips
Buses for school activities	7	7	Student transport (municipal schools)

03 extra buses to support (1 urban and 2 road)

Table 2 Problems found

Problems found		Subsegments	
		Charter	School
Health	Stress caused by passenger/driver relationship	X	X
	Inadequate food	X	X
Safety	Risk of traffic accidents	X	X
	Hearing disorders	–	X
	Lack of camera tracking inside vehicles	X	X
Work organization	Complicated routes (drawn by non-skilled traffic professionals, difficult places to reach with buses)	X	–
	Unconventional hours	X	–
	Full availability for the company	X	X
	Special trips at break times	X	X
Workers	Lack of time for personal activities	X	–
Responsibility	Working with kids	–	X
	Schedule compliance	X	X

Working Time Irregularities

The specificity of the sub-segment of chartering of company employees and student transportation allowed us to understand the existence of shortcomings in the drivers 'working hours, considering that the distribution of these professionals' hours in this organization is adjusted according to the demand of the current contracts.

From conversational interactions not only with the professionals under study, but also with the company consultant, privileged interlocutor, who later joined the ergonomic action group, it was possible to verify that these gaps presented between working hours, reported in the Tables 3 and 4, are almost always filled by unscheduled trips (special trips), which causes a non-regularity of working hours. It is important to emphasize that the time scales are subject to change, given the dynamism of signed and extinguished contracts.

The drivers' reports reinforce that the special trips, sometimes presented during the exercise of the activity, also called by the organizational management as variability, is something common in the development of their work, considering the size

Table 3 Work scale—school transportation driver

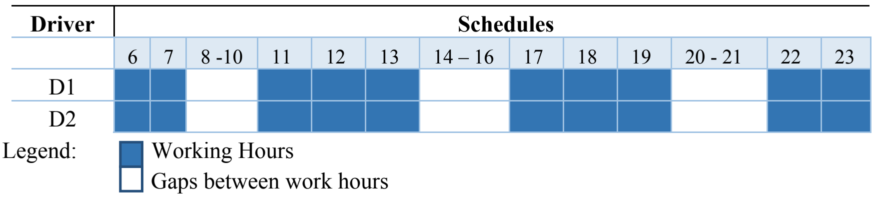

Table 4 Work scale—employee contract driver

Driver	Schedules													
	4	5	6	7	8-12	13	14	15	16	17	18- 20	21	22	23
D3		■	■	■		■	■	■						
D4	■	■				■	■					■	■	
D5			■	■		■	■		■	■				

Legend: ■ Working Hours
□ Gaps between work hours

of the company, as well as its bus fleet be one of the most up-to-date in the region, which demands a high demand for its services. According to the business consultant (privileged interlocutor), this reality of the variabilities inserted in the daily work of these professionals is not something specific of this organization, but rather an intrinsic practice for companies that operate with continuous and eventual charter.

[…] "Special trips always happen. Almost every day we have one." […] [Driver Interview Report, 2018].

[…] "The company says: If you don't want to, you have thousands wanting your place" […] [Driver Interview Report, 2018].

[…] "They have definite schedules, but when it is necessary they make special trips. Here everything is dynamic, nothing is the same. There is something different every day" [People Management Interview Report, 2018].

Within this environment, it can be seen that the working hours of bus drivers do not have regularities, because the variabilities, often reported by the People Manager as something sporadic, are actually usual during the course of their job. The activity performed by these professionals follows the logic represented in Fig. 1.

Reflections of Complications in the Daily Life of Drivers

In the company studied, the driver's activity goes beyond the act of driving the vehicle, considering that these professionals perform vehicle inspections before and after the end of their activities, and some knowledge of car mechanics is needed to better assist them during the daily work. It is also observed that the same worker can work in both the transportation of employees and the transportation of students, depending on the daily demand of the company.

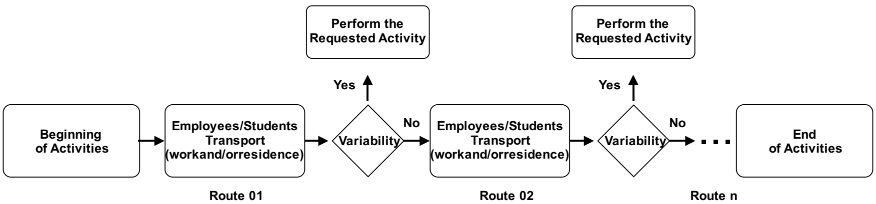

Fig. 1 General scheme of driver performance

Table 5 Concurrences recorded during the research period

Complications	
Unforeseen	Special trips
Bus crash and/or driver replacement	Rental of buses for football teams, military police and other purposes Rent for funerals/burials Election Campaigns/Party Conventions School Games/After School Activities/Congresses/ Driver replacement events were recorded due to the large flow of interstate travel in July (vacation) Religious tourism. From August to December these trips intensify

The work environment, with its irregular working hours, as well as the driver's narratives, reinforce that the complications, presented in Table 5, cause to these professionals a state of "alertness", making them always available, being harmful not only to their personal but also professional development. The high demand for jobs and the low supply of jobs were also exposed in their speeches as a risk factor, making them submit to the reality exposed by their current field of work.

Because they spend many hours working, either at the wheel of vehicles or at the disposal of "special trips", professionals have little time for affective investment in the family and social circle to which they belong. In addition to the long period devoted to work, the constant alertness provides stress and restriction of student ties, whether in formal education or other activities related to their professional training, according to reports.

[…] "When we think we were free, there comes the news of a new trip. So we need to find a way to fit our schedules" […] [Driver Interview Report, 2018].

[…] "I was thinking about continuing my studies, I tried, but because of the hours I couldn't continue" […] [Driver Interview Report, 2018].

The irregularity of work schedules, given the specificity of the company, causes a work overload on these professionals, which impact not only on their professional life, but also on their personal life. Such adaptation to the environment requires time and, failing this, can have negative consequences on the Individual's health, such as lack of attention, concentration, fatigue, stress, among other diseases.

4 Conclusions

To achieve the objective of this research, a methodology based on Ergonomic Work Analysis (EWA) was used, thus, it became possible to know and understand the reality faced by drivers in a company of continuous and eventual charter. This methodology, especially in the social construction stage, clarified the understanding of the performance of the activity performed by these workers, as well as its variability, as far as its occurrence is concerned as well as the damage caused by the use of operators that affect the diversity of activities. Situations and their consequences.

The results found in this research showed that the activity of the drivers of the company studied is not limited only to what is pre-established by the organization, because in addition to their common routine, these workers deal with the fulfillment of alternative schedules that appear in their daily lives, called “special trips”. Thus, these professionals submit to the characteristics and peculiarities of the services pro-vided by the company, such as irregular hours, which cause them some discomfort directly impacting their health and personal life.

The non-workload of these professionals is important for anyone who can achieve a satisfactory service for the population who directly or indirectly uses these transportation services. In this sense, it is essential to adopt practices that encourage the most frequent dialogues among all sectors of the case study, adopting feedback systems that can help the exchange of workers’ experiences and promote the growth of the company as a whole. In addition, it is necessary to implement simple measures such as a redefinition and organization of hours, considering the variables that may arise within the company, an end of pressure for overload and any worker who may have a certain workday. Improving how working conditions offered positively influence the performance of the activity that has satisfactory repercussions for drivers, users and the organization.

The present study sought to highlight that the special trips, often seen by members of the organization as just an occasional event, become continuous throughout the drivers’ activity, generating an overload work that impacts not only on the development of the activities but also in their personal lives.

In the academic field, the research becomes of significant relevance, given the scarcity in the literature about the activity of drivers who work in the chartering of employees and school transportation, stimulating research in this area that is still little explored.

It is also worth noting that this research has limitations inherent to the case study, focusing its study on a particular case, and therefore cannot be generalized to other contexts. Based on the results found through this research, it is suggested that validations be made, with the drivers, of the improvement proposals suggested in this article, as well as to verify if they are contributing to improve the work environment, and if so, There was a higher rate of productivity and satisfaction among employees and transport users.

References

1. Battiston, M., Cruz, R.M., Hoffman, M.H.: Working Conditions and Health of Urban Public Transport Drivers, 3rd edn. Psychology Studies, Rio Grande do Norte (2006)
2. Lerner, J.: Comparative Assessment of Urban Public Transport Practices, 1st edn. National Association of Urban Transport Companies, Curitiba (2009)
3. Ministry of Work. http://www.mtecbo.gov.br/cbosite/pages/home.jsf. Last accessed 2018/08/10
4. National Transport Confederation—CNT. https://www.cnt.org.br. Last accessed 2018/08/10
5. Pereira, B.S.: Working Conditions of Urban Public Transport Drivers: The Impact of Dual Activity on Worker Mental Health, 18th edn. Brazilian Congress of Ergonomics (2016)
6. Saldanha, M.C.: The construction of ergonomic demands: application on artisan fishing using jangada fishing rafts in the beach of Ponta Negra. Work (Reading, MA) **41**, 628–635 (2012)
7. Santos, J.M., Pinto, R.R.S.: Chartering—An Attractive Alternative to Combat Individual Transport, 15th edn. Brazilian Congress of Transport and Transit (2003)
8. Vidal, M.C.: Guide to ergonomic work analysis (EAW) in the company, 1st edn. Virtual Scientific Publisher. Rio de Janeiro (2011) Author, F.: Article title. Journal **2**(5), 99–110 (2016)

Management of Acoustic Comfort in Learning Spaces Using Building Information Modelling (BIM)

Antonio J. Aguilar-Aguilera, M. L. De la Hoz-Torres, M. D. Martínez-Aires and Diego P. Ruiz

Abstract The acoustic environment is a crucial factor in learning spaces. Variables such as reverberation time and sound pressure level may interfere with the student's learning process. In order to guarantee the achievement of acoustic comfort requirements in educational buildings, the design and performance of acoustic conditions should be analyzed from the earliest stages of the project. The analysis of acoustic parameters has usually been performed with specialized software. However, the emergence of the Building Information Modelling (BIM) has represented a new approach to the projects in the Architecture, Engineering and Construction sectors. In this context, the BIM methodology offers one solution to this problem. This study proposes the use of the BIM methodology to improve the acoustic environment of educational buildings. For this purpose, a BIM tool has been developed by the authors to perform a simulation of reverberation time, sound pressure level and critical distance based on the architecture characteristics stored in the BIM model.

Keywords Building information modelling · BIM · Decision support · Learning spaces

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1 Introduction

Acoustic performance analysis is essential in spaces where a teaching-learning process takes place. A poor acoustic environment in classrooms can have an impact on academic, psychoeducational and psychosocial performance [1] and student attainment [2, 3]. It has significant effects on word identification and intelligibility [4] and may cause physical stress [5] and voice problems for teachers [6]. In consequence, acoustical comfort is crucial in determining the quality of educational processes. Many studies show that high values of reverberation time (RT) in classrooms produce low efficiency in verbal communication between teachers and students, and hence, the learning process is slower. Intelligibility and speech recognition performance are degraded by background noise (e.g. of rooms with negative signal-to-noise ratios) or high RT [7, 8].

Due to the effects of poor acoustic conditions on speech perception, short-term memory and general understanding [9, 10], an analysis of the acoustic performance of learning spaces should be carried out at the design stage of the project. National and international acoustical standards for teaching and learning spaces reflect the importance of determining the classroom's acoustics suitability [11–13].

Factors such as the finishing material of interior surfaces, sound insulation and background noise are part of the complex mechanism of speech understanding [14]. Auditory experience within a room is shaped by the materials of its surfaces. The acoustic properties of materials play an important role in acoustic performance since materials absorb sound energy at difference levels and this varies across frequencies. Acoustic comfort can be improved through analysing these factors at the design stage of the project.

In this context, the Building Information Modelling (BIM) methodology offers an opportunity for designers, engineers and architects to develop this analysis. BIM is defined as the process to generate, store, manage, exchange and share information of the building [15]. The 3D BIM model is a digital representation of the physical and functional characteristics of the building [16]. BIM has the potential to improve not only construction processes [17] but also to enable the exploration of alternative approaches. Furthermore, BIM methodology can be used toward a better understanding of environmental conditions [18]. This study presents a design tool integrated in BIM methodology in order to support decision-making and contribute to achieving a comfortable acoustic environment in learning spaces. RT and Sound Pressure Level (SPL) distribution is simulated based on the architecture characteristics stored in the BIM model (geometry and non-geometry data). The tool was tested in two different scenarios with the same dimension and different finishing material acoustic properties.

2 Methodology

2.1 Acoustic Simulation

RT and SPL were included in the simulation of the acoustic performance. On the one hand, RT is defined as the time (in seconds) it takes for the sound from a source to decrease in level by 60 dB after the source has ceased [19]. This acoustical variable can negatively affect speech perception and is often considered the most important acoustical variable that defines the acoustical environment of a classroom [1]. RT was calculated using the formula defined by Sabine, which describes the reverberation phenomenon in the statistical acoustic field theory of the room [19] (Eq. 1).

$$T = \frac{0.161 * V}{A} \tag{1}$$

where V is the room volume (m^3) and A is the total absorption area in the room calculated using the Eq. 2.

$$A = \sum_{i=1}^{n} \propto_{m,i} S_i + \sum_{j=1}^{N} + 4\overline{m_m}V \tag{2}$$

where $\propto_{m,i}$ is the average acoustic absorption coefficient of each facing; S_i is the facing area with coefficient of absorption $\propto_{m,i}$ (m^2); $\overline{m_m}$ is the average sound absorption coefficient in air; V is the volume of the room (m^3).

RT is one of the parameters commonly limited by regulations. Table 1 shows some of the maximum values for RT for various types and sizes of classrooms. These values are established by standards adopted by different governments.

Table 1 Recommendations for RT values in teaching-learning spaces

Standard	Classroom	RT requirements (s)
Spain [20]	Unfurnished and unoccupied rooms, Volume < 350 m^3	RT $\leq$ 0.7
	Unoccupied	RT $\leq$ 0.5
Portugal [21]	Volume $\leq$ 250 m^3	RT $\leq$ 0.12 V1/3
	250 m^3 < Volume $\leq$ 90,000 m^3	RT $\leq$ 0.32 + 0.17 log(V)
	Volume > 9000 m^3	RT $\leq$ 0.05 V1/3
Denmark [22]	Furnished rooms	RT $\leq$ 0.6
France [23]	Furnished, unoccupied rooms	0.8 < RT < 1.0

*(V—room volume)

Meanwhile, the SPL at certain distances from the sources was calculated using Eq. 3.

$$L_{p(r)} = L_W + 10\log\left(\frac{Q}{4\pi r^2} + \frac{4(1-\alpha)}{\alpha S}\right)(\mathrm{dB}) \tag{3}$$

where $L_{p(r)}$ is the SPL at the distance r between the source and receiver; L_W is the acoustic sound power level of the source; α is the average sound absorption coefficient; S is the total absorption area in the room; Q is the directivity coefficient of the sound source. In this case, as human talkers do not radiate speech uniformly in all directions, human voice directivity has been considered (Fig. 1).

The listener position with respect to the source and the room configuration are very important factors since speech perception can be affected through the masking of direct and early-reflected energy by reverberant energy [1]. The distance from the source to the receptor at which the level of direct sound, in the process of its wavefront spreading, becomes equal to the reflected sound level is the Critical Distance (CD). The direct sound is represented in Eq. 3 by the first term of the bracket and the diffuse sound field is represented by the second term. So, the CD is the distance at which the two terms are equal (Eq. 4).

$$CD = \sqrt{\frac{\alpha S Q}{16\pi(1-\alpha)}} \tag{4}$$

In an enclosure such as a room, if the listener is outside the CD around the sound source, the level of reflected or reverberant sound is above that of direct sound and speech perception may be affected by reverberant energy (consisting of early and late reflections) [25]. Sound energy reflected is delayed in time relative to the direct sound and it can change some important aspects of the acoustic information of speech. Therefore, speech intelligibility at the back of a classroom will be affected by reverberation, since acoustic energy is dominated by the reflected sound.

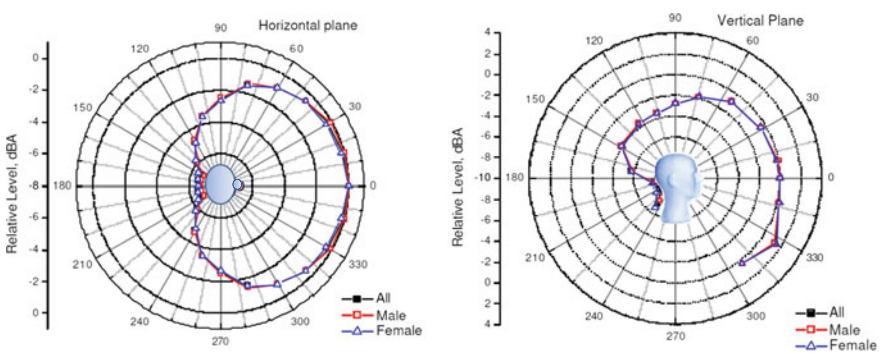

Fig. 1 Vertical and horizontal directivity of male and female talkers [24]

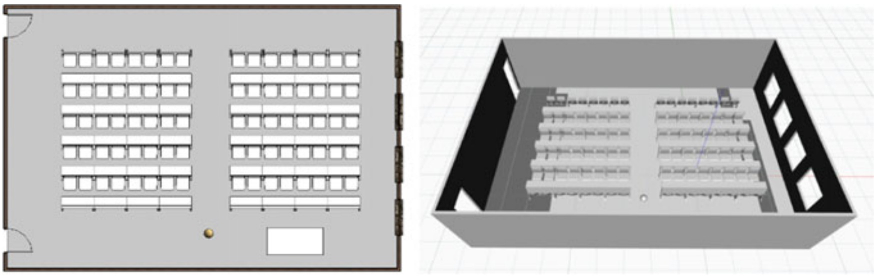

Fig. 2 Classroom size and layout

BIM methodology provides a 3D model on a platform where information can be extracted on demand. The dimensions, surfaces and volume of the rooms can be calculated based on the dimensions of the elements that constitute the BIM model.

2.2 Test Scenario

A basic 3D building was used to test the tool. Figure 2 shows the room where the BIM tool was tested. The room dimensions are 12.50 m × 8.60 m × 2.50 m, 269 m^3 of volume and 320.5 m^2 of absorption area. Two scenarios were considered to perform the acoustic simulation: Scenario A has a low mean coefficient absorption (0.15) and scenario B which has a higher mean coefficient absorption (0.25).

3 Results and Discussion

The SPL distribution and RT associated to the different scenarios are shown in Fig. 3. As expected, scenario A has a lower average absorption coefficient so the value of the RT in this room is higher. In that case, the room would not meet the requirements established by some of the regulations cited in Table 1. At the points furthest from the source, the SPL in scenario A is higher than the same points in scenario B (with a difference of 3 dB). This is mainly due to the fact that the acoustic properties of the finishing materials of the room in scenario A absorb less sound energy than the finishing materials of the room in scenario B.

However, although the SPL in the last positions of scenario A is higher than in scenario B, it does not result in better intelligibility in those positions since it depends almost entirely on the sound energy reflected by the room's surfaces. If the listener position is within the critical distance, the reflected sound will not influence speech perception. However, if the distance between the listener and the source is greater than CD, the reverberation can compromise the intelligibility and perception

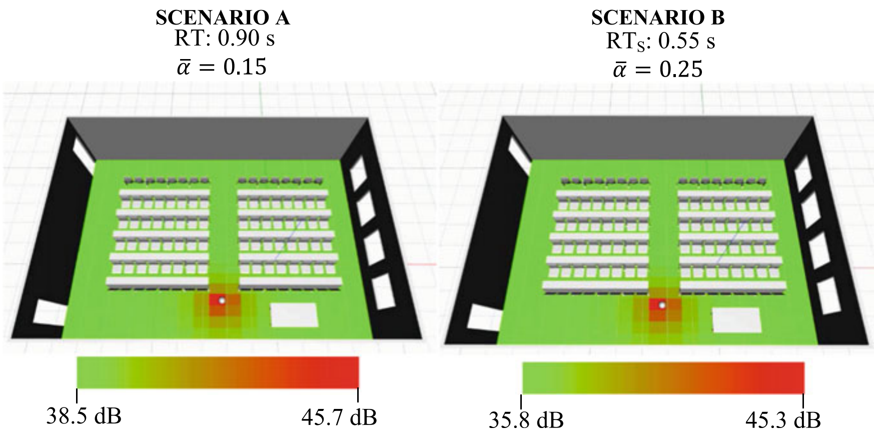

Fig. 3 SPL distribution in scenario A and scenario B

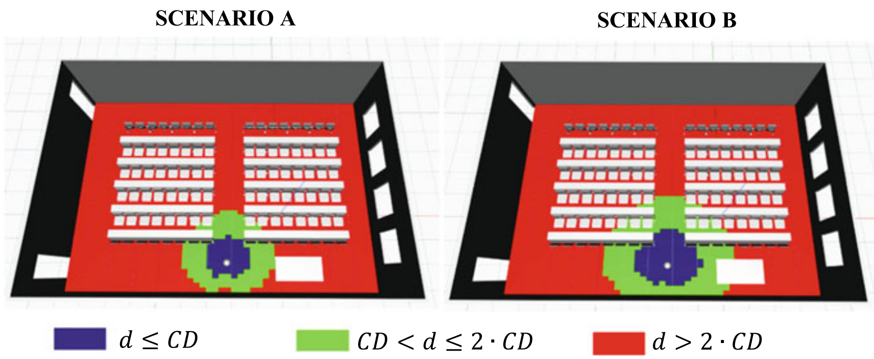

Fig. 4 Critical distance in scenario A and scenario B

of the speech message. For these reasons, the CD is an important variable to consider in learning-teaching spaces since it depends on the characteristics of the room itself. The results obtained from the BIM tool for CD in both scenarios are shown in Fig. 4, where d is the listener-teacher distance.

In addition, the BIM tool simulates the direct sound propagation from the source. Figure 5 shows the direct sound energy distribution depending on the location of the source (Position 1 of the teacher in the center of the class and position 2 of the teacher in the lower left corner).

From the results obtained, it can be concluded that the BIM tool allows the acoustic performance of the room to be simulated from the analysis of the SPL, RT and CD. Analyzing acoustic performance based on the dimensions and acoustic properties of the materials of interior surfaces allows the interference of the acoustic environment conditions with speech perception and general understanding to be considered.

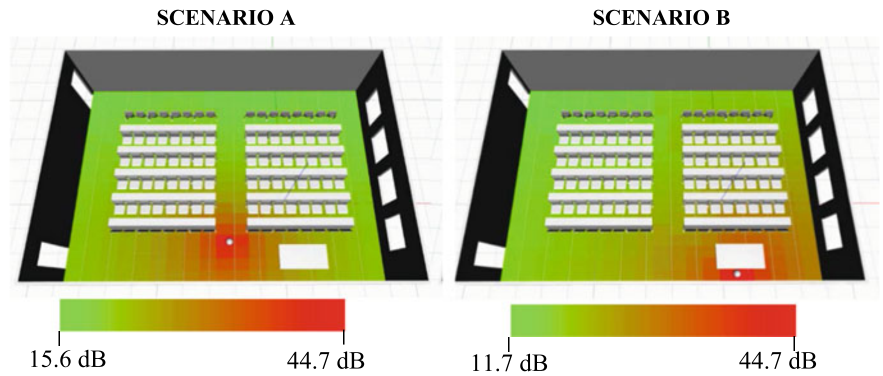

Fig. 5 Direct sound energy distribution in position 1 and position 2

4 Conclusions

The achievement of acoustic comfort in educational buildings requires the design and simulation of acoustic conditions from the initial stages of the project. BIM methodology offers one solution to the acoustic problem of educational buildings. This study proposes a tool to simulate acoustic performance in a BIM implementation for teaching-learning spaces. The time needed for acoustic simulation is reduced and the tool ensures that the buildings will meet the acoustic performance required for intelligibility and the acoustic environment in classrooms. The impact of this tool's adoption on the design process involves: (i) anticipating decision-making to ensure listeners' and teachers' acoustic comfort, (ii) the tool allows direct design-simulation without the translation from BIM to a different software, which avoids error and (iii) using BIM technology to simulate building acoustic performance can also facilitate the sharing of information/knowledge among the designers, engineers, contractors, and facility managers that take part in the project. The results obtained in this study prove that this tool allows designers and acoustic engineers to improve the teaching-learning process in educational buildings and to obtain access to better organized information for material and spatial organization.

References

1. Crandell, C.C., Smaldino, J.J.: Classroom acoustics for children with normal hearing and with hearing impairment. Lang. Speech Hear. Serv. Schools **31**(4), 362–370 (2000)
2. Shield, B.M., Dockrell, J.E.: The effects of noise on children at school: a review. Building Acoust. **10**(2), 97–116 (2003)

3. Shield, B.M., Dockrell, J.E.: The effects of environmental and classroom noise on the academic attainments of primary school children. J. Acoust. Soc. Am. **123**(1), 133–144 (2008)
4. Klatte, M., Hellbrück, J., Seidel, J., Leistner, P.: Effects of classroom acoustics on performance and well-being in elementary school children: a field study. Environ. Behav. **42** (5), 659–692 (2010)
5. Krüger, E.L., Zannin, P.H.: Acoustic, thermal and luminous comfort in classrooms. Build. Environ. **39**(9), 1055–1063 (2004)
6. Kristiansen, J., Persson, R., Lund, S.P., Shibuya, H., Nielsen, P.M.: Effects of classroom acoustics and self-reported noise exposure on teachers' well-being. Environ. Behav. **45**(2), 283–300 (2013)
7. George, E.L., Goverts, S.T., Festen, J.M., Houtgast, T.: Measuring the effects of reverberation and noise on sentence intelligibility for hearing-impaired listeners. J. Speech Lang. Hear. Res. (2010)
8. Neuman, A.C., Wroblewski, M., Hajicek, J., Rubinstein, A.: Combined effects of noise and reverberation on speech recognition performance of normal-hearing children and adults. Ear Hear. **31**(3), 336–344 (2010)
9. Ljung, R., Sörqvist, P., Kjellberg, A., Green, A.-M.: Poor listening conditions impair memory for intelligible lectures: implications for acoustic classroom standards. Build. Acoust. **16**(3), 257–265 (2009)
10. Chetoni, M., Ascari, E., Bianco, F., Fredianelli, L., Licitra, G., Cori, L.: Global noise score indicator for classroom evaluation of acoustic performances in life gioconda project. Noise Mapp. **3**(1), (2016)
11. America, A.S.o. American National Standard: Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools. American National Standards Institute Mellville (2010)
12. Nen 5077. Delft: Noise Control in Buildings—Determination Methods for Performances Concerning Airborne Sound Insulation of Facades, Airborne Sound Insulation, Impact Sound Insulation, Sound Levels Caused by Technical Services and Reverberant Time (2006)
13. Önorm, B.: 8115-2, 2006 12: Schallschutz und raumakustik im hochbau-teil 2: Anforderungen an den schallschutz. Österreichisches Normungsinstitut
14. Nijs, L., Rychtáriková, M.: Calculating the optimum reverberation time and absorption coefficient for good speech intelligibility in classroom design using u50. Acta Acustica United with Acustica **97**(1), 93–102 (2011)
15. Vanlande, R., Nicolle, C., Cruz, C.: IFC and building lifecycle management. Autom. Constr. **18**(1), 70–78 (2008)
16. Azhar, S., Nadeem, A., Mok, J.Y., Leung, B.H.: Building information modeling (BIM): a new paradigm for visual interactive modeling and simulation for construction projects. In: Proc., First International Conference on Construction in Developing Countries, vol. 1, pp. 435–446 (2008)
17. Aguilera, A.A., López-Alonso, M., Martínez-Rojas, M., Martínez-Aires, M.: Review of the state of knowledge of the BIM methodology applied to health and safety in construction. In: Occupational Safety and Hygiene V: Selected papers from the International Symposium on Occupational Safety and Hygiene (SHO 2017), 1st edn, April 10–11, 2017, Guimarães, Portugal, p. 447 (2017)
18. Habibi, S.: The promise of bim for improving building performance. Energy Build. **153**, 525–548 (2017)
19. Sabine, W.C., Egan, M.D.: Collected Papers on Acoustics, ASA (1994)
20. Codigo Tecnico de la Edificación: Documento básico he. Protección frente al ruido. Ministerio de Fomento de España (2009)
21. Decreto do presidente da república n.º 34/2008 de 9 de junho. Diario da república, 1ª série- nº 110 de junho de 2008
22. Danish Transport, Construction and Housing Authority: Bygningsreglement 2018 (building regulations 2018). Copenhagen, Denmark (2017). http://bygningsreglementet.Dk (with link to

english version). Note: Br2018 refers to br2018 vejledning om lydforhold (br2018 guideline for acoustic conditions). http://bygningsreglementet.Dk/tekniskebestemmelser/17/vejledninger
23. Conseil national du bruit. Guide du cnb réglementations acoustiques des bâtiments (2017)
24. Chu, W., Warnock, A.: Detailed Directivity of Sound Fields Around Human Talkers. National Research Council Canada, IRC-RR-104 (2002)
25. Mijić, M., Masovic, D.: Reverberation radius in real rooms. Telfor J. **2**(2), 86–91 (2010)

Exposure to Musculoskeletal Risk of Piano Teachers

Casimira Lima, André Roriz, Andreia Leite, Ana Colim and Paula Carneiro

Abstract Music professionals usually suffer from Musculoskeletal Disorders (MSD). However, there is a bad culture regarding ergonomic risk. Musicians are a professional group subject to the most varied ergonomic risks, from instrument design to the time it takes to perfect their work. This paper aims to understand and evaluate the ergonomic risk in a group of professional musicians, mainly of pianists working at a Portuguese conservatory of music. For the investigation, it was applied a modified Nordic Questionnaire and RULA method. The body regions with higher prevalence of musculoskeletal complaints during the last 12 months were the neck (80%) follow by the lower back (40%). The results from the application of RULA indicate that an ergonomic intervention is needed.

Keywords Ergonomics · Pianists · PRSMD · RULA · WMSD

1 Introduction

1.1 Ergonomics and Musicians

Ergonomics relates to man, in order to design tools, machines, among others so that they can be used with maximum comfort, safety, and efficiency [9].

One of the issues most related to ergonomics is the presence of musculoskeletal disorders (MSD), mainly related to work (WMSD). There are several risk factors of MSD, such as job type, repetitive movements, stress, and awkward postures. Musicians are not usually considered as having a risky activity. However,

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musculoskeletal disorders are very common among these professionals, and sometimes the musculoskeletal stress to which they are subjected may reach the limit of their physiological capacities [2, 7]. For this reason and other similar, such as high competitiveness, many hours of training, requiring great physical ability, introduction into the activity at a very early age, etc., professional musicians are often compared to competitive athletes. However, they are rarely taught about how to prevent or deal with MSD, unlike professional athletes [13]. Several studies suggest that MSD in adult professional musicians is at least as prevalent as in any other professional activity [7, 11, 14].

Since there is such a strong association between the practice of an instrument and MSD, the latter has been referred to as playing-related musculoskeletal disorder (PRMSD) [16].

A literature review shows that there is a high prevalence of MSD among professional musicians, pointing to values between 60 and 80% [2, 5]. In a study of professional musicians from the three main orchestras in northern Portugal, the results show that 84.8% of respondents suffer from musculoskeletal problems related to their professional activity. The most affected areas were the shoulders, and the cervical and lumbar areas [12]. A study on piano students [2] revealed that 34.8% of respondents suffered from MSD. The most affected areas were the neck (29.3%), thoracic spine (21.3%) and upper limbs (between 20.0 and 30.4%). Older students were the hardest affected, suggesting that problems worsen as time goes by. A musician's performance requires physical strength at the upper limb level to precisely execute combinations of fast, complex, repetitive and sometimes asymmetrical movements. This while the remaining muscles make the effort to maintain body posture. Frequent associated static muscle work results in excessive stress on muscles, tendons, and joints, leading to musculoskeletal pain and may even lead to chronic pain syndrome. Musculoskeletal discomfort causes musicians to avoid optimal postures [11]. The combination of poor postures and repetitive movements is particularly problematic and contributes to muscle damage, tendonitis and nerve damage [3, 4, 7, 13]. MSD can be broadly classified as traumatic or atraumatic/overuse. In musicians, the most frequent are atraumatic, which do not have clearly visible signs, such as swelling or bruising. This leads to a more moderate perception of risk and acceptability, which leads to preventive care not being taken [13]. There is also a certain "culture of silence" in relation to pain and musculoskeletal disorders, as the idea that pain is necessary to achieve goals exists among musicians or aspiring professional musicians [2, 4, 13, 15]. Many musicians develop overuse syndromes that manifest even after short periods of practicing their instruments. Continued practice may lead to permanent morphological changes, which may start to manifest early on, such as hyper or hypomobility, scoliosis, winged scapula, among others. These changes may constitute physical limitations that may be detrimental to other activities [4].

There is a high prevalence of PRMSD among pianists however, risk factors directly related to piano are not well studied [2]. Musical instruments were designed without regard to any ergonomic principle. This may lead its use too demanding for their anthropometric capabilities. Some instruments have specific characteristics that may predispose musicians to disorder [4].

Some basic rules must be followed in order to protect the musculoskeletal system: the head, thorax, and pelvis must always be aligned with the longitudinal axis of the body to maintain the natural flexion of the spine (neutral position). Deviation from this position is always non-ergonomic and has a negative impact on the musculoskeletal system [11]. The appearance of postural asymmetries resulting from the design of the instrument is common [4]. While standing musicians can use their whole body to compensate for asymmetrical movements, for sitting musicians this is not so easy to do [11].

1.2 Objectives

This paper aims to understand and evaluate the ergonomic risk in a group of professional musicians, mainly of pianists working at a Portuguese conservatory of music, as well as to give suggestions for the elimination, or mitigation, of musculoskeletal disorder risk for these professionals.

2 Materials and Methods

2.1 Modified Nordic Questionnaire

In order to verify what kind of symptoms the Conservatory musicians felt, a questionnaire was conducted using an online tool, *Google Forms*, and it was based on the Portuguese version of the Nordic Questionnaire [8]. Then, the questionnaire was sent via email to the teachers/musicians of the Guimarães Conservatory of Music being answered anonymously.

2.2 RULA Assessment

Based on the responses to the questionnaires, the study was focused on the pianist/piano teachers. The movement performed by these professionals is essentially static except for the upper limbs. Accordingly, the Rapid Upper Limb Assessment (RULA) method [6] was applied to assess the ergonomic risk. The evaluation was performed on two pianists of the opposite sex but within the same age group.

At first, the worst posture the pianists adopted has been registered through photographs and videos. Then RULA was applied in three phases. In the first phase, the postures of the arm, forearm, and wrist were evaluated. In the second phase, the

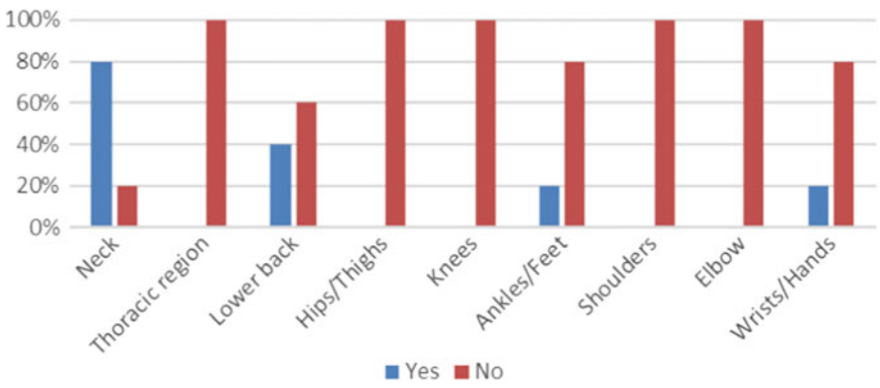

Fig. 1 Prevalence of musculoskeletal pain/discomfort during the last 12 months

postures of the neck, trunk, and lower limbs were assessed. In the two referred phases it was also considered a muscle utilization score and the load/strength score. Finally, in the third phase, the scores of the two phases were crossed and the risk level, as well as the level of action for each pianist posture, was determined

3 Results

3.1 Modified Nordic Questionnaire

The questionnaire application obtained 10 responses, of which fifty percent of responses were piano teachers/pianists. Concerning this sample, four respondents out that felt musculoskeletal pain in the last year affecting the neck (Fig. 1), but the intensity was relatively low. Two pianists presented severe pain in the lower back over the same period, and one of them was absent from professional activity. No responses were found for previously diagnosed musculoskeletal disorders.

3.2 RULA Assessment

RULA evaluation was applied considering two pianists (Fig. 2). The worst posture was considered and the RULA final score was equal to 4 and 5 (for each one, respectively). According to the guidelines of RULA, these scores indicate that an ergonomic intervention is needed, existing musculoskeletal risk related to the postures. A physical factor that influences these scores is the seat used by the pianists. It is common practice using a seat that is adjustable to the pianist's height, but it does not have any lumbar support. Another risk factor is the inexistence of a program of warm-up exercises. In addition, there is no ergonomic prevention plan.

Fig. 2 Posture of the two pianists used for RULA assessment

4 Discussion

Based on the modified Nordic Questionnaire [8], the results obtained are consistent with the literature, and the most affected areas, among professional musicians and more specifically, pianists, are the neck and lumbar regions [2, 4, 5]. The RULA results are also coincident with the results of these previous studies, since these are the body regions with more postural stress noted. The forearm, upper arm, shoulders, and trunk muscles are the regions more affected by the repetition of movements. The high prevalence of disturbances in these zones suggests that a high level of muscular static contraction over long periods of time and forced positions occur during the piano performance. These efforts often and almost strictly involve the use of the muscles of these regions.

RULA analysis also revealed that there are several factors that may lead to the occurrence of PRMSD that are not analogous to all practitioners. It has already been mentioned that musical instruments are not built according to ergonomic principles and people with different anthropometric characteristics may be more likely to develop MSD than others. However, this is not the only differentiating factor between musicians who play the same instrument (even considering different brands, models and different technical characteristics). *Posture is the relational and intentional movement through which musicians express their musical dialogue* [1]. Different musicians express a different body language. In addition, different techniques may have different biomechanical needs, so a musician may be more exposed to a musculoskeletal risk due to the individual technique applied [4, 10]. During the current study, different postures were observed between the pianists, being evidenced on the RULA results. This may also be indicative of why only two of the five pianists report major problems, although they are all in the same age range and have been practicing for about the same number of years. Note that one of the pianists who had the most problems practiced less years ago than the others. Both pianists who reported major problems were female, but there is not well-established correlation in the literature between females and a higher incidence of PRMSD, although several studies point to this [2]. Small sample size that does not allow generalizing results. The response rate to the questionnaires was relatively low, even considering only the conservatory population, so an appropriate or representative statistical study cannot be done. However, this study allows us to perceive some postural patterns existing in pianists. In this case a larger sample would also be important to understand if the most problematic cases are outliers or help to establish a pattern.

The fact that there is no ergonomic prevention plan while worrying, is not uncommon. Music training focuses primarily on sound quality and never on the physical characteristics required to achieve it or the risk of MSD. In addition, music teachers generally lack the technical skills needed to help their students prevent MSD. This is a problem that spreads through the generations as the student often becomes the teacher. Even when musicians seek health help, it is not very effective, as it only serves to treat the disorders suffered and there is no articulation with the assessment of professional activity. That is, to be efficient, interventions must be made by looking at the musician with and without his instrument [2, 4, 15].

4.1 Improvement Opportunities

Although several authors advise the incorporation of warm-up exercises in the musicians' routine, data collected in the literature have shown that this has no impact on the prevalence of MSD. Regarding breaks, the literature shows that they have an impact on MSD reduction and help in learning. Each 60-min period should be followed by a pause, which does not seem to be very relevant [2]. It is also important to create ergonomic prevention plans and they should be part of the curriculum. This prevention should be achieved through collaboration between teachers and specialist health professionals [2, 4, 11, 15]. Although not easily accessible, there are some anthropometric instrument sizing options [4]. As for the piano, the acting plan seems to be mainly focused on the seat. A study by [10] found that although softer cushioning has a better effect on reducing the pressure distribution about postures, the seat characteristics appeared to have no correlative effect. Some methods, such as the Alexander Technique (AT) or Feldenkrais, recognize the unique context in which musicians work. AT aims to make musicians aware of their movement patterns in order to correct them by inhibiting old patterns and redirecting them to new movements [4]. It is also important to be aware of the control of pain and disorder as they begin to appear. Pain seems to be accepted by musicians as something necessary to achieve goals. Thus, teachers should be more alert to signs of disorder, as well as urge students to warn and seek help [13, 15]. If this preventive behavior is taught to students now, tomorrow's teachers will be better prepared and the incidence of PRMSD will be lower.

5 Conclusions

In general, the pianists are a risk group for MSD. The instruments themselves and the supports are not ergonomically designed. It is urgent to act and raise awareness through training, ergonomic plans, medical and physical therapy support, among others. The results obtained in the Nordic Questionnaire as well as in RULA are supported by the literature used throughout the study. However, there are few publications in the area of ergonomics that identify the causes for this type of musician-related musculoskeletal injury and portray these cases from an injury prevention perspective and assess their ergonomic risks. Therefore it's important to do more studies in this area [17]. This study represents a small population of pianist musicians, it would be important to carry out further study in this area, not only for pianists, but for musicians in general.

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References

1. Batson, G.: Traditional and nontraditional approaches to performing arts physical therapy: the dance medicine perspective. Orthop. Phys. Ther. Clin. N. Am. (1997)
2. Bruno, S., Lorusso, A., L'Abbate, N.: Playing-related disabling musculoskeletal disorders in young and adult classical piano students. Int. Arch. Occup. Environ. Health **81**(7), 855–860 (2008). https://doi.org/10.1007/s00420-007-0279-8
3. de Lima, J., Simonelli, A.P.: Análise ergonômica da atividade dos músicos da Orquestra Sinfônica do Paraná: fatores de risco e cargas de trabalho. Cadernos de Terapia Ocupacional Da UFSCar **22**(1), 89–95 (2014). https://doi.org/10.4322/cto.2014.010
4. Dommerholt, J.: Performing arts medicine—instrumentalist musicians, Part II—examination. J. Bodywork Mov. Ther. **14**(1), 65–72 (2010). https://doi.org/10.1016/j.jbmt.2009.02.004
5. Kaufman-Cohen, Y., Portnoy, S., Sopher, R., Mashiach, L., Baruch-Halaf, L., Ratzon, N.Z.: The correlation between upper extremity musculoskeletal symptoms and joint kinematics, playing habits and hand span during playing among piano students. PLoS One **13**(12), 1–13. https://doi.org/10.1371/journal.pone.0208788
6. Mcatamney, L., Corlett, E.N.: RULA: a survey method for the investigation of world-related upper limb disorders **24**(2), 91–99 (1993)

7. Mehrparvar, A.H., Mostaghaci, M., Gerami, R.F.: Musculoskeletal disorders among Iranian instrumentalists. Med. Probl. Perform. Art. **27**(4), 193–196 (2012). Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23247875
8. Mesquita, C.C., Ribeiro, J.C., Moreira, P.: Portuguese version of the standardized Nordic musculoskeletal questionnaire: cross cultural and reliability. J. Public Health **18**(5), 461–466 (2010). https://doi.org/10.1007/s10389-010-0331-0
9. Miguel, A.: Manual de Higiene e Segurança do Trabalho (13[a]). Porto Editora, Porto (2014)
10. Ohlendorf, D., Maurer, C., Bolender, E., Kocis, V., Song, M., Groneberg, D.A.: Influence of ergonomic layout of musician chairs on posture and seat pressure in musicians of different playing levels. PLoS One **13**(12), 1–15 (2018). https://doi.org/10.1371/journal.pone.0208758
11. Ohlendorf, D., Wanke, E.M., Filmann, N., Groneberg, D.A., Gerber, A.: Fit to play: posture and seating position analysis with professional musicians—a study protocol. J. Occup. Med. Toxicol. **12**(1), 1–14 (2017). https://doi.org/10.1186/s12995-017-0151-z
12. Sousa, C.M., Machado, J.P., Greten, H.J., Coimbra, D.: Occupational diseases of professional orchestra musicians from northern Portugal: a descriptive study. Med. Probl. Perform. Art. **31**(1), 8–12 (2016). https://doi.org/10.21091/mppa.2016.1002
13. Stanhope, J.: Physical performance and musculoskeletal disorders: are musicians and sportspeople on a level playing field? Perform. Enhancement Health **4**(1–2), 18–26 (2016). https://doi.org/10.1016/j.peh.2015.11.004
14. Zaza, Christine: Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ **158**(8), 1019–1025 (1998)
15. Zaza, C., Farewell, V.T.: Musicians' playing-related musculoskeletal disorders: an examination of risk factors. Am. J. Ind. Med. (1997). Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edo&AN=ejs1858753&site=eds-live
16. Zaza, C.: Musicians' Playing-Related Musculoskeletal Disorders: An Examination of Physical, Psycological, and Behavioural Factors (Dissertation). University of Waterloo (1995)
17. Žuškin, E., Schachter, E.N., Kolčić, I., Polašek, O., Mustajbegović, J., Arumugam, U.: Health problems in musicians—a review. Acta Dermatovenerol. Croat. **13**(4), 247–251 (2005)

Experimental Assessment of Thermal Sensation and Thermal Comfort of Sedentary Subjects: A Scoping Review

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Abstract Background: Office workers spend most of their time engaged in sedentary tasks. Dissatisfaction with the thermal environment can reduce work efficiency and productivity. Objectives: This study presents the condensed results of a scoping review of the scientific literature assessing thermal sensation (TS) and thermal comfort (TC). The scoping review focuses on the experimental assessment of TS and TC. Eligibility criteria: The scoping review only considered peer-reviewed articles written in English. Grey literature, commissioned reports, and conference papers were excluded. Sources of evidence: The studies were retrieved from the PubMed, Scopus, and Web of Science databases. The search criteria considered the expression ("thermal comfort" OR "therm* sensation" OR "thermosensation") AND ("sedentary"). Charting methods: The data charting process or data extraction was based on the preparation of tables to compile the key findings of the selected articles. Results and conclusions: In total, 39 peer-reviewed articles were considered suitable for the scoping review. The scoping review shows that the existing international standards to predict TC may fail when multisensorial aspects are considered, when TS and TC are assessed over different times during the exposure to a thermal environment, and when different populations are considered.

Keywords Thermal sensation · Thermal comfort · Sedentary · Scoping review

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1 Introduction

Thermal stress can affect cognitive performance and the health of exposed individuals, which are predictive factors of reduced work efficiency and productivity. Individuals, in general, spend about 55% of their time engaged in sedentary activities, a level that rises to 75% among office workers [1, 2]. This study presents the condensed results of a scoping review that assess how the thermal sensation (TS) and the thermal comfort (TC) of individuals engaged in sedentary activities are being experimentally investigated in the scientific literature to identify and summarize the existing research evidence and to identify the current gaps in the scientific literature.

2 Methods

This scoping review follows a review protocol based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA-P) [3]. The scoping review itself follows the PRISMA-ScR guidelines [4]. All items of the PRISMA-ScR guidelines are satisfied in this document, except for item 16, since critical appraisal of individual sources of evidence is not conducted.

2.1 Eligibility Criteria, Information Sources, Search, and Selection of Sources of Evidence

This scoping review only considered peer-reviewed articles published or in press. Grey literature and commissioned reports, conference papers and publications not written in English were excluded. The articles were found in the PubMed, Scopus, and Web of Science databases (the last update was on July 1, 2019). Additionally, a snowballing approach was adopted for the identification of articles and it considered the search for articles in the reference sections of the selected full-text peer-review articles.

The first search consisted of obtaining results for two groups of keywords. The selected terms were linked through the Boolean operators ‘AND’ and ‘OR’ as follows: (“thermal comfort” OR “therm* sensation” OR “thermosensation”) AND (“sedentary”).

The scoping review considers all studies evaluating humans in laboratory experiments. Only experiments conducted in climatic chambers (due to their high degree of control and reproducibility) with healthy adults of both genders engaged in sedentary activities (up to a limit of 1.5 met [5]) were considered. Besides this, only articles evaluating TS and/or TC subjectively were considered suitable.

2.2 Data Charting Process, Data Items, Synthesis of Results, and Critical Appraisal of Individual Sources of Evidence

The data charting process or data extraction was based on summary tables to compile the key findings of the eligible articles. Data items assessed were divided into two groups: general and specific synthesis. In the first group, bibliometric aspects and the experimental design were assessed.

The assessment of the experimental design considered the presence of written consent, duration of the experiment, sample size, characteristics of the sample, objective parameters measured, and scales adopted to conduct subjective assessments. In the specific synthesis, articles were categorized according to the parameters considered in the laboratory assessment of TS and TC.

The risk of bias in individual studies was assessed in this scoping review. Additionally, the risk of meta-biases was not conducted since the selected articles did not support meta-analysis.

3 Results

3.1 Selection and Characteristics of Sources of Evidence

From the information sources and the search strategy defined in the review protocol, 762 articles were identified in the selected databases, from which 110 were duplicate records. After removing duplicates, 23 articles not written in English and 131 records classified as grey literature were excluded. From the remaining articles, 460 were not within the scope of this research or did not meet the eligibility criteria. Two articles were included from the snowballing approach [6, 7]. Finally, 39 peer-reviewed articles were selected for qualitative analysis (Fig. 1).

All the selected articles evaluated the TS and/or the TC reported by participants subjected to different experimental conditions in climatic chambers. The articles were published from 1967 to 2019 in Argentina (1 article), China (8 articles), Denmark (5 articles), France (2 articles), Japan (6 articles), South Korea (3 articles), United Kingdom (5 articles), and the United States (9 articles).

3.2 Synthesis of Results

Only 5 of the selected articles stated that written consent from the subjects was obtained or that the experiments were approved by an ethics committee. The experiments lasted from 28 min [9] to 540 min [10, 11], an average of 172 min. Most studies considered both male and female populations.

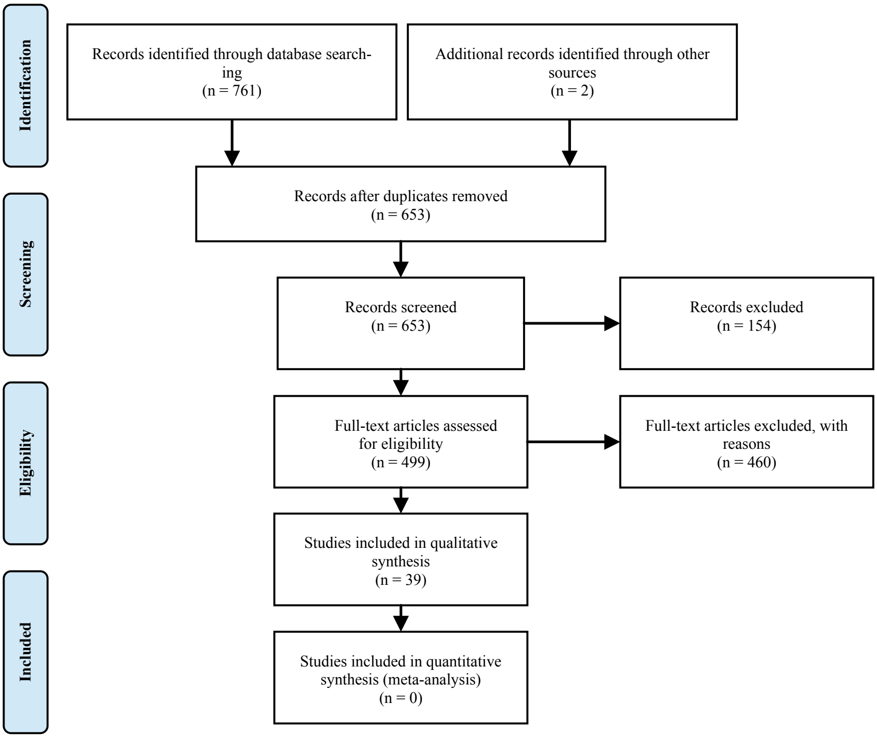

Fig. 1 PRIMA flow diagram for the scoping review. Adapted from Moher et al. [8]

Whenever it was possible, the age is represented by the average and standard deviation. Only 5 articles did not disclose the age of the participants. All the selected articles considered an adult population, even though some included elderly people [12, 13]. Height and weight were disclosed in 23 of the selected articles. Body fat was only reported in 5 studies. Body fat was only reported in 5 studies. Other anthropometric measurements, such as the body max index and skin surface area, were reported by a few articles.

The measurement of the skin temperature is the most used objective parameter to assess TS and/or TC, reported in 25 articles, followed by rectal temperature, reported in 8 articles. Most articles only considered the overall TS and TC. The assessment of local thermal discomfort was only presented in 8 articles.

The 7-point TS scale presented in ISO 7730:2005 [14] and ASHRAE 55-2010 [15] was most often used to assess TS (13 articles). The assessment of TC presented wider variability of scales, yet the use of the two scales can be highlighted: (i) a 4-point scale ranging from +1 (comfortable) to +4 (very uncomfortable) −5 articles, and (ii) a 4-point scale, ranging from −3 (very uncomfortable) to 0 (comfortable) −4 articles.

3.3 Results of Individual Sources of Evidence

The studies included in the qualitative synthesis were classified into five groups, according to the scope of the laboratory experiments (Table 1). These groups were defined as follows: (i) assessment of TC parameters, (ii) effects of other parameters, (iii) effects of fatigue, boredom, performance or similar, (iv) TS or TC of a group, and (v) other aspects.

Table 1 Summary of reviewed articles per category and sub-category

Category	Sub-category	References
Assessment of thermal comfort parameters[a]	Air temperature	Gagge et al. [7], Kakitsuba [10], Kakitsuba and White [11], Griffiths and McIntyre [16], Zhang and Zhao [17]
	Air velocity	Kubo et al. [13], Du et al. [18]
	Clothing insulation	Lee et al. [12], Choi et al. [19], McIntyre et al. [20], Kwon and Choi [21]
	Relative humidity	McIntyre [22]
	Several parameters simultaneously	Berglund and Gonzalez [23], Jin, Zhang [24], Kakitsuba [25], Lee et al. [26], Rohles and Nevins [27], Toftum et al. [28], Fan et al. [29]
Effects of other parameters	Air temperature and noise	Pellerin and Candas [30]
	Color and noise	Fanger et al. [31]
	Interior design	Rohles and Wells [32]
	Period of the day	Fanger et al. [33], Fanger et al. [34]
	Other	Garretón et al. [9], Yang and Moon [35]
Effects of fatigue, boredom, performance or similar	Drowsiness, boredom, and fatigue	Beshir and Ramsey [36]
	Manual dexterity	Castellani et al. [37]
	Mental performance	Wyon et al. [38]
Thermal sensation or comfort of a group	Chow et al. [39], Chung and Tong [40], Grivel and Candas [41], Zhang et al. [42]	
Other aspects	Assessment of ventilation system Comparison of environments Comparison of local and overall thermal comfort Scales and indexes	Cheng et al. [43] Oseland [44] Arens et al. [6] Gonzales et al. [45], McIntyre [46], Hasebe et al. [47]

[a]This classification refers to parameters related to the TC equation (clothing insulation, temperature, humidity, air velocity) [14]

4 Discussion

The 7-point scale proposed both by ASHRAE 55-2010 and ISO 7730:2005 [14] was the most used scale to assess TS, while the assessment used for TC varied greatly across studies Most studies reported the existence of gender differences in TS and TC. Additionally, some studies demonstrated differences in TS and TC experienced by adults and the elderly [12, 13].

The effects of multisensorial aspects were evaluated by a few articles. Older studies did not demonstrate strong correlations of TS and/or TC with such aspects. More recent studies identified that TS and TC may affect and be affected by the noise and/or illumination level [30, 35]. Another finding is that TS and TC can vary over time while the environmental conditions remain constant [10, 11, 28, 30, 43, 44]. Finally, some of the reviewed articles also demonstrated changes in the TC zone of different populations of the World [39–42].

The selected articles differed substantially in their experimental procedures and data treatment. Therefore, the selected articles were only assessed qualitatively and a quantitative synthesis through meta-analysis was not conducted. The fact that none of the selected studies only considered a thermoneutral environment and the use of different scales for the subjective assessment of TS and TC further complicates the comparison of results.

5 Final Remarks

This scoping review sheds light on how TS and TC of subjects engaged in sedentary activities are assessed experimentally in the scientific literature. It assessed a total of 39 articles published from 1967 to 2019 in peer-reviewed journals. The results suggest that current standards may fail to predict TC when multisensorial aspects of the environment are considered (such as noise and illuminance), when the assessment of TS and TC is conducted over the exposure time to a thermal environment, and when different populations are considered.

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References

1. Kim, Y., Welk, G.J.: Characterizing the context of sedentary lifestyles in a representative sample of adults: a cross-sectional study from the physical activity measurement study project. BMC Public Health **15**, 1218 (2015)
2. Thorp, A.A., et al.: Prolonged sedentary time and physical activity in workplace and non-work contexts: a cross-sectional study of office, customer service and call centre employees. Int. J. Behav. Nutr. Phys. Act. **9**(1), 128 (2012)
3. Moher, D., et al.: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst. Rev. **4**(1) (2015)
4. Tricco, A.C., et al.: PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation the PRISMA-ScR statement. Ann. Intern. Med. **169**(7), 467–473 (2018)
5. SBRN: Letter to the Editor: Standardized use of the terms “sedentary” and “sedentary behaviours”. Appl. Physiol. Nutr. Metab. **37**(3), 540–542 (2012)
6. Arens, E., Zhang, H., Huizenga, C.: Partial and whole-body thermal sensation and comfort—part I: uniform environmental conditions. J. Therm. Biol **31**(1), 53–59 (2006)
7. Gagge, A.P., Stolwijk, J.A.J., Hardy, J.D.: Comfort and thermal sensations and associated physiological responses at various ambient temperatures. Environ. Res. **1**(1), 1–20 (1967)
8. Moher, D., et al.: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLOS Med. **6**(7), e1000097 (2009)
9. Garretón, J.Y., Rodriguez, R., Pattini, A.: Effects of perceived indoor temperature on daylight glare perception. Build. Res. Inf. **44**(8), 907–919 (2016)
10. Kakitsuba, N.: Effect of change in ambient temperature on core temperature of female subjects during the daytime and its sex differences. Int. J. Biometeorol. (2019)
11. Kakitsuba, N., White, M.D.: Effect of change in ambient temperature on core temperature during the daytime. Int. J. Biometeorol. **58**(5), 901–907 (2014)
12. Lee, J.Y., et al.: Does wearing thermal underwear in mild cold affect skin temperatures and perceived thermal sensation in the hands and feet of the elderly? J. Physiol. Anthropol. **27**(6), 301–308 (2008)
13. Kubo, H., Isoda, N., Enomoto-Koshimizu, H.: Cooling effects of preferred air velocity in muggy conditions. Build. Environ. **32**(3), 211–218 (1997)
14. ISO: ISO 7730:2005—Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria. International Organization for Standardization, Switzerland (2005)
15. ASHRAE: ANSI/ASHRAE Standard 55-2010. Thermal environmental conditions for human occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers, United States of America (2010)
16. Griffiths, I.D., McIntyre, D.A.: Sensitivity to temporal variations in thermal conditions. Ergonomics **17**(4), 499–507 (1974)
17. Zhang, Y., Zhao, R.: Overall thermal sensation, acceptability and comfort. Build. Environ. **43** (1), 44–50 (2008)
18. Du, C., et al.: Quantifying the cooling efficiency of air velocity by heat loss from skin surface in warm and hot environments. Build. Environ. **136**, 146–155 (2018)
19. Choi, J.W., Lee, J.Y., Kim, S.Y.: Effects of thermal underwear on thermal and subjective responses in winter. J. Physiol. Anthropol. Appl. Human Sci. **22**(1), 29–36 (2003)
20. McIntyre, D.A., Griffiths, I.D., Griffiths, I.D.: The effects of added clothing on warmth and comfort in cool conditions. Ergonomics **18**(2), 205–211 (1975)
21. Kwon, J., Choi, J.: The relationship between environmental temperature and clothing insulation across a year. Int. J. Biometeorol. **56**(5), 887–893 (2012)
22. McIntyre, D.A.: Response to atmospheric humidity at comfortable air temperature: a comparison of three experiments. Ann. Work Exposures Health **21**(2), 177–190 (1978)
23. Berglund, L.G., Gonzalez, R.R.: Evaporation of sweat from sedentary man in humid environments. J. Appl. Physiol. Respir. Environ. Exerc. Physiol. **42**(5), 767–772 (1977)

24. Jin, L., Zhang, Y., Zhang, Z.: Human responses to high humidity in elevated temperatures for people in hot-humid climates. Build. Environ. **114**, 257–266 (2017)
25. Kakitsuba, N.: Physiological responses to changes in relative humidity under thermally neutral, warm and hot conditions. J. Therm. Biol. **59**, 86–91 (2016)
26. Lee, J.Y., Nakao, K., Tochihara, Y.: Validity of perceived skin wettedness mapping to evaluate heat strain. Eur. J. Appl. Physiol. **111**(10), 2581–2591 (2011)
27. Rohles, Jr, F.H., Nevins, R.G.: Thermal comfort: new directions and standards. Aerosp. Med. **44**(7) (1973)
28. Toftum, J., Jørgensen, A.S., Fanger, P.O.: Upper limits for indoor air humidity to avoid uncomfortably humid skin. Energy Build. **28**(1), 1–13 (1998)
29. Fan, X., Liu, W., Wargocki, P.: Physiological and psychological reactions of sub-tropically acclimatized subjects exposed to different indoor temperatures at a relative humidity of 70%. Indoor Air **29**(2), 215–230 (2019)
30. Pellerin, N., Candas, V.: Effects of steady-state noise and temperature conditions on environmental perception and acceptability. Indoor Air **14**(2), 129–136 (2004)
31. Fanger, P.O., Breum, N.O., Jerking, E.: Can colour and noise influence man's thermal comfort? Ergonomics **20**(1), 11–18 (1977)
32. Rohles, F.H., Wells, W.V.: Interior design. Comfort and thermal sensitivity. J. Inter. Des. **2** (2), 36–44 (1976)
33. Fanger, P.O., et al.: Thermal comfort conditions during day and night. Eur. J. Appl. Physiol. Occup. Physiol. **33**(4), 255–263 (1974)
34. Fanger, P.O., Højbjerre, J., Thomsen, J.O.B.: Thermal comfort conditions in the morning and in the evening. Int. J. Biometeorol. **18**(1), 16–22 (1974)
35. Yang, W., Moon, H.J.: Combined effects of acoustic, thermal, and illumination conditions on the comfort of discrete senses and overall indoor environment. Build. Environ. **148**, 623–633 (2019)
36. Beshir, M.Y., Ramsey, J.D.: Comparison between male and female subjective estimates of thermal effects and sensations. Appl. Ergon. **12**(1), 29–33 (1981)
37. Castellani, J.W., et al.: Effect of localized microclimate heating on peripheral skin temperatures and manual dexterity during cold exposure. J. Appl. Physiol. **125**(5), 1498–1510 (2018)
38. Wyon, D.P., et al.: The mental performance of subjects clothed for comfort at two different air temperatures. Ergonomics **18**(4), 359–374 (1975)
39. Chow, T.T., et al.: Thermal sensation of Hong Kong people with increased air speed, temperature and humidity in air-conditioned environment. Build. Environ. **45**(10), 2177–2183 (2010)
40. Chung, T.M., Tong, W.C.: Thermal comfort study of young Chinese people in Hong Kong. Build. Environ. **25**(4), 317–328 (1990)
41. Grivel, F., Candas, V.: Ambient temperatures preferred by young European males and females at rest. Ergonomics **34**(3), 365–378 (1991)
42. Zhang, Z., Zhang, Y., Jin, L.: Thermal comfort of rural residents in a hot–humid area. Build. Res. Inf. **45**(1–2), 209–221 (2017)
43. Cheng, Y., Lin, Z.: Experimental investigation into the interaction between the human body and room airflow and its effect on thermal comfort under stratum ventilation. Indoor Air **26** (2), 274–285 (2016)
44. Oseland, N.A.: Predicted and reported thermal sensation in climate chambers, offices and homes. Energy Build. **23**(2), 105–115 (1995)
45. Gonzales, B.R., et al.: Effects of polyester jerseys on psycho-physiological responses during exercise in a hot and moist environment. J. Strength Cond. Res. **25**(12), 3432–3438 (2011)
46. McIntyre, D.A.: Thermal sensation. A comparison of rating scales and cross modality matching. Int. J. Biometeorol. **20**(4), 295–303 (1976)
47. Hasebe, Y., Iriki, M., Takahasi, K.: Usefulness of R-R interval and its variability in evaluation of thermal comfort. Int. J. Biometeorol. **38**(3), 116–121 (1995)

Ergonomic Analysis of a Pathological Anatomy Service in a Private Portuguese Hospital

Filipa Carvalho, Rita Martins and Rui B. Melo

Abstract The main tasks performed in a pathological anatomy service often expose pathologists and other technicians to awkward and uncomfortable postures that, in combination with others risk factors may be responsible for the development of chronic pain syndromes. This paper focuses on estimating the prevalence of musculoskeletal and visual symptoms among these professionals and attempts to identify possible associations with their actual working conditions. Other objectives of this study were: identify the most painful tasks/workstations, characterize these in terms of the associated musculoskeletal disorders (MSD) development risk and, finally, identify and propose some preventive measures. To fulfill all these objectives, an ergonomic work analysis was done. Data were collected using a questionnaire specifically developed for this purpose. The Chi-square test and Cramer's V coefficient were used to identify possible associations between variables (individual/work-related characteristics) and the prevalence of complaints (musculoskeletal or visual fatigue). Rapid Upper Limb Assessment (RULA) was the method used to quantify the risk associated to MSD development. The main results have highlighted that the work done in this pathological anatomy service entails risk factors such as high work intensity, awkward postures, turning knobs repeatedly, high cognitive and visual demands which may be responsible for the prevalence of musculoskeletal symptoms and the high levels of eyestrain. Additionally, the RULA results revealed that the risk for the development of MSD is present in almost all tasks suggesting that investigation and adjustments in the work situation are relevant. The obtained results are in accordance with those reported by other studies.

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Keywords Musculoskeletal disorders (MSD) · Visual fatigue · Pathological anatomy service · Rapid upper limb assessment (RULA) · Binocular microscopes · Microtomes · Embedding centers · Digital pathology

1 Introduction

The main tasks performed in a pathological anatomy service (PAS) often expose pathologists and other technicians to awkward and uncomfortable postures that, in combination with others risk factors, may be responsible for the development of eyestrain and chronic pain syndromes [1–4].

Several authors reported that Work related musculoskeletal disorders (WRMSD) represent an important cause of occupational disability in developed countries and are responsible for high absenteeism rates [5, 6]. WRMSD are among the most costly health problems that society is facing today affecting millions of workers in Europe and cost employers billions of Euros [7].

Some studies considered that WRMSD are associated with a diversity of risk factors such as: repetitive movements, poor postures, static muscular constraints, strained hand and arm movements, long work-shifts, lack of work-pauses, the combination of strain and repetitiveness, sudden muscular effort, short work cycles, task invariability, short deadlines, high cognitive demands, lack of autonomy over work, low temperatures in the work environment, exposure to vibrations, mechanical compression on tissues, negative psychosocial situations and individual susceptibility [3, 4, 6, 8].

In PAS, workers are exposed to high work intensity levels and posture-related risk factors and therefore susceptible to injury and development of WRMSDs [3, 7, 9]. This injuries development is due to some particularities of the tasks accomplished, namely while using binocular microscopes, microtomes and embedding centers [1, 4] where awkward postures [9, 10], and turning knobs repeatedly are recognized as present [6]. Plus, the association of prolonged microscope use with the development of chronic pain syndromes has been recognized for nearly 3 decades [2].

This paper focuses on estimating the prevalence of musculoskeletal and visual symptoms among PAS professionals, in a Private Portuguese Hospital, and investigating possible associations between variables (individual/work-related characteristics) and the prevalence of complaints (musculoskeletal or visual fatigue). Other objectives of this study were: to identify the most painful tasks/workstations; characterize them in terms of the associated MSD development risk and to identify and propose some preventive measures. To fulfill all these objectives, an ergonomic work analysis was done.

2 Materials and Methods

2.1 Stages of the Study

This study was carried out at a pathological anatomy service (PAS), in a Private Portuguese Hospital, from September 2018 to May 2019. All workers (N = 15) involved in the service were invited and 80% out of these (5 Pathologists/6 Technicians/1 Administrative) agreed to participate and an informed written consent was previously obtained. The confidentiality of data was always guaranteed. Table 1 summarizes some of the main characteristics of the participants.

This study comprised 3 fundamental stages, described in Table 2.

2.2 Data Collection and Procedures

For data collection, different methods, tools and equipment were used according to the specificity of each stage of the study.

To characterize the work situation and the workers, different methods and techniques were used such as: Free and systematized observations, Dialogues with workers; Documental Analysis (e.g.: task procedures, legislation, related studies, …), and a Questionnaire specifically developed for this purpose. The questionnaire was based on the adapted version of the Nordic Musculoskeletal Questionnaire (NMQ), proposed by Serranheira et al. [11] and others available in the literature [1, 12] and information provided by the PAS' workers. The questionnaire comprises 42 questions distributed by four sections described in Table 3.

For the second stage systematic and retrospective observations relying on images collected with a digital camera of a mobile phone were done. To find if the risk for the development of MSD was present in the selected tasks RULA method [13] was applied following the methodology adopted by Carvalho et al. [1] to: (1) tasks

Table 1 Main characteristics of the participants (N = 12)

Variables	Average	sd	min.	máx.	Variables	Yes (%)	No (%)
Age (years)	34.39	9.63	24	58	Eye problems	67	33
Seniority (years)	8.47	7.8	0.83	30	Right handed	17	83
Height (cm)	164	6	157	178	Medical history of chronic illnesses	42	38
Weight (kg)	65	14.29	43	91	Regular physical activity	50	50
BMI (kg/m^2)	23.89	4.9	17.44	32.63	Smoking or acholic habits	0	100
					Second job	25	75

Table 2 Main objectives and characteristics of each stage of the study

Stage of the study	Main objectives	Main characteristics
1st stage	Global characterization of the work situations	Characterization of both the operators and tasks was included; The prevalence of complaints (musculoskeletal or visual fatigue) was assessed based in a self-reported symptoms questionnaire organized by body regions; The associations between variables (individual/work-related characteristics) and the prevalence of complaints (musculoskeletal or visual fatigue) were investigated. The most painful tasks/workstations were identified
2nd stage	Risk characterization	MSDs risk characterization
3rd stage	Risk control	Preventive measures such as technical and organizational ones were proposed

Table 3 Questionnaire sections, main objectives and associated items

Section	Objective	Items
A	Sociodemographic characterization	Gender, age, anthropometric data (height, weight) dominant upper limb, education, marital status and second job
B	Workers' health and lifestyle	Regular physical activity, smoking, alcoholic and caffeine habits, sleeping habits, presence of chronic illnesses, eye problems (myopia, hypermetropia, astigmatism presbyopia), etc.
C	Prevalence of complaints and self-reported symptoms	Presence of musculoskeletal symptoms (annoyance, discomfort and pain); frequency and intensity of pain
D	Workers' perception about work activity and conditions of realization	Number of hours worked per day/week, schedule type, practice of work breaks, environmental conditions (noise, lighting, thermal environment, air-quality and workplace cleanliness), equipment regulations habits (chair, screen, microscope, work desk/bench, …). This section also integrates questions about the probability of developing visual fatigue, general fatigue and the workers perception of stress; an open question to suggest changes to optimize their workplace

selected by workers as more difficult; (2) tasks previously related to accidents; (3) tasks requiring risky postures and repeatability. At the end we used the average scores obtained for each task/subtask considered. The main reasons to select this method are posture, force, and movement associated with the tasks in which the workers are seated or standing, without moving around and, the upper body is predominantly used. Additionally, in some cases screen-based or computer tasks are done and were also assessed with RULA method.

Digital Pathology was also included to be able to compare with Microscopy and the task performed in the Microtome was split into two allowing to differentiate the work done at the level of Thinning (which represents a phase of Microtomy). Thus, the following six tasks were evaluated: Inclusion, Macroscopy, Microtomy, Thinning, Microscopy and Digital Pathology. The first four tasks are accomplished by Technicians and the last two tasks by Pathologists. The Administrative is responsible for all Lab secretarial work [1].

Whenever necessary and possible, RULA was applied to each side (Right/Left) of the body. For an efficient collection of data to be integrated in the application of the RULA method, tasks were recorded, whenever space allowed, in the three anatomical planes: sagittal, frontal and horizontal. Given the repeatability of the tasks, each shoot integrated three complete work cycles.

From Table 4 we can see that RULA was applied in 162 postures distributed by 6 tasks. The tasks assessed were performed by one or two out of four workers (#1, #2, #3 and #4) and during one or two shifts (Morning (M) and Afternoon (A)).

2.3 Data Analysis

For data processing, we resorted to the Statistical Package for the Social Sciences (SPSS©). Descriptive analyses were performed using location (Mean, Median, Frequency, Percentiles) and dispersion parameters (ranges, standard deviation) to summarize the socio-demographic data, job characteristics and the prevalence of complaints. The Chi-square test was used to assess associations between variables (Individuals/Work-related characteristics) and the prevalence of complaints (musculoskeletal complaints per body region/visual fatigue). Table 5 shows the variables considered for the association tests. Whenever possible, variables were

Table 4 Data for RULA analyses

	Tasks	Workers	Shifts	Postures
	Microtomy	#1 and #2	M/A	30
	Microscopy	#3 and #4	M/A	16
	Inclusion	#1 and #2	M	26
	Thinning	#1 and #2	M	16
	Macroscopy	#1 and #2	M/A	68
	Digital pathology	#3	M/A	6
Total	6	4	2	162

Table 5 Variables used in the association Tests

Individuals	Work related Characteristics
• Gender (Male/Female) • Age ($\leq$ 34 Years/>34 years) • PAS Seniority ($\leq$ 3 years/>3Years) • Job Seniority ($\leq$ 6 years/>6Years) • BMI ($\leq$ Normal Weight/ $\geq$ Overweight) • Regularly exercise (Yes/No) • Medical history of chronic illness (Yes/No) • Eye correction (Yes/No) • Caffeine habits (Never/Daily) • Chronic medication (Yes/No) • Marital status (Single or Divorced/Married) • 2nd Job (Yes/No) • Previous work accident (Yes/No)	• Work breaks (Yes/No) • Equipment regulation (Yes/No) • Visual breaks (Yes/No) • Visual demands (Yes/No) • Overtime work (Sporadically/Often) • Job function (Pathologists/Technicians/Administrative)

dichotomized to test possible associations. For the variables Age, PAS Seniority and Job Seniority, the mean or median (according to the observed distribution) were used as dichotomizing criteria.

For the analysis of the Postures we used an Excel spreadsheet adapted to the application of the RULA method. Subsequently, for the calculation of Score A, Score B, RULA Grade Score (RGS) and Risk Index (RI), the SPSS© was used and each variable was automatically obtained.

Bearing in mind the small sample size and the ordinal nature of the variables, to compare RULA results by shifts (M/A) and by task the nonparametric Mann Whitney and Kruskal-Wallis were used, respectively. All these tests were made for the four highlighted variables (Score A, Score B, RGS and RI). For the Kruskal-Wallis test the median value was used. In all cases, a significance level of 0.05 was adopted. Whenever the null hypothesis was rejected the Pairwise Comparison Test was used.

The Action Level 2 of RULA method, which corresponds to a RGS equal to 3 or 4, was considered the level above which a high-risk level of MSD development is present.

3 Results and Discussion

Considering the self-reported symptoms it was possible to identify five body regions with the highest percentage of complaints: cervical (83%), dorsal (75%), lumbar (58%) spine, right hand (67%) and right shoulder (50%). These results are similar to the results reported by other studies [1, 2, 5, 6, 12]. Concerning the frequency of complaints it is shown that the two highest levels of the scale (high/very high) are associated to the regions already reported and with the left shoulder as well (1/3 of the records). The two highest levels of the intensity scale (high/very high) are related to the 5 most affected regions, in a proportion greater than or equal to 40%. The results also show that, at least, 50% of the participants experienced MSDs symptoms over the last 7 days, in all regions assessed.

When questioned about the relationship between the characteristics of the tasks and the presented complaints, the main reasons pointed out by the workers were: the repetitiveness of the arms movements; the flexion/rotation of the head and prolonged sitting. Eighty three percent of the workers reported visual fatigue; 40% out of these considered that the symptoms had some impact in the perception of information. These results are in accordance with other studies [1, 14, 15]. In terms of general fatigue and daily stress, at least 50% of the workers marked levels 7–9 (in a ten-level scale). 50% out of these workers considered that these symptoms could affect their personal life. The main symptoms reported were decreased concentration/attention (83%), mood swings/irritability (83%) and/or discouragement/lethargy (50%).

In general, the Chi-square test revealed that there were no statistically significant associations between the MSD symptoms/Visual Fatigue and the variables (individual/work-related characteristics) ($p > 0.05$).

Table 6 summarizes the results obtained with RULA when evaluating the six tasks. The risk level for the development of MSD, for all the evaluated tasks, is between the Moderate (67.3%) and High (29%). The results suggest that investigation and adjustments in the work situation are relevant for 97.5% of the observed postures (Risk Level $\geq$ 2). These results are similar to the results reported by Carvalho et al. [1].

The global average values of Score A ($\overline{X} = 3.25$) and Score B ($\overline{X} = 3.32$) are quite close. However it seems that the Biomechanical loading at the "neck + trunk + lower limbs" segment set made a major contribution to the overall result of the RGS. For the tasks Thinning, Macroscopy and Inclusion the Biomechanical loading at the upper body was the most important for the final results. However, it is important to highlight that these were the tasks that presented the worst Score A and Score B values corroborating the results shown by Maulik et al. [5].

An analysis of the results of RULA by task allowed us to conclude that all tasks present a RI level of 2, meaning that they require further investigation and possibly changes. Considering the average values of RI, it is possible to highlight Inclusion (RI = 2.7), Microtomy (RI = 2.4) and Macroscopy (RI = 2.2) as the riskiest tasks.

Table 6 Distribution of RULA scoring (n = 162 evaluated postures for 6 tasks)

RULA score					Mean (SD)
Variables	1 n (%)	2 n (%)	3 n (%)	4 n (%)	
Score A	5 (3.1%)	32 (19.8%)	56 (34.6%)	59 (36.4%)	3.25 (1)
Score B	6 (3.7%)	19 (11.7%)	92 (56.8%)	14 (8.6%)	3.32 (1.12)
RGS	–	4 (2.5%)	29 (17.9%)	80 (49.4%)	4.17 (0.94)
RI	4 (2.5%)	109 (67.3%)	47 (29.0%)	2 (1.2%)	2.29 (0.53)

It should also be noted that Digital Pathology and Microscopy have the same average RI value (2).

Considering the results obtained by shift, the Mann Whitney test suggests that there are statistically significant differences on Score B in the Microscopy task ($p = 0.038$) and on RGS in the Macroscopy task ($p = 0.034$).The differences found may be due to: specificities of the body pieces being analyzed at the lab or to the operative modes of each technician. Considering the results obtained by task, the Kruskal-Wallis test suggests that there are statistically significant differences among results from all variables assessed ($p < 0.00$). The Pairwise Comparison Test did not reveal a pattern in difference found on variables Score B, RGS and RI. On the other hand, the differences found for Score A were between the Microscopy and all other tasks except Digital pathology.

4 Solutions Proposed

To reduce the risk of developing MSD and complaints presented by workers some organizational and technical solutions were proposed.

In terms of technical solutions is important to rearrange the Digital Pathology workstation (the pathologist frequently rotates the neck to write the report, which is done on the screen on the right). Additionally, if possible, acquire adjustable microscopes with tilting and telescoping eyepieces, or adapt existing microscopes with longer ocular tubes and platform adapters; select adjustable chairs, desks and other equipment; provide footrests to help workers to support lower limbs.

In terms of organizational solutions, workers should become aware of their posture and better understand the MSD risk factors. Whenever possible workers should take pauses or rotate among tasks and learn how to fit the workstation to their needs.

5 Conclusions

This cross-sectional study was conducted in the pathological anatomy service of a Private Portuguese Hospital.

The main results have highlighted that the work done in this pathological anatomy service entails risk factors such as high work intensity, awkward postures, turning knobs repeatedly, high cognitive and visual demands which may be responsible for the prevalence of musculoskeletal symptoms and high levels of eyestrain. Workers should be trained regarding MSD risk factors, as well as on how to fit the workstation to their needs.

References

1. Carvalho, F., Melo, R.B., Costa, V.: Ergonomic work analysis of a pathological anatomy service in a Portuguese Hospital. Adv. Saf. Manag. Hum. Factors Adv. Intell. Syst. Comput. **491**, 449–462 (2016)
2. George, E.: Occupational hazard for pathologists: microscope use and musculoskeletal disorders. Am. J. Clin. Pathol. **133**(4), 543–548 (2010)
3. Martins, R., Carvalho, F., Melo, R.B.: Prevalence assessment of musculoskeletal and visual symptoms among pathological anatomy service workers. Adv. Intell. Syst. Comput. **1012**, 99–108 (2019)
4. Navy Heath Research Center: Ergonomic Microscopes Reduce the Risk of Musculoskeletal Disorders at Naval Health Research Center's Respiratory Disease Laboratory (Online). Available: https://www.public.navy.mil/navsafecen/Documents/SuccessStories/082_Ergo_Scopes.pdf. Accessed 01 Oct 2018
5. Maulik, S., Iqbal, R., De, A., Chandra, A.M.: Evaluation of the working posture and prevalence of musculoskeletal symptoms among medical laboratory technicians. J. Back Musculoskelet. Rehabil. **27**(4), 453–461 (2014)
6. El-Helaly, M., Elsherbeny, E., Haji, A., Assiri, M., Fadlelmula, A.: Reported musculoskeletal symptoms among laboratory workers, in relation to individual and work-related physical factors. Egypt. J. Occup. Med. **42**(1), 79–92 (2018)
7. Eurofound: Sixth European Working Conditions Survey—Overview Report (2017 update). Publications Office of the European Union, Luxembourg (2017)
8. Franco, G.: Health disorders and ergonomic concerns from the use of the microscope. Am. J. Clin. Pathol. **135**, 170–171 (2011)
9. Thompson, S.K., Mason, E., Dukes, S.: Ergonomics and cytotechnologists: reported musculoskeletal discomfort. Diagn. Cytopathol. **29**(6), 364–367 (2003)
10. Arora, A., Uparkar, S.M.: Ergonomic risk assessment in pathology laboratory technicians. Int. J. Rehabil. Res. **4**(3), 15–19 (2015)
11. Serranheira, F., Uva, A.S., Lopes, M.F.: Caderno Avulso #3 - Lesões Músculo-esqueléticas e Trabalho: Alguns métodos de Avaliação. Sociedade Portuguesa Medicina do Trabalho, Lisboa (2008)
12. Alcaraz-Mateos, E., Caballero-Alemán, F.: Problemas músculo-esqueléticos en patólogos españoles. Prevalencia y factores de riesgo. Rev. Espñola Patol. **48**(1), 9–13 (2015)
13. McAtamney, L., Corlett, N.: Rapid Upper Limb Assessment (RULA). Handb. Hum. Factors Ergon. Methods, pp. 7-1-7–11 (2005)
14. Flavin, R.J., Guerin, M., O'Briain, D.S.: Occupational problems with microscopy in the pathology laboratory. Virchows Arch. **457**(4), 509–511 (2010)
15. Dzhodzhua, V., Serranheira, F., Sacadura-Leite, E., Sousa-Uva, A., Monteiro-Grillo, M.: Healthcare occupational visual demands and visual fatigue. In: International Symposium on Occupational Safety and Hygiene: SHO 2017, pp. 3–5 (2017)

Association Between Upper and Lower Limb Flexibility and Musculoskeletal Symptoms

Joana Azevedo, Adérito Seixas, Sandra Rodrigues, Nuno Ventura, Ricardo Cardoso, Jorge Mota and Isabel Moreira-Silva

Abstract This study aimed to compare upper and lower limb flexibility between workers who did and did not reported musculoskeletal symptoms, in the previous 12 months. The sample consisted of 70 workers from a manufacturing company of water heaters and solar panels. Musculoskeletal symptoms were assessed using the Standardized Nordic Musculoskeletal Questionnaire. Flexibility of the upper and lower limb was assessed with the Appley Scratch Test and the Sit and Reach Test, respectively. Results revealed significant differences in flexibility between workers who did and did not reported musculoskeletal symptoms in the previous 12 months in the shoulder region (p = 0.050) and in the hip/thighs (p = 0.033), with the ones reporting pain in these body regions evidencing significantly lower flexibility values in the upper and lower limbs, respectively. These results highlight the importance of maintaining an adequate flexibility to prevent musculoskeletal symptoms.

Keywords Flexibility · Musculoskeletal symptoms · Upper limb · Lower limb · Workers

1 Introduction

Musculoskeletal disorders (MSDs) describe a group of painful disorders involving the muscles, tendons, joints and nerves, in which all body regions can be affected. In Europe, recent studies have considered upper/lower limbs MSDs and back pain

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to be an increasing and significant health problem, making up approximately 39% of all occupational diseases [1].

Several studies about different workplace interventions have been implemented and evaluated to reduce MSD's. However, only a few of them had shown maintainable positive effects on symptoms and disability outcomes, revealing the difficulty in the management of upper and lower limbs symptomatology [1, 2].

Flexibility can be defined as the amount of movement of a given joint through its normal plane of motion [3]. A previous study conducted in storage and administrative workers investigated the effect of a 6-month workplace program based on static and dynamic stretching exercises on the flexibility and musculoskeletal complaints of both groups [4]. These authors have reported an increase of cervical, trunk and shoulder flexibility, 55% decrease of total body musculoskeletal complaints on storage workers and 46% decrease on upper body complaints of the administrative workers [4]. Similarly, the study conducted by Lee and Gak [5] investigated the effects of a 4 weeks stretching program on the work-related symptoms and pain of bus drivers. These authors also reported a significant decrease in pain intensity after the stretching intervention. Both investigations highlight the importance of maintaining an adequate flexibility on the reduction of musculoskeletal symptoms in different workers.

Although a significant relationship between a decreased spinal flexibility and current symptoms of back pain was reported by Battié et al. [6], there is a lack of studies investigating the association between upper and lower limb flexibility and reported symptoms in these body regions. Thus, the aim of this study was to compare upper and lower limb flexibility between workers who did and did not reported musculoskeletal symptoms, in the previous 12 months.

2 Materials and Methods

2.1 Study Design and Sample

This observational and cross-sectional study was approved by the ethical committee of the local university and by the executive board of the company. This study was conducted in a Portuguese manufacturing company of water heaters and solar panels. Workers from all sectors of the company were invited to participate in the study (administrative, engineers, factory workers and medical department employees). Workers with health problems prior to their employment in the company and that could cause musculoskeletal symptoms were excluded.

Seventy workers volunteered to participate, 27 men and 43 women. The median (interquartile range) age of the participants was 44 (11) years and median (interquartile range) BMI was 25 (5) kg/m^2, which according to the World Health Organization [7], represents a pre-obesity status. All volunteers signed an informed consent form to participate in the study.

2.2 Musculoskeletal Symptoms

Musculoskeletal pain and related symptoms were assessed with the Standardized Nordic Musculoskeletal Questionnaire (NMQ) [8], supplemented with questions about pain intensity. The NMQ has already been validated to the Portuguese population [9], and consists of 27 binary choice questions (yes or no). The questionnaire has three questions correlating to nine anatomic regions (neck, shoulders, elbows, wrists/hands, dorsal region, low back region, hips/thighs, knees and ankles/feet). The first question is "had some troubles or pain in the last 12 months"; the second question is "in the last 12 months felt some limitation caused by work in the daily activities"; and the third is "had some troubles or pain in the last 7 days". The pain intensity in the "last 7 days" includes the numeric pain scale (scale 0–10).

2.3 Flexibility Assessment

Flexibility of the upper and lower limbs was assessed through the Appley Scratch test [10] and the Sit and Reach test [11], respectively. For the Appley Scratch, participants had to stand straight and actively place one arm over their shoulders and then try to reach the other arm along their back in an attempt to touch the fingers of the opposing hand. The distance between the fingertips of the participants' opposing hands was measured in centimetres [10]. A positive value was registered when the participants were capable of touching the fingers of the opposite hands and exceed them, and a negative value was considered when the workers' fingertips stayed apart from each other. For the Sit and Reach test, the participants sat with their feet approximately hip-wide against a testing box and with their knees extended. Then, they were instructed to place the right hand over the left, and slowly reach forward as far as they could by sliding their hands along the measuring tape [11].

2.4 Statistical Analysis

The data was analysed using the Statistical Package for the Social Sciences (SPSS v.25.0) software for Windows. The Shapiro-Wilk test was used to assess the distribution of the studied variables, and since the variables did not follow a normal distribution pattern, non-parametric tests were selected. Descriptive characteristics of the participants (age, BMI) and studied variables were presented as median and interquartile range (IQR). The independent samples Mann-Whitney U test was used to test if flexibility of the upper limb was significantly different in those reporting

Table 1 Sample characteristics ($n = 70$) regarding age, BMI, upper and lower limb flexibility

Variable	Median (IQR); [minim; maxim]
Age (years)	44 (11); [21; 67]
BMI (kg/m^2)	25 (5); [18; 39]
Upper limb flexibility (cm)	1 (17); [−50; 11]
Lower limb flexibility (cm)	17 (11); [3; 41]

pain in the upper limbs and neck, and if flexibility of the lower limbs was significantly different in those reporting pain in the lower limbs and lumbar spine. A p value equal or lower than 0.05 was considered significant.

3 Results

The sample characteristics regarding age, BMI and upper and lower limb flexibility are presented in Table 1.

Regarding the 12-month prevalence of musculoskeletal symptoms, 37 participants (52.9%) reported painful symptoms in the neck, 28 participants (40%) reported pain in the lumbar spine, 18 participants reported pain in the shoulders and elbows (25.7%), 17 participants reported pain in the wrist and hand (24.3%), 9 participants reported pain in the thoracic spine and knees (12.9%), 6 participants reported pain in the hip/thigh (8.6%) and 5 participants reported symptoms in the ankle and foot (7.1%).

The results for the comparison of the flexibility values of the upper and lower limbs between workers reporting and not reporting musculoskeletal pain in the previous 12 months are shown in Table 2.

Significant differences were found in the shoulders and in the hip/thigh, with workers reporting pain in the previous year evidencing significantly lower values of flexibility in the upper and lower limbs, respectively.

4 Discussion

This study aimed to compare upper and lower limb flexibility between workers who did and did not reported musculoskeletal symptoms, in the previous 12 months. Several studies have demonstrated the effectiveness of workplace interventions, focusing on the increase of flexibility and in the improvement of musculoskeletal health [1, 4, 5, 12]. The study conducted by Martins et al. [4] investigated the effect of a 6-month program based on static and dynamic stretching exercises among storage and administrative workers. These authors reported an increase of cervical, trunk and shoulder flexibility, and a 55% decrease of the total body musculoskeletal

Table 2 Flexibility measures according to body regions and the reporting of musculoskeletal symptoms in the last 12 months. Median (IQR) values and Mann-Whitney U test to investigate the existence of differences between groups

	Body regions	Pain	No pain	Mann-Whitney U test
Upper limb flexibility	Neck	1.5 (18.3)	0.5 (16.3)	$U = 602.0$; $p = 0.920$
	Shoulder	−6.3 (20.5)	1.3 (13.5)	**$U = 322.5$; $p = 0.050$***
	Elbow	−4.0 (20.0)	1.3 (14.3)	$U = 324.5$; $p = 0.054$
	Wrist/hand	0.0 (21.0)	1.0 (15.5)	$U = 398.5$; $p = 0.476$
Lower limb flexibility	Lumbar region	16.0 (11.5)	17.0 (14.5)	$U = 515.0$; $p = 0.522$
	Hip/thigh	9.5 (15.3)	17.0 (14.0)	**$U = 111.5$; $p = 0.033$***
	Knee	13.0 (14.5)	17.0 (13.3)	$U = 136.0$; $p = 0.597$
	Ankle/feet	20.0 (20.5)	16.5 (11.0)	$U = 0.149$; $p = 0.700$

*$p \leq 0.05$

complaints in storage workers and a 46% decrease on the upper body complaints of administrative workers. Similarly, the study conducted by Lee and Gak [5] investigated the effects of a stretching exercise program on the work-related symptoms and pain of bus drivers. Although the duration of the intervention was much lower (4 weeks) when compared to the previously mentioned study (6 months) [4], the authors also reported a significant decrease of pain after the stretching intervention in these employees. Shariat et al. [1] also conducted a 6-month stretching program in workers with neck, shoulders and lower back pain, with their results revealing a significant decrease in pain scores in these body regions. The results of these previously mentioned studies suggest a positive effect of flexibility training exercises in the reduction of musculoskeletal symptoms in different body regions, which also proposes a direct association between maintaining an adequate flexibility to decrease musculoskeletal symptoms, among different workers.

Only a few studies have been conducted to specifically investigate associations between flexibility and musculoskeletal symptomatology [6, 13]. Both studies of Battié et al. [6] and Cabral et al. [13] assessed only the flexibility of the back and lower limbs also through the Sit and Reach Test, the same one used to assess lower limb flexibility in the present investigation. In the case of Battié et al. [6], an association between a decreased flexibility and reporting current musculoskeletal symptoms were only found in the back. In the study of Cabral et al. [13], a reduced back and leg flexibility was associated with the occurrence of neck and low back symptoms. The results of the present study are not in line with the previously mentioned studies, as regarding the lower limb flexibility, significant differences were only found in the hip/thighs, with the participants reporting symptoms in this body region evidencing lower flexibility. Concerning the upper limb, our results revealed that participants reporting symptomatology in the shoulders have a significantly lower upper limb flexibility. It is not possible to relate these results to previous studies since, to our knowledge, this investigation is the first addressing this association in the upper limb.

There are, however, limitations that need to be acknowledged. The cross-sectional nature of the study does not allow to draw definite conclusions or to generalize our results, moreover, the specificity of the sample, that is not representative of the population and the choice of the criteria to identify upper and lower limb flexibility, that although largely used in the literature, are not free from criticism. Nevertheless, the present results can inform future studies of good methodological basis on this topic.

5 Conclusion

In this sample, workers reporting musculoskeletal symptoms in the shoulders and hip/thighs have significantly lower flexibility in the upper and lower limb, respectively. These results highlight the importance of maintaining an adequate flexibility to the reduction of musculoskeletal symptoms in different workers.

Future studies could investigate different stretching protocols, which would allow to understand how frequency, intensity, duration, and time of stretch can modulate the effectiveness of the technique.

References

1. Shariat, A., Cleland, J.A., Danaee, M., Kargarfard, M., Sangelaji, B., Tamrin, S.B.M.: Effects of stretching exercise training and ergonomic modifications on musculoskeletal discomforts of office workers: a randomized controlled trial. Braz. J. Phys. Ther. **22**(2), 144–153 (2018)
2. Van Eerd, D., Munhall, C., Irvin, E., Rempel, D., Brewer, S., Van Der Beek, A., Dennerlein, J., Tullar, J., Skivington, K., Pinion, C.: Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. Occup. Environ. Med. **73**(1), 62–70 (2016)
3. Knapik, J., Jones, B.H., Bauman, C.L., Harris, J.M.: Strength, flexibility and athletic injuries. Sport. Med. **14**(5), 277–288 (1992)
4. Martins, P.F.D.O., Zicolau, E.A.A., Cury-Boaventura, M.F.: Stretch breaks in the work setting improve flexibility and grip strength and reduce musculoskeletal complaints. Motriz: Revista de Educação Física **21**(3), 263–273 (2015)
5. Lee, J.-H., Gak, H.B.: Effects of self stretching on pain and musculoskeletal symptom of bus drivers. J. Phys. Ther. Sci. **26**(12), 1911–1914 (2014)
6. Battié, M.C., Bigos, S.J., Fisher, L.D., Spengler, D.M., Hansson, T.H., Nachemson, A.L., Wortley, M.D.: The role of spinal flexibility in back pain complaints within industry. A Prospect. Study. Spine **15**(8), 768–773 (1990)

7. World Health Organization W.: Body Mass Index—BMI. http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi (2019). Accessed 23 May 2019
8. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., Jørgensen, K.: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. **18**(3), 233–237 (1987)
9. Mesquita, C.C., Ribeiro, J.C., Moreira, P.: Portuguese version of the standardized Nordic musculoskeletal questionnaire: cross cultural and reliability. J. Public Health **18**(5), 461–466 (2010)
10. Barlow, J.C., Benjamin, B.W., Birt, P.J., Hughes, C.J.: Shoulder strength and range-of-motion characteristics in bodybuilders. J. Strength Cond. Res. **16**(3), 367–372 (2002)
11. López-Miñarro, P.A., de Baranda Andújar, P.S., Rodríguez-García, P.L.: A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university students. J. Sport. Sci. Med. **8**(1), 116–122 (2009)
12. Lee, H., Chae, D., Cho, S., Kim, J., Yoo, R.: Influence of a community-based stretching intervention on the health outcomes among Korean-Chinese female migrant workers in South Korea: a randomized prospective trial. Jpn. J. Nurs. Sci. **14**(4), 277–287 (2017)
13. Cabral, A.M., Moreira, R.D.F.C., de Barros F.C., de Oliveira Sato, T.: Is physical capacity associated with the occurrence of musculoskeletal symptoms among office workers? A cross-sectional study. Int. Arch. Occup. Environ. Health **92**, 1159–1172 (2019)

Prevalence of Musculoskeletal Symptoms Among Workers of a Portuguese Textile Industry: Association with Body Mass Index and Work Position

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Abstract This study aimed to investigate the prevalence of musculoskeletal symptoms among workers of a Portuguese textile industry, and to verify their association with body mass index (BMI) and work position. 53 workers from the manufacturing sector of a textile industry participated in the study. Sociodemographic and anthropometric characteristics of the sample, as well as occupational variables, were assessed through a characterization questionnaire. The Standardized Nordic Musculoskeletal Questionnaire was used to assess worker's musculoskeletal symptoms. Results revealed that 88.7% of the participants reported musculoskeletal symptoms in at least one body region in the previous year. The four areas with higher 12-month prevalence of symptoms were: the low back region (49.1%), followed by the neck (43.4%), the wrists/hands (39.6%) and the shoulders (37.7%). BMI seems not to be associated with a higher prevalence of musculoskeletal symptoms ($p > 0.05$). However, a statistically significant association was found between the prevalence of musculoskeletal symptoms in the low back region and working in the seated position ($p = 0.011$). To conclude, there is a high prevalence of symptomatology in the textile industry workers. Preventive measures and worksite interventions are needed to reduce work-related musculoskeletal disorders in this population.

Keywords Musculoskeletal symptoms · Workers · Textile industry · Body mass index · Work position

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1 Introduction

Work-related musculoskeletal disorders describe a group of conditions involving the nerves, tendons or muscles caused or aggravated by work [1]. Work-related musculoskeletal disorders have become a major problem worldwide, especially in the industrialized countries, representing a significant impact on worker's quality of life and finances, as well as on the society in general [2].

The textile industry integrates different manual and repetitive tasks, with most companies seeking high productivity at lower costs, imposing an intense work rhythm as well as the need for prolonged shifts. This fact, associated to ergonomically unsuitable job stations and limited time for breaks, can lead to a higher prevalence of musculoskeletal symptoms [3, 4]. A study conducted in Turkey with 283 female sewing machine operators evidenced a high prevalence of musculoskeletal symptoms. According to the authors, the most affected body region was the trunk (62.5%), followed by the neck (50.5%) and the shoulders (50.2%) [5]. Likewise, a study conducted on 162 workers of a textile industry in Brazil revealed that 62.3% of employees reported painful symptoms in more than one anatomical region. The cervical spine was the most reported region, followed by the thoracic spine, the legs and the shoulders [6].

Regarding the influence of individual factors like BMI, previous studies developed specifically in sewing machine operators have demonstrated that BMI is not significantly associated with a higher prevalence of musculoskeletal symptoms [5, 7]. On the contrary, a study conducted on a large working population sample revealed that having a high BMI (overweight or obese) was associated with an increased prevalence of musculoskeletal symptoms [8].

Concerning the association between occupational factors such as the work position and the prevalence of musculoskeletal symptoms, its influence is not consensual. A study with workers of a textile industry revealed that working in a standing position was associated with a higher prevalence of pain [6]. On the contrary, a study conducted in workers involved in sedentary occupational tasks revealed that those who worked mostly in a seated position had a three times higher risk of reporting musculoskeletal pain and related symptoms in more than one body region [9].

Although the textile industry is a strong industry in Portugal, to our knowledge, there are no studies describing the prevalence of musculoskeletal symptoms in these workers, as well as their association with individual and occupational factors. Therefore, the aim of this study was to investigate the prevalence of musculoskeletal symptoms among workers of a Portuguese textile industry, and to verify their association with BMI and work position.

2 Materials and Methods

2.1 Study Design and Sample

This observational and cross-sectional study was approved by the ethical committee of Fernando Pessoa University and by the executive board of the company. This study was conducted in a Portuguese textile industry company. Only the workers from the manufacturing sector that worked at least for 6 months in the company were recruited. Administrative workers, as well as the ones with health problems prior to their employment in the company that could cause musculoskeletal symptoms were excluded.

The total number of employees in the production sector of this company was 93, but only 55 volunteered to participate. Two of them did not met the eligibility criteria, thus, the final sample consisted of 53 female workers with mean age of 42.6 ± 7.1 years and mean BMI of 26.3 ± 4.1 kg/m^2, which according to the World Health Organization [10], represents a pre-obesity status. All volunteers signed an informed consent form to participate in the study.

The participants were all full-time workers who performed long shifts (8/9 h) and repetitive tasks, mainly with the upper limbs and trunk, and the majority of them were from the cut, sewing, packaging and ironing subsectors.

2.2 Musculoskeletal Symptoms

Musculoskeletal symptoms were assessed with the Standardized Nordic Musculoskeletal Questionnaire (NMQ) [11], supplemented with questions about localized pain intensity. This questionnaire has already been validated to the Portuguese population [12]. The NMQ consists of 27 binary choice questions (yes or no). The questionnaire has three questions related to nine anatomic regions (neck, shoulders, elbows, wrists/hands, dorsal region, low back region, hips/thighs, knees and ankles/feet). The first is “had some troubles or pain in the last 12 months”; the second is “in the last 12 months felt some limitation caused by work in the daily activities”; and the third is “had some troubles or pain in the last 7 days” [11]. The pain intensity in the “last 7 days” includes the numeric pain scale (scale 0–10). This questionnaire was explained by the investigator and all the doubts were clarified at the moment of the delivery. The NMQ filling was performed by the participants, outside of their working hours and posteriorly returned to the investigator, anonymously.

2.3 Body Mass Index (BMI)

Height (m) was measured with the participants standing upright and barefoot against a stadiometer (Seca, Hamburg, Deutschland). Weight (kg) was measured using a portable electronic weight scale (Tanita, Tokyo, Japan). BMI was calculated from the ratio between body weight and body height (kg/m^2). Data was then registered in a numbered and anonymized sample characterization questionnaire. Participants were divided into two BMI categories: normal, if BMI was below 24.9 kg/m^2; and overweight, if the BMI value was above 25 kg/m^2 [10].

2.4 Work Position

Work position, defined as the position in which workers spend the majority of their working hours, was self-reported and classified into three categories: seated, standing and both, and also registered in the anonymized sample characterization questionnaire.

2.5 Statistical Analysis

The data was analyzed using the Statistical Package for the Social Sciences (SPSS v.25.0) software for Windows. Descriptive characteristics of the participants (age and BMI) were presented as means ± standard deviation. The 12-month prevalence of musculoskeletal disorders in general and in each body region was described in percentage (%). The Chi-Square test was used to assess the association between the prevalence of musculoskeletal symptoms and BMI and work position. A p value under 0.05 was considered as significant. In Tables 1 and 2, the percentage represents the proportion of participants reporting pain in each body region, divided by category (columns).

3 Results

Results of the NMQ revealed that 88.7% of the workers reported some kind of musculoskeletal symptoms in at least one body region in the last year. Regarding the 12-month prevalence of musculoskeletal symptoms by body region, the most affected one was the low back (49.1%), followed by the neck (43.4%), the wrist/hands (39.6%), the shoulders (37.7%), the knees (22.6%), the ankles/feet (15.1%), the thighs/hips (13.2%), the dorsal region (9.4%) and the elbows (7.5%). The

Table 1 Association between musculoskeletal symptoms and BMI

Body regions	Normal (n = 24)	Overweight (n = 29)	Chi-Square test
Neck (n = 23)	10 (41.7)	13 (44.8)	$X^2(1)$ = 0.053; p = 0.817
Shoulders (n = 20)	9 (37.5)	11 (37.9)	$X^2(1)$ = 0.001; p = 0.974
Elbows (n = 4)	1 (4.2)	3 (10.3)	$X^2(1)$ = 0.718; p = 0.381
Wrists/hands (n = 21)	9 (37.5)	12 (41.4)	$X^2(1)$ = 0.083; p = 0.774
Thighs/hips (n = 7)	2 (8.3)	5 (17.2)	$X^2(1)$ = 0.909; p = 0.297
Knees (n = 12)	6 (25.0)	6 (20.7)	$X^2(1)$ = 0.139; p = 0.709
Ankles/feet (n = 8)	3 (12.5)	5 (17.2)	$X^2(1)$ = 0.230; p = 0.466
Dorsal region (n = 5)	2 (8.3)	3 (10.3)	$X^2(1)$ = 0.062; p = 0.591
Low back (n = 26)	13 (54.2)	13 (44.8)	$X^2(1)$ = 0.458; p = 0.498

Table 2 Association between musculoskeletal symptoms and work position

Body regions	Seated (n = 14)	Standing (n = 31)	Both (n = 8)	Chi-Square test
Neck (n = 23)	6 (42.9)	14 (45.2)	3 (37.5)	$X^2(2)$ = 0.154; p = 0.926
Shoulders (n = 20)	4 (28.6)	14 (45.2)	2 (25.0)	$X^2(2)$ = 1.780; p = 0.411
Elbows (n = 4)	0 (0.0)	3 (9.7)	1 (12.5)	$X^2(2)$ = 1.626; p = 0.444
Wrists/hands (n = 21)	3 (21.4)	15 (48.4)	3 (37.5)	$X^2(2)$ = 2.948; p = 0.229
Thighs/hips (n = 7)	1 (7.1)	3 (9.7)	3 (37.5)	$X^2(2)$ = 4.905; p = 0.086
Knees (n = 12)	2 (14.3)	8 (25.8)	2 (25.0)	$X^2(2)$ = 0.761; p = 0.684
Ankles/feet (n = 8)	2 (14.3)	6 (19.4)	0 (0.0)	$X^2(2)$ = 0.761; p = 0.393
Dorsal region (n = 5)	1 (7.1)	2 (6.5)	2 (25.0)	$X^2(2)$ = 0.062; p = 0.262
Low back (n = 26)	11 (78.6)	10 (32.3)	5 (62.5)	$X^2(2)$ = 0.458; $\boldsymbol{p}$ **= 0.011***

*p < 0.05

association analysis between the presence of musculoskeletal symptoms and BMI and work position is presented in Tables 1 and 2, respectively.

No significant associations were found between BMI and the prevalence of musculoskeletal symptoms, but a significant association between the work position and the prevalence of symptoms in the low back region was found (p = 0.011), with the workers who spend mostly of their working hours in the seated position having a significantly higher prevalence of musculoskeletal symptoms in this body region.

4 Discussion

This study investigated the prevalence of musculoskeletal symptoms among workers of a Portuguese textile industry and verified its association with BMI and work position.

The results of the present study revealed that the prevalence of musculoskeletal symptoms is very high in textile workers, with 88.7% of the participants reporting symptoms in at least one body region in the last year. These results are in line with the study of Van et al. [13], in garment workers, where 92% of the participants complained about musculoskeletal symptoms in the previous year, which is very close to the present results.

The analysis by body regions revealed that the highest prevalence was in the low back (49.1%), followed by the neck (43.4%), the wrist/hands (39.6%) and the shoulders (37.7%). Previous investigations in workers engaging different hand sewing tasks reported a high prevalence of complaints in the neck (57.9%), low back (51.6%) and the shoulders (40.5%) [7]. Likewise, the study conducted by Van et al. [13], in garment workers, revealed that the neck was the body region with higher complaints (72.1%), followed by the shoulders (63.5%) and the low back (62.3%). It seems that the body regions with highest prevalence are almost similar between the previously mentioned studies, differing only in the order of the most affected body regions. In this investigation, the region with higher prevalence was the low back, while in the other studies it was the neck, registering a higher prevalence of symptoms. Overall, the prevalences reported here are also lower when compared to the previously mentioned studies [7]. Regarding the wrist/hands, Van et al. [13] identified a prevalence of symptoms of only 24.2%, which is considerably low, when compared to the prevalence of 39.6% reported in the present study, and considering the repetitive movements performed in the wrist/hands by these workers.

In this study, no significant association was found between BMI and the prevalence of musculoskeletal symptoms in any of the assessed body regions. These results are not in line with a previous investigation, on a large working sample of 44,793 employees, which has concluded that having a higher BMI (overweight or obese) was associated with an increased prevalence of musculoskeletal symptoms, especially in the lower extremity [8], highlighting the role of excessive weight in the overload of the lower limbs joints. Nevertheless, similar results to the ones presented here were found by Öztürk and Esin [5], in female sewing machine operators, since no association was found between the different BMI categories and the prevalence of musculoskeletal symptoms in these employees. Likewise, a previous investigation in workers engaging different hand sewing tasks also confirmed the absence of an association between BMI and the reported symptoms [7]. In this sense, it appears that, particularly in the textile/sewing industries, no evidence of association with BMI has been yet reported, probably due to the sedentary nature of the occupational tasks performed by these workers, where a major part of them work mostly in a seated position, not overloading too much the lower limb joints.

Regarding work position, a significant association was identified between the prevalence of musculoskeletal symptoms in the low back region and working mostly in the seated position. Associations between work position and the prevalence of musculoskeletal symptoms are still not consensual. On one hand some investigations conclude that working in a standing position is associated with a higher prevalence of pain [6], but on the other hand, there are also studies in employees of sedentary occupations reporting that working in the seated position represents a three times higher risk for reporting pain in more than one body region [9]. Specifically for low back symptoms, the study conducted by Gupta et al. [14] reported a positive association between having pain in this body region and the time spent sitting in their occupational setting, which is in line with the results of the present study. Similarly, and precisely in textile employees, Tiwari et al. [15] found that working positions requiring prolonged sitting were significantly associated with the development of low back pain among cotton textile workers, which also confirms the present results.

Although no significant association was found between BMI and the prevalence of musculoskeletal symptoms in any body region, it is important to note that regardless of the reduced sample size, 54.7% of the sample was overweight, which reinforces the need to promote physical activity interventions in labor and leisure context aiming to decrease the BMI of these textile workers whose occupational activity is essentially sedentary. Similarly, as stated in the present study, and also in previous ones, the prevalence of musculoskeletal symptoms in textile workers is high, which also emphasizes the need of different worksite interventions to reduce work-related musculoskeletal disorders in these workers.

Some limitations should be recognized. First, the sample size was small, probably not being representative enough to reveal significant associations between the explored variables. Second, the sample consisted only of female workers, which according to previous investigations, women often report higher musculoskeletal symptoms and in more body regions than men [16]. Third, data related to the assessment of occupational injury risk was not collected, so it is not possible to be sure that the reported symptoms were work-related, or if there were some other underlying health conditions outside of the workplace.

5 Conclusion

There is a high 12-month prevalence of symptoms in the textile industry workers of the sample, with the four most affected body regions being the low back, the neck, the wrists/hands and the shoulders. No significant associations were found between BMI and musculoskeletal symptoms in the analyzed body regions. However, a significant association was found between the prevalence of musculoskeletal symptoms in the low back region and working mainly in the seated position. Preventive measures and worksite interventions are needed to reduce BMI and work-related musculoskeletal disorders in this population.

References

1. Bernard, B.P., Putz-Anderson, V.: Musculoskeletal disorders and workplace factors; a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. Natl. Inst. Occup. Saf. Health (1997)
2. Piedrahita, H.: Costs of work-related musculoskeletal disorders (MSDs) in developing countries: Colombia case. Int. J. Occup. Saf. Ergon. **12**(4), 379–386 (2006)
3. Wang, P.-C., Rempel, D.M., Harrison, R.J., Chan, J., Ritz, B.R.: Work-organisational and personal factors associated with upper body musculoskeletal disorders among sewing machine operators. Occup. Environ. Med. **64**(12), 806–813 (2007)
4. Kaergaard, A., Andersen, J.H.: Musculoskeletal disorders of the neck and shoulders in female sewing machine operators: prevalence, incidence, and prognosis. Occup. Environ. Med. **57** (8), 528–534 (2000)
5. Öztürk, N., Esin, M.N.: Investigation of musculoskeletal symptoms and ergonomic risk factors among female sewing machine operators in Turkey. Int. J. Ind. Ergon. **41**(6), 585–591 (2011)
6. Maciel, Á.C.C., Fernandes, M.B., Medeiros, L.S.: Prevalência e fatores associados à sintomatologia dolorosa entre profissionais da indústria têxtil. Revista Brasileira de Epidemiologia **9**, 94–102 (2006)
7. Dianat, I.: Musculoskeletal symptoms among handicraft workers engaged in hand sewing tasks. J. Occup. Health **58**, 644–652 (2016)
8. Viester, L., Verhagen, E.A., Hengel, K.M.O., Koppes, L.L., Van der Beek, A.J., Bongers, P. M.: The relation between body mass index and musculoskeletal symptoms in the working population. BMC Musculoskelet. Disord. **14**(1), 238–246 (2013)
9. De Vitta, A., Canonici, A.A., De Conti, M.H.S., Simeão, S.F.D.A.P.: Prevalência e fatores associados à dor musculoesquelética em profissionais de atividades sedentárias. Fisioterapia em Movimento **2**(2), 273–280 (2017)
10. World Health Organization: Body Mass Index. http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. Last accessed 23 Oct 2019
11. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., Jørgensen, K.: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. **18**(3), 233–237 (1987)
12. Mesquita, C.C., Ribeiro, J.C., Moreira, P.: Portuguese version of the standardized Nordic musculoskeletal questionnaire: cross cultural and reliability. J. Public Health **18**(5), 461–466 (2010)
13. Van, L., Chaiear, N., Sumananont, C., Kannarath, C.: Prevalence of musculoskeletal symptoms among garment workers in Kandal province, Cambodia. J. Occup. Health **58**(1), 107–117 (2015)
14. Gupta, N., Christiansen, C.S., Hallman, D.M., Korshøj, M., Carneiro, I.G., Holtermann, A.: Is objectively measured sitting time associated with low back pain? A cross-sectional investigation in the NOMAD study. PLoS ONE **10**(3), 1–18 (2015)
15. Tiwari, R.R., Pathak, M.C., Zodpey, S.P.: Low back pain among textile workers. Indian J. Occup. Environ. Med. **7**(1), 27–29 (2003)
16. Widanarko, B., Legg, S., Stevenson, M., Devereux, J., Eng, A., Cheng, S., Douwes, J., Ellison-Loschmann, L., McLean, D., Pearce, N.: Prevalence of musculoskeletal symptoms in relation to gender, age, and occupational/industrial group. Int. J. Ind. Ergon. **41**(5), 561–572 (2011)

Ergonomic Assessment in Waste Sorting Jobs with Different Methods

Jorge Cunha, Paula Carneiro and Ana Colim

Abstract The workers' health and safety are necessary for an active and sustainable life. That implies the creation of a safe and healthy environment throughout the active life of a workforce. The goal is to explore the contribution of several ergonomics evaluation methods applied in the fight against occupational diseases, work-related musculoskeletal disorders (WMSDs) in urban waste sorting posts, respectively in the multi-purpose line, green line and the line of Waste Electrical and Electronic Equipment (WEEE) in a waste management company. To achieve this goal, it was considered an analysis to the Nordic Musculoskeletal Questionnaire (NMQ), three observational methods, namely the Rapid Upper Limb Assessment (RULA), the Rapid Entire Body Assessment (REBA), the Job Strain Index (SI) and the Sonex software to the multi-purpose line and to the green line. To the WEEE line, it was considered analysis to the NMQ, two observational methods, namely the Key Indicator Method (KIM), Mital's Guide and the Sonex software. The application of NMQ shows the multi-purpose line is the one with the highest prevalence in symptomatology. In the application of observational methods, the comparative study shows that none of the methodologies is ideal, compared to others, to evaluate waste sorting tasks associated with repetitive movements, manual handling of loads (MHL) and inadequate postures. It is also possible to realize the Sonex software, being useful for the overall evaluation of the working position and not for each task that comprehends, having as a disadvantage, the evaluation conducted after the symptoms begin to show.

Keywords WMSDs · Ergonomic analysis methods · Sorting lines

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1 Introduction

Work-related musculoskeletal disorders (WMSDs) are still a major concern for workers and according to the National Council for Occupational Safety and Health, in the recycling industry there are WMSDs located in various parts of the human body namely in the back, shoulders, hands, and fingers, caused by risk factors: frequently repeated movements (arms and fists extension-flexion) and inappropriate posture.

There are other studies included in the recycling industry where WMSDs are found: due to awkward postures [1]; in areas of our body such as the lower back, shoulders, elbow, wrist, neck [2]; the dorsal region, shoulders, lower back, due to constant rotation of the trunk, repetitive movements and tasks executed with your body bent [3].

According to the National Council for Occupational Safety and Health Report [4], the processes allocated to the conveyor waste sorting activity are characterised by fast, frequent, intense, severe and repetitive movements. Another study [5] has also noted that static postures and manual handling of loads are risk factors associated with the conveyor belt activity. For the Health and Safety Executive [6], workers with this kind of job are likely to adopt an inappropriate and uncomfortable posture (including stretching, twisting, flexing and extending body segments); high level of force exerted; repetitive lifting and load carrying, especially if they were projected inappropriately, increasing the risk for workers to develop WMSDs. The Health and Safety Executive [7] mentions that the risk for WMSDs comes from repetitive movements while disassembling, moving and carrying products that consist of heavy loads.

Consequently, a waste management company has developed a study involving the application of different ergonomic assessment methods in municipal waste sorting jobs with the following goals: to assess the risk of WMSDs in three different sorting jobs; to conduct a comparative analysis of the applied methods; to identify ergonomic improvement proposals for sorting jobs.

2 Materials and Methods

The study was conducted on 9 workers that were executing their tasks in the selected places. In the multi-purpose line, the M1, M2 and M3 tasks (Fig. 1) were analysed respectively. The study was also carried out on 3 workers from the green line with the V1, V2, V3 and V4 tasks (Fig. 2), and on 5 workers from the Waste Electrical and Electronic Equipment (WEEE) line namely the white line area, the cold line area, the tv and monitors circuit area (Fig. 3).

To characterise these places of study according to their organisation and space distribution, the internal regulation and working procedures were analysed and visits were paid to the facility when the work in the field began (July 2016). To

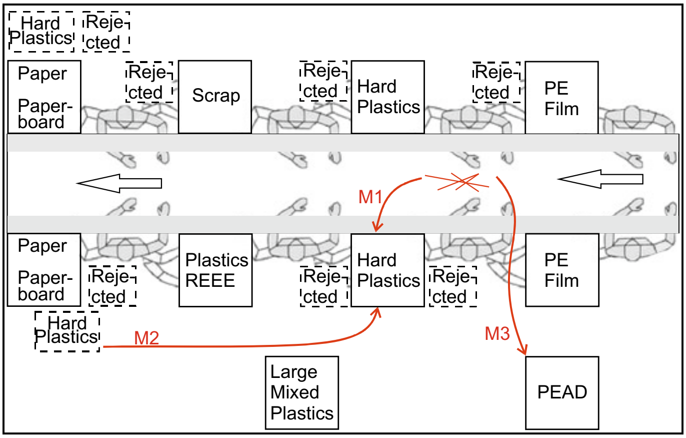

Fig. 1 Multi-purpose line process flow

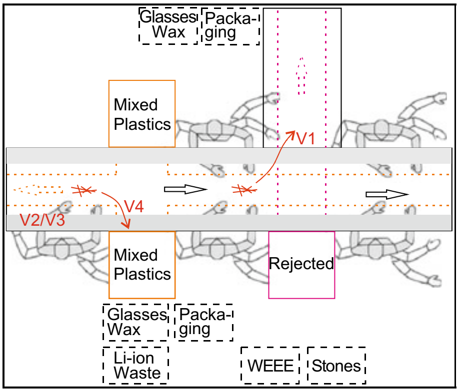

Fig. 2 Green line process flow

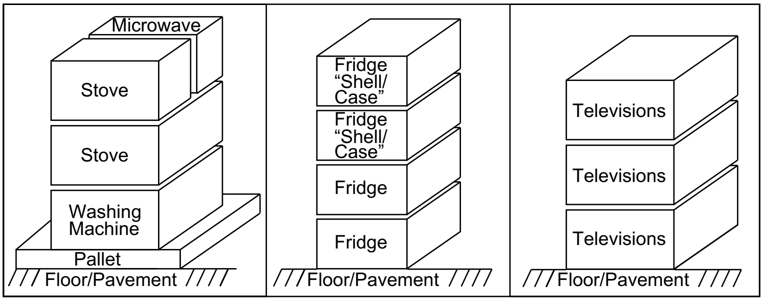

Fig. 3 WEEE line process flow

characterise the activities, for several weeks a direct and indirect observation (videos and photos) was carried out in the workplace. As for characterising the workers, an analysis to work incidents was made, as well as the data on age, gender, admission date and function were collected. Later on, the reason and goals of this research were explained to all workers in a reunion in loco, and afterwards, the Portuguese version of the Nordic Musculoskeletal Questionnaire was distributed and completed [8].

For the data processing, the Microsoft Excel program and the Statistical Package for Social Sciences version 24 were used.

For the method selection (post bibliographic review of literature and activity characterisation), risk factors were considered and then the following observational methods were selected: multi-purpose line and green line—Rapid Upper Limb Assessment (RULA) [9], Rapid Entire Body Assessment (REBA) [10], Strain Index (SI) [11], Sonex [12]; WEEE Line—Mital guide developed by (Nicholson and Ayoub, 1993 quoted by [13]), Key Indicator Method (KIM) developed in 1996 (Steinberg et al. 1997 quoted by [14]) and Sonex [12].

The comparison between the different methods was qualitative and oriented towards prevention, assessing the most significant risk factors to better respond to the ergonomic needs of the working place.

3 Results and Discussion

Table 1 represents the synthesis of the NMQ answers given by the workers from all three working places. The repetition of the symbol means the response percentage is greater than 50, the contrary means the response percentage is between 26 and 49. As for the symbols, we have □—complaints concerning the last 12 months; ■—complaints regarding the past seven days; ○—complaints regarding the past twelve months (had to avoid activities); ●—pain scale experienced from a complaint (with higher pain score).

In Table 1 we can compare with evidence from other studies previously mentioned, verifying that there are coinciding answers in all parts of the body, except

Table 1 Synthesis of the responses given to the Nordic Musculoskeletal Questionnaire

Body parts	Multi-purpose line				Green line		WEEE line
Neck	□ □	■	○			●	●
Shoulders	□	■		●	□		●
Fist/hand	□						
Lower back	□ □	■ ■	○	●			●
Hips/thighs	□						●
Knees	□	■	○				
Ankles/feet	□ □	■	○				

for the knees. This comparison is made at a general level and cannot be compared individually per function. The results demonstrate that in the NMQ, the multi-purpose line is the one with the highest symptomatology prevalence.

Both in the RULA and REBA methods, it was observed that depending on the task being performed, the worker is subject to different levels of action for the multi-purpose line. The opposite is no longer detected in the green line. Also, the 'muscle use' parameter is difficult to solve in almost all of them, since the task itself requires frequent repetition (more than 4 times per minute).

As for the tasks referred to the multi-purpose line analysed by RULA, the M3 is the one with the lowest level of action and suggests that more observation is necessary and changes to the task may be required. The M1 and M2 tasks, on the other hand, require a careful investigation and changes should be made soon.

As for the M1 task, the results highlight the hypothesis of studying improvement solutions to reduce the value of incidence in the parameters "wrist, neck and trunk". On to the M2 task, the most pronounced value is the parameter "arm" and the load.

In the green line, for the V2 and V3 tasks, we emphasise the need to study improvement hypotheses for the "arm" parameter and the V4 task, improvements for the "wrist" parameter.

Concerning the REBA method, in the multi-purpose line, the M1 task is the one that presents the lowest level of action and indicates that an action is required. The M2 and M3 tasks, however, show the need for action shortly.

As for the M1 task, we highlight the hypothesis of studying improvement solutions to reduce the scores from the "trunk and wrist". In the M2 task, the most pronounced value is the parameter "arm" and "load". Finally, the M3 task requires a study of the "arm and wrist" parameters.

In the green line, all tasks need a study for solutions in the "arm" parameter. The V1 and V4 tasks would also add from a study referred to the "trunk and wrist" parameter.

Concerning the SI method, in the multi-purpose line, from the tasks analysed, the M2 and M3 are the ones that present the lowest risk, namely regarding the level of action corresponding to a safe working place. The M1 task represents a level of action applicable to a dangerous working place with serious risks of WMSDs.

As for the M1 task, the results highlight the hypothesis of studying improvement solutions to reduce the value of incidence in the "efforts per minute" parameter. In the tasks M2 and M3, no pronounced value stands out.

In the green line, the V3 and V4 tasks are represented as dangerous working places, in which the V3 task is associated with the risk of WMSDs and the V4 scenario with high risk of WMSDs.

The V3 task needs a search for solutions in the "effort intensity" and "hand/wrist posture" parameters because although this scenario has the highest values in those parameters, as it happens few times per minute, it makes the level of action not so high. The V4 task requires a search for solutions in the "effort per minute" parameter.

As for the Mital and KIM guide methods, there's a greater risk of MSDs if only one worker performs the tasks on both lines. It was also found that the waste weight parameter is the main factor to take into account in this situation.

In the Mital guide method, it was attempted to optimise all values that come into the calculation formula through hypothesis, except for the weight value and, even though two workers were performing the task, the value of risk is still higher than 1 in the first few levels.

In the KIM method, in the white line, it was found that handling washing machines present the highest risk of MSDs, mainly due to its weight, posture and loading position. In the cold line and tv and monitors circuit, it was found that only tasks that require lifting, carrying and lowering the whole waste have greater chances of risk essentially due to its weight, frequency per day, adopted posture and loading position.

Regarding the results from the Sonex, between the green line and the WEEE line, there are no issues concerning the following parameters: hands and fingers; arms and elbows; shoulders; neck and upper back; lower back; buttocks and hip; knee; ankle; foot and organisational factors. In the green line there's a risk of MSDs associated with the working task and tool parameters. In the WEEE line and multi-purpose line, there's risk of MSDs associated with the working task, environment and tool parameters.

3.1 Comparative Study

For the physical and biomechanical risk factors, since the methods used (Mital and KIM guide) had different numerical scales expressing results in different levels of action and with different interpretations, in order to ease the comparison between the methods, the adopted approach was the one used in the study in [15]. By comparing them, it was found that in some tasks there were levels of action with similarities between both methods, such as lifting, carrying and lowering washing machines by an operator; lifting, carrying and lowering television "shell/case" by one or two workers; lifting, carrying and lowering television "shell/case" by two workers. All the other tasks are different, standing out by the larger dispersion the lifting, carrying and lowering of washing machines by two workers. In terms of percentages, we can say that approximately both methods correspond in 62% similarities, corresponding to 26 similar responses against not so similar 16 responses.

As for the physical and biomechanical risk factor—inappropriate posture and repetitive movements, since the methods used (RULA, REBA and SI) also differ among themselves, to ease up the comparison between the results from the RULA and REBA methods, we adopted the comparison used in the study [16]. Through a comparative analysis, we were able to perceive that some tasks have similarities in levels of action such as M2 task between the RULA and REBA methods; V1 task between the REBA and SI methods; V3 task between the RULA and SI methods.

In terms of percentages, we can state that all three methods in all scenarios are not once at the same level of action.

About Sonex, its comparison with the rest becomes difficult because of the way it presents the results. Through software analysis, it turns out that it only makes sense to complete any knowledgebase if there's any discomfort. This leads to a post-symptom analysis, which is against the remaining methods that work as prevention before any discomfort appears.

3.2 Proposals for Improving Working Conditions

The M1 task on the multi-purpose line, we recommend at least one more out port for solid waste in order to reduce the amount of effort per minute; raise awareness among workers to collect waste only in half of the belt width and leave the rest for the operator on the other side; a more reduced distance between the operator and the out port to avoid the lateral rotation of the trunk; a reduced space between the operator and the conveyor belt with the waste (the threshold) puts the operator further away from the belt, and favours a bigger flexion of the trunk. As for the M2 task, this one is recommended to be always executed by two workers; check the possibility of moving the container in the frontal plane rather than in the lateral plane, to avoid arm abduction. As for task M3, it's recommended to eliminate the location of the out port from the HDPE waste to the operator's back and locate it near the conveyor belt to avoid trunk twisting, high-level of flexion and arm rotation.

In the green line for the V1 task, it's recommended to turn the lateral margin existent in the rejects conveyor belt a little bit larger; to reduce the space between the operator and the conveyor belt with the food waste. It's recommended for the V2 task to modify and/or acquire a conveyance with an appropriate conveyor belt to avoid the agglomeration of waste on the sorting belt, to eliminate this task. For the V3 task it's recommended to acquire a bag opener machine to be incorporated into the feeding conveyor and in the V4 task it's recommended to hire another worker to collect mixed plastics and/or to move an operator from the end of the line to the beginning of the line and to raise awareness among the workers so they get closer to the out ports and avoid lateral deviation of the fist and arm rotation.

In the WEEE line it's necessary to acquire a robotic arm for handling waste.

4 Conclusions

The application of NMQ shows that the multi-purpose line is the one with the highest musculoskeletal symptomatology prevalence.

The results of the comparative study show that none of the methods applied is the most appropriate concerning others since there are differences in the values of action, as well as different advantages and disadvantages. It's therefore concluded that some of the methods studied are closer to the "ideal method" than others depending on the parameters to be analysed.

It's also possible to realise that the Sonex software is useful in the overall evaluation of the working place and not for each task in it, having as a disadvantage the post evaluation of the symptom's appearance.

The use of various methods has proven to be beneficial in the evaluation of several tasks, validating their level of action and identifying the main risk factors to find improvement proposals for sorting jobs, to eliminate or reduce the risk implicit in the tasks.

From this study, it can also be concluded that there are improvement proposals in all three working places through layout changes, workers' awareness and acquisition of material to be incorporated along the sorting lines.

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References

1. Gutberlet, J., Baeder, A.M., Pontuschka, N.N., Felipone, S.M.N., dos Santos, T.L.F.: Participatory research revealing the work and occupational health hazards of cooperative recyclers in Brazil. Int. J. Environ. Res. Public Health **10**, 4607–4627 (2013)
2. Jayakrishnan, T., Jeeja, M., Bhaskar, R.: Occupational health problems of municipal solid waste management workers in India. Int. J. Environ. Health Eng. **2**, 42 (2013)
3. Lopes, A.F.T.: Estudo da prevalência de problemas Músculo-esqueléticos de origem Ocupacional num centro de triagem de Resíduos valorizáveis. Universidade do Porto (2015)
4. NCOSH: Sustainable and safe recycling: protecting workers who protect the planet. National Council for Occupational Safety and Health, MassCOSH (2015)
5. Pires, L.E.: Contributo para a validação de uma estratégia de diagnóstico do risco de LMELT: empresas de triagem de resíduos orgânicos. Universidade Nova de Lisboa (2011)
6. HSE: Conveyor belt workstation design. Health Saf. Exec. vol. GEIS4 (2012)
7. HSE: Waste electrical and electronic equipment recycling (WEEE). Health Saf. Exec. (2018)
8. Mesquita, C., Ribeiro, J., Moreira, P.: Portuguese version of the standardized nordic musculoskeletal questionnaire: cross cultural and reliability (2010)
9. McAtamney, L., Corlett, E.N.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**, 91–99 (1993)
10. McAtamney, L., Hignett, S.: Rapid entire body assessment (REBA). Appl. Ergon. **31**, 201–205 (2000)
11. Steven Moore, J., Garg, A.: The strain index: a proposed method to analyze jobs for risk of distal upper extremity disorders. Am. Ind. Hyg. Assoc. J. **56**, 443–458 (1995)
12. Pavlovic-Veselinovic, S., Hedge, A., Grozdanovic, M.: An expert system for risk assessment of work-related musculo-skeletal disorders. Int. J. Ind. Ergon. **53**, 130–139 (2016)
13. Colim, A.S.: Tarefas de manipulação manual de cargas: selecção de métodos de avaliação de risco. Universidade do Minho, Guimarães (2009)
14. Steinberg, U.: New tools in Germany: development and appliance of the first two KIM ("lifting, holding and carrying" and "pulling and pushing") and practical use of these methods. Work **41**, 3990–3996 (2012)

15. Simões, R.M.S.S.: Análise e Avaliação de Tarefas de Movimentação Manual de Cargas. Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa (2015)
16. Kong, Y.K., Lee, S., Lee, K.S., Kim, D.M.: Comparisons of ergonomic evaluation tools (ALLA, RULA, REBA and OWAS) for farm work. Int. J. Occup. Saf. Ergon. **24**, 218–223 (2018)

Association Between Manual Handling of Loads and Occupational Low Back Pain: A Case-Control Study with Brazilians Workers

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Abstract The association between Manual Handling of Loads (MHL) and Occupational Low Back Pain (OLBP) in Brazilian workers was investigated. With this objective, a case-control study was conducted with 84 workers from different productive sectors. The data, collected by means of filling forms and by specific measuring instruments, were statistically treated with a significance level fixed at $p < 0.05$. The association between variables was accomplished by the technique of multiple logistic regression. The results indicated that the OLBP was statistically associated with the unitization of loads. (OR = 18.57), package handle (OR = 3.60), load weight (OR = 2.15), task frequency (OR = 7.35), distance traveled (OR = 2.04), trunk flexion (OR = 1.96), trunk rotation (OR = 1.41) and amount of load (OR = 1.17). This association indicate that ergonomic interventions should be implemented because recurrences of low back pain episodes may evolve to chronic cases and result in the functional incapacity of the worker.

Keywords Manual handling of loads · Occupational low back pain · Brazilian workers

1 Introduction

The global economy and its effects have imposed on companies the need to incorporate new management methods to achieve established performance goals. These organizational rearrangements have also led, however, to deregulation in

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labor relations. Despite the incorporation of technologies for the automation of production processes, numerous tasks continue to be performed under inadequate conditions, especially when Manual Handling of Loads (MHL) is required.

In Brazil, the rule which regulates this issue is the CLT (Consolidation of labor laws), in the Article Number 198 of Law No. 5452, May 1, 1943, which provides that a worker can handle loads weighing up to 60 kg [1]. The Labor Inspection Secretariat (SIT) through Regulatory Standards (NR) also establishes provisions complementary to Chapter V of the CLT. These norms constitute obligations, rights and duties to be fulfilled by employers and workers in order to ensure safe and healthy work, preventing the occurrence of occupational diseases and accidents. With regard to MHL, Regulatory Standard 17 (NR 17), which deals with ergonomic aspects of working conditions, clarifies that cargo handling whose weight could compromise the worker's health or safety should not be required or admitted [2, 3]. However, it is noted that Brazilian law does not provide parameters for the technical basis for MHL, leaving this requirement highly subjective. Thus, focusing only if the weight limit exceeds 60 kg does not seem to be sufficiently capable of promoting worker safety, as the established weight limit is too high according to recommended ergonomic standards and may trigger occupational low back pain [4–8]. In fact, low back pain is a public health problem worldwide. In Brazil, although there are no epidemiological studies investigating the real picture of how workers involved in this type of activity become ill, the financial data provided by the Ministry of Social Security (MPS) estimated that in 2016, 62% of cases due to work incapacity are due to spinal injuries. The data also revealed that these benefits represented a financial burden of R$117.3 million for both companies and society in general. In 2017, the number of sickness benefits due to low back pain amounted to 83.763 [9].

This high incidence of OLBP in workers handling cargo has led companies and the scientific community to conduct studies to identify the main risk factors and then to implement control measures. Studies on the risks of MHL in the Brazilian context are still scarce. Thus, epidemiological studies from an ergonomic perspective, that seek to investigate the genesis of low back pain morbidity in this population are relevant. The objective of this study was to investigate the association between MHL and OLBP in Brazilian workers from various productive sectors.

2 Materials and Methods

2.1 Study Design

This is a case-control and cross-sectional study conducted with workers from different productive sectors who perform MHL tasks. Eighty-four workers participated in the study, including 36 vegetable loaders, 10 airport baggage handlers, 6 baggage road-boarding agents, 10 stockmen and 22 finished product baggers. All workers were male with a mean age of 41 $\pm$ 3 years, average height of 1.73 $\pm$ 0.06 m, average weight of 79.5 $\pm$ 8.3 kg and average BMI of 25.6 $\pm$ 2.7 kg m^{-2}. The

Table 1 Independent variables investigated (n = 22)

Variables[a]	Coding	Variables[a]	Coding
MHL on ground level[b]	X_1	Task frequency	X_{12}
Platform use[b]	X_2	Task duration	X_{13}
Site paving[b]	X_3	Travelled distance	X_{14}
Obstacle in the path[b]	X_4	Lifting horizontal distance	X_{15}
Clothing[b]	X_5	Lifting vertical distance	X_{16}
Safety equipment[b]	X_6	Horizontal transport distance	X_{17}
The person's grip on the object[b]	X_7	Vertical transport distance	X_{18}
Weight of load	X_8	Trunk flexion	X_{19}
Amount of load[c]	X_9	Trunk extension	X_{20}
Unitization of loads	X_{10}	Trunk rotation	X_{21}
Stacking of loads	X_{11}	Trunk lateral flexion	X_{22}

Note: [a]Continuous variable except where indicated; [b]Dichotomous variable; [c]Discrete variable

average time of service provided by these professionals was 9 ± 3 years and average working day of 8.1 ± 1.4 h. None worker claimed to have performed any surgical procedure on the spine, have mobility compromised or have clinical diagnosis of chronic low back pain.

The individuals were divided into two mutually exclusive groups, called case and control. In the case group were allocated 42 workers affected by recurrent episodes of low back pain, while in the control group were allocated 42 workers without LBP symptoms outcoming after entering the profession. In addition, controls were matched to cases according to the similarity of working conditions, the working hours (±2 h) and the time of service in the activity (±3 years).

The variables investigated in this study were dependent and independent in nature. The dependent variable (Y) referred to the development of occupational low back pain in workers. Operationally, this variable was dichotomized to present the following response categories: absence of low back pain (0) or presence of low back pain (1). The independent variables (X_n) referred to the characteristics of the MHL performed by the workers, which could act individually or jointly in the etiology of the OLBP (see Table 1).

2.2 Collection Procedures

Data collection occurred during the first quarter of 2019 and was systematized into two steps. In the first stage, data related to workers' characteristics were collected. In the anthropometric assessment, the *Starrett*® tape was used to measure worker height, while the weight was determined by the *Avanutri*® digital scale. Measurements were taken with the individual in the standing position and with the head held in the Frankfurt horizontal plane. Body Mass Index (BMI) was obtained according to criteria established by the World Health Organization (WHO).

In the second step, data related to the task characteristics were collected by means of a form. The variables X_1, X_2, X_3, X_4, X_5, X_6 and X_7 were collected under the qualitative aspect. The other variables were measured quantitatively. Variable X_8 was obtained from the shipping document provided by the company. Variables X_9, X_{10} and X_{11} were accounted for and documented in the worker form at the end of the MHL process. *Vollo*® digital timer was used to determine variables X_{12} and X_{13}. The X_{14} variable was determined using the Echolife® digital pedometer. Variables related to load gripping distances X_{15}, X_{16}, X_{17} e X_{18} were measured by the measuring tape *Starrett*®, both in the origin and destiny of the movement. Variables related to the arc of spinal motion X_{19}, X_{20}, X_{21} e X_{22} were measured using the *Trident*® goniometer. These measures were taken at four stages of the task.

2.3 Data Analysis

Statistical analyses were performed on the Statistical Package for Social Sciences 24 (SPSS) for *Windows*®. Univariate data analysis, descriptive statistics was used to synthesize and represent the numerical and categorical variables of the study. In addition, the nonparametric Kruskal-Wallis and Mann-Whitney tests were used for comparison between groups.

In the multivariate analysis of the data, the multiple logistic regression techniques was used to investigate the association between Y and X_n, expressed by odds ratio (OR). Initially, multicollinearity between two or more independent variables was verified by the Variance Inflation Factor (VIF) and Tolerance (T) tests. The selection of independent variables was performed by the Forward Stepwise (Wald) method, based on the capability of discrimination they add to the set of variables that explain the development of OLBP in workers. The significance of the estimated coefficients was determined by the Omnibus test. The fit quality of the model was verified by the log-likelihood tests, Nagelkerke pseudo-R^2 and Hosmer-Lemeshow tests. In all statistical tests the significance level was adopted ($p < 0.05$).

2.4 Ethical Clearance

This study was registered in the National Research Ethics System (SISNEP) and approved by the Research Ethics Committee (CEP) of the Federal University of Sergipe Foundation (FUFS), under protocol number 91502718.1.0000.5546.

All the selected workers signed the Free and Informed Consent Term (TCLE) and were instructed on the voluntary nature of the study, the procedures to be adopted in the course of the field research and the use of the information collected.

3 Results and Discussion

3.1 Characteristics of MHL

All workers performed the MHL on the ground (X_1), 33.3% used height leveling platforms at least once (X_2). Regarding the site paving (X_3), it was noticed that 70.2% of the task was performed in locals with inadequate paving. Just 26.2% cases and 33.3% controls accomplished the tasks in adequate areas. Besides that, there were significative differences ($p = 0.004$) between the groups regarding the obstacles in the path (X_4). The controls presented greater difficulty in this respect than the cases, as 57.1% of them worked under intense flow of vehicles and people in the place.

In addition to these factors, 86.9% of the workers wore inappropriate clothing (X_5). They developed their duties in the open, and were therefore subject to inclement weather. In general, the garments were made of material that did not lead to perspiration to the outside of the fabric, causing the retention of sweat and additional heat load increasing the feeling of thermal overload. In addition, the recurrent use of open footwear, which did not give stability when workers are carrying loads, and no head protection.

Only 8.3% of workers used safety accessories (X_6), specifically gloves for hand protection and improvement of adherence to the package as well as closed shoes to protect feet against load fall and stability along the path, as established by the Occupational Health and Safety (OSH) guidelines. On the other hand, it was found that 76.2% of the task was performed with loads that had a suitable support point (X_7) since they made palm grip possible.

On average, workers moved 242 ± 74 load units (X_9), with an average weight of 46.1 ± 7.3 kg (X_8). In both groups, the average stacking of these loads in the warehouse was 8 ± 2 packages per stack (X_{11}). In both groups, the average stacking of these loads in the warehouse was 8 ± 2 packages per stack (X_{11}). Unitization of the loads in the manual cars had an average of 12 ± 4 units (X_{10}). Thus, considering the additional weight of the car, it can be inferred that workers pushed/pulled volumes weighing in excess of half a ton. The task frequency (X_{12}) obtained by the workers was 7 ± 1 average lifting per minute. Significant differences were found in this variable ($p = 0.017$), as the controls presented twice the load lifting per minute than the cases. The average distance traveled by workers with respect to cargo transportation was 34.9 ± 25.6 m (X_{14}) with an average total duration of the task performed by the workers of 51.9 ± 13.4 min (X_{13}). Significant differences were also found between the groups regarding the distance covered ($p = 0.001$) and task duration ($p = 0.005$). The cases traveled longer distances and took more execution times than the controls.

It was observed that the load gripping distances in relation to the sagittal plane of the workers in the load lifting/lowering was 32.6 ± 8 cm (X_{15}), average horizontal distance and 91 ± 43.7 cm the vertical distance from the ground (X_{16}). In the load's transport, the average horizontal distance was 29.1 ± 5.4 cm (X_{17}) and the vertical mean distance was 104.8 ± 39 cm (X_{18}). These variables were influenced by the lifting and transport techniques adopted by the workers, as well as the initial and final heights of the moved loads.

Regarding the arc amplitude motion of the spine, the average trunk flexion performed by the workers was 54.6 ± 25° (X_{19}), the average extension was 18.7 ± 6.2° (X_{20}), the average rotation was 83.6 ± 27.8° (X_{21}) and lateral flexion was 14.5 ± 8.2° (X_{22}). The cases differed significantly from the controls regarding trunk extension and lateral flexion ($p = 0.001$), presenting the highest angular amplitudes in the execution of the task. In line with the gripping distances, the biomechanics ratify the lifting/lowering of loads above the shoulder line. This is due to the height of the truck body and the stacking of the loads, as well as the recurring use of the shoulders for their transport.

3.2 Factors Associated with OLBP

The proposed association was modeled by the multiple logistic regression technique, which verified the influence of the variables X_n on the variable Y. All values of T were greater than 0.1 and those of VIF less than 10, showing the absence of multicollinearity between the variables X_n.

Omnibus test revealed that the model presented statistically significant adequacy ($\chi^2 = 69.31$; $p < 0.000$) to predict the development of OLBP in the workers, and allowed to reject the hypothesis that all coefficients entered were null.

Regarding the quality of the model fit, the log-likelihood test (χ^2 (1) = 7.812) found that the independent variables were significant for the model. This was confirmed by the Cox-Snell pseudo R^2 that indicated that the model was able to explain about 71.1% of the variations in the dependent variable, while Nagelkerke's pseudo R^2 reported an explanation of 97.3%. Finally, the Hosmer-Lemeshow test allowed to reject the hypothesis that there were significant differences between the classifications made by the model and those observed in the field research ($\chi^2 = 15.98$; $p > 0.05$), confirming its adherence to the data.

The independent variables explanatory for the development of OLBP in workers as a function of MHL were X_{10}, X_7, X_8, X_{12}, X_{14}, X_{19}, X_{21} and X_9. According to the model parameters, workers who unitized loads under the handcart had 20.43 times greater chance of reporting low back pain than those who did not (OR = 20.43; 95% CI = 11.34–23.73). When handling loads with packaging without proper handles or foothold, lumbar seizures were 11.34 more likely to occur (OR = 11.34; 95% CI = 1.42–16.32). The increase in the unit weight of the moved load increased the chances by 9.06 times (OR = 9.06; 95% CI = 1.69–11.61). The task frequency increased the odds by 7.35 times (OR = 7.35; 95% CI = 1.72–10.26). Distant path in cargo transportation increased the chances of the worker belonging to the case group by 5.23 times (OR = 5.23; 95% CI = 1.28–8.42). Furthermore, it was observed that the increase in the trunk flexion angle of the worker increased the chances by 3.08 times (OR = 3.08; 95% CI = 1.27–6.87), while in the trunk rotation by 2.87 times (OR = 2.87; 95% CI = 1.15–4.93). Finally, the amount of cargo handled by workers increased the probability by 1.18 times (OR = 1.18; 95% CI = 1.02–3.88).

These results are in accord with the studies of Másculo and Vidal [4], Jäger et al. [10] and Neumann et al. [11]. Several papers report that, during the MHL can occur overload on the spine able to damage the intervertebral discs. Dreischarf et al. [12], Monteiro et al. [5, 7, 9], Jiemjai [13] and Wong e Lee [14] associated these factors to the increasing of the intradiscal compression at the L3/L5 level.

Given the risk factors for low back pain identified in this study, some ergonomic recommendations were presented to the company managers. At the time, it was highlighted the availability of a range of equipment on the market that provides mechanical assistance for the loading and unloading of goods. In order to reduce the effects related to the amount of loads, unitization, task frequency and the distance traveled, it was suggested the use of forklifts or mechanical traction cars. Regarding the risks related to the weight of the load, packing handle, flexion and trunk rotation, the use of lifting devices was suggested. Santos and Monteiro [6] pointed out that these devices have been widely used in MHL demanding activities due to their flexibility and handling capacity of a wide variety of loads in terms of size, shape and weight. In addition, it reduces the risk of damage to goods, whether due to improper handling or adverse weather conditions [8]. It was also emphasized and recommended to the managers that in the short term or if there was no possibility of using automated mechanisms, training should be carried out with workers, especially with regard to cargo handling techniques. The effectiveness of these techniques has been proven in studies such as those by Másculo and Vidal [4], Monteiro et al. [7] and Gonçalves [15], who related the decrease in body-load distance as a reducing factor for lumbar spine overload.

4 Conclusions

The hypothesis previously considered that there was an association between MHL and the development of OLBP was confirmed in the present study. The modeling employed in this investigation suggested that low back pain reported by workers was statistically associated with load unitization, packing handle, load weight, task frequency, distance traveled, trunk flexion, trunk rotation and amount of load. The results show that control measures should be implemented immediately, since the recurrences of low back pain episodes may evolve to chronic cases. Then, the chances of the worker returning with the same physical conditions as before will be lower.

Although there is a need for longitudinal research to investigate other variables inherent to the task, some contributions were achieved in this cross-sectional study. From the theoretical point of view, the study made it possible to fill the gap in the literature regarding studies of the working conditions of professionals whose physical capacity is exploited to almost exhaustion. From a practical point of view, it identified the main risk factors that may be found in the genesis of morbidity caused by low back pain in these professionals in the Brazilian context.

In general, it is envisioned that when implemented, the ergonomic propositions will enable gains for all actors involved. For the workers increasing the efficient performance of their duties and preservation of physical integrity; for the managers of the companies, by optimizing the commercial operations and increasing the economic performance indicators; and for the government, due to the reduction of direct and indirect expenses with the public health and social security system.

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References

1. Brasil: http://www.planalto.gov.br/ccivil_03/decreto-lei/Del5452.htm. Last accessed 4 Sep 2019
2. SIT: https://enit.trabalho.gov.br/portal/index.php/seguranca-e-saude-no-trabalho/sst-menu/sst-normatizacao?view=default. Last accessed 4 Sep 2019
3. Brasil: http://trabalho.gov.br/images/Documentos/SST/NR/NR17.pdf. Last accessed 4 Sep 2019
4. Másculo, F.S., Vidal, M.C.: Ergonomia: Trabalho Adequado e Eficiente, 1st edn. Elsevier Brasil, Rio de Janeiro (2013)
5. Monteiro, L.F., Santos, J.W., Franca, V.V., Santos, V.M., Alsina, O.L.S.: Measurement of physical overload in the lumbar spine of baggage handlers at a Brazilian airport. In: Arezes, et al. (eds.) Occupational Safety and Hygiene, vol. 1, pp. 87–92. CRC Press, Taylor & Francis Group, London (2017)
6. Santos, J.W., Monteiro, L.F.: Avaliação das condições de trabalho de agentes de bagagem e operadores de rampa de um Aeroporto Brasileiro. Revista Gestão Industrial **13**(1), 38–56 (2017)
7. Monteiro, L.F., et al.: Correlation between manual lifting of loads and low back pain in workers of a supply center of vegetables and fruits. In: Arezes, et al. (eds.) Occupational and Environmental Safety and Health, vol. 1, pp. 457–465. Springer, Switzerland (2019)
8. Santos, J.W., Monteiro, L.F.: Prospecção tecnológica sobre acessórios para a estabilização da coluna lombar durante o transporte manual de cargas. Revista Brasileira de Gestão e Inovação **5**(3), 173–194 (2018)
9. Monteiro, L.F., Santos, J.W., Barreto, J.C.M., Santos, V.M., Franca, V.V., Alsina, O.L.S.: Análise Biomecânica da Atividade de Transporte Manual de Bagagem em um Aeroporto Brasileiro. In: Arezes, P., et al. (eds.) International Symposium on Occupational Safety and Hygiene, vol. 1, pp. 209–211. Portuguese Society for Occupational Safety and Hygiene (2016)
10. Jäger, M., Jordan, C., Luttmann, A., Laurig, W., Dolly, G.: Evaluation and assessment of lumbar load during total shifts for occupational manual materials handling jobs within the Dortmund Lumbar Load Study. Int. J. Ind. Ergono. **5**(1), 553–571 (2000)
11. Neumann, W.P., et al.: A posture and load sampling approach to determining low-back pain risk in occupational settings. Int. J. Ind. Ergon. **27**(2), 65–77 (2001)
12. Dreischarf, M., Aboulfazl, S., Arjmand, N., Antonius Rohlmann, A., Schmidt, H.: Estimation of loads on human lumbar spine: a review of in vivo and computational model studies. J. Biomech. **49**(6), 833–845 (2015)

13. Jiemjai, C., et al.: D2-1 L4/L5 disc compression force in phases of manual human handling. Jpn. J. Ergon. **53**(2), 388–390 (2017)
14. Wong, T.K.T., Lee, R.Y.W.: Effects of low back pain on the relationship between the movements of the lumbar spine and hip. Hum. Mov. Sci. **23**(1), 21–34 (2004)
15. Gonçalves, M.: Variáveis biomecânicas analisadas durante o levantamento manual de carga. J. Phys. Educ. **4**(2), 85–90 (1998)

Automatic Identification of Hand-Held Vibrating Tools Through Commercial Smartwatches and Machine Learning

Luis Sigcha, Ignacio Pavón, Stefania Nisi and Guillermo de Arcas

Abstract This work presents an application of wearable technology and machine learning techniques for automatic identification of the use time of hand-held vibrating tools in the workplace. The proposed system is an automatic recognition system based in a commercial smartwatch that can be used in tasks related to the risk assessment produced by exposure to vibrations that affects the hand-arm system. The system can identify with high accuracy, three types of machine families and identify a single model within a single tool family. At present, it is possible to use intelligent wearable devices for the development of technological solutions that can help to improve the current methodologies for quantifying the effects produced by the exposure to hand-held vibrating tools, as well as its level of impact on workers' health. In the near future, the use of systems similar to this may allow the analysis of the occupational risks produced by exposure to mechanical vibrations in the workplace in an automated, precise and low-cost way, as well as being part of risk management systems integrated into the concept of industry 4.0.

Keywords Vibration risk assessment · Hand-arm vibration · Wearable · Machine learning

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1 Introduction

Exposure to vibrations in working environments occurs mainly in industries such as transport, construction, and processes. The vibrations that affect the human body can have high impact in the health depending on variables such as time, intensity, zone affected and type of vibration to which the worker is being exposed [1].

Several studies have shown that prolonged exposure to these vibrations can cause different types of injuries and discomfort for the exposed subject [2].

The vibrations produced by vibrating tools and motorized processes can be transmitted to the body through the hand-arm system, this phenomenon is known as hand-arm vibrations. The continued exposure to this type of vibrations can produce vascular disorders, neurological disturbances, and musculoskeletal effects; among these stands out the Raynaud's phenomenon or commonly named vibration-induced white finger [3].

In Europe, the Directive 2002/44/CE is designed to regulate the exposure to vibrations from an industrial point of view. The directive sets the minimum health and safety provisions regarding the exposure of workers in the workplace specifically derived from physical agents such as mechanical vibrations [4].

1.1 Wearables

Devices named wearables are becoming popular because they can be carried on the body or integrated into clothing or other accessories. These types of devices generally mount low-cost sensors named Microelectromechanical systems (MEMS), that allows them to measure physical variables (movement, body temperature, heart rate, etc.).

The addition of sensors gives wearables interesting features used in applications such as biometric and security [5–7].

One of the principal applications of wearables has been the detection of activities and movement, for these purposes it has been used specific wearable devices and commercial devices with several sensors [8–10].

1.2 Wearables for Vibration Assessment

There are some previous experiences where wearable-based solutions with MEMS accelerometers have been used for the assessment of vibrations in the workplace.

In [11] a mobile application was developed to measure and analyze the exposure to the whole body vibrations. This system was tested in agricultural tractor operators. Another example was presented by Wolfgang [12, 13], comparing a system based on an iPod and a specific application with a standard vibration analyzer.

In both cases, the results have shown that this kind of systems are easy and low-cost methods for risk assessment with high confidence.

One of the most important wearable devices are smartwatches. These devices have similar features to a smartphone and can have a diversity of sensors that are integrated. These devices can be used as a platform for the development of new applications related to health, wellness, safety, sports, fitness, communication, and business [6, 7].

At present, there are initiatives that use specific wearable devices in risk assessment. In these applications, the systems take advantage of the diversity of existing sensors, the portability, and the energy autonomy capabilities of the devices, which makes them an excellent option for the collection of information in an economical and discreet way [14, 15].

1.3 Hand-Arm Vibration Assessment Through Wearables

An early study made by Tarabini [16] analyzed the advantages and disadvantages of using MEMS accelerometers for the measurement of hand-arm and whole-body vibrations. The study concludes that it is possible to design smart systems with MEMS accelerometers inside any type of hand tool, operators' interface, or inside the car seats, tractors or truck structures, in order to provide a solution to easily obtain measurements for evaluation and prevention of occupational hazards.

Other examples were presented in [17, 18], in these works it has been developed portable devices with wireless connectivity for measuring vibrations that affect the hand-arm system. These studies demonstrates a new approach to safety management with low-cost devices in real-time.

While in Liu's study [19] it is presented a mobile application that uses the accelerometer of a smartphone. The system was placed on the hand using a glove-type adapter, obtaining a versatile and low-cost solution for the initial assessment of risks, education, training, and worker's awareness.

In [20] Pavón presented a measurement system to analyze the magnitude of vibrations, this system is based on a specific application installed on a commercial smartwatch with an accelerometer MEMS type. The authors conclude that this type of device can be used in certain tasks of vibration risk management (training or initial assessment) due to certain technical restrictions on the accelerometer imposed by the operating system.

On the other hand, Matthies [21], proposed the use of automatic classification algorithms to estimate the exposure to vibrations (instead of metering). The system is based on identifying the type of tool and the time of use by using the microphone and accelerometer of a smartwatch. Despite the excellent results presented by Matthies, difficulties are identified for the detection of tools in noisy environments (environments that are frequently found in workplaces) when using the microphone.

For this reason, in this work, it is presented a system for the automatic identification of nine different hand-held vibrating tools. The system uses tri-axial accelerometer signals of commercial (unmodified) smartwatches available in the market. In addition, the performance of several supervised classification algorithms have been tested with the use of principal component analysis to increase the accuracy in the identification.

2 Methodology

In order to test the proposed system, two commercial smartwatches with MEMS sensors were selected. These devices were used as an acquisition and storage system. The inertial signals were recorded through a software application developed in previous studies [15].

A set of nine motorized tools were used to make the experiments. The set consists of three different models for each family in which includes drills, jigsaws, and electric screwdrivers.

2.1 Experimentation Protocol

For the acquisition of vibration data from the smartwatch, it was necessary the recording of three samples of at least 90 s for each tool model. The inertial signals were recorded during operation and switching on each of the models of machines.

The tests with the tools included drilling a marble block in the case of the drilling machines, cutting a piece of wood in the case of the jigsaws, and screwing wood in the case of electric screwdrivers as shown in Fig. 1. This procedure was repeated for each example of each family using the two smartwatches from different brands.

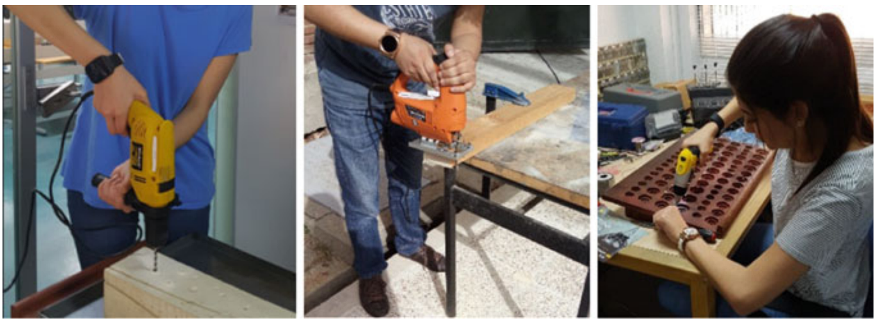

Fig. 1 Tools used for the experimental protocol

2.2 Signal Processing

The data obtained from the experimentation was analyzed to delete erroneous or inaccurate samples, due to the processes of turning on and off the smartwatches.

In order to obtain discriminant features to train and test the classification algorithms, the inertial signals were split in temporal windows of 1.28 s with an overlap of 50%. The spectrum of these windows was extracted by means of Fast Fourier Transform (FFT). Finally, each FFT bin was expressed in dB according to Eq. 1.

$$\mathrm{dB} = 20\log(acc/10e-6) \tag{1}$$

Additionally, for each analysis window, a set of statistical features were obtained from the signals in the time and frequency domains. The statistical features include standard deviation, median, mean, 25th and 75th percentiles, and the obliquity.

2.3 Training of the Classification Models

A database was created with the features obtained from the raw signals. The database was composed of rows of data that represent the features calculated from each temporal window. A total of 402 features from each temporal window were calculated.

A principal component analysis (PCA) was applied, in order to reduce the number of features and improve the data representation, three different numbers of principal components were tested to analyze the performance in the system.

The evaluation of the classification algorithms was made by splitting the dataset into two sections. The 80% of observations were used to training, and 20% were assigned for evaluation, this division was carried out randomly.

In order to test the performance of the proposed classification models, 4 linear classification algorithms and 4 non-linear classification algorithms were tested. Some performance metrics were calculated, the accuracy was selected as the main metric. The accuracy is the percentage of correct predictions.

3 Results

Two main experiments were carried out to test the selected classification models. The first experiment consists in evaluating the performance of the system to identify the use of a family tool among the three families tested. The second experiment consists in identifying a single model within a single tool family.

Table 1 Results of the tool family identification

	Linear model: polynomial classifier			Non-linear model: K-nearest neighbors		
Principal components	30	40	70	30	40	70
Mean accuracy (%)	94.24	94.76	95.50	94.36	94.62	95.08
Standard deviation	0.305	0.297	0.311	0.356	0.483	0.861

3.1 Experiment 1: Tool Family Identification

The first experiment was made to analyze the performance of the classification models for the identification of different tool families.

Table 1 shows the results achieved by the best two models tested, the table shows the average accuracy when performing five separate tests of training and evaluation, using different numbers of principal components.

According to Table 1, the polynomial classifier presents better results for linear models, when using 70 principal components, with an accuracy of 95.5%. Meanwhile, the K-nearest neighbors classification model is the best non-linear algorithm.

3.2 Experiment 2: Identification of a Specific Tool Model

The results for the identification of a specific model within a single-family of tools are shown in Table 2. The results corresponding to each family of machines tested (drills, jigsaws, and electric screwdrivers) are shown separately.

Table 2 Identification of a specific tool model

		Linear model: polynomial classifier			Non-linear model: Parzen classifier		
	Principal components	30	40	70	30	40	70
Drill	Mean accuracy (%)	84.66	88.84	84.90	90.84	91.00	90.82
	Standard deviation	1.25	1.06	1.43	0.94	0.48	0.86
Jigsaw	Mean accuracy (%)	79.04	82.10	80.86	88.50	90.44	88.04
	Standard deviation	1.04	1.34	1.50	0.90	0.80	0.97
Screwdriver	Mean accuracy (%)	94.98	95.92	95.46	97.70	97.80	97.32
	Standard deviation	0.54	0.59	0.84	0.26	0.68	0.30

For all three families, the polynomial classifier has the best performance for linear algorithms, while the Parzen algorithm has the best performance for nonlinear algorithms. In all cases, the best performance is obtained by using 40 principal components.

4 Conclusions

In this work, a methodology has been developed for training and testing machine learning models for the automatic classification of hand-held vibrating tools through a system based on commercial smartwatches only using a triaxial accelerometer.

The results suggest that it is possible to use supervised machine learning techniques to design a system that allows the identification of time of use, of at least three different kinds of hand-held vibrating tools. Different tools can be identified through linear and non-linear classification algorithms with classification accuracy from 79% up to 98%. For this experiment, we used a selection of nine hand machines (drills, jigsaws, and electric screwdrivers).

The precise knowledge of the time of use of hand-held vibrating tools can have several applications, for example, the estimation of the daily exposure to the vibrations A(8) or the analysis of work patterns. This information may be useful both for risk prevention and for studies of the effects of the hand-arm vibrations.

The results show that by using the accelerometer of smartwatches located on the wrist of the user's (dominant) hand, it is possible to get enough information from the acceleration signals for tool identification. The smartwatches used in these tests have a MEMS triaxial accelerometer with a sampling frequency of 200 Hz.

The proposed system can easily classify the three types of tool families tested using only the frequency spectrum obtained from the tri-axial accelerometer.

Although the results obtained in the automatic classification of tools, an important limitation in commercial smartwatches was identified for the analysis of certain types of manual machines (e.g. radial tools) to have higher frequency spectra than those that can be analyzed with commercial smartwatches [15].

Difficulties are also identified when analyzing tools that present transient events in their use (e.g. electric hammers), due to the fact that they do not offer stationary samples that can be analyzed with accuracy through time windows, therefore future studies may focus on the development and evaluation of new data representation methods and automatic classifiers for vibroacoustic signals that address this problem.

References

1. Griffin, M.: Enciclopedia de salud y seguridad en el trabajo. https://higieneyseguridadlaboralcvs.files.wordpress.com/2012/04/oit-enciclopedia-de-salud-y-seguridad-en-el-trabajo.pdf. Last accessed 01 Sep 2019
2. Dong, R.G., Sinsel, E.W., Welcome, C.W., Xu, X.S., McDowell, T.W., Wu, J.Z.: Review and evaluation of hand–arm coordinate systems for measuring vibration exposure, biodynamic responses, and hand forces. Saf. Health Work. 159–173 (2015)
3. Valenzuela, P.W.: Efectos a la salud por la exposición a vibraciones. http://prevencionar.com/2012/03/27/efectos-a-la-salud-por-la-exposicion-a-vibraciones/. Last accessed 21 June 2019
4. DIRECTIVE 2002/44/EC of the European parliament and of the council. DIRECTIVE 2002/44/EC of the European parliament and of the council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (2002)
5. Jean-Michel, S.: Market opportunities for advanced MEMS accelerometers and overview of actual capabilities vs. required specifications. In: PLANS 2004. Position Location and Navigation Symposium. IEEE, Monterey (2004)
6. Sazonov, E., Neuman, M.R.: Wearable sensors: Fundamentals, Implementation and Applications. Academic Press, Amsterdam (2014)
7. Page, T.: A forecast of the adoption of wearable technology. Int. J. Technol. Diffus. **6**, 12–29 (2015)
8. Labrador, M.A., Lara, O.D.: Human activity recognition: using wearable sensors and smartphones, 1st edn. CRC Press Taylor & Francis, California (2013)
9. Yang, C., Hsu, Y.: A review of accelerometry-based wearable motion detectors for physical activity monitoring. Sensors **10**(8), 7772–7788 (2010)
10. Ramos, F., Moreira, A., Costa, A., Rolim, R., Almeida, H., Perkusich, A.: Combining smartphone and smartwatch sensor data in activity recognition approaches: an experimental evaluation. In: International Conference on Software Engineering & Knowledge Engineering. SEKE, California (2016)
11. Cutini, M., Bisaglia, C.: Whole body vibration monitoring using a smartphone, Ageng 2014. In: International Conference of Agricultural Engineering (AgEng) 8. Zurich (2014)
12. Wolfgang, R., Burgess-Limerick, R.: Using consumer electronic devices to estimate whole-body vibration exposure. J. Occup. Environ. Hyg. **11**(6), 77–81 (2014)
13. Wolfgang, R., Di Corleto, L., Burgess-Limerick, R.: Can an iPod touch be used to assess whole-body vibration associated with mining equipment? Ann. Occup. Hyg. **58**(9), 1200–1204 (2014)
14. Pavón, I., Sigcha, L., Arezes, P., Costa, N., De Arcas, G., López JM.: Wearable technology for occupational risk assessment: potential avenues for applications. Occup. Saf. Hyg. VI. (2018) (CRC Press)
15. Sigcha, L., Pavón, I., Arezes, P., Costa, N., De Arcas, G., López, J.M.: Occupational risk prevention through smartwatches: precision and uncertainty effects of the built-in accelerometer. Sensors **18**(11), 3805 (2018)
16. Tarabini, M., Saggin, B., Scaccabarozzi, D., Moschioni, G.: The potential of micro-electro-mechanical accelerometers in human vibration measurements. J. Sound Vib. **331**(2), 487–499 (2012)
17. Morello, R., De Capua, C., Meduri, A.: Wireless measurement system for estimation of human exposure to vibration during the use of handheld percussion machines. IEEE Trans. Instrum. Meas. 2513–2521 (2010)
18. Aiello, G., La Scalia, G., Vallone, M., Catania, P., Venticinque, M.: Real time assessment of hand-arm vibration system based on capacitive MEMS accelerometers. Comput. Electron. Agric. **85**, 45–52 (2012)
19. Liu, B., Koc, A.B.: Hand-Arm vibration measurements and analysis using Smartphones. In: American Society of Agricultural and Biological Engineers. ASABE, Kansas City (2013)

20. Pavón, I., Sigcha, L., Arezes, P., Costa, N., De Arcas, G., López JM.: Wearable technology usefulness for occupational risk prevention: smartwatches for hand-arm vibration exposure assessment. Occup. Saf. Hyg. V. (2017) (CRC Press)
21. Matthies, D., Bieber, G. & Kaulbars, U.: AGIS: automated tool detection & hand-arm vibration estimation using an unmodified smartwatch. In: 3rd International Workshop on Sensor-based Activity Recognition and Interaction. ACM, Rostock (2016)

Changes in Postures of Male Drivers Caused by Long-Time Driving

Marko Cvetkovic, Denise Soares, Pedro Fonseca, Sara Ferreira and J. Santos Baptista

Abstract Professional drivers spend the majority of the working time steering a vehicle in a prolonged static posture. Therefore, pain in a particular region of the can appear and lead to musculoskeletal disorders. This study investigates the range of adopted driving angles after long-time driving. Driving postures were analyzed in a laboratory using software to establish three-dimensional angles performed by the driver. Parametric (*Paired Sample*) and nonparametric (*Wilcoxon*) tests were implemented to determine if there is any statistically significant difference among joint angles during initial recording (from zero to the 5th min), 40th, 80th, and 120th min. Upper libs generated the most substantial change in adopted angles taking into account the 5th and 120th min. Comparing postures with another study it could be seen that the range of motion is more extensive in this study. The reason could be the participants' stature or lack of adjustment possibilities due to the interior dimensions of the driving simulator.

Keywords Long-time driving · Preferred driving posture · Male driver

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1 Introduction

In a drivers' working environment, it can be found many potential risks or threats that may influence their health status. Beside acute injuries (car accidents or similar), long-time exposure to physical harm such as vibration, or awkward prolonged sitting positions can cause pain and possible musculoskeletal disorders [1]. Therefore, a vehicle venue and ergonomic design play an essential role in preventing/causing total body discomfort.

Several studies [2–6] have tried to analyze behaviors and postures while driving using different devices and approaches. The last twenty years provided new methods using three-dimensional tools to establish a less uncomfortable position as well as driving angles [5].

It is crucial to establish a unique method, several participants, the duration of each experiment, and the precisely marked body landmarks during the data acquisition [7].

What is more, one of the problems referred by Schmidt et al. [7] is upper limb position on the steering wheel (describing hand position on the steering wheel as hours spot on a clock—traditional is 10 and 2, and new suggestion discusses 3 and 9) that can change angles in the shoulder, elbow, and wrist.

The objective of this study is to analyze the driving posture of male participants during long-time driving. Additionally, driving positions will be compared with another study driving angles and their recommendations. For this purpose, data were collected during a steering driving simulator for two hours.

2 Methodology

2.1 Sample Characterization

This study was conducted with a sample population comprising 25 male participants. After data analyzing, three males were excluded due to poor data quality. Selected participants were in the age range of 20 to 40 years old (with an average of 26.59 $\pm$ 4.2 years and stature mean value of 176.42 $\pm$ 6.12 cm, and weight 75.9 $\pm$ 15.9 kg). As exclusion criteria were considered if drivers had less than six months, the driving license, driving more than two hours per day, had a surgical intervention or pain in major joints (ankle, knee, hip, shoulder, wrist, and elbow) that can influence posture during long-duration driving.

2.2 Main Joint Angles

For a more straightforward observation of the changes of the adopted/preferred driving postures, eight reflective markers were positioned on anatomical landmarks

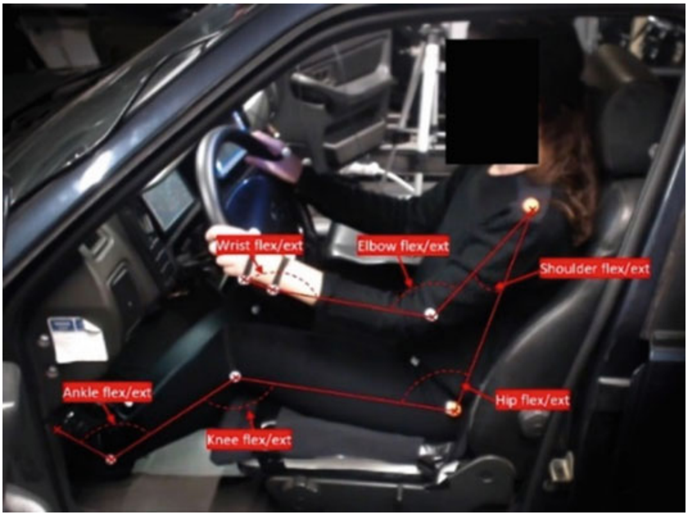

Fig. 1 Definition of joint angles

corresponding to major joints (see Fig. 1). Only the left side of the driver's body was considered in this study. Therefore, markers were placed on the joints, according to the following landmarks: lateral metatarsal head (foot); lateral and medial malleolus (ankle); lateral and medial epicondiles of the femur (knee); great trochanter (hip); right and left acromion (shoulder); lateral epicondyle of the humerus; radial styloid process and heal of ulna (wrist); head of the 2nd and 5th metacarpus. These markers were used to calculate joint angles according to the scheme depicted in Fig. 1.

2.3 Experimental Procedure

The data collection was done using cameras and the driving simulator called "DriS," [8], which was developed in cooperation between two institutions—Faculty of Engineering of the University of Porto (FEUP) and the Polytechnic of Porto—School of Engineering (ISEP). The DriS is a vehicle modified by implementing additional parts, such as a steering wheel, pedals, ignition key, monitor, among others, developed for a driving simulator. The virtual environment mimics a vehicle movement on a highway, and its behaviors along the trajectory.

Preferred driving posture was recorded in four segments using six Logitech c920 HD Pro cameras. Camera calibration was done using a cube with $20 \times 20 \times 20$ (cm) of dimension, which was placed on the drivers' seat. The calibration was repeated after the experimental protocol was completed.

The data acquisition starts at the same time as the simulation, with 5 s recording during the first 5 min of the test. Additional 5-second recordings were performed at the 40th, 80th and 120th min of the trial. In order to guarantee synchronization between all cameras, an LED light, placed next to the driving steering wheel, was lighten when starting the trial. The driver was instructed to place his hands on a 3 and 9 h position on the steering wheel [7].

2.4 Preferred Interior Dimensions

The drivers preferred interior adjustment was regulated before every trial for each participant independently. Based on SAE J1100 [9], the correction could be made on horizontal points (the distance between the heel and hip point—in the range from 800 until 980 mm) and in the backrest angle. Horizontal and vertical distance for the steering wheel could not be corrected, and they stayed the same for all participants.

2.5 Data Analyzing

The *Shapiro-Wilk test* was performed to establish if the data were normally distributed. In order to confirm if there are any statistically significant differences among a 3D joint angle, a *Paired Sample T-test* was performed. Some of the parameters are not linearly distributed, therefore the *Wilcoxon test* was applied. To determinate if a correlation between adopted angles could be found during the 120 min, *Pearson's r* was applied. Moreover, nonparametric *Spearman's test* was used in case of non-normal distribution. Correlations were considered statistically significant when $p \leq 0.05$.

3 Results

3.1 Preferred Interior Dimensions

The hip to heel and hip to steering wheel points are mutually dependent (see Table 1). The reason is that the steering wheel could not be adjusted nor in the horizontal or vertical direction. Higher mean values of the selected hip to heel points could be explained by the drivers' stature.

Table 1 Participants' preferred interior dimensions (an adapted version of [5])

	Interior dimensions	Min	Max	Mean	Std. deviation
Horizonstal	Steering wheel to heel point—L11 (mm)	340	340	340	N.A.
	Hip point to heel point—L53 (mm)	**800**	**980**	**942.27**	**36.52**
	Hip point to the steering wheel (mm)	**460**	**640**	**602**	**36.52**
Vertical	Steering wheel to heel point—H17 (mm)	625	625	625	N.A.
	Hip point to heel point—H30 (mm)	260	260	260	N.A.
	Hip point to the steering wheel (mm)	360	360	360	N.A.
	Seat cushion length (mm)	480	480	480	N.A.
	Backrest angle (°)	N.A.	N.A.	**113.17**	**3.29**

N.A.—Not applicable
The bold numbers are representing the potential changes in the preferred seat position before the driving process. Furthermore, the standard numbers are illustrating the seat position that could not be adjusted

3.2 Adopted Joint Angles After Prolonged Driving

The observed 3D joint angles and its changes, after 120 min of the ride, are presented in Fig. 2. The ordinal numbers 1st, 2nd, 3rd, and 4th (Fig. 2) correspond to the 5th, 40th, 80th and 120th min of driving. It can be seen that 2 h of steering the simulator can cause changes of several joint angles, leading the driver to adopt a more comfortable driving posture.

It is noticeable that the lower extremities do not show substantial changes during time. In examining the mean values, the Wilcoxon test showed that there is no statistically significant difference between the first and last recording periods ($Z = -0.730$, $p = 0.465$). Similar results are seen at the ankle ($p = 0.540$) and knee ($p = 0.084$) joint angle.

An opposite trend is observed with the mean value of the upper limbs, with the value of the joint angle showing differences after 40 min of driving with the driver adopting a more extended posture. Although the *Paired Sample test* shows that this change is not statistically significant ($p > 0.05$) in the first 80 min, at the end of the data collection the shoulder ($p = 0.007$), elbow ($p = 0.002$), and wrist ($p = 0.009$) present statistical differences from the first recording moment.

After the 3rd recording moment, the correlation between elbow and shoulder tends to be highly correlated. The opposite happens with the knee and hip angles, with a decreased and low correlation. Although the relationship between knee and hip is moderate, it still exists and should be taken into consideration (Table 2).

4 Discussion

In order to design the better interior dimensions of the driver's seat position, nonadjustable pedals, steering wheel, and the driving seat can interfere with the outcome of the experiment. This problem can be drastically reflected in the case of

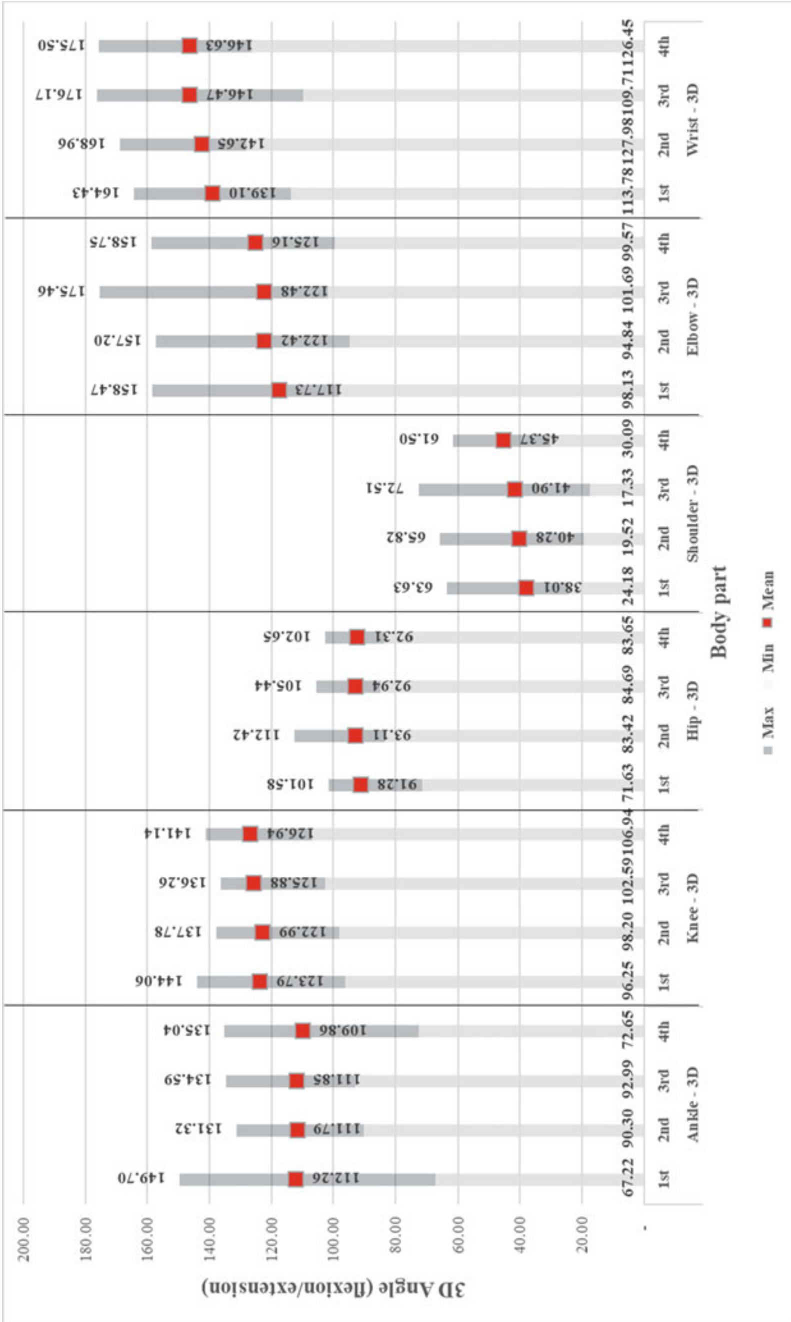

Fig. 2 Joint angles variation along with the driving simulation recording

Table 2 *Pearson's* correlation between upper- and lower-limbs joint angles during the long-time driving (correlation is significant at $p < 0.05$)

3D joint angle	Minute			
	0–5th	40th	80th	120th
Elbow/shoulder	0.766	0.766	0.876	0.825
Knee/hip	0.527	0.523	0.303	0.45

prolonged sitting when the driver feels discomfort/pain in a specific part of the body and selects a new posture in order to be more comfortable [10, 11].

During the period between the 5th and 40th min, the driver adopted a posture with minimal joint angle variation. Hanson et al. [5] reported similar findings but taking into consideration the period from 5th to 20th min. The opposite happened with [12] were 30 min of experimental data was enough to obtain reliable results and to conclude optimum driving posture. Our observation showed that this trend continues until the 80th min when some joint angles start to change. The upper limbs, which have the most significant changes in the angles, start showing variation at the 80th min until the end of the experimental protocol. On the other side, the lower limb joint angle changes are minimal throughout the entire protocol.

Due to the participants' average height of 176.42 ± 6.12 (cm), they can be classified as tall persons [6], which is noteworthy since [4] concluded that tall males tend to have a more open posture. Although the effect on the posture of long-time driving is in agreement with a previous study [4], the adopted posture along time does not means that the drivers felt more comfortable [6] (Table 3).

The interpretation of the results in the current study refers to the minimum and maximum values of joint angles during the entire period of driving, which can be seen as similar to those reported by [4]. However, the ankle angle does differ from all studies, with several possible reasons for that fact. Schmidt et al. [7] mentioned a problem with determining a unique approach in defining optimum or preferred joint angles.

Table 3 3D joint angles

	Flexion/extension of main joint angles (°)					
	Ankle	Knee	Hip	Shoulder	Elbow	Wrist
Porter et al. [4]	80–113	99–138	90–115	19–75	86–164	–
Park et al. [13]	82–116	120–152	103–131	7–36	86–116	–
Vogt et al. [14]	103	119	99	22	127	–
Hanson et al. [5]	90–111[a]	109–157[a]	92–109[a]	14–68[a]	96–160[a]	159–219[a]
Kyung et al. [6]	82–88[b]	84–91[b]	79–87[b]	1–29[b]	85–120[b]	129–170[b]
Current study	67–149[c]	96–141[c]	71–112[c]	17–73[c]	95–159[c]	110–176[c]

[a]left side of the body; [b]group number 1; [c]the total range of adopted angles during 120 min of laboratory drive

5 Conclusion

This study investigated male drivers' preferred interior dimensions, and the adopted lower- and upper-limbs joint angles during a long-time driving. It was observed that the vehicle venue could affect the positions of the driver during 120 min of steering the simulator. Changes could be seen in limb postures, with prevalence on the upper limbs, with the lower-limb angles, such as the hip, generally remaining the same. Moreover, participants' stature can explain a more open posture during the duration of the experimental protocol.

References

1. Serrano-Fernández, M.-J., Boada-Grau, J., Robert-Sentís, L., Vigil-Colet, A.: Predictive variables for musculoskeletal problems in professional drivers. J. Transp. Heal. **14**, 100576 (2019)
2. Peng, J., Wang, X., Denninger, L.: Effects of anthropometric variables and seat height on automobile drivers' preferred posture with the presence of the clutch. Hum. Factors **60**, 172–190 (2018)
3. Peng, J., Wang, X., Denninger, L.: Ranges of the least uncomfortable joint angles for assessing automotive driving posture. Appl. Ergon. **61**, 12–21 (2017). https://doi.org/10.1016/j.apergo.2016.12.021
4. Porter, J.M., Gyi, D.E.: Exploring the Optimum Posture for Driver Comfort. Inderscience (1998)
5. Hanson, L., Sperling, L., Akselsson, R.: Preferred car driving posture using 3-D information. Int. J. Veh. Des. **42**, 154–169 (2006)
6. Kyung, G., Nussbaum, M.A.: Specifying comfortable driving postures for ergonomic design and evaluation of the driver workspace using digital human models. Ergonomics **52**, 939–953 (2009)
7. Schmidt, S., Amereller, M., Franz, M., Kaiser, R., Schwirtz, A.: A literature review on optimum and preferred joint angles in automotive sitting posture. Appl. Ergon. **45**, 247–260 (2014)
8. Leitão, J.M., Moreira, A., Santos, J.A., Sousa, A.A., Ferreira, F.N.: Evaluation of driving education methods in a driving simulator. Comput. Graph. Vis, Educ (1999)
9. SAE J1100: Motor vehicle dimensions. Soc. Automot. Eng. Warrendale, USA, Stand. (2002)
10. Anshel, J.: Visual Ergonomics Handbook. Chapter 1. Editor (s): Jeffrey Anshel, Corporate Vision Consulting, Encinitas (2005)
11. Jeong, Y., Park, W.: Differences between obese and non-obese drivers in preferred vehicle interior components setting and driving posture. Ergonomics **60**, 731–742 (2017). https://doi.org/10.1080/00140139.2016.1211322
12. Barkla, D.M.: Chair angles, duration of sitting, and comfort ratings. Ergonomics **7**, 297–304 (1964)
13. Park, S.J., Kim, C.-B., Kim, C.J., Lee, J.W.: Comfortable driving postures for Koreans. Int. J. Ind. Ergon. **26**, 489–497 (2000)
14. Vogt, C., Mergl, C., Bubb, H.: Interior layout design of passenger vehicles with RAMSIS. Hum. Factors Ergon. Manuf. Serv. Ind. **15**, 197–212 (2005)

Thermal Comfort in Bus Cabins: A Review of Parameters and Numerical Investigation

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Abstract Review studies regarding the thermal comfort of bus cabins haven't been found in the literature. Thus, this investigation's objective is to analyze the parameters of thermal comfort that could be subject to modeling in bus cabins. The proposed analysis comprises a brief review of the parameters considered relevant in the standardized thermal comfort models and the survey of these parameters in research directed to the bus environment. To achieve that, searches were conducted on the literature databases Emerald, Web of Science, ScienceDirect and Scopus, employing the method of systematic review Ordinatio to find review and research papers in two scopes: the first crossed the keyword bus with the terms Predicted Percentage Dissatisfied, Predicted Mean Vote, Thermal Comfort Model, Thermal Comfort, Thermal Discomfort, and Thermal Stress, as well as the abbreviations PPD and PMV; the second combined the keywords automobile and vehicular with the same terms related to thermal comfort as the first scope. The results identified fifteen papers on thermal comfort in buses, three of which investigated the drivers and that only approached the parameter of air temperature quantitatively. In contrast, passenger studies were more complete because they analyzed all the important parameters. Therefore, this paper concludes that, the researches directed to bus passengers are more grounded in terms of thermal comfort parameters and that although driver studies have their merits, they did not sufficiently represent the complexities of these parameters and, taking that into account, this investigation will function as a guide for future studies of this nature.

Keywords Thermal comfort · Bus cabins · Review of parameters

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1 Introduction

Comfort analysis in buses may be regarded as complex especially due to the wide array of parameters that it encompasses, which may involve different knowledge areas. Studies directed at passenger comfort in buses point to the following parameters as the most relevant: thermal comfort, acoustics, lighting, vibration, air quality, acceleration, and ergonomics [1, 2]. These parameters influence the quality of service and the choice for this transportation mode [3, 4].

Regarding the thermal field, Alahmer et al. [5] and Croitoru et al. [6] infer that this type of comfort for vehicle users (whether public or private transportation) has been gaining attention due to two relevant aspects: comfortable mobility and the increase in time spent inside vehicles. Concerning the drivers, the two aforementioned works observe aspects that are impactful to safe driving: reducing the drivers' stress and improving their visibility.

Moreover, finding an optimal temperature range to maintain a comfortable thermal sensation for bus passengers while avoiding excessive consumption of fuel has been the focus of previous studies [7–10]. Thus, studies in this knowledge area applied to bus drivers may solve three types of problems, separately or combined: thermal satisfaction affording comfortable mobility, better performance in safe driving, and fuel economy.

Considering this context, an encompassing search for papers (research and review) about thermal comfort in buses was conducted and it evidenced the lack of review papers gathering studies on bus thermal comfort parameters, which is a gap to be filled by this proposal, considered unprecedented in the literature.

Thus, this investigation's objective is to analyze the parameters of thermal comfort that could be subject to modeling in bus cabins. The analysis of this investigation goes beyond the survey of previous works developed about bus environment regarding the thermal comfort parameters; it also makes a short review of the parameters used in the calculations of standardized thermal comfort models.

2 Methodological Aspects

The methodology adopted in this study employed the nine steps of the Methodi Ordinatio, which is a Multi-Criteria Decision Aid methodology for papers selection, proposed by Pagani et al. [11]. The method mentioned results in a ranking the selected papers and that takes into consideration the three most relevant criteria considered when choosing an academic paper, which are: the year of the research, the Impact Factor (IF) of the journal and the number of Citations (Cit) of the articles.

In step 1, definition of the research intention, it was centered on the accomplishment of a bibliographical survey of the main works about the thermal comfort in buses. Then, in step 2, preliminary exploratory research in the literature databases, it was possible to identify the bases with the largest number of results that were Emerald, Scopus, ScienceDirect and Web of Science.

Afterwards, in step 3, it was possible to define the combination of the keywords “bus”, “automobile” and “vehicle” with the terms “Predicted Percentage Dissatisfied”, “Predicted Mean Vote”, “Thermal Comfort”, “Thermal Discomfort”, and “Thermal Stress”, as well as the abbreviations “PPD” and “PMV”. In addition, in step 3, we preferred not to limit the temporal amplitude and defined the bases to be used in this survey.

Thus, during the 4th stage, a definitive search in the databases was performed, which resulted in 196 studies. Given this preliminary result, it was possible to employ the filtration process that is step 5 of the method, whose criteria for filtration and elimination were: elimination of duplicate works; exclusion of works from books, book chapters and conference articles; paper that did not have titles and those that did not analyze thermal comfort on buses.

This way, there were only 15 relevant works that were submitted to the 6th stage, which refers to the identification of IF and Cit. For this, the number of citations from each paper was collected from the Google Scholar website and the journal Impact Factor were the Journal Citation Reports (JCR) found on the InCites Journal Citation Reports website by Clarivate Analytics. Subsequently, the articles were sorted according to InOrdinatio index [11], then downloaded and systemic reading, steps 7, 8 and 9 respectively.

3 Results and Discussion

Considering the result of the systematic literature review method and the objective described in the introduction, this section will expose a short review on the parameters of thermal comfort models and at the same time will discuss the parameters used in the 15 papers found in the databases, but with greater emphasis on studies that analyzed drivers comfort.

Of the 15 remaining papers, 12 approached the passengers [2, 8–10, 12–19] and three explored the thermal comfort of drivers [20–22]. Given that this investigation focuses on the parameters of thermal comfort in driver cabins, the analysis will take the last three papers as basis.

In summary, the studies of Pimenta and Assunção [20] and Assunção, Jardim and De Medeiros [22] centered on the thermal sensation as it relates to the drivers’ health, finding that thermal discomfort is associated with hypertension [20] and the prevalence of vocal complaints [22]. On the other hand, Ismail et al. [21] investigated the correlation between performance and thermal comfort, in a qualitative study that questioned drivers about the influence of factors seen as relevant in thermal comfort models on their performance.

The standardized thermal comfort models widely used in the literature are the Fanger PMV-PPD and the adaptive model. According to Yao et al. [23], the Fanger model was incorporated into ISO standards in the 1980s and still is the basis for the

ISO 7730, ASHRAE 55, and EN 15,251 standards [24]. Fanger [25] developed the Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) model. It enables the prediction of the mean vote of the thermal sensation of a large group of people exposed to the same environment [5, 24] and the percentage of people dissatisfied with it [26].

Furthermore, Croitoru et al. [6] infer that this model started from the hypothesis that the occupants of an environment are in a state of thermal comfort when their bodies balance heat exchanges. This hypothesis is considered by numerous authors as a stationary or stable model [5, 6, 23, 24, 26].

However, field studies on thermal comfort, especially in naturally-ventilated buildings, demonstrate a certain discrepancy between Fanger's estimated PMV value and the real mean vote given by the occupants of those environments [23]. To circumvent this situation, two proposals are widely used in the literature. The first is the extended PMV model proposed by Fanger and Toftum [27], which incorporates an 'expectation factor'. This factor consists of a coefficient that ranges from 0.5 to 1, which generates a new model that connects the PMV with this coefficient [27]. The other alternative to determine thermal comfort is the adaptive model [24].

The adaptive model has been gaining more attention in the literature, especially in field studies conducted in naturally-ventilated or mixed environments. That is explained by the fact that the model was conceived based on studies of this nature [6, 23, 24, 26] in which the occupants can react to the changes in the thermal environment so as to maintain their thermal comfort. Moreover, Rupp et al. [24] affirm that this model has already been incorporated into the foremost standards, such as ASHRAE 55 in 2004 and EN 15,251 in 2007. Similarly to the extended PMV model, the adaptive model employs a coefficient, named adaptive coefficient, and is related to the initial Fanger's PMV.

Overall, the mentioned models employ, in addition to their coefficients, basically six parameters that belong to two groups (environmental and personal) to assess the state of thermal comfort of the occupants [28]. According to the aforementioned authors, the environmental group comprises four parameters related to the environment (air temperature, mean radiant temperature, air velocity, and air relative humidity) and the personal group comprises two parameters that are occupant-dependent (metabolic rate and clothing insulation).

- **Air Temperature**

Regardless of the assessed environment, air temperature (t_a) is considered one of the main parameters related to human performance [29]. However, regarding air temperature in vehicles, Simion et al. [30] state that it depends on the season and the position on the globe, and Table 1 of ISO 7726 [31], indicates that air temperature must always be taken into account when analyzing heat exchanges via skin convection or the breathing around individuals.

- **Mean Radiant Temperature**

Differently from the occupants of a building, the occupants of a vehicle are continuously exposed to solar radiation and, therefore, the mean radiant temperature

Table 1 Thermal comfort parameters used in bus studies

Review paper reference	t_a	t_{rm}	V_a	RH	M	I_{cl}
Zhu et al. [12]	x	x	x		x	
Velt and Daanen [10]	x	x	x	x	x	x
Ismail et al. [21]	x		x			x
Pala and Oz [13]	x	x	x	x	x	x
Pimenta and Assunção [20]	x					
Assunção et al. [22]	x					
Zhang et al. [2]	x	x	x	x		x
Lin et al. [14]	x	x	x	x	x	x
Mansour et al. [9]	x	x	x	x		
Shek e Chan [8]			x	x		
Khamis et al. [16]	x	x	x	x		
Lin et al. [17]			x			
Mui e Shek [18]	x			x		
Conceição et al. [19]	x		x			

(t_{rm}) is to be considered in those environments. It is possible to obtain this parameter through two different manners: calculating the radiation received by the human body [32] and the Stefan-Boltzmann law [31]. Studies usually determine the t_{rm} via the Stefan-Boltzmann law, which, according to ISO 7726 [31] depends on whether the convection is natural or forced.

The parameters of the heat exchange equations in Table 1 of ISO 7726 [31] show that the t_{rm} is fundamental in the calculations of sensible heat exchange via skin convection, sensible heat via skin radiation, and via conduction from the skin surface to the external surface.

- **Air Velocity**

Air velocity (V_{ar}) is important for the occupants' thermal comfort, seeing that airflow is one of the ways in which a person may have located discomfort [33]. According to Table 1 of ISO 7726 [31], it affects heat losses through skin convection and skin evaporation.

- **Air Relative Humidity**

ASHRAE 55 defines relative humidity (RH) as the ratio between the amount of water vapor in the air and the amount of water vapor that the air is able to support under specific conditions of temperature and pressure [34]. The effect of relative humidity in cabins on the passengers' thermal comfort and sensation has been studied by Alahmer et al. [35], through the simulation of Berkeley and Fanger's model. According to Table 1 of ISO 7726 [31], this parameter influences latent heat exchanges via skin evaporation and breathing.

- **Metabolic Rate**

The metabolic rate (M), differently from the ones previously mentioned, is a personal parameter. It is the only one responsible for naturally generating heat, whereas the others are considered losses [25]. Methods to measure the M rate include ISO 8996 [36] which measures oxygen consumption (indirect calorimetry), and, more commonly, the tables of ISO 8996 [36]. This parameter is employed in the calculations of latent heat exchange via breathing evaporation and breathing convection [31].

- **Clothing Insulation**

The other parameter in the personal group is clothing insulation (I_{cl}). According to ISO 7726 [31], it influences sensible heat exchanges via skin radiation and skin convection, and latent heat exchanges via skin evaporation. According to ISO 9920 [37], its unit of measurement is expressed by "clo" (1 clo = 0.155 m^2 K/W). In general, ISO 7730 [33] brings, in its Appendix C, estimated values for clothing widely employed by the academic community.

In view of the important parameters for the calculations of thermal comfort, Table 1 shows those already used by the studies surveyed in the systematic literature review to express thermal comfort in buses, either of passengers or drivers.

In Table 1, only parameters regarding this knowledge field have been exhibited. Thus, most of studies carried out on passengers encompass the six parameters of thermal comfort in its amplitude, and the three studies dealing with drivers [20–22] have limited the exposure of all these important variables to this knowledge field.

Besides, in the work of Ismail et al. [21], there is no information whether the parameters or the instruments used have been measured. Actually, they have approached this in the Methodology section, where a questionnaire has been applied and the drivers have answered five questions for each parameter out of the six shown. However, the two other works on drivers [20, 22] have measured the variable air temperature, but have not informed which equipment was used for that purpose.

The works [2, 9, 10, 12–14, 16] have been carried out on passengers and they have used all necessary parameters to application of standardized models. Moreover, Velt and Daanen [10] and Zhu et al. [12] have surveyed votes of thermal sensation and preference, which are subjective parameters widely used in similar studies, and these votes are standardized. Therefore, one can say that the approach on passengers is more complete than on drivers.

4 Conclusions

In brief, this paper conducted a review of the parameters of internationally standardized models that are considered relevant in the analysis of thermal comfort in vehicular cabins. Furthermore, it also reviewed the studies of this knowledge area directed at buses in order to ascertain the thermal parameters that have been approached in driver and passengers cabins. The results evidenced that, in terms of thermal comfort analysis in buses, there are more studies directed at the passengers than at the drivers. Moreover, the ones that focused on the drivers did not investigate all of the six parameters that are relevant in thermal comfort studies.

Therefore, this paper has a theoretical relevance with two contributions. The first was filling the gap evidenced by the literature review, concerning the lack of review papers regarding thermal comfort in bus driver cabins. The second was identifying the limitations of analysis of the environmental and personal parameters considered by the standardized models of thermal comfort. The latter contribution serves as a guide for future research directed at thermal comfort analysis in the work environment of these professionals.

References

1. Nguyen, T., NguyenDinh, N., Lechner, B., Wong, Y.D.: Insight into the lateral ride discomfort thresholds of young-adult bus passengers at multiple postures: Case of Singapore. Case Stud. Transp. Policy. **7**, 617–627 (2019)
2. Zhang, K., Zhou, K., Zhang, F.: Evaluating bus transit performance of Chinese cities: developing an overall bus comfort model. Transp. Res. Part A Policy Pract. **69**, 105–112 (2014)
3. Morton, C., Caulfield, B., Anable, J.: Customer perceptions of quality of service in public transport: evidence for bus transit in Scotland. Case Stud. Transp. Policy. **4**, 199–207 (2016)
4. Lai, W.-T., Chen, C.-F.: Behavioral intentions of public transit passengers—the roles of service quality, perceived value, satisfaction and involvement. Transp. Policy **18**, 318–325 (2011)
5. Alahmer, A., Mayyas, A., Mayyas, A.A., Omar, M.A., Shan, D.: Vehicular thermal comfort models; a comprehensive review. Appl. Therm. Eng. **31**, 995–1002 (2011)
6. Croitoru, C., Nastase, I., Bode, F., Meslem, A., Dogeanu, A.: Thermal comfort models for indoor spaces and vehicles—current capabilities and future perspectives. Renew. Sustain. Energy Rev. **44**, 304–318 (2015)
7. Yik, F.W.H., Yiu, J., Burnett, J.: Air-conditioning and mechanical ventilation design for queuing enclosures in a bus terminus. Build. Serv. Eng. Res. & Technol. **16**, 9–16 (1995)
8. Shek, K.W., Chan, W.T.: Combined comfort model of thermal comfort and air quality on buses in Hong Kong. Sci. Total Environ. **389**, 277–282 (2008)
9. Khamis Mansour, M., Musa, M.N., Wan Hassan, M.N., Saqr, K.M., Mansour, M.K., Musa, M.N., Hassan, M.N.W., Saqr, K.M.: Development of novel control strategy for multiple circuit, roof top bus air conditioning system in hot humid countries. Energy Convers. Manag. **49**, 1455–1468 (2008)
10. Velt, K.B., Daanen, H.A.M.: Optimal bus temperature for thermal comfort during a cool day. Appl. Ergon. **62**, 72–76 (2017)
11. Pagani, R.N., Kovaleski, J.L., Resende, L.M.: Methodi Ordinatio: a proposed methodology to select and rank relevant scientific papers encompassing the impact factor, number of citation, and year of publication. Scientometrics **105**, 2109–2135 (2015)
12. Zhu, X., Lei, L., Wang, X., Zhang, Y.: Air quality and passenger comfort in an air-conditioned bus micro-environment. Environ. Monit. Assess. **190** (2018)
13. Pala, U., Oz, H.R.: An investigation of thermal comfort inside a bus during heating period within a climatic chamber. Appl. Ergon. **48**, 164–176 (2015)

14. Lin, T.-P., Hwang, R.-L., Huang, K.-T., Sun, C.-Y., Huang, Y.-C.: Passenger thermal perceptions, thermal comfort requirements, and adaptations in short- and long-haul vehicles. Int. J. Biometeorol. **54**, 221–230 (2010)
15. Xie, X.-L., Shen, F.-L., Lin, F.: Distributions of air-conditioning air supply parameters and passenger compartment temperature of highway sleeper bus. Chang. Daxue Xuebao (Ziran Kexue Ban)/Journal Chang. Univ. (Natural Sci. Ed. 30, 93–98 (2010)
16. Khamis Mansour, M., Musa, M.N., Hassan, M.N.W., Abdullah, H., Saqr, K.M.: Development of a novel control strategy for a multiple-circuit roof-top bus air-conditioning system in hot humid countries. Int. J. Mech. Mater. Eng. **2**, 200–211 (2007)
17. Lin, Z., Jiang, F., Chow, T.T., Tsang, C.F., Lu, W.Z.: CFD analysis of ventilation effectiveness in a public transport interchange. Build. Environ. **41**, 254–261 (2006)
18. Mui, K.W., Shek, K.W.: Influence of in-tunnel environment to in-bus air quality and thermal condition in Hong Kong. Sci. Total Environ. **347**, 163–174 (2005)
19. Conceição, E.Z.E., Silva, M.C.G., Viegas, D.X.: Airflow around a passenger seated in a bus. HVAC R Res. **3**, 311–323 (1997)
20. Pimenta, A.M., Assunção, A.Á.: Thermal discomfort and hypertension in bus drivers and chargers in the metropolitan region of Belo Horizonte. Brazil. Appl. Ergon. **47**, 236–241 (2015)
21. Ismail, A.R., Atikah Abdullah, S.N., Abdullah, A.A., Ab Hamid, M.R., Md. Deros, B.: Relationship between thermal comfort and driving performance among Malaysian bus driver. ARPN J. Eng. Appl. Sci. **10**, 7406–7411 (2015)
22. Assunção, A., Jardim, R., de Medeiros, A., Assuncao, A., Jardim, R., de Medeiros, A.: Voice complaints among public transport workers in the metropolitan region of belo horizonte, Brazil. Folia Phoniatr. Logop. **65**, 266–271 (2013)
23. Yao, R., Li, B., Liu, J.: A theoretical adaptive model of thermal comfort—adaptive predicted mean vote (aPMV). Build. Environ. **44**, 2089–2096 (2009)
24. Rupp, R.F., Vásquez, N.G., Lamberts, R.: A review of human thermal comfort in the built environment. Energy Build. **105**, 178–205 (2015)
25. Fanger, P.O.: Thermal Comfort. Analysis and Applications in Environmental Engineering. Danish Technical Press, Copenhagen (1970)
26. Djongyang, N., Tchinda, R., Njomo, D.: Thermal comfort: a review paper. Renew. Sustain. Energy Rev. **14**, 2626–2640 (2010)
27. Ole Fanger, P., Toftum, J.: Extension of the PMV model to non-air-conditioned buildings in warm climates. Energy Build. **34**, 533–536 (2002)
28. Frontczak, M., Wargocki, P.: Literature survey on how different factors influence human comfort in indoor environments. Build. Environ. **46**, 922–937 (2011)
29. Cui, W., Cao, G., Park, J.H., Ouyang, Q., Zhu, Y.: Influence of indoor air temperature on human thermal comfort, motivation and performance. Build. Environ. **68**, 114–122 (2013)
30. Simion, M., Socaciu, L., Unguresan, P.: Factors which influence the thermal comfort inside of vehicles. Energy Procedia. **85**, 472–480 (2016)
31. ISO, International Organization for Standardization: Ergonomics of the thermal environment-Instruments for measuring physical quantities (ISO 7726) (1998)
32. Thorsson, S., Honjo, T., Lindberg, F., Eliasson, I., Lim, E.-M.: Thermal comfort and outdoor activity in Japanese Urban Public Places. Environ. Behav. **39**, 660–684 (2007)
33. ISO, International Organization for Standardization: Ergonomics of the thermal environment-Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria (ISO 7730) (2005)
34. ASHRAE, A.S.: Standard 55–2013. Therm. Environ. Cond. Hum. Occup. **58** (2013)
35. Alahmer, A., Abdelhamid, M., Omar, M.: Design for thermal sensation and comfort states in vehicles cabins. Appl. Therm. Eng. **36**, 126–140 (2012)
36. ISO, International Organization for Standardization: Ergonomics of the thermal environment-Determination of metabolic rate. (ISO 8996) (2004)
37. ISO, International Organization for Standardization: Ergonomics of the thermal environment —Estimation of thermal insulation and water vapour resistance of a clothing ensemble. (ISO 9920 2007, Corrected version 2008-11-01) (2009)

Musculoskeletal Symptoms and Skin Temperature Variations in Solid Waste Collectors

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Abstract One of fundamental activities required in a modern society is the collection of urban solid waste. Due to the intensity of the workload, the required physical exertion may result in musculoskeletal symptoms of the collectors. Thus, the aim of this study was to identify musculoskeletal symptoms in urban solid waste collectors and to propose safety measures to minimize the impacts on workers' health. For the development of this work, the Nordic Musculoskeletal Questionnaire (NMQ) was applied in order to identify the prevalence of discomfort or pain in the body regions of 9 waste collectors. Additionally, thermal images were captured in these workers in 4 activity steps and the results were compared with the

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NMQ responses. The result of the NMQ showed that the highest number of complaints was in the regions of the dorsal spine (with grade 4), lumbar (5) and knees (5), during the period of past 12 months. Thermographic image showed a temperature increase in the backbone regions of 0.33 °C and lumbar region of 0.70 °C. Considering the results collected through the NMQ and thermography, the variations in the initial and final skin temperature values correspond to the musculoskeletal symptoms reported by the workers, especially in relation to the lumbar and dorsal region. In order to reduce the risk of injury and to improve performance, it is suggested to apply different organizational measures, including training and occupational gymnastics before initiation of the working activities.

Keywords Thermography · Urban waste collectors · Musculoskeletal symptoms · Occupational health · Safety at work

1 Introduction

Management of produced urban solid waste is one of the challenges of large urban centers. The increased production of waste is further-on affected by population growth, increased consumption, cultural factors and the expansion of urban areas [1, 2]. Therefore the work performed by urban cleaning service is essential, in order to keep the city clean and organized.

In Brazil, there are 58 federal legal instruments regulating the sweeping and waste collection activity [3]. Although there are a number of regulations, some risks remain and should be further managed by using assertive measures after a careful analysis of the working conditions, and for example applying containers for reducing the number of accidents or musculoskeletal injuries [4].

The main causes of accidents in the activity of waste collection are related to the operation of the compactor, the fall from the truck, getting injured by sharp materials or high physical exertion [5]. High physical exertion can severely impact the health of those workers. As a preventive measure is recommended to reduce workload, take more frequent breaks, slow the pace of walking and use a different collection methods [6]. The workload of household waste collectors is often proportional with the population growth of cities [7]. In order to achieve their goals and demands, the waste collectors need to consider quality and safety requirements, maintain their workload pace and the time of collection.

Ergonomic principles can be applied to reduce musculoskeletal problems, having different methods for each evaluation. Some methods are qualitative, such as the Nordic Musculoskeletal Questionnaire (NMQ), which assesses the presence of pain or discomfort during the period of last twelve months in anatomical regions of the musculoskeletal system [8–10]. Other methods are quantitative, such as the Infrared Thermography (IT), which is a non-invasive method, commonly applied in medicine, mechanical, civil and electrical engineering [11–13]. Thermography makes possible to evaluate functional changes in the region of interest [13–15] and to identify abnormalities present in the body by increasing or decreasing skin temperature.

Different studies correlated pain produced body regions with the results from infrared thermographic images [16–18]. The studies from the association of Ergonomic Work Analysis (AET) [14–16] indicate that infrared thermographic images can help in identifying regions of the body with the potential to manifest injuries. These analyzes are testified through health-related complaints, signalized by workers through the application of ergonomic analysis questionnaires such as it is the NMQ.

Still, there are no studies were found using together the NMQ and Infrared Thermography in the ergonomic evaluation in solid waste collection. Given the mentioned above, the aim of this study was to identify musculoskeletal symptoms in urban solid waste collectors and to verify if the results of these methods are aligned and follow the same trend during different phases of collection. Finally, safety measures were proposed in order to minimize risks for workers health.

2 Methodology

This is a descriptive semi-quantitative study with exploratory nature. The research was conducted in 2019, in two companies of solid urban waste collection, in the municipalities of Recife, in the states Pernambuco and Rio Grande do Norte, Brazil. The development of this work was part of the research project "*Proposta da análise dos riscos do processo da coleta de resíduos sólidos urbanos*", approved by the Ethics Committee of the Federal University of Pernambuco, with protocol number 04112918.9.0000.5208. All study participants signed the Informed Consent Form.

2.1 Workers

The collection team consisted of 1 driver and 3 collectors. Workers were asked to perform the activity normally as they usual do. Nine male collectors participated in the study with characteristics as illustrated in Table 1.

Table 1 Characteristics of the analyzed collectors

Collector (nr)	1	2	3	4	5	6	7	8	9	Mean ± SD
Service-function (years)	2	3	20	10	12	21	1	21	5	10.55 ± 8.38
Service-company (years)	2	3	10	10	3.5	5	3.5	5	4	5.10 ± 2.92
Age (years)	24	32	51	38	34	44	34	44	35	37.33 ± 7.98
Height (cm)	165	161	172	174	195	179	175	179	176	175.11 ± 9.61
Initial weight (kg)	56.5	84.5	81.4	80.5	81.0	80.1	63.8	75.2	67.0	74.44 ± 9.69
Final weight (kg)	55.0	83.0	80.7	80.0	80.0	79.0	63.0	74.0	66.9	73.51 ± 9.70
Weight difference (kg)	−1.5	−0.8	−1.1	−1.5	−0.7	−0.5	−1.0	−1.1	−0.8	−1.00 ± 0.34
Initial BMI (kg/m^2)	20.8	26.6	28.1	27.9	21.4	25.1	26.4	25.0	20.6	24.65 ± 2.98*

*Initial BMI of 24.65 ± 2.98 kg/m^2 is classified as overweight, grade I obesity

2.2 Collecting Process

The workers gather at the company base at 7 am. First the teams are formed, followed-by a labor gymnastics, which is always performed before starting with the collection activity. Soon after, workers leave to the field inside the collecting truck at about 7:30 am. When they arrive at the collection point, one of the collectors goes through the streets manually collecting the waste, which is deposited in front of the houses, while the others are throwing the waste bags into the truck compactor, moving from one collecting point to the other on the platform, which is located at the rear of the truck. The driver sets the pace of the collection. The collected waste is compacted after filling the opened part of the truck. When there is scattered or larger waste, the rake and shovel are used to facilitate the collection. When the truck is full of waste, the driver forwards it to the landfill to discharge all collected waste. The collection process takes place in the morning and in the afternoon. After the morning collection, the team finds a place where they can have lunch and rest in the shade for an hour before returning for the afternoon collection. On a normal day, workers return to base around 5 pm. The working day differ between days of the week, where on Monday, Tuesday and Wednesday there is more waste, the work is heavier and takes longer to finish (between 17 and 18 h), while on Thursday and Friday the work is lighter and finishes earlier (between 13 and 14 h).

2.3 Nordic Musculoskeletal Questionnaire (NMQ)

The Nordic Musculoskeletal Questionnaire (NMQ) was applied in order to identify the musculoskeletal symptoms reported in workers during the development of the activity. Through the "yes" or "no" answers, the questionnaire allows the worker to indicate the body regions which presented discomfort or pain in the last 7 days and/ or 12 months, and if for this reason they were prevented from performing any physical activity, or if there was a need to consult the medic. The questionnaire analyzes regions as neck, shoulders, elbow, wrists and hands, dorsal and lumbar spine, hip and thighs, knees, legs and ankles. However, in this study the hip and thigh, knees and ankle regions were not analyzed.

2.4 Termography

The skin temperature was evaluated by recording images with the FLIR infrared camera, model T460, resolution 320×240 pixels, thermal sensitivity <0.05 °C.

An automatic calibration was always performed prior to using the thermal camera. The thermographic photos were taken within two meters of distance from the worker, in total four times during the workday:

1. Beginning of the workday, before starting the morning collection (base measurement);
2. After morning collection, after the first cycle (field measurement);
3. After lunch and rest, before afternoon collection, start of the second cycle (field measurement);
4. After completion of the afternoon collection and return to base (base measurement).

During the capture of the thermographic images, the workers were asked to remove their hat, shirt, watch, bracelet and necklace, lift their trousers over their knees and lower their socks, and position themselves in a specific manner. For the ergonomic analysis, the thermographic images were taken from the front and back of the worker (in this work only back images were considered), aiming to include the different body regions considered by the NMQ: neck; shoulders; elbows; fists/hands; columns; and legs.

The images were treated with the software "*FLIR Tools*", considering the body emissivity of 0.98, the ambient temperature and the relative humidity of the air. Circular and rectangular geometric figures were applied in order to obtain greater coverage of the body region to be evaluated, considering the maximum temperature of each of the analyzed body parts, as shown in Fig. 1.

3 Results

The results from the NMQ shows that 4 workers made complaints in the lumbar spine region during the last 7 days and 5 workers during the last 12 months. In the backbone region, 4 workers have complained in the last 12 months, and in the knees 4 collectors have complained in the last 7 days and 6 in the last 12 months, as shown in Table 2.

The NMQ results show that the dorsal, lumbar spine and knees were the body regions in which collectors made the most complaints in the last 7 days, being 1.4 and 4 respectively and in the last 12 months, being 4.5 and 5, respectively.

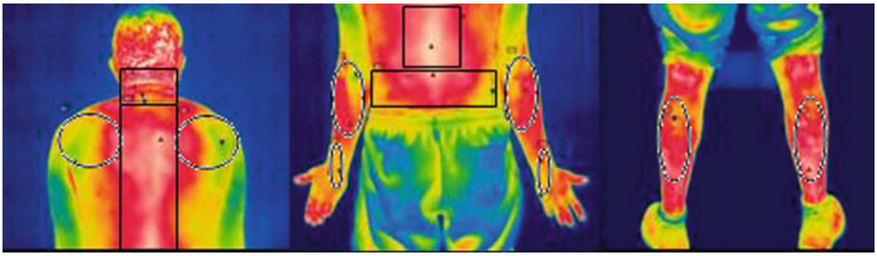

Fig. 1 Analysis of thermal images

Table 2 Results from the Nordic Musculoskeletal Questionnaire (NMQ)

Collector (nr)	1	2	3	4	5	6	7	8	9	Total (n)*
Neck	n/n	n/n	n/n	n/n	n/n	n/n	n/n	n/y	n/n	0y/1y
Shoulders	n/n	n/n	n/n	n/n	n/n	n/n	n/n	n/n	n/n	0y/0y
Elbow	n/n	n/n	n/n	n/n	n/n	n/n	n/n	n/n	n/n	0y/0y
Fists and hands	n/n	n/s	n/n	n/n	n/n	n/n	n/n	n/n	n/n	0y/1y
Back column	n/y	n/y	n/n	n/n	n/n	n/n	n/y	n/n	y/y	1y/4y
Lumbar spine	n/y	n/y	y/y	n/n	n/n	n/n	y/y	y/n	y/y	4y/5y
Hip and thighs	n/y	n/y	n/y	n/n	n/n	n/n	n/n	n/n	n/n	0y/3y
Knees	n/y	n/y	n/n	y/y	y/y	y/y	n/n	y/y	n/n	4y/6y
Legs	n/y	n/y	n/n	n/n	n/n	n/n	n/n	n/n	n/n	0y/2y
Ankles	n/y	n/y	n/n	n/n	n/n	n/n	n/n	n/n	n/n	0y/2y

*7 days/12 months; y = yes; n = no

Table 3 Mean skin temperature (TM) ± standard deviation (SD) and its variations throughout the day

N	Region	Skin temperature during morning (°C)			Skin temperature during afternoon (°C)			Daily vari–ation (°C)
		TM1 ± SD	TM2 ± SD	ΔT morn–ing ±SD	TM3 ± SD	TM4 ± SD	ΔT after–noon ±SD	TM4–TM1 ± SD
1	Neck	35.14 ± 0.30	34.97 ± 1.00	–0.17 ± 1.00	35.06 ± 0.82	34.92 ± 0.76	–0.14 ± 1. 03	–0.22 ± 0.86
2	Shoulder E	34.40 ± 0.73	34.49 ± 1.05	0.09 ± 0.77	34.88 ± 1.07	34.26 ± 0.59	–0.62 ± 0.99	–0.14 ± 0.72
3	Shoulder D	34.30 ± 0.71	34.54 ± 0.91	0.24 ± 0.68	35.21 ± 1.19	34.12 ± 0.73	–1.09 ± 0.92	–0.18 ± 0.44
4	Elbow and	33.77 ± 1.07	34.13 ± 1.05	0.36 ±1.02	35.18 ± 0.88	33.84 ± 0.80	–1.34 ± 0. 97	0.07 ± 0.91
5	Elbow D	33.93 ± 0.90	34.28 ± 1.03	0.35 ± 0.81	35.09 ± 1.21	34.42 ± 0.70	–0.67 ± 1.03	0.49 ± 0.88
6	Fist / Hand E	34.11 ± 0.87	34.67 ± 0.83	0.56 ± 0.42	35.26 ± 0.83	34.38 ± 0.76	–0.88 ± 0.66	0.27 ± 0.55
7	Fist / Hand D	34.12 ± 0.68	34.71 ± 0.75	0.59 ± 0.61	35.36 ± 0.90	34.36 ± 0.72	–1.00 ± 0.83	0.24 ± 0. 56
8	Back column	34.68 ± 0.83	34.48 ± 1.02	–0.20 ± 0.65	35.21 ± 0.65	35.01 ± 0.61	–0.20 ± 0.41	0.33 ± 0. 64
9	Lumbar spine	34.20 ± 1.05	34.24 ± 0.85	0.04 ± 0.69	34.91 ± 0.52	34.90 ± 0.66	–0.01 ± 0.37	0.70 ± 0.78
10	Leg and	34.04 ± 0.47	34.70 ± 0.68	0.66 ± 0.66	34.86 ± 0.79	34.19 ± 0.64	–0.67 ± 0.65	0.15 ± 0. 55
11	Leg D	33.91 ± 0.42	34.54 ± 0.98	0.63 ± 0.75	34.83 ± 0.69	34.22 ± 0.53	–0.61 ± 0.83	0.31 ± 0.57

**TM* Mean skin temperature calculated from data of 9 collectors

The following table shows the average skin temperatures of different body regions and their variations throughout the day. In red color was presented the reduction of skin temperature, while in green color the increase.

As shown in Table 3, there was an increase in the average workers' skin temperature in the morning (ΔT morning), where the body regions that presented the greatest temperature variation were in the wrists/hands (0.56 °C left and 0.59 °C right) and the legs (0.66 °C left and 0.63 °C right). In the afternoon collection (ΔT afternoon), an average reduction in skin temperature is observed in all regions of the body. The possible explanation for the reduction in skin temperature in the afternoon (ΔT afternoon) can be found in the fact that the last thermographic image

(TM4) was captured at the company base. At the end of the activity, the workers were transported in the collection vehicle, giving sufficient time for the body to cool-off before the last thermal image was captured.

The variation in skin temperature between late afternoon skin temperature (TM4) and early morning skin temperature (TM1) in the elbows, wrists and hands, dorsal spine, lumbar and leg regions increased, especially the right elbow, dorsal and lumbar spine regions, with a temperature variation of 0.49, 0.33 and 0.70 °C respectively. Five from nine collectors reported to have experienced during the past 12 months discomforts or pain in the lumbar spine, while four collectors reported it in the back column.

Some challenges were identified through the development of this study. Since the activity is performed outdoor, the subject is exposed to frequent changes in thermal and weather conditions. Further on, the workers don't have access to sanitary facilities, restaurants and resting places. This means that the workers find alternative ways to deal with their physiological needs, and rest in the shades on the ground. Such conditions may favor skin temperature increase in TM3, since after eating and sleeping the body naturally accelerates the metabolic process and energy expenditure. In addition, workers usually lie on the floor, which in the analyzed tropical region is normally warm.

One of the limitations from the present study is related to the time when the last thermographic image was taken. Before taking the TM4 image, the workers were transported from the field to the company base, giving enough time for the skin to cool-off. For future works it is recommended to study on a larger sample, in order to obtain greater consistency in the data and perform a better analysis of the influence on health of workers. The studies could assess the efforts and physical exertion of collectors. It is recommended to study average worker skin temperatures to provide a more comprehensive reading on conditions in the region of interest. Future studies should consider a higher number of samples in order to obtain greater consistency in the data and thus perform a better analysis of the health demands of the worker. It is recommended to study workers' average skin temperatures to provide a more comprehensive reading of the condition of the region of interest.

4 Conclusions

The result of the NMQ showed that the highest number of complaints was in the regions of the dorsal spine (with grade 4), lumbar (5) and knees (5), during the period of past 12 months.

By analyzing the thermal images it was found that there was an increase in the temperature of the legs, hands and wrists in the morning shift. In the afternoon there was a cooling of the skin in most regions of interest. Comparing skin temperature at the beginning with the end of the activity, there was an increase in the right elbow, lumbar and dorsal spine region.

Considering the results collected through the NMQ and thermography, the variations in the initial and final skin temperature values correspond to the musculoskeletal symptoms reported by the workers, especially in relation to the lumbar and dorsal region. Home waste collection workers are often exposed to a number of risks that should be analyzed and controlled. Performing work with high physical exertion on daily basis might cause musculoskeletal disorders on long-terms. In order to reduce the risk of injury and to improve performance, it is suggested to apply different organizational measures, including training and occupational gymnastics before initiation of the working activities.

References

1. Carvalho, F.V., Silva, M.D., da; Silva, L.M., De S., Borges, C.J., Silva, L.A., Robazzi, M.L., Do, C.C.: Occupational risks and work accidents: perceptions of garbage collectors. J. Nursing UFPE/Revista de Enfermagem UFPE **10**(4), 1185–1193, Reuol (2016). https://doi.org/10.5205/reuol.8464-74011-1-sm.1004201603
2. Jacobi, P.R., Besen, G.R.: Solid waste management in São Paulo: the challenges of sustainabitily. Revista-online Estudos Avançados **25**(71), 135–158 (2011)
3. Santos N.D., Barkokébas Júnior, B., Zlatar T., Cruz, F.M., Da, C., Lago, E.M.G.: Instrumentos legais referente a varrição, coleta domiciliar e transporte de resíduo solido urbano. In: XXV Simpósio de Engenharia de Produção (2018a)
4. Santos, N.D., Barkokébas Júnior, B., Zlatar, T., Cruz, F.M., Da, C., Lago, E.M.G.: Segurança do trabalho, produtividade e qualidade: análise da coleta de resíduos sólidos urbanos. In: XXXVIII Encontro Nacional de Engenharia de Producao (2018b)
5. Diniz, N., Castro, P., Lago, E., Cruz, F., Zlatar, T., Wasnievski, D., Pereira, A., Barkokébas Junior, B.: Work-related accidents in urban solid waste collection. Occup. Environ. Saf. Health (2018). https://doi.org/10.1007/978-3-030-14730-3_5
6. Kemper, H.C.G., Aalst, R.V., Leegwater, A., Maas, S., Knibbe, J.J.: The physical and physiological workload of refuse collectors. Ergonomics (1990)
7. Sousa Junior, A.M., Iber F.M.V.F., Silva Neto, F.F., Gurgel, J.L.M., Gama, R.A.P., Análise Ergonômica do Trabalho E Aplicação Do Método RULA: um estudo de caso no serviço de limpeza de logradouros públicos. In: Encontro Nacional de Engenharia de Produção. São Paulo (2010)
8. Cardoso, R.K., Rombaldi, A.J., Silva, Da M.C.: Osteomuscular disorders and associated factors among solid waste collectors of two middle-sized cities from the South of Brazil. Revista Dor **15**(1), 13–16 (2014) (Brazil). https://doi.org/10.5935/1806-0013.20140004
9. Pataro, S.: Lombalgia Em Trabalhadores De Limpeza Urbana. Universidade Federal da Bahia. Brazil, Dissertação de Mestrado (2011)
10. de Sousa, M.N.A.: Distúrbios osteomusculares autorreferidos entre os trabalhadores da limpeza urbana, pp. 133–151 (2017)
11. de Freitas, J.G., Carasek, H., Cascudo, O.: Utilização de termografia infravermelha para avaliação de fissuras em fachadas com revestimento de argamassa e pintura. Ambiente Construído, Porto Alegre **14**(1), 57–73 (2013)
12. Teixeira, G.G.D.: Confiabilidade metrológica em termografia aplicada em sistemas elétricos. Dissertação de Mestrado. Universidade Federal de Minas Gerais. Brazil (2012)
13. Brioschi, M.L., Okimoto, M.L.L.R., Vargas, J.V.C.: The utilization of infrared imaging for occupational disease study in industrial work. Work **41**(Suppl. 1), 503–509 (2012). https://doi.org/10.3233/wor-2012-0203-503

14. Marçal, M.A., Silva, F.D.B., Neto, L.M.: Termografia infravermelha: avaliação da sobrecarga músculo esquelética na região lombar e membros inferiores em uma linha de produção. V Congresso Latinoaméricano y IV Congresso Peruano de Ergonomía. Lima (2016)
15. Silva, J.R.R., Da Marçal, M., Oliveira, J.A. Do, N., Soares, M.M.: Análise Ergonomica Da Tarefa Dos Enfermeiros Das Clínicas Cirúrgicas Da Internação Do Hospital Das Clínicas Da Ufpe. In: Blucher Engineering Proceedings, no. 1, pp. 686–696 (2016)
16. Guertler, C., Speck, G.M., Mannrich, G.: Occupational health and safety management in Oyster culture. In: Aquacultural Engineering. Elsevier B.V. (2015). https://doi.org/10.1016/j.aquaeng.2015.11.0020144-8609
17. Alexandre, D., Prieto, M., Beaumont, F., Taiar, R., Polidori, G.: Wearing lead aprons in surgical operating rooms: ergonomic injuries evidenced by infrared thermography. J. Surg. Res. **209**, 227–233 (2017). Elsevier Inc. https://doi.org/10.1016/j.jss.2016.10.019
18. Holm, C.A., Pahler, L., Thiese, M.S., Handy, R.: Evaluation of physiological strain in hot work areas using thermal imagery. J. Thermal Biol. **61**, 8–15, Elsevier (2016). https://doi.org/10.1016/j.jtherbio.2016.07.013

Evaluation of the Thermal Environment Influence on Cognitive Performance in Students in Northeast Brazil

Pedro Filipe da Conceição Pereira, Evandro Eduardo Broday, Antônio Augusto de Paula Xavier and Adriana da Silva Simões

Abstract The environment in which people live has a major influence on their activities. An environment that offers comfort is essential for better results. The feeling of comfort for each individual is a complicated arrangement of numerous factors, of which we can highlight thermal comfort. Based on this, the present study aimed to analyze the effects that thermal environments have on the cognitive performance of students from a university in Northeast Brazil. For this, a sample of engineering students went through five areas of reasoning tests: verbal, abstract, numerical, mechanical and spatial reasoning that are part of the reasoning test series (BPR-5) and aims to classify general cognitive performance. The tests were performed on three consecutive days with average dry bulb temperature: 20.07, 33.7 and 22.94 °C. In addition to the tests, the students answered a questionnaire about perception, assessment and thermal preference of the environment. With the data, it was possible to evaluate the influence that the thermal environment exerts on the cognitive performance of the students. It was found that considering the number of total hits, student's performance was higher at 22.94 °C.

Keywords Thermal comfort · Cognitive performance · BPR-5

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1 Introduction

Throughout history, concerned about the external influence that the environment gives him, man has become more demanding regarding his thermal comfort, since discomfort can negatively influence his health and his performance, which implies a lower efficiency in their activities [1–3].

Given the influence of the environment on human living conditions, some studies such as those by Zhang et al. [4], Wang et al. [5], Mishra and Ramgopal [6], Maula et al. [7] for example, have already been designed to assess the relationship between thermal comfort and cognitive performance of individuals.

In addition to the negative aspects caused by thermal discomfort to human activities, studying this relationship is essential for a better environmental dimensioning and, consequently, a better correspondence in terms of energy saving, a very current theme in research area.

To this end, it is important to study the influence that thermal comfort exerts on the cognitive performance (which deals with the connected mental aspects and perception). In order to study this subject, the test BPR-5 was applied with students from Northeast Brazil, with the aim of providing more adequate teaching environments to facilitate the learning process.

2 Materials and Methods

2.1 Characterization of the Sample and Study Variables

The sample was defined by accessibility at a Federal University in Brazil. A total of 26 volunteers from engineering courses participated. The variables and the respective indicators of the parameters that were used to perform the present study are listed in Table 1.

2.2 Operationalization of Research

The data for the study were obtained during the experiment, which was performed on three consecutive days, with a daily session. Each session consisted of a test followed by a questionnaire. The tests were performed at three different dry bulb average temperature levels: 22.94, 20.07 and 33.7 °C. The temperatures were chosen to project the environment within the comfort range (22.94 °C) and within the range of cold discomfort (20.07 °C) and heat discomfort (33.7 °C) according to ISO 7730 (2005).

Table 1 Study variables

	Variables	Indicators
Thermal comfort variables	Personal	Metabolic rate (W/m^2) Clothing insulation (clo) Height (m); weight (kg); age and gender
	Environmental	Air temperature—Ta (°C) Mean radiant temperature—Trm (°C) Air velocity—Var (m/s) Relative Humidity—HR (%)
Subjective parameters	Thermal sensation Thermal evaluation Thermal preference	7-point thermal sensation scale from ISO 7730 (2005) [8] and scales from ISO 10551 (1995) [9]
Performance	Reasoning	BPR-5 [10]

It was also measured the humidity of the air throughout the experiment in intervals of 60 s. This method was chosen in order to verify the uniformity of the thermal environment conditions that the students were submitted to.

Students who attended the test days were first advised on the procedures, the purpose of the research and the BPR-5 tests that would be performed, as well as signing the informed consent. To answer the test battery the students used computers previously prepared with the questions. In order to prevent participants from having contact with the test before the experiment, the website link was only available at the time of the test.

At a certain air temperature previously set for the day, testing began. As soon as they arrived at the place, the students were instructed to remain in the environment and to make the minimum effort, during a certain period, in order to have thermal stabilization until the beginning of normal activities. After the initial time interval, the reasoning tests started, with a maximum duration of 40 min and at the end of the test, the participant answered questionnaires about perception and thermal assessment. Figure 1 shows the process briefly.

After the experiment, the students were released to perform their activities normally.

2.3 Measurement of Environmental and Personal Variables

The environmental variables were obtained through the use of a BABUC/A/M microclimatic station, which has devices that perform these measurements, besides recording the data by creating a local file and allowing the transfer of data for another device, such as a computer or notebook, where data can be processed in whatever way is convenient for the researcher. The equipment meets the requirements of ISO 7726 [11].

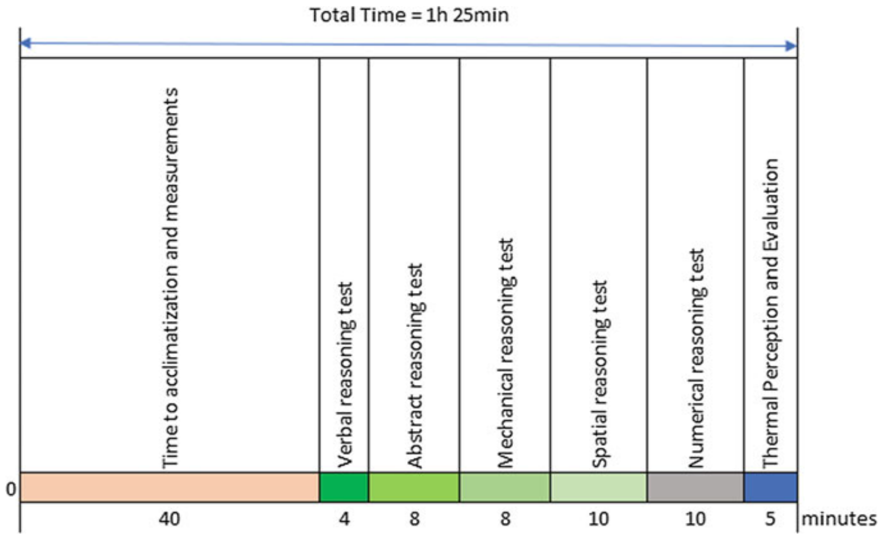

Fig. 1 Experimental procedure

The microclimate station was installed in the center of the room, at a height of 0.60 m, following what is established by ISO 7726 in relation to the ground, given that individuals are seated. The station was programmed to measure the variables every 60 s since students entered the classroom.

The metabolic rate was set at 70 W/m^2. The clothing insulation was obtained through the answers provided by the students on the test days of how they were dressed. Height (m), weight (kg), age and gender were collected on the first day of the test.

Data on the subjective parameters, such as thermal sensation and thermal preference of the surveyed participants, were obtained through the questionnaire answers on the students' perception, assessment and thermal preference, based on the 7-point perception and preference scales. The ISO 10551-based questionnaire was answered by students shortly after the battery of reasoning tests.

2.4 *Cognitive Assessment Using BPR-5*

Student performance was assessed by the BPR-5 tool, which is used to measure the general cognitive functioning of individuals. The test presented to the students contained tests in the five reasoning areas of the tool. Table 2 shows how the test occurred.

For the application of the test the software *BPR-5 info* was used.

Table 2 BPR-5 reasoning tests

Test	Description	Specific capacity
Verbal reasoning (RV)	Test consisting of 4 items involving analogy between words	Vocabulary extension Ability to establish abstract relationships between verbal concepts
Abstract reasoning (RA)	Test consisting of 4 items of abstract content. involving analogy with geometric figures	Ability to establish abstract relationships in new situations for which little previously learned knowledge is available
Mechanical reasoning (RM)	Test consisting of 4 items consisting of engravings that portray a physical-mechanical problem and answer option	Practical knowledge of mechanics and physics; Ability to integrate information in texts with the descriptive picture of the problem situation
Spatial reasoning (RE)	Test consisting of 4 items involving the three-dimensional movements of a series of cubes	Ability to visualize, that is, to form visual mental representations and manipulate them, transforming them into new representations
Numerical reasoning (RN)	Test comprises 4 items involving the arithmetic relationship of a linear or alternating series of numbers	Reasoning ability with numerical symbols in quantitative problems Knowledge of basic arithmetic operations

3 Results and Discussions

3.1 Questionnaire Analysis

A descriptive analysis of the sample was made for treatment and removal of the data not significant for the research. The total sample consisted of 26 students, of which 20 are male and 6 females. The average age observed was around 22 ± 2.11 years. The average weight for female was 65.54 ± 6.5 kg and for men the average was 64.76 ± 6.99 kg. The approximate average height for women was 1.67 ± 0.015 m and for men was 1.74 ± 0.056 m. Data were collected on each test day for some environmental variables, the mean and standard deviation for each of these variables and the Predicted Mean Vote—PMV and Predicted Percentage of Dissatisfied—PPD, according to ISO 7730 are shown in Table 3.

For the temperatures on the three days it is noted that for the lowest temperature day the average was 20.07 °C, for the hottest day the average was 33.7 °C and for the moderate temperature was 22.94 °C. The lowest average PPD was 15.21% on the day with an average temperature range of 22.94 °C. Table 4 shows each individual's thermal perception for the temperature ranges studied.

For an average dry bulb temperature range of 20.07 °C, 73.08% of participants reported being "slightly cool" (−1), "Cool" (−2) or "Cold" (−3), while 26.92% of the students found the environment neutral (0). The average observed PMV was −1.61.

Table 3 Mean and standard deviation of environmental variables and indices on each test day

Variable	Day 1 (20.07 °C)		Day 2 (33.7 °C)		Day 3 (22.94 °C)	
	Average	SD	Average	SD	Average	SD
HR (%)	69.20	0.16	64.52	0.67	67.57	0.24
Ta (°C)	20.07	0.014	33.70	0.13	22.95	0.019
Trm (°C)	19.69	0.02	33.74	0.13	22.48	0.02
Var (m/s)	0.10	0.00	0.10	0.00	0.10	0.00
PMV	−1.61	0.11	2.95	0.05	−0.68	0.18
PPD	56.98	5.80	98.83	0.24	15.21	6.71

Table 4 Percentage of votes for thermal perception for each temperature

Thermal sensation	Temperature		
	20.07 °C (%)	22.94 °C (%)	33.7 °C (%)
Cold (-3)	11.54	3.84	0.00
Cool (2)	11.54	3.85	0.00
Slightly cool (−1)	50.00	19.23	0.00
Neutral (0)	26.92	73.08	0.00
Slightly warm (1)	0.00	0.00	3.85
Warm (2)	0.00	0.00	57.69
Hot (3)	0.00	0.00	38.46

For the calculated dry bulb average temperature range of 22.94 °C the average established PMV was −0.68, 73.08% of the subjects stated they were comfortable, 19.23% said they were “slightly cool”, the other students judged the environment as “cool” or “cold”. Regarding the average temperature range of 33.7 °C, for the dry bulb, it was observed that 96.15% of the students said they were “warm” (2) or “hot” (3), 3.85% of the participants reported feeling “slightly warm” (1). It is noted that unlike what happened for the other temperature ranges no student was comfortable for such temperature range. The average observed PMV was 2.95.

3.2 *BPR-5 Reasoning Test*

For the dry bulb temperature averages and the environmental variable averages described above, for each research day, the following values were found for the total number of correct answers (20) in relation to each reasoning test per participant. Students who took the test had their identity preserved; therefore, only one number was used to designate it. Figure 2 shows the test results.

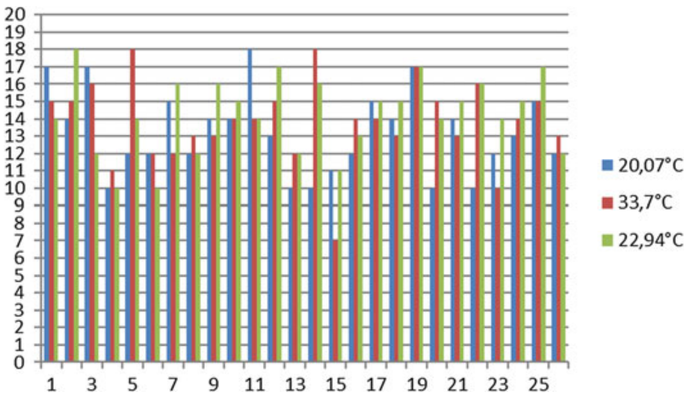

Fig. 2 Number of BPR-5 hits per test day per student

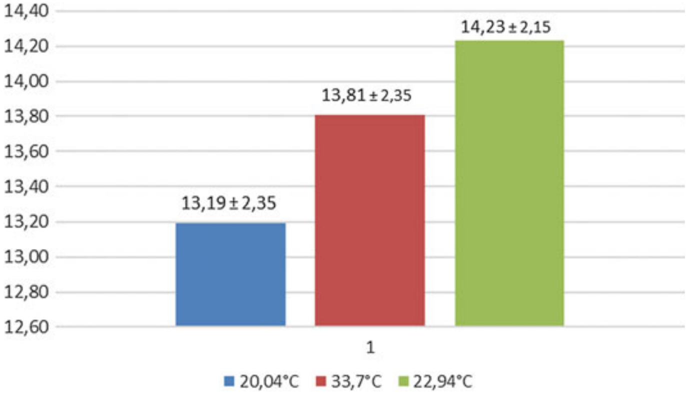

Fig. 3 BPR-5 hit averages on each test day

It was observed that no student answered all 20 questions that evaluated the test and the highest grade was applied 18 questions. Figure 3 shows the average of the values obtained on each test day.

The average of the BPR-5 test battery shows that the performance was higher for the average dry bulb temperature of 22.94 °C. Table 5 shows the percent division of hits for BPR-5 for each test day.

Thus, for a day with a temperature of 22.94 °C, 18 students were able to achieve 70% of the total questions, i.e., a grade greater than or equal to 14 questions.

Table 5 Performance distribution for a BPR-5

Performance	20.07 °C	33.7 °C	22.94 °C
$\leq 50\%$	5	2	2
$50\% \leq X \leq 70\%$	9	9	6
$\geq 70\%$	12	15	18

4 Conclusions

From the data analysis, it was possible to evaluate the influence of the thermal environment on students from Northeast Brazil. The study showed in relation to the number of hits of BPR-5 that the performance was clearly superior to 22.94 °C, considered moderate temperature range, in which 18 students, from a sample of 26, had a performance equal to or above 70% of questions, even testing at this temperature being performed on the last day of testing and students could possibly be fatigued.

The second highest percentage of correct answers was 30.7 °C and 20.07 °C, respectively. The study of thermal environments and their influence on human performance goes far beyond avoiding the challenges of working outside the thermal comfort environment. Conducting research in this area is important, not only to help not decrease productivity and the quality of human activities, but also to save energy.

Through this study, it is expected that the thermal environment of the classrooms are better planned, universities and schools, so that the learning process is facilitated for students.

References

1. Sarbu, I., Sebarchievici, C.: Aspects of indoor environmental quality assessment in buildings. Energy Build. **60**, 410–419 (2013)
2. Ricciardi, P., Buratti, C., Singh, M.K., Ooka, R., Rijal, H.B., Kumar, S., Kumar, A., Mahapatra, S.: Progress in thermal comfort studies in classrooms over last 50 years and way forward. Energy Build. **188–189**, 149–174 (2019)
3. Broday, E.E., Moreto, J.A., Xavier, A.A.P., Oliveira, R.: The approximation between thermal sensation votes (TSV) and predicted mean vote (PMV): a comparative analysis. Int. J. Ind. Ergon. **69**, 1–8 (2019)
4. Zhang, F., Haddad, S., Nakisa, B., Rastgoo, M.N., Candido, C., Tjondronegoro, D., de Dear, R.: The effects of higher temperature setpoints during summer on office workers' cognitive load and thermal comfort. Build. Environ. **123**, 176–188 (2017)
5. Wang, D., Xu, Y., Liu, Y., Wang, Y., Jiang, J., Wang, X., Liu, J.: Experimental investigation of the effect of indoor air temperature on students' learning performance under the summer conditions in China. Build. Environ. **140**, 140–152 (2018)
6. Mishra, A.K., Ramgopal, M.: A comparison of student performance between conditioned and naturally ventilated classrooms. Build. Environ. **84**, 181–188 (2015)

7. Maula, H., Hongisto, V., Koskela, H., Haapakangas, A.: The effect of cooling jet on work performance and comfort in warm office environment. Build. Environ. **104**, 13–20 (2016)
8. ISO—International Organization for Standardization: Ergonomics of the thermal environment —analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. ISO 7730. Geneva (2005)
9. ISO—International Organization for Standardization: Ergonomics of the thermal environment —assessment of the influence of the thermal environment using subjective judgement scales. ISO 10551. Geneva (1995)
10. Primi, R., Almeida, L.S.: Estudo de validação da Bateria de Provas de Raciocínio (BPR-5). Psicol. Teor. e Pesqui. **16**, 165–173 (2000)
11. ISO—International Organization for Standardization: Ergonomics of the thermal environment —instruments for measuring physical quantities. ISO 7726. Geneva (1998)

Heuristic Evaluation of Bra Wearability

Rosiane Alves and Laura Martins

Abstract Bra usage in work environment has become a habit due to the structural need of breasts support, performed activities and social and professional interactions. However, previous studies indicate that the interaction between configuration characteristics, female body diversity and performed activities may result in physical and thermic discomfort. These and other wearability problems may be aggravated by prolonged use in labor contexts. Considering the lack of wearability evaluation methodologies, this article aims to present a heuristic evaluation of wearability as one of the possible methods of classifying bra performance. Based on the eleven bra wearability heuristics, evaluations were conducted by six specialists. Each specialist inspected three different bra models. The data acquired confirmed that the heuristic evaluation is a viable method to classifying bra performance, capable of point out structural problems that are not commonly perceived by users. Furthermore, the evaluation is applicable both in the prototype phase and the evaluation of commercially available bras. Identified problems and qualities can be used as parameters for redesigning evaluated bras or as guidelines in new projects.

Keywords Wearability heuristic · Labor bras · Heuristic evaluation

1 Introduction

Female participation in the labor market demanded less limiting clothing, which propelled, in the early twentieth century, in the replacement of corsets by bras. Since then, its use became a habit. As an example, a research performed in Nigeria discovered that the percentage of women wearing bras only during work hours was 40.5% and during the whole day was 43.3% [1]. However, whether due to the

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prolonged use or by the nature of the performed activities, bra usage in labor environment can result in excess discomfort.

Previous researches show that the causes of discomfort may be lack of uniformity of body measurements methods for determining correct bra size and its standardization, improper adjustment, misuse of materials, prioritization of aesthetics, limited support while performing some activities [2–5]. These and other wearability problems have been investigated in a variety of contexts. However, no previous studies of bra usage in labor context were found.

It is highlighted that, besides the market classification of bras, such as fashion, sport, among others, the category of labor bra does not exist. Therefore, women, including the seamstress, use the commercially available bras in their labor context, regardless of its category.

In the apparel industry, each seamstress is specialized in specific parts of a garment. The activities are repetitive and performed in a cycle of less than 90 s, in a seated position, with greater movement of the arms. Therefore, the use of a bra adapted to their activities would be relevant for their comfort and productivity.

Therefore, this research was conducted from the perspective of clothing ergonomics. However, in this field there is no methodological variety when compared to human-computer interface area, for instance. Moreover, and based in a theoretic and methodological transposition of usability, which assigned to wearability the measurement concept in which a clothing can be dressed and used by a group of users to achieve their goals with effectiveness, efficiency and satisfaction in specific contexts [6], the first phase of the research identified metrics and proposed heuristics of bra wearability [7].

Therefore, the objective of this article is to present the heuristics of bra wearability as a methodological strategy for classification of performance of different bra models commonly wore by seamstress in labor context.

2 Bra Wearability Heuristics

The heuristics or principles are a set of rules and methods that aim discovering or solving a problem. In human-computer interaction field, ten heuristics were proposed by Nielsen [8]. Later, Jordan presented eleven principles of usable design [9]. Those served as foundation for proposing bra wearability heuristics, which are guiding principles for new designs, evaluation of prototypes and/or bras available in the market [7], listed and described below:

- **H1—Prioritization of Support:** bra's ability to support and stabilize the breasts in different postures adopted and while performing movements.
- **H2—Focus on silhouette**: bra's ability to shape the breasts and the silhouette, making it seemingly firm, smaller or larger. Also harmonizing with outer clothing and contribute to postural balance.
- **H3—Recognition of Modesty**: bra's ability to provide coverage of the breasts and nipple concealment.

- **H4—Consideration of comfort**: bra's ability to contribute to overall wearer comfort (physical, psychologic and thermophysiological).
- **H5—Appropriate elevation**: bra's ability to lift the breasts.
- **H6—Consistency for the adjusting or fitting tasks:** when the method applied in the tasks of dressing, adjusting, fitting the breasts and undressing the bra are consistent with procedures and methods employed in previous use of other bras.
- **H7—Feedback for adjusting or fitting tasks**: it regards the bra's mechanisms involved in the tasks of adjustment, responding to the actions performed by the wearers. These responses (visual, sound and somesthetic) should be received immediately, recognized and retained during the use.
- **H8—Preventing Errors for Tasks of adjusting or fitting**: it concerns that, during the tasks of dressing and adjusting the bra, the possibility of errors is minimized by the arrangement of the bra's subunits, and, in case errors occur, they can be easily corrected.
- **H9—Considering body variations for adjusting or fitting**: it concerns the level of consideration of body characteristics by the bra's design, which includes variations in the breasts such as shape, size, degree of ptosis, proportionality regarding the chest. It is evaluated by the level of pressure or looseness the bra exerts on the body.
- **H10—Informational Clarity**: it regards the level of information clarity presented in tags and labels about functionality, fitting methods, wear options, available sizes and bra's size identification by the wearers.
- **H11—Application of technology**: it concerns the application of technology in project processes in molding, materials and sealing sample techniques.

3 Method

This research was approved by the Ethics Committee of Researches Involving Humans of the Federal University of Pernambuco in April, 2015, CAAE: 42670915.7.0000.5208. Data collection was performed in three phases: (1) Questionnaire applied to 200 seamstresses to identify metrics and determine the heuristics; (2) Wearability test with 30 seamstresses; (3) Heuristics evaluation by six specialists.

However, the data presented in this article regards only the third stage of the research—the heuristics evaluation, which was performed through observation of bra's interface in order to identify problems and/or qualities.

Although this kind of evaluation is based in the intuition of the specialist evaluators, it is advised that it follow some rules—the heuristics themselves [8]. Based on these rules, the heuristics evaluation becomes a systematic inspection of the product's design interface for usability [8–10].

This type of evaluation can be performed by five specialist evaluators [8], with implications in the results, which means that 95% of the problems will be identified if the evaluators are specialists in both usability and product design; 85% if they are only usability specialists; and 50% if they are not specialists. However, the relevance of the results also depends on the strategies employed during the evaluations [10].

Accordingly, the requirements for specialist selection were: (1) knowledge in usability and/or fashion-clothing ergonomics; (2) being female, due to the familiarity in performing the tasks of dressing, adjust and undress the bra. Data collection adopted the following procedures: (1) Pilot test with 5 specialists with no complications; (2) Heuristic evaluation by 6 specialists mediated by form with questions regarding whether or not the bra's interface agreed with the wearability heuristics, with 3 answer options: (1) Yes—Fully Agree; (2) Yes—Partially Agree; (3) No—Disagree. If marked options 2 or 3, it was necessary to describe the problem identified and a correction suggestion. Data was inserted in the SPSS and analyzed.

4 Heuristic Evaluation of the Bras Wearability

The specialists evaluated three different bra models (see Fig. 1) that were used by a group of 30 seamstresses during the wearability tests. However, the results presented here are only regarding the heuristics evaluation.

The interfaces and features of the three bra models (see Table 1) were inspected by the specialists and verified in correspondence with each bra wearability heuristic and descripted in items 4.1 to 4.18.

4.1 H1: Prioritization of Support

Bra 2 presented higher prioritization of support, with Fully (83.3%) and Partially (16.7%) capacity to support the breasts. Partially results regarded the absence of underwires. Bra 3, Fully (50%) and Partially (50%), considered due to the excess of

Bra 1 (B1)	**Bra 2 (B2)**		**Bra 3 (B3)**
External - Right	External - Front		External - Right
			
Interior - Reverse	External - Back		Interior - Reverse
			

Fig. 1 Bras evaluated by the specialists

Table 1 Description of the main configurative aspects of bras

Aspects	Bra 1	Bra 2	Bra 3
Cup-shape	Push-up	Sports bra (**M1/M2**)	Full coverage
Cup-bulge	With foam	**M1**: foam and lining **M2**: Without foam	Without foam
Wires	Hard and thin wires	Without wires	Without wires
Gore	Average: 4 cm	High: 17 cm	Average: 6 cm
Straps-width	1.6 cm (48)/ 1.0 cm (46)	2.5 cm	2.0 cm
Straps-position	Vertical	Racerback	Vertical
Straps-material	Elastic	Fabric	Elastic
Regulators-straps	Back	Without regulators	Front
Side band	Without steel boning	Without steel boning	Steel boning
Back band	3–4 cm	11 cm	7–8 cm
Openings	Back	**M1**: partial in the back **M2**: Without opening	Back
Fastenings	Hooks 3X2	**M1**: Hooks 3X2 **M2**: Without hooks	Hooks 3X2
Fabric	83% PC 17% Elast.	**M1**: 85% PC, 15% Elast. Lining: 100% PES. **M2**: 82% PC, 18% Elast.	75% PC 25% Elast.
Padding of the cup	100% PES	100% Polyurethane (PU)	Without padding

M1: Model 1 of bra 2. **M2**: Model 2 of bra 2—for the seamstress with larger breasts

flexibility of the cups without underwire, which does not support larger breasts. Bra 1 presented low capacity of supporting the breasts with Fully (33.3%) and higher Partiality (66.7%). Possible due to a narrow sideband, insufficient cup size, open neckline, thin straps.

4.2 H2: Focus on Silhouette

Bra 1 presented greater conformity with H2, with potential of modifying Fully (50%) and Partially (33.3%) the shape of breasts. Bra 2 presented higher Partially focalization (66.7%) due to the absence of underwires and the presence of bulges that do not adhere to the skin, resulting in failure outlining each breasts. Bra 3 presented discrepancy for H2—Partially (33.3%) and Disagree (50%), due to the gore (i.e. the center piece) that draw the breasts together, the flexibility of the cups and the absence of underwires in the base.

4.3 H3.1: Recognition of Modesty—Breast Coverage

Bra 2 fully cover the breasts (83.3%). In contrast, bras 1 and 3 provide partial coverage (66.7%). To the specialists, bra's 1 cup has a low neckline, which can expose the superior part of the breasts. And bra 3, with a single fabric layer in the cups, contributes to the transparency of the nipples.

4.4 H3.2: Recognition of Modesty—Nipple Concealment

Bras 1 and 2 fully meet H3 (100%)—both have foamed bulges that prevents transparency of the nipple. Bra 3 shows a result of Partially (50%) or Disagree (50%), because of its transparent cup, lack of bulges and lining.

4.5 H4: Consideration of Comfort

All the bras results were Partially—B1 (66.7%), B2 (50%), B3 (33.3%)—considering comfort regarding the following aspects: (1) bra 1—thins straps, synthetic fabric, open neckline and presence of underwires; (2) Bra 2—excess pressure in the band and tall armholes, racerback straps without sliders and cups with three layers of materials; (3) bra 3—bands with excess pressure.

4.6 H5: Appropriate Elevation

Bra 1 presents potential of elevation of the breasts Fully (80%) and Partially (20%). Bras 2 and 3, elevation Fully (50%), Partially (33.3%) or Disagree (16.7%).

4.7 H6.1: Consistency for the Adjusting or Fitting Tasks—Vertically

To the specialists (100%), bra 3 presented higher consistency in the tasks of adjusting the straps vertically. While the bra 1 Fully (50%) and Partially (50%), due to location of the back sliders, that requires being undressed to adjust straps. Bra 2 show a result of Disagree (83.3%) because of absence of sliders.

4.8 H6.2: Consistency for the Adjusting or Fitting Tasks—Horizontally

Bra 3 presented total consistency (100%) in the adjustment of the band. Bra 1 presents full consistency (83.3%) in a smaller percentage and bra 2 presented Disagree in higher percentage (50%). In the case of the bra 2, the band can only be regulated with the closure mechanisms positioned in the back, which demands higher physical effort.

4.9 H6.3: Consistency of the Task of Fitting the Breasts

Bra 1 was considered Fully (100%) consistent in the task of fitting the breasts. Bra 3 presented consistency of Fully (66.7%) and Partially (33.3%). Bra 2 presented a higher percentage of Disagree (50%), due to the high neckline, the rigidity of the straps and the absence of delimitation of the cups.

4.10 H7.1: Immediate Feedback in the Adjustment Task

Bra 1 and Bra 3 presented higher percentage to immediate response in Partially (66.7%). B1, due to deficiency in the response while adjusting the straps and the visual feedback due to the shallow cups. B3 did not present a sound response or good proprioceptive information. However, it presented good visual response for the tasks of fitting and closing. B2 presented results of Fully (33.3%), Partially (33.3%) and Disagree (33.3%). It had visual and proprioceptive feedback, but no response of breasts fitting.

4.11 H7.2: Feedback—Adjustment Conservation

Bra 2 presented higher capacity with Fully (83.3%) and Partially (16.7%). Possibly the compression performed by this bra contributes to the conservation of adjustment. However, the absence of sliders and underwire controlling can cause a sensation of disengaged breasts throughout the day. Following, bra 3 presented potentiality with Fully (66.7%) and Partially (33.3%). While bra 1 presented higher percentage for Partially feedback (50%) and relevant for Disagree (16.7%), because its fastening mechanisms can be easily open, the cups are shallow and the underwires and band can compress the skin.

4.12 H8: Preventing Errors for Tasks of Adjusting or Fitting

Bra 1 presented capacity of error prevention Fully (83.3%) and Disagree (16.7%). Bra 3, Fully (66.7%) and Disagree (33.3%). For the specialists there is almost no difference from the inside and outside of the bra 3.

The Bra 2 presented low capacity—Fully (33.3%), Partially (33.3%) and Disagree (33.3%). That result may be due to the similarities between the outside and the inside of bra 2, which can induce dressing the bra inside out.

4.13 H9: Consideration of Body Variations for Adjusting or Fitting

In this heuristics it was evaluated the design of the straps, the band, the cups and their relation to adjustment.

4.14 H9.1: Design of Straps and Sliders—Vertical Adjust

The bra's straps of bra 3 presented higher conformity with Fully (100%) for H9. Bra 1, Partially (83.3%), and bra 2, Disagree (83.3%). According to specialists, bra's 1 straps are narrow and can cause discomfort in women with larger breasts. Bra's 2 straps did not presented sliders, which restrains adjustment.

4.15 H9.2: Design of the Band, Gore and Fastener—Horizontal Adjust

The subunits of the band (gore, wings, backside and closure mechanisms) of B3 presented full conformity—Fully (83.3%) for H9. Bra 1 and Bra 2, lower consideration with Fully (50%). For the specialists, the narrow band of B1 makes it difficult for women with larger breasts to use it. And the model of B2 makes regulations impossible, maintaining compression.

4.16 H9.3: Design of the Cups and Underwires for Breast Fitting

The cups and underwires of Bra 1 presented conformity of Fully (50%) and Partially (50%). B1 and B2, less conformity with Fully (33.3%) and Partially

(50%). However, for the specialists, the cups and underwires of B1, only favor women with smaller breasts. In B2, the foamed bulges do not present delimitation or fitting of the breasts.

4.17 H10: Informational Clarity

According to the evaluator, the information in tags and labels of bra 3 presented clarity of Fully (50%) and Partially (50%). There were data about the size, but lack of information about functionality, adjustment and guidelines of use. The tags and labels of Bra 1 presented low clarity, with Fully (16.7%) and Partially (83.3%) with information regarding only the size. According to the majority of the specialists, in the tags and labels of bra 2 it was not found informational clarity (Disagree—66.7%).

4.18 H11: Application of Technology with Contribution to Wearability

Major technology application was found in bra 2, Fully (60%) and Partially (40%), due to the combination of materials which turned the cups in heating points. In Bra 1, the lowest application, with Fully (40%) and Partially (40%) were associated with the fastenings, small cups and narrow straps. Bra 3 presented Partially (60%) due to the roughness of the seams and the fabric.

5 Conclusion

The evaluations performed by the specialists were based on the bra wearability heuristics and confirmed the assumption that wearability heuristics evaluation is a viable method for bra performance classification, besides indicating structural problems that are not commonly perceived by the wearers.

It is important to emphasize that this was the first study regarding wearability heuristics evaluation which resulted in a list of problems that could be used as parameters for redesigning evaluated bras and/or propose new guidelines for bra designs in labor context. In this case, heuristic evaluation is also recommended in sealing sample stage of clothing designing, because it allows rapid prototype judgment. It is understood that the presented data contribute to strengthen the relationship between ergonomics and fashion design, also providing support for systematic wearability evaluation.

However, as the previous references were product evaluation heuristics, it is recommended further studies of the wearability heuristics evaluation in order to verify the effect of the following variables: evaluator's specialization and its implications in problem and qualities identification; contributions to the teaching-learning process; comparison between heuristics evaluation and wearability tests in academy and in the industry; use of objective tests during specialists inspection and in virtual environments; proposition of new wearability heuristics for different artifacts and segments of clothing.

References

1. Odebiyi, D., Aweto, H., Gbadebo, O., Oluwole, A., Aiyegbusi, A., Olaogun, M., Lee, L.J.: Association between suitability of bra fit and pectoral girdle myalgia in Nigerian women. Int. J. Therapy Rehabil. **22**(9), 428–433 (2015)
2. Brown, N., White, J., Brasher, A., Scurr, J.: An investigation into breast support and sports bra use in female runners of the 2012 London Marathon. J. Sports Sci. 1–9 (2014)
3. Mcghee, D., Steele, J.R.: How do respiratory state and measurement method affect bra size calculations? Br. J. Sports Med. **40**, 970–974 (2006)
4. RISIUS, Debbie: An investigation of breast support for older women. Thesis (Doctorate). University of Portsmouth, UK (2012)
5. Zheng, R., Yu, W., Fan, J.: Development of a new chinese bra sizing system based on breast anthropometric measurements. Int. J. Ind. Ergon. **37**, 697–705, 2007
6. Alves, R.P., Martins, L.B.: Vestibilidade: transposição teórica e metodológica com base na ABNT NBR 9241-11/210. In: 13º Colóquio de Moda on electronic proceedings, pp. 1–16. Bauru, SP (2017)
7. Alves, R.P., Raposo, M.C.F., Martins, L.B.: Métricas e Heurísticas para Vestibilidade do Sutiã Laboral. Estudos em Design (on-line). **27**(1), 91–107 (2019)
8. Nielsen, J.: Usability Engineering. Elsevier, USA (1994)
9. Jordan, P.W.: An Introduction to Usability. Taylor & Francis, London (1998)
10. Cybis, W., Betiol, A.H., Faust, R.: Ergonomia e usabilidade: conhecimentos, métodos e aplicações, 2nd edn. Novatec, São Paulo (2010)

Reducing 3M by Improved Layouts and Ergonomic Intervention in a Lean Journey in a Cork Company

T. Melo, A. C. Alves, I. Lopes and A. Colim

Abstract The study presented in this paper aimed to obtain improvements in the production processes and methods used by co-workers of a cork company. For the study, the authors applied the tools and principles of Lean Thinking, Ergonomic, and Total Productive Maintenance. The research methodology used in the project development was the Action-Research, whose first step is to diagnose the current situation of the study area. For this purpose, tools as spaghetti diagram, time studies, anthropometric analysis and NIOSH Equation were applied. Several problems were detected such as long distances, confined factory space and improper distribution of production tools. One of the most serious problems was the lift of heavy cutting tools from shelves that imposed hard work conditions to the workers. In order to solve these problems, the improvement proposals required the redefinition of the layout, as well as the organization of cutting tools through the implementation of 5S, attending to the anthropometric data. With the implementation of the project, it was possible to reduce the occupied space in 27%, the distances traveled and the time spent on them in 63% (annual savings of 234 km and 65 h), the movements costs in 71% (gain of 1332 €/year) and the time and wastebasket related to production stoppages by the lack of space in 100% (annual gain of 26 h and 1530 €). Furthermore, the time to search for production tools was reduced by 75% and an increase in the production line efficiency by 27% was also verified. With these *muda* reductions, *mura* and *muri* were also reduced, improving the work conditions.

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Keywords Ergonomics · Layouts · Lean thinking · TPM · 5S

1 Introduction

For survival in a world where competition is prevalent, companies aim to constantly improve their operating performance [1]. There are philosophies that aim to adapt to the current reality, allowing companies to achieve improvements in production systems in order to fully meet market demands. One of these philosophies is the Lean Production philosophy, which consists of the development of processes and methods aimed at the continuous reduction of waste [2]. Thus, allied to this model comes to the concept of Lean Thinking, which translates into the thought of "doing more with less" [3]. This can be done by the reduction of the 3M's: *Muda*- activities that do not add value; *Mura*- variability in the production flow both in quantity and quality; *Muri*- It means overload, referring to situations in which operators or machines operate above their limits, consequently resulting in wasted time, energy and risk of injury [4].

In addition to the lean principles of waste reduction and value creation, human factors and ergonomics are key elements of the lean planning process [5]. Previous studies have investigated the impact of human factors and worker behaviours on company performance, as well as the importance of Lean and the effects on worker safety and health [6]. It was concluded that ergonomic workplaces reduces injury rates while improving productivity and quality [7].

Furthermore, in order to increase effectiveness in workplaces, higher availability of resources is needed. This can be achieved for equipment using a maintenance management methodology called Total Productive Maintenance (TPM), which focuses on engaging all employees to increase the productivity of the company's physical assets, optimizing human-machine interaction [8].

The study presented in this paper aimed to improve a cork company sector (Gaskets area) by implementing Lean Production and TPM, having the support of an ergonomic intervention. This company is a world leader in the cork sector, whose main activity is to convert cork into a diversity of end products.

This paper is structured in five main sections. After this first introduction that presents the objective, Sect. 2 presents the research methodology. Section 3 presents the project area description and analysis, and Sect. 4 presents the improvement proposals and results. Finally, Sect. 5 presents the conclusion.

2 Research Methodology

In order to explore the dualism between theory and practice, the methodology used was Action-Research, which is divided into five iterative phases: Diagnosis, Action planning, Action implementation, Outcome assessment and Learning specification [9].

In the diagnostic phase, a critical analysis of the initial situation was made in order to raise the existing problems in the study area. As an aid, tools as spaghetti diagram, time studies, anthropometric analysis, and NIOSH Equation were used. The next step concerns Action Planning, where improvement plans were defined to overcome the limitations found in the first phase. Afterward, to the Actions Implementation phase, tools such as SLP, CORELAP, CRAFT and 5S were applied. Finally, it proceeded with the Results Assessment phase, which consisted of the assessment of the impact of improvements. Lastly, in the Learning Specification phase, it was identified as the main conclusions about the results obtained.

3 Description and Critical Analysis of the Initial Situation

3.1 Study Area Characterization and Problems Identification

One section of the company, Home & Office (H&O) section, was in a process of moving the production tools into another area, the gaskets section. So, space was needed to incorporate these tools into the gasket's layout. In total, the resources of the study section (gaskets area), illustrated in Fig. 1, occupied an area of 68 m^2. The main problems identified in this area are described in the following sections.

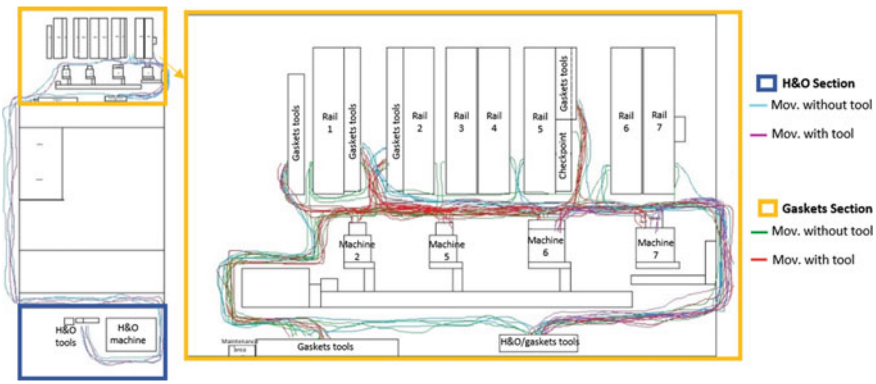

Fig. 1 Initial state I spaghetti diagram on the left and initial state II on the right

Long distances from production tools to workplaces. The movement of the production tools was made according to the orders. Two initial states were identified, due to the location of the H&O tools in two different places:

(1) Initial state I—The production tools of the H&O products were in a cabinet of the H&O section, so whenever an order was placed it was necessary to move it to the gaskets section, for its production, taking 180 m for each side.
(2) Initial state II—An order comes for an H&O production tool that was already placed on a wall from the gaskets section at a distance of about 35 m from the production machine (machines 6 and 7).

The possible movements related to the transport of production tools are represented by the spaghetti diagram in Fig. 1.

To measure the distances traveled, a distance matrix was used. This matrix considered all the possible movements in a working day, whose results are presented in Table 1. Based on that, the average cost of moving the production tools was calculated (see Table 1), knowing that it can be done manually or using a carrier, which is already amortized. Hence, the average amount that the company spends with the operator responsible for the production tools was calculated considering: (a) hour/man cost; (b) distance traveled/second = 1 m; (c) man/meter cost. It was also important to carry out a study of the time that the operator spent on travels, presented in Table 1.

Confined factory space. When producing on the two largest production machines, the aisle space was clogged by the input material. Thus, whenever a passage of a wastebasket or a pallet of an end product was required, production would be interrupted to stow the material as well as the operator's seat to allow them to pass through.

In order to measure the average downtime per day, a time study was performed using the timing technique described by Costa and Arezes [10]. The times of each operation were obtained by the following steps: (1) operations timing (TO); (2) Assignment of an activity factor (FA), related with rhythm of work, to each observation through subjective assessment; (3) Obtaining the normalized time (TN) of each operation, through Eq. 1, where AR is the reference activity or rate, taking the value of 100.

$$TN = TO \times \frac{FA}{AR} \tag{1}$$

Table 1 Summary of distances traveled, times and costs

	Distance traveled		Time		Costs	
	1 Day (km)	1 Year (km)	1 Day (min)	1 Year (h)	1 Day (€)	1 Year (€)
State I	1433	373	24	104	7.19	1870
State II	1164	303	19	84	4.85	1260

To obtain a representative result of the real-time of the operation, there is a minimum number of necessary measurements, given by Eq. 2:

$$N' = \frac{Z.s}{\varepsilon.m} \tag{2}$$

where N' represents the number of measurements required, Z is 1.96 resulting from a 95% confidence level and ε an accuracy of ±5%. The s and m refer to the standard and average deviation, respectively.

So, for the "End Product Pallet Exit" and "Wastebasket Exit" operation, an FA of 100 and 120 respectively were considered, and 5 observations were made and sufficiently demonstrated.

Knowing the normalized time of operations, the number of operators linked to the stops and that the average number of units per day for the final product pallet is 1 and for the wastebasket is 2, the results shown in Table 2 were obtained.

Improper distribution of the production tools. Another problem related to the production tools was their distribution on the existing shelves. Initially, the distribution of production tools was made following the rule first come first served, so whenever a new tool appeared, it was assigned a sequential origin number, which represented its location. The cabinets for the placement of the production tools included 17 racks per column, ranging in width from 0.15 to 1.73 m in height.

This distribution method has been shown to be inefficient for three main reasons: location identification became a long and difficult number to remember; the locations did not consider any criteria, so, for example, the most used tools could be occupying shelves of increased manipulation difficulty and more distant and, additionally, many of the tools were believed to be obsolete; and, finally, heavy tools, with an average of 40 k, that provoked *muri* in the workers.

Given the lack of standardization, i.e., *mura* was present, as well as the distance from production tools explained before, a time study was conducted to the operation "search for a production tool". After 40 observations, the number of observations was found to be sufficient since the value of N′ resulted in less than 40. For this operation it was considered that the value of FA was constant and equal to 100, therefore the normalized time resulted from the average time of looking for a production tool with a value of 39 s.

Table 2 Time study for operations involving production downtime

Operation	Normalized time (min:s)	Production downtime/day	Production downtime/year	Production downtime cost/year
End product pallet exit	00:51	≃6 min	≃26 h	1530 €
Wastebasket exit	02:30			

4 Improvement Proposals and Results

4.1 Layout Redefinition

To reduce the distances traveled between the production tools and the workplaces and to increase free space, the productive area layout was redefined. Through the Systematic Layout Planning (SLP) approach, the study began with the identification of the space need and the definition of the available space [11]. First, in order to reduce the number of cabinets required, the first step of the 5S technique was implemented, separating the useful from the useless, as the workspace should have only the necessary. For this step, it was considered that the production tools without movements in the last three years were obsolete. Regarding the gaskets, initially, there were 452 tools, 145 of which were obsolete allowing a reduction of about 32%. For H&O tools, from an initial state of 137 units, 41 had not been used for more than three years, resulting in a reduction of 30%. The reduction in the number of tools allowed the elimination of three cabinets, which occupied an area of about 5 m^2, as well as the clearance of 1.86 m^2 of the wall space.

Then, an analysis was made to the number of rails needed in the section, in order to verify the possibility of reducing their number, increasing the free space. For this, the average production amount per day and the capacity of the rail were taken into account and it was considered that two full rails and four cut rails to create an aisle were needed. From this study, it resulted that besides being able to cut four rails for the creation of the passage aisle, one could be removed from the area.

Having obtained the space requirements, it was concluded that 50 m^2 were needed for the study area, i.e., 27% less than the initial area. The available area was defined as the space in front of the production machines that covers about 80 m^2, since this is where all resources are intended to be allocated, preventing them from being far from the workplaces.

Subsequently, a relationship diagram was built taking into account the flow of materials and the relationship between the necessary resources. For the elaboration of layout alternatives, the CORELAP method was used [11].

Afterward, to better visualize existing movements in the new layout, a spaghetti diagram was elaborated, shown in Fig. 2. Additionally, the CRAFT method was applied, in order to evaluate the new layout in terms of costs [11].

Table 3 summarizes the results of the study of distances traveled, times and costs for the final layout proposal.

Finally, by cutting the rails 3, 4, 5 and 6, represented in Fig. 2, it was possible to eliminate the problem of the production stoppages, allowing the passage of both wastebaskets and final product pallets. Therefore, the gain from this improvement was 100%, which means a saving of 26 h and 1530 € per year. In addition, a very important gain of qualitative character is employee satisfaction.

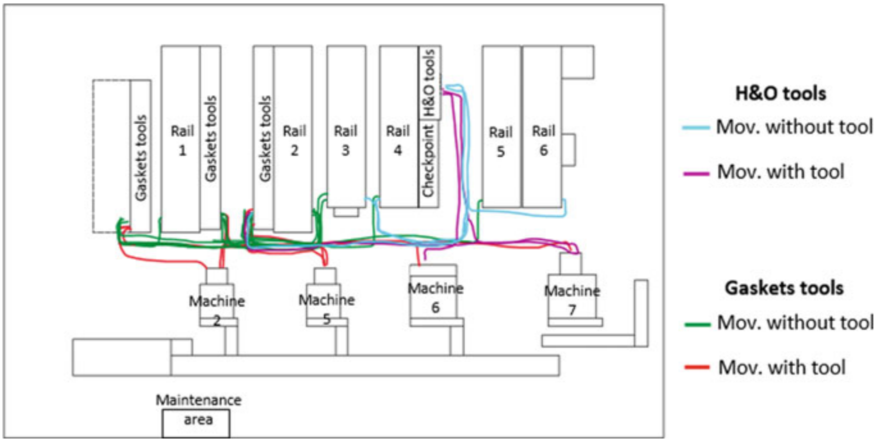

Fig. 2 Spaghetti diagram of layout proposal—Gaskets section

Table 3 Summary of distances traveled, times and costs of the final layout

	Distance traveled		Time		Costs	
	1 Day	1 Year	1 Day	1 Year	1 Day	1 Year
Final state	0.534 km	139 km	9 min	38 h	2.07 €	538 €

4.2 Organization of Production Tools

To the production tools organization, it was applied the 5S technique, whose first step was already explained in Sect. 4.1 when calculating space requirements.

In the second step "Set in order", to organize the production tools and to reduce the problem associated with their improper distribution, the use criteria, as well as the ergonomics, were considered, i.e., it was considered that the most used tools should be at an ergonomically better level. Therefore, in the first instance, through the elaboration of ABC analyzes, the class of the production tools was obtained. Then, to define the ergonomically better interval, an anthropometric study was performed. According to Barroso et al. [12], human anthropometric dimensions follow a normal distribution, which is described by the average, μ, and standard deviation, σ. To acquire anthropometric limits, percentiles are used, which indicates the percentage of people in a given population who have a body size equal to or less than a certain value. Thus, for this case and taking into account the anthropometric data of the adult Portuguese working population [12] for the characteristics, for a satisfaction of 95% of the male population, it was found that class A tools should be distributed over the shelves between 831 and 1302 mm, relative to the range between shoulders and wrists' height, i.e., the maximum and minimum height of rack. Then, in order to distribute the class B tools, an ergonomic assessment was developed, applying the NIOSH (*National Institute of Occupational Safety and*

Health) Equation [13]. From the study, it was found that when the lift of the tool starts at the lower levels, the risk of disorder presented is slightly lower, which confirms that class B tools should be allocated below 831 mm. Finally, the class C tools were distributed over the upper levels. In addition, the proximity of the tools to the respective production machines, where these are used, was also considered.

For the next step "Shine", an industrial vacuum was used and, to prevent the accumulation of dirt, shutters were applied to the shelves.

At the step "Standardize", the aim was to establish standards to support the 3S previously described. As there were problems with the location identification, the production tools were identified by cabinet number, column identification of the respective cabinet, and rack number depending on the column, for example, "4-B4".

The 5S technique ends with the "Sustain" step. The method used to ensure compliance with the 5S technique was Kamishibai, which consists of filling out a card with questions that assess the state of the area during internal audits.

After the implementation of the 5S technique, and in addition to the layout redefinition, a new time study was conducted to the operation "search for a production tool". Assuming the same assumptions as in Sect. 3, it was concluded that the time to "search for a production tool" after the implemented improvement proposals took 10 s, which means a reduction of 75%.

Additionally, it is important to mention that with the new layout and the organization of the production tools, the OEE (Overall Equipment Effectiveness) value was analyzed and it was concluded that on average a gain of 27% was obtained, as the OEE went from 69% to 88%.

5 Conclusion

This paper presented a study developed in the context of a master dissertation project that implemented Lean Thinking principles, Total Productive Maintenance and ergonomic tools to improve a sector of a cork company, by reducing *muda*, *mura,* and *muri* (3M). Examples of 3M reduced were the transports (*muda*), the overburden of people when they lift the tools (*muri*) and the improper distribution and uncertain local where to find the tools (*mura*). The benefits that resulted from implementing Lean Production, Ergonomics and TPM were recognized by the company where the project was carried out. This success emphasizes the need for the company to continue pursuing the Lean journey and, simultaneously, ergonomic improvement. *Mura* and *muri* should be the main focus and concern of companies because people will have better work conditions to perform well and if the symptoms of *muda* are eliminated, *muda* will reduce by sure.

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References

1. Knol, W.H., Slomp, J., Schouteten, R.L.J., Lauche, K.: Implementing lean practices in manufacturing SMEs: testing ‘critical success factors’ using Necessary Condition Analysis. Int. J. Prod. Res. **56**(11), 3955–3973 (2018). https://doi.org/10.1080/00207543.2017.1419583
2. Womack, J.P., Jones, D.T., Roos, D.: The Machine that Changed the World. Macmillan Publishing Company, New York (1990)
3. Womack, J., Jones, D.T.: Lean thinking: banish waste and create wealth in your corporation. In: Womack, J.P., Jones, D. (eds.). Simon & Schuster, New York (1996)
4. Liker, J.: The Toyota Way: 14 Management Principles from the World’s Greatest Manufacturer. McGraw-Hill Education (2004). ISBN-13:978-0071392310
5. Alves, A.C., Ferreira, A.C., Maia, L.C., Leão, C.P., Carneiro, P.: A symbiotic relationship between Lean Production and Ergonomics: insights from Industrial Engineering final year projects. Int. J. Ind. Eng. Manage. (IJIEM) **10**(4), 243–256 (2019)
6. Arezes, P.M., Dinis-Carvalho, J., Alves, A.C.: Workplace ergonomics in lean production environments: a literature review. Work **52**(1) (2015). https://doi.org/10.3233/WOR-141941
7. Botti, L., Mora, C., Regattieri, A.: Integrating ergonomics and lean manufacturing principles in a hybrid assembly line. Comput. Ind. Eng. **111**, 481–491 (2017). https://doi.org/10.1016/j.cie.2017.05.011
8. Suzuki, T.: TPM in Process Industries. Productivity Press, OR, Portland (1994)
9. O’Brien, R.: An Overview of the Methodological Approach of Action Research. Faculty of Information Studies, University of Toronto, Toronto (1998)
10. Costa, L.G., Arezes, P.: Introdução ao Estudo do Trabalho. Universidade do Minho, Guimarães (2003)
11. Muther R., Hales, L.: Systematic Layout Planning, 4th edn. (2009)
12. Barroso M.P., Arezes P.M., da Costa, L.G., Miguel, A.S.: Anthropometric study of Portuguese workers. Int. J. Ind. Ergon. **35**(5), 401–410 (2005)
13. Waters, T., Putz-Anderson, V., Garg, A., Fine, L.: Revised NIOSH Equation for the design and evaluation of manual lifting tasks. Ergonomics **36**(7), 749–776 (1993)

Psychosocial Issues

Differences on Work Demands, Work Organization and Health COPSOQ II Dimensions Between Workers from Different Hierarchical Levels in a Portuguese Municipality from 2015 Until 2019

Camila A. Ribeiro, Teresa P. Cotrim, Vítor Reis, Maria João Guerreiro, Susana Candeias, Ana Sofia Janicas and Margarida Costa

Abstract The constant changes in work processes has led to increased psychosocial risks; 28% of European workers are afflicted by mental disorders and job loss due to depression. The rising costs associated with workers mental health, highlight the need for strategic changes in the workplace. A prospective study was proposed seeking to understand and identify how workers are affected by these emerging risks, according to the nature of the activity and the hierarchical level to which they belong. The population of this study included 1667 workers of a Portuguese municipality and was obtained a response rate of 54% in 2015, 70% in 2017 and 79% in 2019. A self-administered questionnaire was used. The questionnaire was composed of sociodemographic questions, and the Portuguese medium version of Copenhagen Psychosocial Questionnaire II (COPSOQ II). For the present study the scales Work demands, Work organization and Health dimensions were selected. The results pointed out that Operational assistant workers are mostly aged 50 and over, had less training opportunities and perform more physical tasks, representing a vulnerable group. The White-Collar workers also presented critical values in several scales related to mental overload. To conclude the psychosocial risks, affect the professional categories in a different way

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and this must be taken into consideration especially in order to propose intervention measures.

Keywords Psychosocial risk factors · COPSOQ II · Professional category · Municipal workers

1 Introduction

The constant transformations in the productive processes had caused several changes on workers' demands. They are exposed to psychosocial risk factors, which can trigger a psychic burden and consequent somatic translation, as well as job loss due to mental disorders [3].

According to the European Agency for Safety and Health at Work, 28% of European workers are afflicted by mental disorders and job loss due to depression, which is the second most common cause of sick leave, followed by lower back pain [4]. The rising costs associated with occupational diseases, work accidents, workers turnover, absenteeism and early retirement reflect the impact of psychosocial risk factors on workers' health, highlighting the need for strategic changes in the workplace [1, 11].

Some studies had pointed out that the hierarchical level, represented by professional categories, is a strong predictor of sick leave and absenteeism, especially due to the nature of their activities [5, 9, 14].

Therefore, it was develop a study that seeks to understand and identify how workers are affected by these emerging risks of psychosocial origin, according to the nature of the activity and their professional category, to make possible the development of psychosocial risk management policies promoting workers' health and wellness.

2 Methodology

2.1 Methods

The analysis was done using a questionnaire composed by questions related to the sociodemographic variables, the nature of the work activity through a three-point nominal scale, training in the last two years through a scale of "yes" or "not" and the Work demands, Work organization and Health dimensions of the Portuguese medium version of COPSOQ II [15].

The COPSOQ is an instrument developed by the National Occupational Institute of Denmark, and tested in several studies, in order to standardize and monitor different psychosocial aspects in the workplaces [15]. The scales from the Work demands, Work organization and Health dimensions of the Portuguese medium version of COPSOQ II, regarding Quantitative demands, Rhythm, Emotional demands, Cognitive demands, Labour insecurity, Development Possibilities, Meaning of work, Commitment to the workplace, General health, Stress, Burnout, Sleeping problems and Depressive symptoms were used in this study. The scales are scored with a 5-point Likert scale and classified as critical, intermediate and favourable, based on two cut-off points.

2.2 Population and Sample

The population of this study included 1667 workers of a Portuguese municipality. In 2015 the response rate was of 54%, with a total of 888 participants. In 2017, the sample comprised 1167 participants, corresponding to a response rate of 70%, and in 2019 the sample was composed of 1313 participants, a response rate of 79%.

2.3 Procedures

The questionnaire was self-administered during the years 2015, 2017 and 2019. Workers were asked about their interest in participating in the study and those who agreed to volunteer signed the Informed Consent Form. The inclusion criterion was to be a municipality worker for at least one year, and the missing values were excluded. The confidence level assumed for the statistical analysis was 95%.

3 Results

3.1 Sociodemographic Characterization

The sample showed an average age of 46.9 years (sd = 8.3) in 2015, 48.4 years (sd = 8.7) in 2017, and 49.5 years (sd = 9.2) in 2019. The mean age had an increase in both follow-ups and the differences were statistically significant, according to an ANOVA ($P \leq 0.001$).

The sample is mainly composed of women in the three data collection moments. In the first two moments, workers in the technical assistant category had a higher percentage, but in 2019 we obtained a higher participation of workers in the operational assistant category (Table 1).

Looking at the professional category and age, workers in the Operational Assistant category are mostly aged 50 and over and, comparing with the other occupational categories, the differences were statically significant according to an ANOVA ($P \leq 0.001$) for the three data collection moments.

Table 1 Sociodemographic characterization

		2015		2017		2019	
		N	%	N	%	N	%
Gender	Woman	561	65.6	694	61.9	759	61.5
	Man	294	34.4	428	38.1	475	38.5
Professional category	Operational assistant	300	34.4	377	33.1	480	38.2
	Technical assistant	339	38.8	431	37.8	445	35.4
	White collars	234	26.8	332	29.1	331	26.4

3.2 Work Related Variables

Analysing the variable Training in the last two years, we found that in 2015 just over half of the workers received training (51.9%), which was similar in 2017. In 2019, the number of workers who received training increased (56.7%) and the difference between 2019 and the other two periods was statistically significant according to an ANOVA ($P = 0.005$) (Table 2).

Regarding the nature of the work activity, in 2015, workers who referred that the nature of their activity was both, physical and mental, had a higher percentage (48.3%). In 2017 and 2019 the mental demands presented the higher percentage (Table 2).

When analysing the variables Training in the last two years, Nature of the work activity and Professional category, we found that workers in the operational assistant category identify mainly physical demands ($P \leq 0.001$ for all years of the research) and had less training opportunities ($P \leq 0.001$ for all years of the research), when compared with the other categories by year, according to an Qui-square test.

Table 2 Work activity and training characterization

		2015		2017		2019	
		N	%	N	%	N	%
Training in the last two years	Yes	450	51.9	564	50.0	626	56.7
	No	417	48.1	564	50.0	479	43.3
Nature of the work activity	Mental	398	45.8	598	52.0	658	50.8
	Physical	51	5.9	62	5.4	87	6.7
	Both	420	48.3	491	42.7	550	42.5

3.3 COPSOQ II Dimensions

The scales belonging to the Work demands and Health dimensions of COPSOQ II, correspond to those in which the highest value is the most critical were: "Cognitive demands", "Emotional demands", "Rhythm", "General Health", "Burnout" and "Sleeping problems". These scales had the worst results. Comparing the three years, the Work demands' scales that had significant differences, according to an ANOVA, and that increased over the years were "Quantitative demands" ($P \leq 0.001$), "Rhythm" ($P \leq 0.001$) and "Emotional demands" ($P \leq 0.001$), meaning that the results got worst through the years. Those results that decreased in 2019, were "Cognitive demands" ($P \leq 0.001$), meaning that they improved (Table 3). The Health scales also showed significant differences in "General health perception" ($P \leq 0.001$), "Burnout" ($P \leq 0.001$), "Stress" ($P \leq 0.001$) and "Depressive symptoms" ($P = 0.014$), and the results improved from 2015 to 2019. Only the "Sleeping problems" ($P = 0.029$) scale had a higher average in 2019, comparing with the previous moments of the research (Table 3), meaning that the results got worst.

Concerning the scales from the Work Organization and Content dimension, the lower value corresponds to the most critical result: "Commitment to the workplace", "Development Possibilities", "Meaning of work". The scale "Commitment to the workplace" had the lowest values. Comparing the years of research, it was found that "Development Possibilities" ($P \leq 0.001$) and "Meaning of work" ($P \leq 0.001$) had statistically significant differences according to an ANOVA, and the results were worse in 2019. The scale "Commitment to the workplace" ($P = 0.022$) had a slight increase from 2015 to 2017 (Table 3). The scale "Labour insecurity" ($P \leq 0.001$), whose highest value corresponds to the most critical result, decreased from 2015 to 2017 (Table 3).

Comparing the COPSOQ II Scales between professional categories, the Operational Assistant category had a higher percentage of critical results in the scales "Labour insecurity" ($P \leq 0.001$ for all years of the research) and "General health perception" ($P \leq 0.001$ for 2015 and 2017), according to an ANOVA. They also presented better results in the scales "Meaning of work" ($P \leq 0.001$ for 2015 and 2017; $P = 0.012$ for 2019) and "Commitment to the workplace" ($P \leq 0.001$ for 2015 and 2019).

The Technical Assistant category presented a higher percentage of critical results in the scales "Stress"($P \leq 0.01$ for 2015 and 2019), "Burnout" ($P \leq 0.001$ for 2017 and 2019), "Sleeping problems" ($P = 0.023$ for 2019) and "Depressive Symptoms"($P = 0.010$ for 2019), according to an ANOVA.

Finally, the White-collar workers had a higher percentage of critical results in the scales "Quantitative demands" ($P \leq 0.001$ for all years of the research), "Rhythm" ($P \leq 0.001$ for all years of the research), "Cognitive demands" ($P \leq 0.001$ for 2017 and 2019), "Emotional demands" ($P \leq 0.001$ for 2017), "General Health perception" ($P \leq 0.001$ for 2019), "Burnout" ($P \leq 0.001$ for 2015) and "Stress" ($P = 0.012$ for 2017), according to an ANOVA. This occupational group also presented better results in the scales "Labour insecurity" ($P \leq 0.001$ for all years of the research) and "Development possibilities" ($P \leq 0.001$ for 2015 and 2017).

Table 3 COPSOQ II dimensions characterization

Year		2015		2017		2019	
N		888		1167		1313	
	COPSOQ II	Mean	S.D.	Mean	S.D.	Mean	S.D.
Work demands	Quantitative demands**	2.3	0.9	2.3	0.8	2.5	1.0
	Rhythm**	3.0	1.0	2.9	1.0	3.3	1.4
	Cognitive demands**	3.5	0.8	3.6	0.7	3.2	1.0
	Emotional demands**	3.3	1.2	3.1	1.2	3.4	1.0
Work organization and content	Development Possibilities**	3.5	0.8	3.6	0.8	3.4	0.9
	Meaning of work**	3.9	0.8	4.0	0.7	3.6	0.9
	Commitment to the workplace	3.2	0.9	3.3	0.9	3.3	0.8
	Labour insecurity**	3.3	1.4	2.8	1.5	2.8	1.2
Health	General health perception**	2.8	0.9	2.9	0.9	2.5	1.0
	Sleeping problems*	2.6	1.1	2.5	1.1	2.7	1.0
	Burnout**	2.8	1.0	2.7	1.0	2.6	1.0
	Stress**	2.7	0.9	2.6	0.9	2.4	1.0
	Depressive symptoms*	2.5	1.0	2.4	0.9	2.4	1.0

$^{*}p \leq 0.050$; $^{**}p \leq 0.001$

4 Discussion

The average age of the sample was higher in the follow up, what corresponds to the ageing process of the working population in the municipality.

The sample presented a majority of workers in the Technical assistant category in 2015 and 2017. In 2019 the number of workers in the Operational assistant category increased and these workers were mostly aged 50 and over, had less training opportunities and performed more physical tasks, in all moments of the research, representing a more vulnerable group. Studies indicate that high physical demands can reduce the ability to work over the years and lead to increased musculoskeletal complaints [13], what may lead to worse results on health perception.

The scales "Quantitative demands", "Rhythm", "Emotional demands", "Development Possibilities" and "Meaning of work" had more critical results in 2019, which can be explained by the changes made by the municipality administrative units in the last two years, regarding the reorganization of departments and changes in management. At the same time the scales "Health" and "Labour Insecurity" presented better results. The contractual stability and reduced labour insecurity seem to contribute to improving workers' health and quality of life [7].

Psychosocial risks affect professional categories in a different way and these analysis must be taken into consideration especially in order to propose intervention measures [12].

Workers in the Operational Assistant category had more critical results in the "Labour insecurity" and "General health" perception. The lower the hierarchical level, the greater the physical demands of the activity, which may affect workers' health [14]. Despite the high physical demands of the tasks, operational assistant workers presented good results in the scales "Meaning of work" and "Commitment to the workplace". Studies indicate that in order to maintain health, the "Meaning of work", "Labour insecurity" and "Social support from colleagues and supervisors" may be considered predictors of worse health if they have high critical results [2].

In this study, the Technical Assistant category presented more critical results in the "Stress", "Burnout", "Sleeping problems" and "Depressive Symptoms", with worse results in 2019, which corroborates other studies that showed that intermediate categories often have critical percentages of stress, burnout, and emotional demands [10].

In 2017 and 2019, the White-Collar workers presented critical values in a larger number of scales: "Quantitative demands", "Rhythm", "Cognitive demands", "Emotional demands", "General Health perception", "Burnout" and "Stress", when compared with the other professional categories, which may represent a mental overload and consequent somatic translation. Other studies have identified that the higher the hierarchical level, the greater the cognitive demands [14]. Also, some studies indicate that high quantitative demands can exacerbate the association of sleep problems with risk of long-term sickness absence [8]. On the other hand, high skill discretion is directly related to reduced risk of work exit generally and retirement and health-related exit specifically [5].

In general, there is a longitudinal association between changes in exposure to psychosocial work factors and health, what needs to be considered when deploying measures to improve the psychosocial work environment of older workers [6].

5 Conclusion

Whereas psychosocial risks do not affect all hierarchical levels equally, workplace interventions should be proposed to address the needs of each group, containing or reducing the risks that may compromise health and well being of workers. Especially when there is an ageing population that still largely faces physical demands at work, and with no equal opportunity for training and development at work.

In the future, some focus groups will be conducted to identify these specific group requirements in order to propose interventions that seek to promote healthier workplaces for all workers.

References

1. Ahola, K., Salminen, S., Toppinen-Tanner, S., Koskinen, A., Väänänen, A.: Occupational burnout and severe injuries: An eight-year prospective cohort study among finnish forest industry workers. J. Occup. Health **55**(6), 450–457 (2013). https://doi.org/10.1539/joh.13-0021-OA
2. Burr, H., Pohrt, A., Rugulies, R., Holtermann, A., Hasselhorn, H M.: Does age modify the association between physical work demands and deterioration of self-rated general health? Scand. J. Work Environ. Health (c), 0–10 (2017). https://doi.org/10.5271/sjweh.3625
3. Dejours, C., Abdoucheli, E., Jayet, C.: Psicodinâmica do trabalho, 1[a] Edição. Psicologia do trabalho 2. Trabalho: aspectos psicológicos (2014). ISBN: 978-85-224-1061-3
4. EU-OSHA: Work-related stress. European Agency for Safety and Health at Work, 2001–2002 (2006)
5. Fleischmann, M., Carr, E., Stansfeld, S.A., Xue, B., Head, J.: Can favourable psychosocial working conditions in midlife moderate the risk of work exit for chronically ill workers? A 20-year follow-up of the Whitehall II study. Occup. Environ. Med. (2017). https://doi.org/10.1136/oemed-2017-104452
6. Havermans, B.M., Boot, C.R.L., Hoekstra, T., Houtman, I.L.D., Brouwers, E.P.M., Anema, J. R., van der Beek, A.J.: The association between exposure to psychosocial work factors and mental health in older employees, a 3-year follow-up study. Int. Arch. Occup. Environ. Health **91**(1), 57–66 (2018). https://doi.org/10.1007/s00420-017-1261-8
7. Kompier, M., Ybema, J.F., Janssen, J., Taris, T.: Employment contracts: cross-sectional and longitudinal relations with quality of working life, health and well-being. J. Occup. Health **51** (51), 193–203 (2009). https://doi.org/10.1539/joh.L8150
8. Madsen, I.E.H., Larsen, A.D., Thorsen, S.V., Pejtersen, J.H., Rugulies, R., Sivertsen, B.: Joint association of sleep problems and psychosocial working conditions with registered long-term sickness absence. A Danish cohort study. Scand. J. Work Environ. Health **42**(4), 299–308 (2016). https://doi.org/10.5271/sjweh.3571
9. Magee, C., Stefanic, N., Caputi, P., Iverson, D.: Occupational factors and sick leave in Australian employees. J. Occup. Environ. Med. **53**(6), 627–632 (2011). https://doi.org/10.1097/JOM.0b013e31821df4cf
10. Maldonado-Macìas, A., Camacho-Alamilla, R., Torres, S.G.V., Alcaraz, J.L.G., Limín, J.: Determination of Burnout syndrome among middle and senior managers in manufacturing industry in Ciudad Juarez. Proc. Manuf. **3**(Ahfe), 6459–6466 (2015). https://doi.org/10.1016/j.promfg.2015.07.927
11. Marchand, A., Blanc, M.E.: The contribution of work and non-work factors to the onset of psychological distress: an eight-year prospective study of a representative sample of employees in Canada. J. Occup. Health **52**(3), 176–185 (2010). https://doi.org/10.1539/joh.L9140
12. Metzler, Y.A., Bellingrath, S.: Psychosocial hazard analysis in a heterogeneous workforce: determinants of work stress in blue- and white-collar workers of the european steel industry. Front. Public Health **5**(August) (2017). https://doi.org/10.3389/fpubh.2017.00210
13. Oakman, J., Neupane, S., Nygärd, C.H.: Does age matter in predicting musculoskeletal disorder risk? An analysis of workplace predictors over 4??years. Int. Arch. Occup. Environ. Health **89**(7), 1127–1136 (2016). https://doi.org/10.1007/s00420-016-1149-z
14. Rugulies, R., Aust, B., Pejtersen, J.H.: Do psychosocial work environment factors measured with scales from the Copenhagen Psychosocial Questionnaire predict register-based sickness absence of 3 weeks or more in Denmark? Scand. J. Public Health **38**(3 Suppl), 42–50 (2010). https://doi.org/10.1177/1403494809346873
15. Silva, C., Amaral, V., Pereira, A., Bem-Haja, P., Pereira, A., Rodrigues, V., Cotrim, T., Silvério, J., Nossa, P.: Copenhagen Psychosocial Questionnaire - COPSOQ - Portugal e países africanos de língua oficial portuguesa 1–46 (2012)

Impact of Psychosocial Risk Factors on Workers' Health: Contributions of a Subjective Health Indicator

Carla Barros, Pilar Baylina and Liliana Cunha

Abstract The purpose of this study was to evaluate the impact of psychosocial risks factors on professionals' drivers using a subjective health indicator—the Nottingham Health Profile (NHP). The results shows that professionals' drivers are exposed to huge amount of psychosocial risk factors related to, such as, high demands and work intensity, working hours, emotional demands and some work characteristics. NPH subscales (physical mobility, pain, energy level, sleep, social isolation and emotional reaction) showed significantly associations with psychosocial risk factors, but most particularly the work intensity and working hours with the dimension of emotional reaction. These results reinforce the fact that work activity in transportation remains severe in terms of working conditions, given an ever-increasing work intensification scenario, associated with time constraints and day-to-day experienced pressure. New research in this area will have important implications for the understanding of subjective health on mental health and well-being determining factors.

Keywords Psychosocial risk factors · Workers' health · Subjective health

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1 Introduction

In the context of work, health and well-being are affected by physical risks but also by psychosocial risks factors. In last decade, several studies demonstrated the impact of psychosocial risks on health in general [12, 22, 25]. In fact, psychosocial characteristics of work have changed in response of growing demands on working life. The changes in how work is organized and performed had a huge impact on the type and nature of risks associated with work [13]. These demands need specific attention to new relations between psychosocial risks and the effects on health and well-being.

The impact of risk factors related to the work context—such as psychosocial risk factors—are reflected in worker's health and well-being. Psychosocial risks are related to the way work is conceived, organized and managed, as well as the social work context. Psychosocial risks including high demands and intensity of work, emotional demands, lack of autonomy, poor social relations, ethical and values conflicts in the workplace may have a negative impact on workers' health [8, 15, 18]. According to EU-OSHA [11], the effects of adverse working conditions, namely psychosocial risks appear to have an impact on mental and physical health. Working beyond regulated working hours, a lack of autonomy increase mental strain as well as sleep and health problems [1].

A deeper analysis of the impact of psychosocial risk factors allow us a deeper analysis of other relations between health and work, less visible that appeals to a subjective dimension of health, centered on worker's perspective [2, 4].

In this sense, it is important to rethink psychosocial risks from the workers' perspective, considering workers' statements, perceptions, complaints and feelings. The personal and interpersonal dimension of work activity discloses less visible effects of work on health status [10, 17], revealing the importance of a more individual-centered perspective based on subjective worker experience. This approach comprehends emotional, physical, social and subjective feelings of well-being that reflect an individual's subjective evaluation [9].

This provides information beyond the traditional medical measures, and helps to understand the variability in individual responses to similar working conditions. Assessing perceived health status can provides us a set of global statements about individual perceptions in relation to impairment diseases and/or disability [16, 19, 23]. In fact, working and living conditions are experienced differently by each one and their effects depend not only on the professional career and the work context, but also on the perception that each one may have as a function of their physical, psychological and social specificities. This approach give us additional data—allowing individuals to evaluate their own health status—that corresponds to more factors known to influence health and well-being to be take into account.

The aim of this study was to explore the relationships between psychosocial risk factors and perceived health, using a subjective health indicator with three major domains of perceived distress: emotional (energy level and emotional reaction), physical (pain, physical mobility and sleep), and social (social isolation).

2 Methods

2.1 Study Design and Ethics

A cross sectional study was conducted in Portuguese professionals' drivers. The study protocol was approved by the Ethics Committee of Fernando Pessoa University and University of Porto and from the different organizations involved. Data were collected in several professional drivers' providers using a self-administered paper and pencil questionnaire, followed by the researchers' guidance. Participants received all materials consisting of the Inquérito Saúde e Trabalho—INSAT,[1] a covering letter explaining the purpose of the survey, and the guidelines to complete the questionnaire. Participation was voluntary, all of the participants gave their informed consent to participate, and their confidentiality and anonymity were ensured. The instruments were handed out together with a response envelope to return the questionnaire to the researchers.

2.2 Participants

A total of 175 professional drivers from the north and centre of Portugal (95.5%) with the following types: 19.4.% bus drivers; 44.8% taxicab driver; 22.4% truck driver; 9.1% ambulance drivers, and 3.6% drivers for waste management. The majority of the participants were men, 95.4%; ranging age from 21 to 71 (M = 48.5; SD = 17.48). The levels of education reported were basic education (6.1%), lower secondary school (47.5%); upper secondary school (34.1%); undergraduate (5.5%) (Table 1). Participants also represented a considerable range in their years of experience, from those who only have one year of practice to others who had been working for more than 43 years (M = 8.64; SD = 8.57). 88.0% of the participants were employed under permanent contract, with irregular shifts and work schedules (52.8%) and weekend work schedule (70.5%).

2.3 Instruments

This study was supported by the INSAT, a self-reported questionnaire organized in different axes, that measure working conditions, health and well-being, and the relationship between them [3, 5, 6, 21].

Concerning the main goal of the present study, only the psychosocial risk factors and NHP scale were used. The psychosocial risk factors were: high demands and work intensity; lack of autonomy; work relations with coworkers and managers;

[1]Portuguese acronym of Health and Work Survey.

Table 1 Socio-demographic characteristics

Socio-demographic characteristics		Total sample (%)
Gender	Men	95.4
	Women	4.6
Age	20–29 years old	8.8
	30–39 years old	23.8
	40–49 years old	33.8
	50–59 years old	24.6
	>60 years old	8.4
Transport types	Truck driver	11.0
	Taxicab driver	22.0
	Bus drivers	60.7
	Drivers for waste management	1.8
	Ambulance drivers	4.5

employment relations with the organization; emotional demands; ethical conflicts; and work characteristics. These categories are organized in different items. All items were measured on a 6-point Likert scale ranging from 0 (not being exposed) to 6 (being exposed with high discomfort). In terms of psychometric properties, INSAT has a good internal consistency, in a Rasch PCM analysis, with a reliability coefficient >0.8 [7].

The Nottingham Health Profile (NHP) is a general instrument that provides a set of perceptions of health status; it provides multiple outcomes that can be used to measure the effects of exposure conditions. The Portuguese version of Nottingham Health Profile (NHP) [14] is integrated on the INSAT and is used to measure subjective physical, emotional, and social aspects of health. It includes 38 questions in 6 health dimensions: physical mobility (8 items), pain (8 items), social isolation (5 items), emotional reactions (9 items), energy (3 items), and sleep (6 items). These items are measure using a dichotomous scale 'yes' or 'no'for each item of the different health dimensions.

2.4 Statistical Analysis

The SPSS for Windows, version 25.0, was applied to perform the statistical analysis. The significance level adopted was $p \leq 0.05$. Frequency and percentage analysis were performed on the psychosocial risk factors (variables of the INSAT questionnaire—psychosocial factors, codified in 0 (no) and 1 (yes) and for NHP health dimensions, codified in 0 (no) and 1 (yes). An inferential analysis, using Qui Square tests (χ^2) of independence was performed to verify if risk factors and the six dimensions of NHP were independent.

3 Results and Discussion

3.1 Descriptive Analysis

The characterization of psychosocial work factors ("yes" answers) that have a significant impact on professionals' drivers is presented in Table 2.

Data shows that professionals' drivers are exposed to huge amount of psychosocial risk factors related to, such as, high demands and work intensity, working hours, emotional demands and some work characteristics.

NHP responses were converted to the associated score values allowing the calculation of the frequency by dimension ("yes" answers), presented in Table 3.

According to the exposed, emotional reaction is the dimension with more health complaints such as emotional stress, depression or anxiety that reveals a state of emotional vulnerability and perceived weak mental health.

Table 2 Characterization of psychosocial work factors

Psychosocial risk factors	Sample (n = 175)
High demands and work intensity	% Yes
Intense work pace	56.7
Dependent on colleagues to do my work	31.1
Dependent on direct clients' requests	54.2
Have to follow production norms or meet strict deadlines	42.8
Have to adapt permanently to changes in methods or instruments	42.9
Have to deal with contradictory instructions	39.0
Exposed to highly demanding situations	38.8
Working hours	
Have to continue working beyond my assigned timetable	64.8
Have to "skip" or shorten a meal or not have a break	69.1
Have to maintain permanent availability at any time of the day	55.2
Lack of autonomy	
Have no freedom to decide how to do work	40.3
Not be able to participate in decisions concerning my work	34.4
Work relations with coworkers and managers	
Need help from colleagues and not have	34.4
Not having my opinion taken into consideration for the functioning of the department	23.3
Impossible to express myself	31.3
Not having recognition by managers	32.9
Employment relations with the organization	
Career progress is almost impossible	50.9

(continued)

Table 2 (continued)

Psychosocial risk factors	Sample (n = 175)
Remuneration does not allow me to have a satisfactory standard of living	54.6
Lack the means to carry out my work	21.3
In general, I feel exploited	29.2
Emotional demands	
Have to endure the demands of the public	82.8
Have to deal with situations of tension in the relations with the public	66.3
Exposed to the risk of verbal aggression from the public	75.5
Being exposed to the suffering of the others	59.9
Ethical and values conflicts	
Have to do things I disapprove	24.4
My professional conscience is shaken	13.0
Lack the means to do a job well done	21.3
Work characteristics	
Lonely work	40.4
Varied work	70.6
Unpredictable work	71.7
Complex work	33.5

Table 3 Characterization of NHP health dimensions

NHP health dimensions	% Yes (n = 175)
Pain	22.3
Energy level	12.0
Sleep	18.3
Emotional reaction	41.1
Social isolation	13.7
Physical mobility	17.1

3.2 Independence Analysis Between Health Dimensions and Psychosocial Risk Factors

In order to accomplish the second objective, an inferential analysis using Qui Square tests of independence (χ^2) was performed to analyze the relation between risk factors and the six dimensions of NHP. In Tables 4 and 5 are presented all significant interactions found ($p < 0.05$).

As shown in these tables there are statistical associations between several risk factors and NHP dimensions. Emotional reaction is the NHP dimension with more risk factors associated (15), followed NHP Energy (13) and Sleep (13), Social Isolation (9), Physical Mobility (8) and finally Pain (4). Looking to psychosocial

Table 4 Qui square tests between risk factors and NHP dimensions (pain, energy and sleep)

Risk factors	Pain	NHP dimensions	
		Energy	Sleep
Intense work pace		$\chi^{2(1)} = 11.109$ $p < 0.001$	
Dependent on colleagues to do my work			$\chi^{2(1)} = 4.572$ $p < 0.05$
Dependent on direct clients' requests		$\chi^{2(1)} = 6.936$ $p < 0.05$	$\chi^{2(1)} = 21.164$ $p < 0.001$
Have to follow production norms or meet strict deadlines	$\chi^{2(1)} = 4.605$ $p < 0.05$		$\chi^{2(1)} = 4.465$ $p < 0.05$
Have to deal with contradictory instructions		$\chi^{2(1)} = 13.981$ $p < 0.001$	$\chi^{2(1)} = 32.309$ $p < 0.001$
Have to continue working beyond my assigned timetable		$\chi^{2(1)} = 9.749$ $p < 0.05$	$\chi^{2(1)} = 22.104,$ $p < 0.001$
Have to "skip" or shorten a meal or not have a break		$\chi^{2(1)} = 7.153$ $p < 0.05$	$\chi^{2(1)} = 10.707$ $p < 0.01$
Exposed to the risk of verbal aggression from the public	$\chi^{2(1)} = 4.125$ $p < 0.05$		$\chi^{2(1)} = 4.041$ $p < 0.05$
Have to deal with situations of tension in the relations with the public	$\chi^{2(1)} = 4.069$ $p < 0.05$		
Lonely work	$\chi^{2(1)} = 14.781$ $p < 0.001$	$\chi^{2(1)} = 6.936$ $p < 0.05$	
Unpredictable work	$\chi^{2(1)} = 13.676$ $p < 0.001$	$\chi^{2(1)} = 6.607$ $p < 0.05$	$\chi^{2(1)} = 15.200$ $p < 0.001$
Have to do things I disapprove		$\chi^{2(1)} = 7.126$ $p < 0.01$	$\chi^{2(1)} = 33.860$ $p < 0.001$
Career progress is almost impossible		$\chi^{2(1)} = 4.057$ $p < 0.05$	
Remuneration does not allow me to have a satisfactory standard of living		$\chi^{2(1)} = 6.753$ $p < 0.05$	$\chi^{2(1)} = 8.041$ $p < 0.05$
Lack the means to do a job well done		$\chi^{2(1)} = 11.290$ $p < 0.05$	$\chi^{2(1)} = 13.137$ $p < 0.001$
My professional conscience is shaken		$\chi^{2(1)} = 13.507$ $p < 0.001$	$\chi^{2(1)} = 5.605$ $p < 0.05$
In general, I feel exploited		$\chi^{2(1)} = 12.502$ $p < 0.001$	$\chi^{2(1)} = 12.216$ $p < 0.001$

Table 5 Qui square tests between risk factors and NHP dimensions (emotional reaction, social isolation, and physical mobility)

Risk factors	NHP dimensions		
	Emotional reaction	Social isolation	Physical mobility
Intense work pace	$\chi^{2(1)} = 6.502$ $p < 0.05$	$\chi^{2(1)} = 5.728$ $p < 0.05$	
Dependent on colleagues to do my work	$\chi^{2(1)} = 5.428$ $p < 0.05$		$\chi^{2(1)} = 7.076$ $p < 0.05$
Dependent on direct clients' requests	$\chi^{2(1)} = 35.343$ $p < 0.001$	$\chi^{2(1)} = 7.049$ $p < 0.05$	$\chi^{2(1)} = 8.926$ $p < 0.05$
Have to follow production norms or meet strict deadlines	$\chi^{2(1)} = 8.490$ $p < 0.05$	$\chi^{2(1)} = 9.026$ $p < 0.05$	$\chi^{2(1)} = 5.346$ $p < 0.05$
Have to deal with contradictory instructions	$\chi^{2(1)} = 9.013$ $p < 0.05$	$\chi^{2(1)} = 5.365$ $p < 0.05$	
Have to continue working beyond my assigned timetable	$\chi^{2(1)} = 10.754$ $p < 0.05$	$\chi^{2(1)} = 11.125$ $p < 0.05$	$\chi^{2(1)} = 5.496$ $p < 0.05$
Have to "skip" or shorten a meal or not have a break	$\chi^{2(1)} = 18.731$ $p < 0.001$		
Exposed to the risk of verbal aggression from the public			$\chi^{2(1)} = 5.317$ $p < 0.05$
Have to deal with situations of tension in the relations with the public	$\chi^{2(1)} = 11.793$ $p < 0.05$		$\chi^{2(1)} = 12.056$ $p < 0.05$
Lonely work	$\chi^{2(1)} = 4.201$ $p < 0.05$		$\chi^{2(1)} = 8.074$ $p < 0.05$
Unpredictable work			
Have to do things I disapprove	$\chi^{2(1)} = 16.077$ $p < 0.001$		
Career progress is almost impossible	$\chi^{2(1)} = 11.747$ $p < 0.05$		$\chi^{2(1)} = 7.390$ $p < 0.05$
Remuneration does not allow me to have a satisfactory standard of living	$\chi^{2(1)} = 15.065$ $p < 0.001$	$\chi^{2(1)} = 14.553$ $p < 0.001$	
Lack the means to do a job well done	$\chi^{2(1)} = 10.019$ $p < 0.05$	$\chi^{2(1)} = 5.132$ $p < 0.05$	
My professional conscience is shaken	$\chi^{2(1)} = 5.112$ $p < 0.05$	$\chi^{2(1)} = 28.877$ $p < 0.001$	
In general, I feel exploited	$\chi^{2(1)} = 21.4752$ $p < 0.001$	$\chi^{2(1)} = 13.026$ $p < 0.001$	

risk factors, “Have to continue working beyond my assigned timetable”, “Have to follow production norms or meet strict deadlines”, to be “Dependent on direct clients’ requests” are risk factors which have a high impact in five of the six NHP dimensions.

In fact, the effects of adverse working conditions, namely psychosocial risks appear to have an impact on mental and physical health. Working beyond regulated working hours, work intensity and emotional demands increase mental strain as well as lack of energy and sleeping problems that induce an important set of health problems [1].

4 Conclusions

This study focused on the effect of psychosocial risk factors on perceived health among professionals’ drivers. Other studies have focused on the contribution of studding subjective health to get a different perspective of health problems.

A particularly interesting result of this study is that the sample was predominantly male, and there was a greater manifestation of complaints associated with emotional reactions. If, not very often, more complaints of this type are attributed to women [24], it is clearly visible here that this dimension is related to work and not to a gender issue [20].

New research in this area will have important implications for the understanding of subjective health on mental health and well-being determining factors. Such knowledge will serve to strengthen information of health dimensions, which will contribute to a better awareness and intervention on working contexts.

References

1. Arlinghaus, A., Nachreiner, F.: Health effects of supplemental work from home in the European Union. Chronobiol. Int. **31**(10), 1100–1107 (2014)
2. Barros, C.: Fatores psicossociais de risco no trabalho de hoje. In: Roxo M.M. (Coord.). Trabalho sem fronteiras? O papel da regulação, pp. 141–159. Coimbra, Almedina (2017)
3. Barros-Duarte, C., Cunha, L., Lacomblez, M.: INSAT: uma proposta metodológica para análise dos efeitos das condições de trabalho sobre a saúde. Laboreal **3**(2), 54–62 (2007)
4. Barros, C., Cunha, L.: Avaliação dos fatores psicossociais de risco: contributos do Inquérito INSAT. In: Neto, H.V., Areosa, J., Arezes, P. (Org). Manual sobre Riscos Psicossociais no Trabalho, pp. 333–346. Civeri Publishing, Vila do Conde (2014)
5. Barros-Duarte, C., Cunha, L.: INSAT2010—Inquérito Saúde e Trabalho: outras questões, novas relações. Laboreal **6**(2), 19–26 (2010)
6. Barros, C., Carnide, F., Cunha, L., Santos M., Silva C.: Will I be able to do my work at 60? An analysis of working conditions that hinder active ageing. WORK J. Prev. Assess. Rehabil. **51**, 579–590 (2015)

7. Barros, C., Cunha, L., Oliveira, A., Baylina, P., Rocha, A.: Development and validation of a health and work survey based on the Rasch model among Portuguese Workers. J. Med. Syst. **41**(79), 1–9 (2017)
8. Brisson, C., Gilbert-Ouimet, M., Duchaine, C., Trudel, X., Vézina, M.: Workplace interventions aiming to improve psychosocial work factors and related health. In: Siegrist, J., Wahrendorf, M. (eds.) Work Stress and Health in a Globalized Economy: The Model of Effort-Reward Imbalance, pp. 333–363. Springer, Cham (2016)
9. Canguilhem, G.: Une pédagogie de la guérison est-elle possible? Écrits sur la médicine. Éditions du Seuil, Paris (2002)
10. Clot, Y., Leplat, J.: La méthode clinique en ergonomie et en psychologie du travail. Le Travail Humain **4**(68), 289–316 (2005)
11. EU-OSHA: Second European Survey of Enterprises on New and Emerging Risks (ESENER-2). Overview Report: Managing Safety and Health at Work. Publications Office of the European Union, Luxembourg (2016)
12. Eurofound and EU-OHSA: Psychosocial Risks in Europe: Prevalence and Strategies for Prevention. Publications Office of the European Union, Luxembourg (2014)
13. Eurofound: Working Conditions and Workers' Health. Publications Office of the European Union, Luxembourg (2019)
14. Ferreira, P.L., Melo, E.: Percepção de saúde e qualidade de vida: validação intercultural do perfil e saúde de Nottingham. Nursing **135**, 23–29 (1999)
15. Gollac, M., Bodier, M.: Mesurer les facteurs psychosociaux de risque au travail pour les maîtriser. Rapport du Collège d'expertise sur le suivi des risques psychosociaux au travail. Ministre du travail, de l'emploi et de la santé (2011)
16. Hunt, S.M., McEwen, J.: The development of a subjective health indicator. Sociol. Health Illn. **2**(3), 231–246 (1980)
17. Ilies, R., Aw, S., Pluut, H.: Intraindividual models of employee well-being: what have we learned and where do we go from here? Eur. J. Work Organ. Psychol. **24**(6), 827–838 (2015)
18. Letellier, M.-C., Duchaine, C.S., Aubé, K., Talbot, D., Mantha-Bélisle, M.-M., Sultan-Taïeb, H., et al.: Evaluation of the Quebec healthy enterprise standard: effect on adverse psychosocial work factors and psychological distress. Int. J. Environ. Res. Public Health **15**(3), 426 (2018)
19. Nawito, Z., El-Azkalany, G., El-Sayad, M.: Nottingham health profile assessment of health-related quality of life in primary knee osteoarthritis patients: relation to clinical features and radiologic score. Egypt. Rheumatol. **40**(4), 265–268 (2018)
20. Silva, C., Carnide, F., Barros, C., Cunha, L., Santos, M.: Reações emocionais reportadas ao trabalho: uma questão de mulheres? In: Proceedings Book of the International Symposium on Occupational Safety and Hygiene, pp. 362–370. Portuguese Society of Occupational Safety and Hygiene, SPOSHO (2015)
21. Silva, C., Barros, C., Cunha, L., Carnide, F., Santos, M.: Prevalence of back pain problems in relation to occupational group. Int. J. Ind. Ergon. **52**, 52–58 (2016)
22. Stansfeld, S.A., Candy, B.: Psychosocial work environment and mental health—a meta-analytic review. Scand. J. Work Environ. Health **32**, 443–462 (2006)
23. Yüksel, S., Elhan, A., Gökmen, D., Küçükdeveci, A., Kutlay, S.: Analyzing differential item functioning of the Nottingham Health Profile by Mixed Rasch Model. Turk. J. Phys. Med. Rehabil. **64**(4), 300–307 (2018)
24. Wieclaw, J., Agerbo, E., Bo Mortensen, P.: Psychosocial working conditions and the risk of depression and anxiety disorders in the Danish workforce. BMC Public Health **8**, 280 (2008)
25. WHO Health Impact of Psychosocial Hazards at Work: An Overview. World Health Organization, Geneva (2010)

Physical and Psychosocial Safety Climate Scales: Psychometric Evidence and Invariance Measurement in a Portuguese Sample

Cátia Sousa, Gabriela Gonçalves and António Sousa

Abstract Accident prevention is one of the key rules for workplace safety, and the safety climate has been linked to the possibility of influencing not only the safety behavior of workers but also the occurrence of accidents. Thus, this study aims to present the psychometric evidence of the physical and psychosocial safety climate scales in a Portuguese sample. From a sample of 844 participants, 505 men and 339 women, aged between 17 and 68 years (M = 37.09, SD = 10.57), the results show that the one-factor solution yielded the best fit to the data with acceptable reliability in both scales. The invariance measure between professions was only observed in the psychosocial safety climate scale, thus alerting to the susceptibility to different professional populations of the physical safety climate scale. Understanding the safety climate is critical to reducing occupational disease, injuries and accidents, and further study should deepen the psychometric qualities of both scales.

Keywords Physical safety climate · Psychosocial safety climate · Psychometric properties · Invariance measurement · Portuguese sample

1 Introduction

The safety climate concept was originally developed by Zohar [27], who defined it as a set of properties (e.g., management decisions, organizational norms and communication) of the workplace environment, perceived by employees and having a significant impact on the individual behavior and organizational performance [8, 11, 27]. That is, it is the sum of an organization's collaborators' shared per-

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ceptions of workplace safety policies, procedures, and practices [13, 27]. Although the constructs used to assess the safety climate are varied, the domains measured usually include manager commitment, supervisor support, safety awareness, safety training, communication and knowledge, and co-worker support [21, 22].

According to [3] the safety climate has two dimensions: physical and psychosocial. The physical safety climate concerns the perception of policies, procedures and practices regarding the importance and value that organizations place on physical safety within their facilities [3]. The psychosocial safety climate highlights the value and importance of psychosocial health within the organization [9] and is related to psychological and social freedom, such as the risk of aggression, violence, bullying or high pressure at work. It refers to activities that are carried out by employees to maintain their own psychological safety in the workplace or to help to develop an environment that supports psychosocial safety. This may include, for example, starting an incident report, organizing or planning work to reduce work stress [3].

In recent years studies on safety climate have multiplied revealing relationships with occupational accidents (e.g., Ajslev et al. [1], Kim et al. [16], Kvalheim et al. [17]), safety performance (e.g., Chen et al. [6], Huang et al., [14]), stress, burnout and well-being (e.g., Chen et al. [6], Melo et al. [18], Silla and Gamero [23]), safety behaviors (e.g., Bronkhorst et al. [4], Smith et al. [25]), among others. The safety climate is thus an important construct, namely in professions exposed to different risk agents [7] or of high physical and emotional wear (e.g., Jimmieson et al. [15], Olds et al. [20]). Its importance derives mainly from its ability to influence the safety behavior of workers at the individual, group and organizational levels [24].

Given the growing importance of the perception of safety climate in the various professional activities, this study aims to present the metric evidence of physical and psychosocial safety climate scales in a Portuguese sample.

2 Methodology

2.1 Sample

The sample consisted of 844 participants, 505 men and 339 women, aged between 17 and 68 years (M = 37.09, SD = 10.57). Most of the respondents (53.8%) are married or living in common law marriage and have higher education (53.4%). In terms of professional activity, about 37.9% (n = 320) are nurses, 23.8% are workers in water supply and wastewater treatment systems, 12.4% are emergency first responders and the others have non-risk professions.

2.2 Instruments

The following instruments were applied.

Physical Safety Climate Scale—originally developed by Bronkhorst [3] and based on the work of Hall et al. [12]. It is a scale composed of 12 items and 4 dimensions: (1) Priority given to the physical safety climate (e.g., item 1 "Employee physical well-being is a priority for this institution"); (2) commitment to the physical safety climate (e.g., item 4 "In my workplace, my supervisor acts quickly when it comes to correcting problems/situations that affect the physical health of employees"); (3) communication about the physical safety climate (e.g., item 7 "There is good communication about the physical safety issues that affect me") and (4) participation in promoting the physical safety climate (e.g., item 12 "Prevention physical injury involves all levels of the institution"). Answers are given on a 5-point Likert scale (1—strongly disagree to 5—strongly agree).

Psychosocial Safety Climate Scale—originally developed by Bronkhorst [3] and based on the work of Hall et al. [12]. It is a multidimensional scale, consisting of 12 items that evaluate 4 dimensions through a 5-point Likert scale (1—strongly disagree to 5—strongly agree): (1) Priority given to the psychological safety climate (e.g., item 1 "The psychological well-being of employees is a priority for this institution"); (2) commitment to the psychological safety climate (e.g., item 5 "My supervisor considers the psychological health of employees to be of great importance"); (3) communication on the psychological safety climate (e.g., item 8 "I am always reminded of information on psychological well-being in my workplace"); and (4) participation in the promotion of a psychological safety climate (e.g., item 11 "Employees are encouraged to be involved in health and psychological safety issues").

2.3 Procedures

Prior to data collection, an authorization from the Scientific Committee was requested. After its approval and assurance of ethical criteria, participants were asked to answer a self-report paper-and- pencil questionnaire with an average completion time of 15 min. The questionnaire was completed in a single session and all participants contributed on a voluntary basis. Data collection was performed in several places, collectively and individually, namely in university classes, public and private companies, public libraries, and other public places. No compensation was offered to participants.

2.4 Item Translation

A translation/back translation process was carried out in accordance to Muñiz et al.'s [19] procedure. Finally, an expert panel of faculty members from a large national University validated the questionnaire in terms of its content, format, sequence, and layout. No interpretation problems were detected in the pretest with a sample of 20 participants who were not included in the final sample.

2.5 Data Analysis

Data analysis was performed using the SPSS 25 statistical package and AMOS 20 software. The pattern of missing data was examined for the individual items of all scales. For the Safety Climate Scales psychometric properties evaluation, we conducted exploratory factor analysis (EFA), confirmatory factor analysis (CFA) and calculated Cronbach's reliability coefficient to gauge internal consistency. To analyze the measurement invariance across gender we used a multi-group confirmatory factor analysis adopting the maximum likelihood estimator (ML). As suggested by Chen [5] the following criteria were used to determine acceptable model fit: ΔCFI ≤ -0.01, ΔRMSEA ≤ 0.015, for tests of metric and scalar invariance.

3 Results

3.1 Descriptive Statistics

Table 1 shows the descriptive characteristics of the items of the Physical and Psychosocial Safety Climate scales. On both scales the means range between 3.72 and 2.89. Histograms and measures of skewness and kurtosis (skewness from −0.31 to 1.02 and kurtosis from −1.06 to −0.25) showed that the distributions of the two scales items were normal, with all below 2 and 7, respectively [2, 10], and none of the variables were multicollinear or singular (inter-item correlations <0.80; [26]).

3.2 Exploratory Factorial Analysis

In order to understand the structure of the physical and psychosocial safety climate scales, exploratory factor analysis was used. Regarding the physical safety climate scale, the KMO index presented a value of 0.95, and there was a correlation between the items under study (Bartlett's sphericity test = 8628.35; df = 66; $p = 0.000$). The analysis of the main components, considering the criterion of

Table 1 Physical and psychosocial safety climate scales items

Physical safety climate						Psychosocial safety climate				
Item	M	SD	Cronbach's alpha (α) if item deleted	Sk SE = 0.08	Ku SE = 0.17	M	SD	Cronbac's alpha (α) if item deleted	Sk SE = 0.08	Ku SE = 0.1
1	3.57	1.21	0.95	−0.480	−0.686	3.11	1.25	0.97	−0.054	−0.998
2	3.41	1.20	0.94	−0.348	−0.752	3.14	1.23	0.97	−0.128	−0.936
3	3.41	1.11	0.94	−0.381	−0.592	2.94	1.24	0.97	0.007	−0.960
4	3.66	1.14	0.94	−0.678	−0.253	3.32	1.21	0.97	−0.312	−0.820
5	3.72	1.16	0.94	−0.694	−0.317	3.36	1.21	0.97	−0.301	−0.901
6	3.72	1.16	0.94	−0.636	−0.381	3.29	1.21	0.97	−0.207	−0.843
7	3.68	1.15	0.94	−0.447	−0.437	3.06	1.19	0.97	−0.004	−0.753
8	3.51	1.09	0.94	−0.287	−0.709	2.96	1.22	0.97	0.004	−0.966
9	3.34	1.15	0.94	−0.315	−0.535	3.06	1.18	0.97	−0.082	−0.812
10	3.32	1.12	0.94	−0.238	−0.470	2.93	1.15	0.97	0.021	−0.784
11	3.16	1.09	0.95	−0.252	−0.395	2.89	1.21	0.97	0.102	−0.888
12	3.25	1.00	0.95	−0.345	−0.705	3.03	1.29	0.97	−0.026	−1.06

eigenvalues greater than 1 for the determination of the factors to be retained, and varimax rotation, allowed to observe 1 factor that explains 64.6% of the variance of the obtained results. The psychosocial safety climate scale had a KMO index of 0.96 (Bartlett's sphericity test = 12,121.62; df = 66; p = 0.000). The analysis of the main components allowed to observe 1 factor (75.99% of the variance). This one-factor structure of both scales does not correspond to the original four-factor structure.

3.3 Confirmatory Factorial Analysis

Given the results of the exploratory factor analysis, several models (see Table 2) were tested in the confirmatory factor analysis using the maximum likelihood estimator for both scales. The first model contemplates the originally proposed model, with 4 dimensions. The second model concerns the one-factor structure obtained in EFA. A third model with a 2nd order factor was also tested. The unifactorial solution is the one with the best results on both scales, although RMSEA values are poor on both scales.

3.4 Internal Reliability

The physical safety climate scale presents a Cronbach alpha of 0.94 and the psychosocial safety climate scale an internal consistency value of 0.97.

3.5 Invariance Measurement

The invariance measurement analysis of physical and psychosocial safety climate scales between professional activities was conducted using multigroup CFA with

Table 2 Goodness of fit indicators for the Portuguese version of the physical and psychosocial safety climate scales

Physical safety climate	χ^2	DF	CMIN/DF	CFI	NFI	TLI	RMSEA
Original	2028.4	52	39	0.773	0.769	0.659	0.212
Unifactorial	1341.5	54	24.84	0.852	0.847	0.786	0.168
Second-order factor	2045.05	54	37.87	0.771	0.767	0.669	0.209
Original	1595.8	52	30.69	0.873	0.870	0.810	0.188
Unifactorial	1639.4	54	30.36	0.870	0.866	0.812	0.187
Second-order factor	1649.3	54	30.54	0.869	0.865	0.810	0.187

Table 3 Measurement invariance tests across professional activity

Model	χ^2	df	$\Delta\chi^2$	Δdf	CFI	RMSEA (90% CI)	AIC	ΔCFI	ΔRMSEA
Physical climate safety									
Configural	1581.18	216			0.849	0.088 (0.084–0.092)	1869.18		
Metric	1878.43	249	297.25	33	0.820	0.089 (0.085–0.093)	2100.43	−0.029	0.001
Scalar	2111.42	285	232.99	36	0.798	0.088 (0.085–0.092)	2261.42	−0.022	−0.001
Psychosocial safety climate									
Configural	2075.95	216			0.850	0.102 (0.098–0.106)	2363.95		
Metric	2159.50	249	83.55	33	0.846	0.097 (0.093–0.100)	2381.50	−0.004	−0.005
Scalar	2298.93	285	139.43	36	0.838	0.093 (0.089–0.096)	2448.93	−0.008	−0.004

the unifactorial solution as the baseline model. Four professional groups were compared (nurses, workers in water supply and wastewater treatment systems, emergency first responders and non-risk professionals). As shown in Table 3, the configural invariance model of the physical safety climate scale between professions seemed to provide an acceptable fit to the data. Then, the comparison of the configural model with the metric model showed that ΔCFI it is not within the recommended limits (e.g., Chen [5]) and there is no adequate statistical support for metric invariance among professional groups. After establishing the metric invariance, the scalar invariance model was fitted to the data. The change in the value of the CFI provided no empirical support for scalar invariance among professional groups. Regarding the psychosocial safety climate scale, the configural invariance model presented an acceptable fit to the data, although the RMSEA is slightly above what is considered acceptable. The comparison of the configural model with the metric model and the metric model with the scalar model showed that ΔCFI and ΔRMSEA were all within the recommended limits (e.g., Chen [5]), showing adequate statistical support for metric and scalar invariance among professional groups.

4 Discussion and Conclusion

This study aimed to present the metric evidences of the physical safety and psychosocial safety climate scales in a Portuguese sample. The results showed that the unifactorial model is the best solution for both scales. It was not possible to observe the original 4-factor model. The one-factor solution showed good internal consistency values in both instruments. Regarding the physical safety climate scale, it was not possible to observe the invariance measure for the professional groups, making it less generalizable and alerting to the susceptibility to different professional groups. This means that the perception of the physical safety climate is influenced by the type of occupational activity, that is, it is possible that workers exposed to higher risks have a stronger perception of the physical safety climate than workers exposed to less occupational risks. In contrast, the psychosocial safety climate scale provided adequate statistical support for metric and scalar invariance.

Note that while some results are promising (e.g., internal consistency), some adjustment indices obtained are poor. These values may express the heterogeneity of literacy that may imply different degrees of understanding of the items, thus raising some questions about the psychometric qualities of the scales that deserve further investigation.

References

1. Ajslev, J., Dastjerdi, E., Dyreborg, J., Kines, P., Jeschke, K., Sundstrup, E., Jakobsen, M., Fallentin, N., Andersen, L.: Safety climate and accidents at work: cross-sectional study among 15,000 workers of the general working population. Saf. Sci. **91**, 320–325 (2017)
2. Bentler, P., Wu, E.: EQS for Windows User's Guide. Multivariate Software Inc, Encino (2002)
3. Bronkhorst, B.: Behaving safely under pressure: the effects of job demands, resources, and safety climate on employee physical and psychosocial safety behavior. J. Saf. Res. **55**, 63–72 (2015)
4. Bronkhorst, B., Tummers, L., Steijn, B.: Improving safety climate and behavior through a multifaceted intervention: results from a field experiment. Saf. Sci. **103**, 293–304 (2018)
5. Chen, F.: Sensitivity of goodness of fit indices to lack of measurement invariance. Struct. Equ. Model. **14**, 464–504 (2007)
6. Chen, Y., McCabe, B., Hyatt, D.: Impact of individual resilience and safety climate on safety performance and psychological stress of construction workers: a case study of the Ontario construction industry. J. Saf. Res. **61**, 167–176 (2017)
7. De Andrade, A., Moraes, T., Tosoli, A., Wachelke, J.: Burnout, clima de segurança e condições de trabalho em profissionais hospitalares. Revista Psicologia: Organizações e Trabalho **15**(3), 233–245 (2015)
8. DeJoy, D.: Behavior change versus culture change: divergent approaches to managing workplace safety. Saf. Sci. **43**(2), 105–129 (2005). https://doi.org/10.1016/j.ssci.2005.02.001
9. Dollard, M., Bakker, A.: Psychosocial safety climate as a precursor to conducive work environments, psychological health problems, and employee engagement. J. Occup. Organ. Psychol. **83**(3), 579–599 (2010)
10. Finney, S., DiStefano, C.: Non-normal and categorical data in structural equation modeling. In: Hancock, G., Mueller, R. (eds.) Structural Equation Modeling: A Second Course, pp. 269–314. Information Age Publishing, Greenwich (2006)
11. Fishbein, M., Ajzen, I.: Predicting and Changing Behavior: The Reasoned Action Approach. Taylor & Francis Group, New York (2010)
12. Hall, G., Dollard, M., Coward, J.: Psychosocial safety climate: development of the PSC-12. Int. J. Stress Manage. **17**(4), 353–383 (2010)
13. Huang, Y.H., Ho, M., Smith, G.S., Chen, P.Y.: Safety climate and self-reported injury: assessing the mediating role of employee safety control. Accid. Anal. Prev. **38**(3), 425–433 (2006)
14. Huang, Y-h., Sinclair, R., Lee, J., McFadden, A., Cheung, J., Murphy, L.: Does talking the talk matter? Effects of supervisor safety communication and safety climate on long haul truckers´safety performance. Accid. Anal. Prev. **117**, 357–367 (2018)
15. Jimmieson, N., Tucker, M., With, K., Liao, J., Campbell, M., Brain, D., Page, K., Barnett, A., Graves, N.: The role of time pressure and different psychological safety climate referents in prediction of nurses' and hygiene compliance. Saf. Sci. **82**, 29–43 (2016)

16. Kim, K., Park, S., Lim, H., Cho, H.: Safety climate and occupational stress according to occupational accidents experience and employment type in shipbuilding industry of Korea. Saf. Health Work **8**(3), 290–295 (2017)
17. Kvalheim, S., Antonsen, S., Haugen, S.: Safety climate as an indicator for major accident risk: can we use safety climate as an indicator on the plant level? Int. J. Disaster Risk Reduction **18**, 23–31 (2016)
18. Melo, E., Sousa, C., Sousa, A., Gonçalves, G.: Clima de segurança física e burnout: Efeitos nos comportamentos de segurança física dos enfermeiros. In: Arezes, P.M., Baptista, J.S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Miguel, A.S., Perestrelo, G. (eds.) International Symposium on Occupational Safety and Hygiene—Proceedings Book of the SHO2018, pp. 28–30. SPOSHO, Guimarães (2018)
19. Muñiz, J., Elosua, P., Hambleton, R.: Directrices para la traducción y adaptación de los tests. Psicothema **25**(2), 151–157 (2013)
20. Olds, D., Aiken, L., Cimiotti, J., Lake, E.: Association of nurse work environment and safety climate on patient mortality: a cross-sectional study. Int. J. Nurs. Stud. **74**, 155–161 (2017)
21. Olsen, E.: Exploring the possibility of a common structural model measuring associations between safety climate factors and safety behaviour in health care and the petroleum sectors. Accid. Anal. Prev. **42**(5), 1507–1516 (2010)
22. Seo, D., Torabi, M., Blair, E., Ellis, N.: A cross-validation of safety climate scale using confirmatory factor analytic technique. J. Saf. Res. **35**(4), 427–445 (2004)
23. Silla, I., Gamero, N.: Psychological safety climate and professional driver`s well-being: the mediating role of time pressure. Transp. Res. Part F: Traffic Psychol. Behav. **53**, 84–92 (2018)
24. Smith, G., Huang, Y.-H., Ho, M., Chen, P.: The relationship between safety climate and injury rates across industries: need to adjust for injury hazards. Accid. Anal. Prev. **38**(3), 556–562 (2006)
25. Smith, T., Eldridge, F., DeJoy, D.: Safety-specific transformational and passive leadership influences on firefighter safety climate perceptions and safety behavior outcomes. Saf. Sci. **86**, 92–97 (2016)
26. Tabachnick, B., Fidell, L.: Using Multivariate Statistics, 4th edn. Allyn & Bacon, Needham Heights (2001)
27. Zohar, D.: Safety climate in industrial organizations: theoretical and applied implications. J. Appl. Psychol. **65**(1), 96–102 (1980)

Psychosocial Hazards Evaluation in ICU Workers

Diana França, Pietro Scaramuzzo and Ema Sacadura-Leite

Abstract Psychosocial hazards evaluation is fundamental in healthcare settings, where workers are particularly exposed to this kind of risk factors, due to the nature of their work. The aim of this study was to assess psychosocial hazards in healthcare workers of Intensive Care Units (ICU). We applied a questionnaire including sociodemographic data, the COPSOQ II short version and the MBI-HSS to 93 workers of ICU and 20 of an Occupational Health Department, to compare the two of them. We found out that ICU workers had worse results in 8/26 dimensions of the COPSOQ and higher levels of emotional exhaustion. The only domain with better results was the one regarding meaning of work. The MBI-HSS evaluation showed a high rate of workers with emotional exhaustion (43.01%), mostly in men, but low personal accomplishment and high levels of depersonification were found in 25.81 and 12.90%.

Keywords Psychosocial hazards · Healthcare workers · Intensive Care Units

1 Introduction

Psychosocial hazards include a set of factors related to work organization, environment and social context, which have the potential to cause, directly or indirectly, not only psychological but also physical harm to workers [1, 2].

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This group of hazards is especially significant in healthcare workers, because their job is highly onerous in terms of workload, cognitive and emotional demands [3–8]. If not controlled, these hazards can cause decreased productivity, increased workplace conflicts, physical symptoms like headache or sleep disturbances, psychological suffering, like anxiety or irritability, or even psychiatric disorders, like depression or burnout [5, 9]. Therefore, psychosocial risk assessment is essential among healthcare workers.

In healthcare, Intensive Care Units (ICU) workers are particularly exposed to psychosocial hazards due to the nature of their work and type of patients [6, 8, 10]. In fact, these professionals have been reported to have, for example, higher prevalence of stress and burnout when compared to other healthcare workers [4, 10], although different working conditions can influence the results.

The aim of this study was to assess psychosocial hazards in healthcare workers of ICU and compare the results with those of another healthcare department's workers.

2 Methods

We conducted a cross-sectional, observational study, collecting data between January 2019 and March 2019. We included in the study healthcare workers from the Intensive Care Units (ICU) of a university hospital, including both adult and pediatric ICU (n = 200). Paper questionnaires were given to the heads of the ICUs, who where explained the purpose of the study and asked to inform the workers of their departments and to distribute the questionnaires. The researchers then went back to the departments twice to collect the completed ones. The questionnaires included:

- an initial section, elaborated by the authors, explaining the purposes of the study and concerning the participants' sociodemographic data, namely gender, age, profession and work schedule;
- the Portuguese adaptation of the Copenhagen Psychosocial Questionnaire II (COPSOQ II), in its short version [11];
- the Portuguese version of Maslach Burnout Inventory-Human Services Survey (MBI-HSS) [12].

The COPSOQ is a tool used to evaluate the psychosocial work hazards and risks, measuring different aspects which can influence the work environment and the person's adaptation to it. The Portuguese short version of the COPSOQ II consists of 41 questions, each scored on a Likert scale from 1 to 5. The interpretation of the instrument is not performed item by item, but the questions are grouped into 26 dimensions, each of them measuring a psychosocial hazard or risk. The answers obtained by each dimension are divided into three thirds: favourable health situations, intermediate situations or risk situations [11].

The MBI-HSS is among the most used instruments to measure burnout and contains 22 questions which evaluates 3 dimensions: 9 questions for emotional exhaustion, 5 for depersonification and 8 for personal accomplishment [12].

These instruments were also applied to the workers of the Occupational Health Department (OHD) of the same hospital, with the aim of comparing the ICU workers with them. Although both groups are constituted of health-care workers who deal daily with patients, their jobs have very different demands from the psychosocial point of view. ICU professionals perform shift and night work and have closer contact with critically ill patients, having to deal with death often. On the other hand, OHD workers deal with patients who are mostly healthy or have simpler pathology and do not perform shift or night work. However their jobs require them to deal with frequently unadjusted expectations from their patients and to mediate conflicts, which can sometimes involve legal issues.

This study was authorized by the ethical committee of the hospital where it took place.

Regarding statistical analysis, the association between qualitative variables was assessed by chi-square or Fisher's exact test for categorical variables accepting a significance level of 5%. No associations between numerical variables were tested. For data collection and analysis, Microsoft Excel and IBM SPSS were used.

3 Results

3.1 Sample and Sociodemographic Data

We included in the study 93 healthcare workers working in ICU, most being female (72; 77.41%). The mean age was 38 years (22–63). Seventy-six were nurses (81.72%), 10 nurse assistants (10.75%) and 6 physicians (6.45%). One participant didn't answer the question about his profession. Seventy-six (81.72%) participants reported to work not only on day time but, sometimes, they have to work during the night too. However, only 70 (75.27%) had a regular shift work schedule:

- 10 of them referred working about 4 or 5 nights a month,
- 39, 6–8 times in a month, and
- 21 reported working more than 9 nights a month, i.e., more than twice a week.

The questionnaire was also filled by 20 workers of the OHD, who were also mostly women (14) and had a mean age of 44 years (27–62). Seven of them were physicians, 6 nurses, 1 nurse assistant, 3 secretaries and 3 were safety technicians. None of them performed shift or night work.

3.2 COPSOQ

For the ICU workers, the domains of the COPSOQ II that showed more risk situations were the high cognitive (79%) and emotional (73%) demands, the high pace of work (52%), the existence of work-family conflict (32%) and the perception of job insecurity (27%) (Fig. 1).

When comparing men with women, we found out that men had worst perception of quantitative demands ($p < 0.005$), self-rated health ($p < 0.005$), quality of sleeping ($p = 0.005$), burnout ($p < 0.005$) and stress ($p = 0.003$).

Regarding the different professions, we observed that being a nurse assistant was associated to significantly worse perception of high cognitive demands ($p = 0.019$) and high emotional demands ($p = 0.002$). Also, they felt they have less influence on their work, comparing to other workers ($p = 0.006$). Physicians were the ones who felt having more possibilities of development ($p = 0.004$).

Age and the type of schedule (including doing shift work or not, and doing or not night-work) did not seem to influence the perception of the domains evaluated in the COPSOQ.

3.3 MBI

We found that 40 (43.01%) of the workers experienced high emotional exhaustion and 12 (12.90%) high depersonification. Twenty-four (25.81%) felt low personal accomplishment (Table 1). One person didn't answer to all the questions, so she was excluded from the evaluation of these results.

We observed that males had higher levels of perceived emotional exhaustion than females ($p = 0.005$). No significant relationship was observed between age, profession and type of work schedule and the results of the burnout evaluation.

3.4 Comparison with OHD Workers

When comparing with OHD workers, we found out that people working in the ICU had worst results in 8 out of the 26 dimensions of the COPSOQ. They had better results in only one dimension: meaning of work (Table 2).

In the MBI-HSS evaluation, UCI workers had significantly higher emotional exhaustion ($p = 0.008$). However there was no difference between the two groups, concerning depersonalization and personal accomplishment.

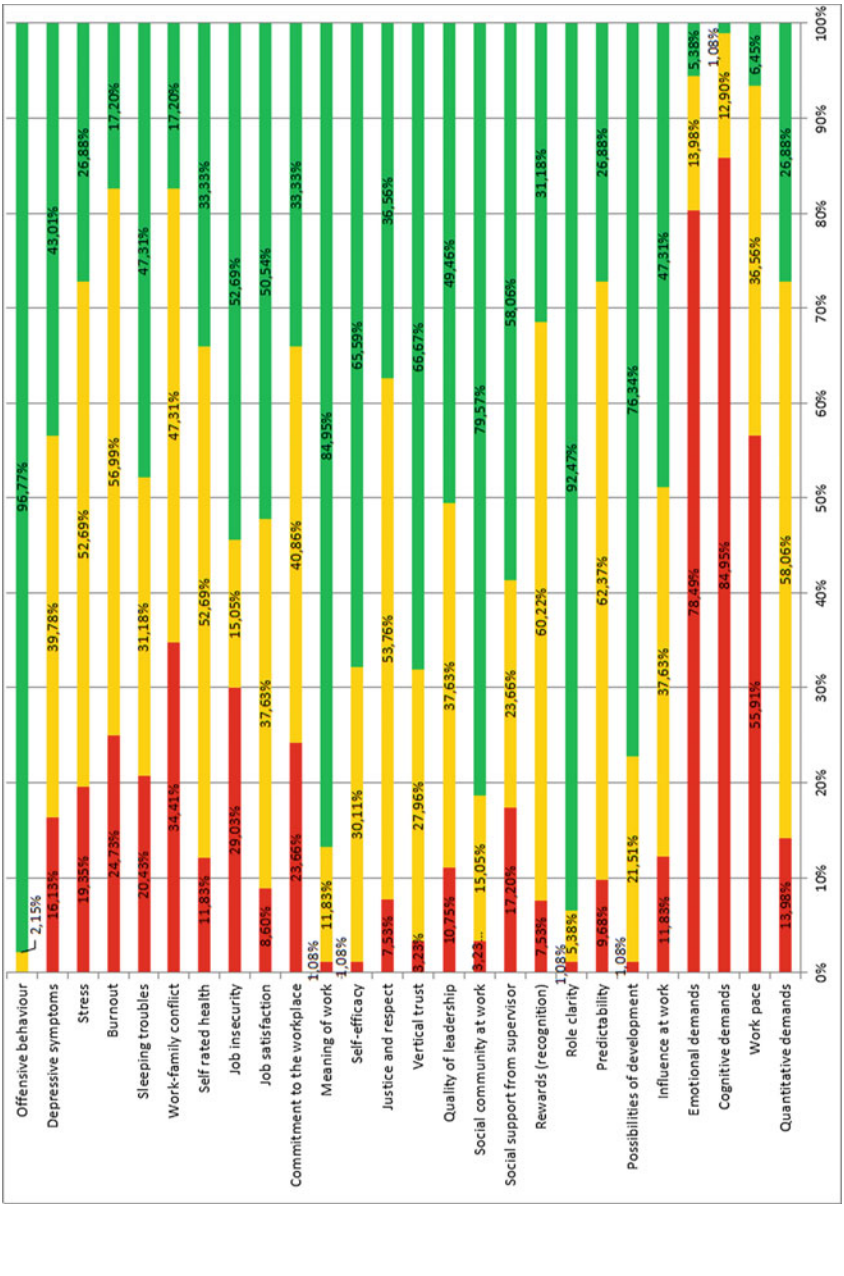

Fig. 1 Results of the COPSOQ II evaluation in ICU workers. Red sections represent high risk, yellow moderate situations and green favourable health situations

Table 1 Results of the MBI-HSS evaluation

	Emotional exhaustion	Depersonification	Personal accomplishment
High	40 (43.01%)	12 (12.90%)	26 (27.96%)
Moderate	30 (32.26%)	27 (29.03%)	42 (45.16%)
Low	22 (23.66%)	53 (56.99%)	24 (25.81%)

Table 2 Comparison in results of the COPSOQ II between ICU and OHD workers

	Worst in ICU workers	No significant difference	Better in ICU workers
Quantitative demands[a]		x	
Work pace[a]	p = 0.011		
Cognitive demands[b]	p = 0.015		
Emotional demands[b]	p = 0.001		
Influence at work[a]		x	
Possibilities of development[a]		x	
Predictability[a]		x	
Role clarity[a]		x	
Rewards (recognition)[a]	p = 0.047		
Social support from supervisor[a]	p = 0.032		
Social community at work[a]		x	
Quality of leadership[a]	p = 0.050		
Vertical trust[a]		x	
Justice and respect[a]		x	
Self-efficacy[a]		x	
Meaning of work[a]			p = 0.049
Commitment to the workplace[a]		x	
Job satisfaction[a]		x	
Job insecurity[a]		x	
Self rated health[b]		x	
Work-family conflict[a]	p = 0.023		
Sleeping troubles[b]		x	
Burnout[a]		x	
Stress[a]	p = 0.035		
Depressive symptoms[a]		x	
Offensive behaviour[a]		x	

[a]Fisher's exact test; [b]Chi-square test

4 Discussion

Our evaluation of psychosocial hazards found that ICU workers had very high rates of excessive cognitive and emotional demands, high pace of work and work-family conflict. Our findings are consistent with what is described in literature and the bad results in these domains are probably due to the fact that these workers deal with critically ill patients and need to make a number of difficult decisions daily, many times quickly and under pressure [4, 6, 7, 13, 14]. In fact, when comparing with OHD workers, who don't deal with critical patients or death, nor do shift or night work, it is confirmed that the last have better results in those domains [6, 7, 13].

On the other side, between the two groups, ICU workers showed better results in the dimension "meaning of work". This is probably because, even if their job is more demanding, when there are good outcomes, they cause a better and bigger impact in their perception of the utility of their work [15]. Also regarding the COPSOQ II evaluation, we observed that ICU workers had higher perception of work-family conflict, which is probably due to the need, for most of them, to do shift and night-work [16].

We observed that nurse assistants had significantly worse perception of high cognitive and emotional demands and of influence on their work. This may be due to lack of adequate and up-to-date training and preparation, considering that they need to deal daily with unstable patients too [17, 18]. In a similar way, the positive correlation between being a physician and feeling more possibilities of development is probably due to a bigger number of opportunities for learning in their job [18]. This results show us the importance of proper training of the workers of all professions in ICU.

Regarding the burnout evaluation, we observed that the ICU workers had a higher rate of emotional exhaustion when compared with the OHD workers. This is probably due to the fact that their job implied frequent contact with death, making of end-of-life decisions and deal with patients' families [19]. We also found a moderate rate of low personal accomplishment. That dimension is usually related to the emotional exhaustion even if both of them assess individual dimensions of burnout. There was no significant difference in personal accomplishment of MBI between ICU and OHD workers. It was not possible to estimate a total rate of burnout in the studied sample. However, we know that burnout syndrome is defined by the presence of three features: high emotional exhaustion, low personal accomplishment and high depersonalization [12]. This last represents the interpersonal dimension of burnout and it can have a strong impact in patients' care. In our study, we found that 12.90% of UCI's workers showed high levels of depersonalization, which is significantly lower than the prevalence of burnout (considering the three dimensions) reported in literature for healthcare workers [4, 5, 10]. Literature has reported that higher levels of burnout are usually associated with male sex, younger age of the workers and shift and night-works [4, 10, 20, 21], which was not confirmed in our study. However, when comparing men with women, we found in COPSOQ II scale that men had worst perception of quantitative demands, self-rated health, quality of sleeping, burnout and stress.

Finally, we need to be very careful in the interpretation of the results, considering the limitations of this study. In fact, this was a cross-sectional study, with a relatively small sample, based on voluntary participation. This means that the people most concerned with this issue and possibly the most affected by it, may have been more likely to participate than the ones who didn't answer to the questionnaire. Also, the members of the two groups studied (ICU and OHD workers) had very different sized and were not paired by sex, age, nor profession, which may make the two samples not properly comparable.

5 Conclusions

Our evaluation of psychosocial hazards found that ICU workers were exposed to higher rates of several psychosocial hazards, namely work pace, emotional and cognitive demands, when compared with other healthcare workers, which is probably due to the nature of their work, namely the need of dealing with critically ill patients, making frequently difficult decisions and dealing with patients' families in hard emotional situations. Adequate training may be one useful strategy to improve the perception of cognitive and emotional demands in these workers [17, 18]. Work-family conflicts can be associated with irregular work schedules, including shift and night work. On the other hand, rewards (recognition), social support from supervisor and quality of leadership are not specific of ICU workers activities but they are more related with work conditions in general [6–8].

Despite the high rates of emotional exhaustion, we found that depersonification was not as frequent as reported in literature. This may be because the significance of work can positively impact its perception; also it may suggest that burnout rates are low.

References

1. Cox, T. Griffiths, A.: The nature and measurement of work stress. In: Wilson, J.J.R., Corlett, E.N. Evaluation of human work. 2nd edn. Taylor & Francis, London (1995)
2. OSHA: Risk assesment in health care, http://www.osha.mddsz.gov.si/resources/files/pdf/E-fact_18_-_Risk_assesment_in_health_care.pdf
3. Sacadura-Leite, E., Sousa-Uva, A.: Stressores ocupacionais, stress e burnout em profissionais de saúde. In: Manual de Saúde Ocupacional em hospitais, 1st edn. Diário de Bordo, Lisboa (2018)
4. Chuang, C.H., Tseng, P.C., Lin, C.Y., Lin, K.H., Chen, Y.Y.: Burnout in the intensive care unit professionals—a systematic review. Medicine **95**(50), e5629 (2016)
5. Marôco, J., Marôco, A.L., Leite, E., Bastos, C., Vazão, M.J., Campos, J.: Burnout em profissionais de saúde portugueses: uma análise a nível nacional. Acta Med. Port. **29**(1), 24–30 (2016)
6. Sacadura-Leite, E., Sousa-Uva, A., Ferreira, S., Costa, P., Passos, A.: Working conditions and high emotional exhaustion in hospital nurses. Rev. Bras. Med. Trab. **17**(1), 69–75 (2019)

7. Costa, P.L., Passos, A.M., Silva, A.S., Sacadura-Leite, E., Tavares, S.M., Spanu, F., et al.: Overcoming job demands to deliver high quality of care in the hospital setting across the Europe: the role of teamwork and positivity. JWOP **30**, 105–112 (2014)
8. Moura, P., Serranheira, F., Sacadura-Leite, E.: Psychosocial risks in psychiatry and anaesthesiology residents in a Portuguese General Hospital. Med. Lav. **107**(2), 129–140 (2016)
9. Ballester-Arias, A.R., García, A.M.: Occupational exposure to psychosocial factors and presence of musculoskeletal disorders in nursing staff: a review of studies and meta-analysis. Rev. Esp. Salud. Publica **7**, 91 (2017)
10. Silva, J., Soares, R., Costa, F., Ramos, D., Lima, F., Teixeira, L.: Psychosocial factors and prevalence of burnout syndrome among nursing workers in intensive care units. Rev. Bras. Ter. Intensiva **27**(2), 125–133 (2015)
11. Silva, C.S.: Copenhagen Psychosocial Questionnaire. Fundação para a ciência e teconologia PTDC/SAU-ESA/66163/2006 (2006)
12. Malasch, C., Jackson, S., Leiter, M.: The Maslasch Burnout Inventory manual. In: Evaluating Stress: A Book of Resources, 1st edn. The Scarecrow Press (1997)
13. Viotti, S., Converso, D., Loera, B.: Job satisfaction, job burnout and their relationships with work' and patients' characteristics: a comparison between intensive care units and not-intensive care units. G. Ital. Med. Lav. Ergon. **34**(2 Suppl B), B52–B60 (2012)
14. Johnson-Coyle, L., Opgenorth, D., Bellows, M., Dhaliwal, J., Richardson-Carr, S., Bagshaw, S.M.: Moral distress and burnout among cardiovascular surgery intensive care unit healthcare professionals: a prospective cross-sectional survey. Can. J. Crit. Care Nurs. **27**(4), 27–36 (2016)
15. Lee, S.: A concept analysis of 'Meaning in work' and its implications for nursing. J. Adv. Nurs. **71**(10), 2258–2267 (2015)
16. Lembrechts, L., Dekocker, V., Zanoni, P., Pulignano, V.: A study of the determinants of work-family conflict among hospital nurses in Belgium. Nurs. Manag. **23**(7), 898–909 (2015)
17. Michie, S.: Causes and management of stress at work. Occup. Environ. Med. **59**(1), 67–72 (2002)
18. Schaufeli, W.B., Bakker, A.B., Van Rhenen, W.: How changes in job demands and resources predict burnout, work engagement, and sickness absenteeism. J. Organiz. Behav. **30**, 893–917 (2009)
19. Aiken, L.H., Clarke, S.P., Sloane, D., Sochalski, J., Silber, J.: Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. JAMA **288**(16), 1987–1993 (2002)
20. Wisetborisut, A., Angkurawaranon, C., Jiraporncharoen, W., Uaphanthasath, R., Wiwatanadate, P.: Shift work and burnout among health care workers. Occup. Med. **64**(4), 279–286 (2014)
21. Cañadas-De la Fuente, G., Ortega, E., Ramirez-Baena, L., De la Fuente-Solana, E., Vargas, C., Gómez-Urquiza, J.L.: Gender, marital status, and children as risk factors for Burnout in nurses: a meta-analytic study. Int. J. Environ. Res. Public Health **15**(10), 1–13 (2018)

Depression and Loneliness Among Workers Exposed to Noise

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Abstract It has been found that workers are suffering from some mental and physical symptoms, such as anxiety, depression, aggressiveness, loneliness. Therefore, the question can be raised on whether workers exposed to noise suffer from various degrees of depression and Loneliness. Do some of the individual characteristics of these workers affect these levels? Two tests of depression and Loneliness were applied on a sample of 277 workers exposed to high noise levels. The results showed that 3.2% of the study sample suffer from high level of depression, while 54.9% have Average level, only 36.8 have low level, and 5.1% have very low level. Moreover, le level of depression had high significant positive correlation of (0.258**) with age and significant negative correlation of (0.127*), with sex as well as high significant negative correlation of (−0.327**), with the type of job. The results of loneliness test showed that about 2.53% of the subjects have low level of loneliness, while 23.11% have Average level. Most important however is that 63.18% have high level of loneliness and even more than 11.19% have high level of loneliness. It should be noticed that the results of the loneliness are higher than those of depression despite the fact that there was a significant positive correlation (0.134*) between them. Perhaps this very high percentage suffering from loneliness could be explained as indication or warning towards an increase of depression among subjects. It seems that some workers exposed to high level of noise are suffering from depression and loneliness. However, further studies are necessary to control other factors.

Keywords Depression · Loneliness · Noise · Individual characteristics

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1 Introduction

Noise can be considered as a source of complaints and a factor of conflict at work or even between neighbors. It can have a negative impact on the physical health of a person, depending on the severity and duration of exposure and the sensitivity of the concerned person. Overall, it can have negative repercussions, which usually appear in the symptoms of anger, stress, insomnia, depression, hearing problems, and can evolve their impact on public health to pose a threat to human [6, 9, 11, 12, 38].

Despite that there are many studies that have shown that the noise is considered as an important factor in increasing the blood pressure ratio, vascular disease, increased intake of sedatives, and the percentage of doctor visits, as well as the high rate of symptoms and self-complaints [4, 7, 24, 27, 30, 34, 35, 39]. However, the researchers warn of the consequences of limiting the noise as the only factor causing the appearance of these symptoms, but must take the type of work and other environmental conditions in addition to taking the side of health and individual emotion into account at the same time. So most of these studies suggest that there may be implications for health because of exposure to noise, but at the same time recommends more research and study in this direction [7, 10, 15].

Melamed et al. [23] found that exposure to noise level affects work satisfaction for male workers and lead to irritability, agitation and irritability. Noise has also led to the severity of somatic complaint, anxiety, depression and symptoms of anxiety among female workers. Exposure to high levels of noise were also associated with the increase in accidents and sickness absence for both sexes [26].

In the same way Wolpe [37], thinks that depression is due to several factors, and that the most important is the anxiety because if an individual suffers from anxiety for a long time he may become depressed. By the same approach Montgomery [25], believe that anxiety is a part of depression, therefore the anxiety is one of the main symptoms of depression, and all the symptoms that are included in the tests of anxiety are useful in the registration of any change in the severity of depression. Therefore, the clear communication in pathological symptoms of anxiety and depression disorder is not enough to separate them for the presence of these symptoms in both [25].

In this context, Olvat [29] pointed out that textile workers exposed to high noise seems to have aggressive response compared to the control sample of non-exposed workers. Yoon et al. [40], also found that the department of international telephone workers who work under the noise levels of between 57 and 70 decibels suffer from anxiety and depression. Beutel et al. [7] found that indicators of depression and anxiety increased steadily with levels of annoyance to the noise and that both depression and anxiety increased with the degree of overall noise annoyance. They found that noise annoyance was defined as the highest annoyance rating from any of the categories of noise, regardless of the specific noise source (aircraft, road traffic, railway, etc.) and time period (daytime or sleep). In the same context, Orban et al. [31] suggest that exposure to residential traffic noise may increase the risk of high depressive symptoms in middle-aged and older adults.

Nérome and Enjolbert [28] found that people living near the airport of Roissy-Charles de Gaulle suffer from a lack of sleep, anxiety and depression because of exposure to aircraft noise compared to residents who are not exposed to this noise. In addition, these effects appeared more among individuals whose age was more than 60 years, and living next to the airport for more than 10 years.

Furthermore, Ypsilanti et al. [41], pointed out that people at high risk of depression have a chronic tendency to feel lonely and isolated and that although depression does not necessary lead to loneliness but feeling lonely is often a predictor of depression. In the same context, Van Winkel et al. [36], found that loneliness functions as both a symptom of depression and a predictor of depression. They propose to address loneliness as soon as possible after it has developed in order to ease the beginning of depressive symptoms. They concluded that loneliness was followed by an increase in negative judgments of social company and a higher frequency of being alone.

Many researchers think that social and demographic changes have led to an increased prevalence of loneliness and social isolation in modern society [18, 19, 22]. It was also found to be as additional risk factors of cardiovascular disease [14]. Still this matter might be different for workers exposed to noise because as they have expressed when they were interviewed in one of our unpublished study, they created social isolation seeking quietness as a way to recover from the effect of noise. Like lie-down in an isolated room, avoid contact with people or do not attending any social event like a wedding ceremony. However, this self-created social isolation might well become as a psychological loneliness later.

Therefore, it might be necessary to look for more important psychological and physical symptoms of noise on workers who are exposed to high noise levels. The question can be raised on whether workers exposed to noise suffer from various degrees of depression, and Loneliness. Do some of the individual characteristics of these workers affect these levels?

2 Method

2.1 Study Tool

Two separate tests of depression and Loneliness were applied on a sample of 277 worker exposed to high noise levels. A noise meter was also used to measure le levels of noise.

Tests of depression. Tests of depression Adel Abdullah Muhammad [1] adapted the test of depression that was originally prepared by Russell [33]. The test includes 54 items. The subject chooses one of the words appropriate to his feeling. Scores are given: 1-2-3-4-5, for the positives items. While the following indirect (negative) phrases (2-9-12-15-18-23-25-27-29-30-34-35-37-40-43-50-52-54), are given the opposite of these markings. The total score of the scale ranges from: 54, that indicates the nonexistence of depressive feelings to 270, as the maximum presence of depressive feelings. The higher the score, the higher the level of depression. The reliability of the scale was assessed using different methods. The Alpha coefficient of Cronbach was found to be 0.75. The split-half method 0.78. While the internal consistency showed that correlation coefficients ranged from 0.64 to 0.78. Thus, it is clear that this test has an acceptable degree of consistency.

Psychological Loneliness Test. Russell [33] originally prepared this test, to measure an individual's sense of psychological loneliness. It was developed and adapted to its Arabic Form by Majdi Mohamed El Dessouky [21]. The test consists of 20 items formulated in the form of questions. The subject answers each question with one answer from four choices: never—rarely—sometimes—always. The following items are marked from 1 to 4: 2-3-4-7-8-11-12-13-14-17-18. While the next items are marked the opposite from 4 to 1: 1-5-6-9-10-15-16-19-20. The total score obtained by each subject is then calculated by adding all his marks on the test. The overall score of the scale ranges from 20 to 80 degrees so that the high score indicates a strong sense of psychological loneliness and vice versa. The reliability of the scale was found via the Alpha coefficient of Cranach, 0.42, and the internal consistency method: 0.45.

Noise Measurements. Four noise meters Type CDA 830 were used to measure the level of noise in decibel. Measurements were taken at the level the worker's ear of the worker.

2.2 The Study Sample

The test of depression and the Psychological Loneliness test were applied on a sample of 277 workers exposed to high level of noise ranging from 78 to 92 dB(A). They worked for different companies including Sewing workshop, Turnkey construction workshop and Milk factory. Some of their individuals' characteristics are shown in Table 1.

2.3 Procedure

The two tests of depression and loneliness at the same time on each worker who volunteer to participate in the study the application of each both tests took between 20 and 30 min. Measurements of noise were taken near all the machines when they were being used. However, they were not related to each worker who participate in the application of the two tests. The statistical package for the social sciences was used to calculate frequencies, means, percentages, and correlations.

Table 1 Some individuals characteristics of the study sample

Characteristics	Sex		Age							Status				
Categories	Male	Female	<20	21–25	26–30	31–35	36–40	41–45	45<	Single	Married	Divorced	Widower	
Frequency	177	100	2	24	122	83	38	7	1	136	122	12	6	
Percentage	63.97	36.1	0.7	8.7	44	30	13.7	2.5	0.4	49.1	44	4.3	2.2	
Characteristics	Job								Educational level					
Categories	Simple worker	Qualified worker	Technician	Administrative	Engineer	Official	High official	Did not mention	Without level	Primary	College	Secondary	University	Did not mention
Frequency	95	128	4	16	17	5	5	7	7	46	77	108	33	6
Percentage (%)	34.3	46.2	1.4	5.85	6.1	1.8	1.8	2.5	2.5	16.6	27.8	39	11.9	2.2

3 Results

Table 2, shows that although only 5.1% of the total sample of workers exposed to high noise suffer from a very low degree of depression, and 36.8% of them suffer from a low degree, still there are 54.9% who suffer from a moderate degree of depression, and therefore need to take appropriate preventive steps. More than that, 3.2% suffer from a very high level of depression, which calls for urgent steps to control this serious mental state. Moreover, le level of depression had highly significant positive correlation of (0.258**), with age and significant negative correlation of (−0.127*), with sex as well as highly significant negative correlation of (−0.327**), with the type of job.

The results of loneliness test showed that only 2.53% of the study sample have low level of loneliness, while 23.11% have Average level. Most important however is that 63.18% have high level of loneliness and even more than those 11.19% have high level of loneliness (see Table 3). These results are quite different from that of depression despite the fact that the results in Table 4 showed a positive correlation of (0.134*) between the latter and loneliness. Moreover, there were no significant correlations with the individual characteristics. This absence of correlation seem to be somehow contradictory to some previous general studies. For example, in 2017, the BBC in England conducted a survey in which over 55,000 individuals aged 16 years and over took part to explore attitudes and personal experiences of loneliness. The results showed that 16–24 year olds experience loneliness more often and more intensely than any other age group and that 40% of reported feeling lonely often or very often, compared to only 29% of people aged 65–74 and 27% of people aged over 75 said the same. Similarly, the insurance company Aetna [2] carried out a survey of more than 20,000 U.S. adults' age 18 years and more. The results indicated that 46% of them report sometimes or always feeling alone. The age group of 18–22 years had highest rates of loneliness. However, loneliness is not necessary limited a specific age group but can be experienced at all stages of life as it is the case with older age [8, 13, 20, 32].

Table 2 Distribution of sample subjects on depression scores

Depression levels	Frequencies	Percentage (%)
Very low (54–96)	14	5.1
Low (97–139)	102	36.8
Average (140–182)	152	54.9
High (183–225)	9	3.2
Very high (226–270)	0	0.0
Total	277	100.0

Table 3 Distribution of sample subjects on loneliness scores

Level	Frequency	Percentage (%)
Low (<40)	7	2.53
Average (40–49)	64	23.11
High (50–59)	175	63.18
Very high (60–79)	31	11.19

Table 4 Correlation between depression scores to some individual characteristics

	Depression	Loneliness	Sex	Age	Status	Education
Loneliness	0.134(*)					
Sex	−0.127(*)	0.109				
Age	0.258(**)	−0.089	−0.078			
Status	−0.065	−0.029	−0.132(*)	0.007		
Educational	−0.114	0.017	0.215(**)	−0.028	−0.224(**)	
Job	−0.327(**)	−0.070	0.191(**)	−.164(**)	−0.096	0.463(**)

*$P < 0.05$ **$P < 0.01$

4 Discussion

The result of the present study confirmed the trend of previous researchers that noise is a psychosocial stressor that may affect health, even at low levels [3]. Basner et al. [5] have studied Auditory and non-auditory effects of noise on health. They pointed out that chronic exposure to noise has been associated with increased stress, anxiety, depression, blood pressure, heart disease incidence, distractibility, annoyance, tinnitus, hyperacusis, and other health problems. It should be noticed that the results of the psychological loneliness test are much higher compared to those of depression despite the fact that there was a significant positive correlation (0.134*) between the variables. Perhaps this very high percentage suffering from loneliness could be explained as indication or warning towards an increase of the percentage of depression among the study sample. In this case, preventive measures are needed to avoid this situation. According to Ypsilanti et al. [41], people at high risk of depression have a chronic tendency to feel lonely and isolated and that although depression does not necessarily lead to loneliness but feeling lonely is often a predictor of depression.

Finally, it can be concluded that some workers exposed to high level of noise are suffering from depression and loneliness but further studies are necessary to control many other factors.

References

1. Adel Abdullah Muhammad: Test of depression, test of depression. Egyptian Library Aonfjlou, Cairo, Egypt (1997)
2. Aetna the insurance company: Let's talk about loneliness and young adult mental health. (2018). https://www.familyaware.org/loneliness
3. Babisch, W.: The noise/stress concept, risk assessment and research needs. Noise Health **4**, 1–11 (2002)
4. Babisch, W., Pershagen, G., Selander, J., Houthuijs, D., Breugelmans, O., Cadum, E., et al.: Noise annoyance—a modifier of the association between noise level and cardiovascular health? Sci. Total Environ. **452–453**, 50–57 (2013)
5. Basner, M., Babisch, W., Davis, A., et al.: Auditory and non-auditory effects of noise on health. Lancet **383**, 1325–1332 (2002)
6. Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S.: Auditory and non-auditory effects of noise on health. The Lancet **383**(9925), 12–18 (2014)
7. Beutel, M.E., Junger, C., Klein, E.M., Wild, P., Lackner, K., Blettner, M. et al.: Noise annoyance is associated with depression and anxiety in the general population—the contribution of aircraft noise. PLoS One **11** (2016)
8. Beutel, M.E., Klein, E.M., Brahler, E., Reiner, I., Junger, C., Michal, M., Wiltink, J., Wild, P. S., Munzel, T., Lackner, K.J., Tibubos, A.N.: Loneliness in the general population: prevalence, determinants and relations to mental health. BMC Psychiatry **17**, 97 (2017)
9. Clement, G., Lorant, V., Schimit, C.: Nuisauce Sonore, Statut socio-économique et Santé: Une analyse du recensement de 2001, environnement et comportements a risque pour la santé. FNRS, Ecole de Santé Publique, ULB, Bruxelles (2006)
10. Cohen, A.: Industrial noise and medical, absence, and accident record data on exposed workers. In: Proceedings of the International Congress on Noise as a Public Health Problem, Dubrovnik, Yugoslavia, 13–18 May 1973. U.S. Environmental Protection Agency, Washington, D.C. 550/9-73-008, pp. 441–453 (1973)
11. Cohen, S., Gary, W., Evans, G., Stokols, D., Krantz, D.S.: Behavior, Health and Environmental Stress. Plenum Press, New York (1986)
12. Fournier, L.R., Wilson, G.F., Swain, C.R.: Electrophysiological, behavioral, and subjective indexes of workload when performing multiple tasks: manipulation of task difficulty and training. Int. J. Psychophysiol. **31**, 129–145 (1999)
13. Hansen, T., Slagsvold, B.: Late-life loneliness in 11 european countries: results from the generations and gender survey. Soc. Indic. Res. **129**, 445–464 (2016)
14. Holt-Lunstad, J., Smith, T.B.: Loneliness and social isolation as risk factors for CVD: implications for evidence-based patient care and scientific inquiry. Heart **102**, 987–989 (2016)
15. Jonsson, A., Hansson, L.: Prolonged exposure to a stressful stimulus as a cause of raised blood pressure in man. Lancet (1977)
16. Kaltenbach, M., Maschke, C., Heb, F., Niemann, H., Führ, M.: Health impairments, annoyance and learning disorders caused by aircraft noise. Int. J. Environ. Protect. **6**, 15–46 (2016)
17. Knipschild, P.: Medical effects of aircraft noise: drug survey. Int. Arch. Occup. Envir. Health **40** (1977)
18. Kryter, K.D.: The handbook of hearing and the effects of noise: physiology, psychology, and public health. Academic Press, New York (1994)
19. Lorant, V., Schmit, C.: Influence des musan ces sonores et atmosphériques sur la santé subjective des individus, Environnement et comportements a risque pour la santé, FNRS, Ecole de Santé Publique, ULB, Bruxelles (2006)
20. Luhmann, M., Hawkley, L.C.: Age differences in loneliness from late adolescence to oldest old age. Dev. Psychol. **52**, 943–959 (2016)
21. Majdi Mohamed El Dessouky: UCLA loneliness scale (version 3). Egyptian Library Aonfjlou, Cairo, Egypt (1998)

22. Masi, C.M., Chen, H.Y., Hawkley, L.C., Cacioppo, J.T.: A meta-analysis of interventions to reduce loneliness. Pers. Soc. Psychol. Rev. **15**, 219–266 (2011)
23. Melamed, S., Luz, J., Green, M.S.: Noise exposure, noise annoyance and their relation to psychological distress, accident and sickness absence among blue-collar workers–the Cordis Study. Isr. J. Med. Sci. **28**(8–9), 629–635 (1992)
24. Melamed, S., Fried, Y., Froom, P.: The interactive of chronic exposure to noise and job complexity on changes in blood pressure and job satisfaction: a longitudinal study of industrial employees. J. Occup. Health Psychol. **6**(3), 182–195 (2001)
25. Montgomery, S.A., Montgomery, D., Baldwin, D., et al.: The duration, nature and recurrence rate of brief depressions. Prog. Neuropsychopharmacol. Biol. Psychiatry. **14**, 729–735 (1990)
26. Muhammad Ahmad A.-H.: Noise Pollution, 1st edn. Itrac for Printing, Publishing and Distribution (2003)
27. Münzel, T., Sørensen, M., Schmidt, F., Schmidt, E., Steven, S., Kröller-Schön, S., Daiber, A.: The adverse effects of environmental noise exposure on oxidative stress and cardiovascular risk. Antioxid. Redox Signal. **28**(9), 873–908 (2018)
28. Nérome, S., Enjolbert, J.-P.: Insomnia pour les riverains de l'aéroport Roissy Charles de Gaulle sonre, n° 106. (2004)
29. Olvat, H.M.: Behavioral physiology: physiological psychology. University House of Thought (1986)
30. Omar, H., Beutelb M., Goria, T., Schulzc, A., Blettnerd, M., Pfeiffere, N., Rostockh, T.,; Lacknerf, K., Sørenseng, M., Prochaskaa, J.H., Wilda, P.S., Münzela, T.: Annoyance to different noise sources is associated with atrial fibrillation in the Gutenberg Health Study. **264**, 79–84 (2018)
31. Orban, E., McDonald, K., Sutcliffe, R., Hoffmann, B., Fuks, K.B., Dragano, N., Viehmann, A., Erbel, R., Jöckel, K.-H., Pundt, O., Moebus, S.: Residential road traffic noise and high depressive symptoms after five years of follow-up: results from the Heinz Nixdorf Recall Study. Environ. Health Perspect. **124**(5), 578–585 (2016)
32. Rico-Uribe, L.A., Caballero, F.F., Olaya, B., Tobiasz-Adamczyk, B., Koskinen, S., Leonardi, M., Haro, J.M., Chatterji, S., Ayuso-Mateos, J.L., Miret, M.: Loneliness, social networks, and health: a cross-sectional study in three countries. PLoS ONE **11**, e0145264 (2016)
33. Russell, D.: UCLA Loneliness Scale (Version 3): reliability, validity, and factor structure. J. Pers. Assess. **66**, 20–40 (1996)
34. Shepherd, D., Dirks, K., Welch, D., McBride, D., Landon, J.: The covariance between air pollution annoyance and noise annoyance, and its relationship with health-related quality of life. Int. J. Environ. Res. Public Health. **13** (2016)
35. Steptoe, A., Kivimaki, M.: Stress and cardiovascular disease: an update on current knowledge. Annu. Rev. Public Health **34**, 337–354 (2013)
36. van Winkel, M., Wichers, M., Collip, D., Jacobs, N., Derom, C., Thiery, E., Myin-Germeys, I., Peeters, F.: Unraveling the role of loneliness in depression: the relationship between daily life experience and behavior. Psychiatry. **80**(2):104–117 (2017, Summer)
37. Wolpe, J.: The experimental model and treatment of neurotic depression. Behav. Res. Ther. **17**, 55–565 (1979)
38. World Health Organization (WHO) Burden of disease from environmental noise. Quantification of Healthy Life Years Lost in Europe. World Health Organization (WHO). Geneva, Switzerland (2011)
39. Xia, N., Li, H.: Loneliness, social isolation, and cardiovascular health. Antioxid. Redox Signal. **28**(9), 837–851 (2018)
40. Yoon, J.H., Won, J.U., Lee, W., Jung, P.K., Roh, J.: Occupational noise annoyance linked to depressive symptoms and suicidal ideation. PLoS One. **9**(8), e105321 (2014)
41. Ypsilanti, A., Lazuras, L., Powell, P., Overton, P.: Self-disgust as a potential mechanism explaining the association between loneliness and depression. J. Affect. Disord. **243**, 108–115 (2019). https://doi.org/10.1016/j.jad.2018.09.056

Self-Harm and Suicide in the Army: Systematic Review

M. M. Ribeiro, M. M. Fernandes, M. I. Santos and T. F. B. X. Silva

Abstract As one of the three main causes of death in people between the ages of 15 and 44 years old, Suicide is, according to data from WHO, responsible, annually, for a million deaths. These numbers do not include suicide attempts, that are usually 10–20 times more frequent that suicide itself. This systematic review proposes to gather relevant information on the topic of self-harm and suicide in the Army, in accordance with the PRISMA-P statement for systematic review and meta-analysis protocols. This systematic review was based on relevant published articles found on five online databases (SCOPUS, PubMed, Science Direct, EBSCOhost e Web of Science), with a total of six keywords combinations. The information from the 13 selected articles was compiled into three groups. The first group addresses issues regarding the use of licit and illicit drugs and their relationship with self-harm and suicide; the second group focuses gender-related issues; and the third group addresses issues related to the identification of the main causes and of the individuals that resort to self-harm and suicide. No significant answers were found for the prevention of suicide and self-inflicted injuries in Armed forces.

Keywords Self-harm · Suicide · Army

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1 Introduction

Suicide stands as one of the three main causes of death in people between the ages of 15 and 44 years old. According to data from the World Health Organization (WHO), it is responsible, annually, for a million deaths (corresponding to 1.4% of the total of deaths). These numbers do not include suicide attempts, that are usually 10–20 times more frequent that suicide itself [30].

Most people who tend to commit suicide do not necessarily want to die, they just want to put an end to their pain (real or imagined), and need to be helped. Suicide that leads to death and is deliberate and deliberately committed to destroy oneself is known as successful suicide [2]. If suicide is committed but does not lead to death, in this case it is called attempt suicide, which is often said of those who sometimes pave the way for their “escape” in advance, although in some cases they may not have helpers [22]. If the injury is deliberately done to a body part without the intention of death, it is called self-harm [7].

Research shows that for every suicide that leads to death, there are between 100 and 200 unsuccessful attempts and the suicide rate, in the following 12 months is about 100 times higher for those that self-harm [8]. There is suicide in all age groups, but their frequency is higher among young people and soldiers, due to their particular conditions [6]. Suicide is not a uniform phenomenon, but it can be defined as a continuous process, in which there is the thought of suicide at one extreme and the act of committing suicide at the other extreme [5].

Research on military forces show that suicide is not accidental among soldiers; but the origin of thoughts, behaviors, situations, and interpersonal relationships is the period before military service. Some military personnel experience extreme isolation and suffering, and find no opportunity to receive help and suffer from excitability disorders that often lead to daring reactions, such as committing suicide [20].

In Nouri et al. [20], several aspects were considered risk factors that lead to suicide impairment, such as age, gender, race, religion, marital status, occupation, psychological and physical disorders, drug misuse and personality disorders. In different situations, the most common risk factors that lead to suicide are psychological disorders and previous suicide attempts. Depressive disorders constitute 80–95% of recognizable psychological disorders in repetitive behaviors in some people’s family history [5].

Ennis’ [6] research on suicide, on soldiers belonging to ground forces of Islamic Republic of Iran’s Army, showed that there is a significant relationship between low education, previous suicide attempts, dissatisfaction with military service, conflicts with others, and inadequate psychological status with the increase of suicidal ideas. In Chinese adolescents, weak family relationships [14] and in Nicaragua [10], communication problems and parental conflicts, are among the factors that lead to thinking of and committing suicide. In Linehanna [13], it is stated that 39–90% of participants had previous experience of attempted suicide. In Shakeri [23], it is found that those who embark on suicide share personal characteristics such as being an introvert, or having a tendency to psychological self-torture and unstable behavior, more than those of the control group do. Suicide among soldiers has negative psychological and social effects, and is considered a serious challenge for the country's Health system and Army.

Work-related psychosocial risks are aspects of work design, management, and organizational context, with potential for harm to health and safety at work [11].

In general, the emergence of suicide cases in military corporations can lead to fear and terror in young soldiers that may lead them to develop antagonistic feelings towards authorities. On the other hand, it is possible that some authority figures may attribute inadequate scores for self-harm or suicide in soldiers following these actions to avoid further cases, which may lead to the increase of self-harm. Investigating the phenomenon of self-harm and suicide is a technical, complex, scientific and generally preventable subject. Appropriate intervention can openly adjust or eradicate suicide [3].

Based on the above information, the objective of this systematic review was to identify factors that lead military personnel to self-harm or suicide when in active duty.

2 Methodology

The methodology employed on this systematic review follows the reporting guidelines of the PRISMA-P statement for systematic review and meta-analysis protocols [12, 18, 24]. The focus was on literature regarding reports of self-harm or suicide of active military personnel in the army. Links to the use of legal or illegal and/or gender-related substances were taken into consideration. The research strategy consisted of a comprehensive search that could locate the broadest spectrum of articles for the above subject, and was performed on selected electronic databases, namely: PubMed, Scopus, Science Direct, EBSCOhost and Web of Science. For each electronic database used, were used a combination of the keywords "Suicide", "self-inflicted injuries", "military" and "self-mutilation".

The eligibility criteria only included articles published and peer reviewed, where information related to self-mutilation or suicide of active military personnel in the armed forces was found. We considered only articles published from 2014 to 2018, and written in English. All studies considered for in-depth analysis were critically evaluated on issues such as quality and content of the research methodology and study outcomes. Such evaluation is significant to minimize the bias of individual studies and thus to prevent the inclusion of data that may compromise the accuracy of the results of this review.

3 Results

The initial search strategy identified 1841 citations. After exclusion of duplicates and non-relevant ones, 1016 full-text articles were analyzed. After applying the eligibility criteria, 13 studies were considered for the final analysis Fig. 1.

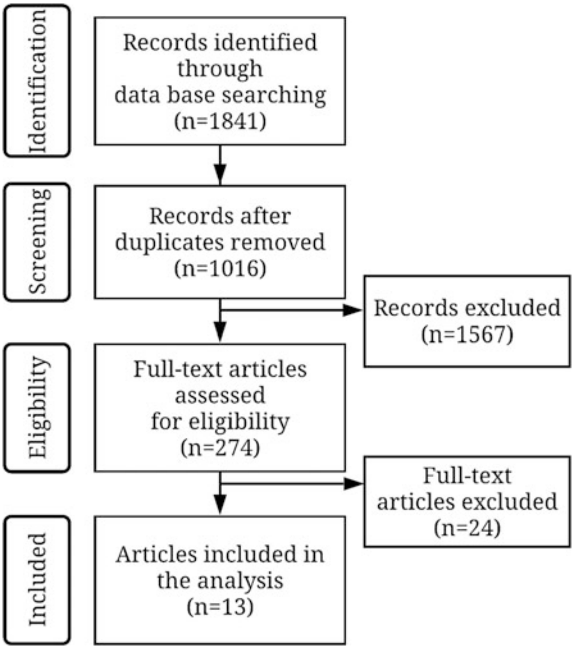

Fig. 1 Flow chart of identification and selection of articles for the systematic review (Adapted from [19])

4 Discussion

Of the 13 articles analyzed, three relate suicide attempts or suicide itself to licit or illicit chemicals, including alcohol, energy drinks and drugs.

Mash et al. [15] examined the relationship between alcohol use and energy drinks, independently and in combination, and the rates of serious consideration and/or suicide attempt in US Army soldiers.

Similarly, Haberman Mash et al. [9] reassessed 3813 US Army soldiers using the Department of Defense's Survey of Health-Related Behaviors among Active Service Military Officers. They examined the associations between reasons for drinking, level of alcohol use and suicide. Six percent of soldiers reported suicidal thoughts and behavior in the 12 months prior to the survey.

Cohen et al. [4] decided to examine the relationship between recurrent alcohol dependence and depression on the development of the subsequent risk of suicidal ideation among the National Guard forces. Based on the information obtained, they concluded that alcohol dependence and depression worked together to shape the risk of incident suicidal ideation among Army National Guard service members.

Regarding gender issues, two articles addressed the relationship between suicide and gender. Matarazzo's research [16] confirmed that the lesbian, gay, bisexual, and transgender (LGBT) community also has a higher risk of suicide.

On the other hand, Street [26] research was based on the US Army study called "The Army Study to Assess Risk and Resilience in Service Members (Army STARRS)" which found that the proportionate increase in the US Army suicide rate among soldiers occurred during displacement and was significantly higher among women than men were. Following that, eight articles addressed suicide attempts and suicide itself. For Shelef et al. [25], suicide is the leading cause of death of soldiers in Israel's peacetime defense forces. The most prevalent diagnosis was personality disorders. Soldiers with mood/anxiety disorders made up the smallest group and included major depression, dysthymia, anxiety, and posttraumatic stress disorder. Interestingly, these disorders occur in greater proportion among men than in women in the military.

Ursano et al. [27, 28] conducted new research using administrative data from the Army STARRS Study. The odds of suicide attempts among soldiers in a unit with five or more attempts in the previous year were more than double the number of soldiers in a unit without previous attempts.

In the same year, Ursano et al. [29] indicated that the risk among enlisted soldiers peaked in the second month of service and after decreased steadily, while the risk among officers remained relatively stable over time.

Ribeiro et al. [21] looked for similar clues among soldiers. The authors realized that many soldiers who die by suicide contact health care shortly before death, presenting an opportunity for suicide prevention.

The following year, Millner et al. [17] revealed that, for both men and women, being in the Regular Army, compared to being in the National Guard or the National Reserve. Army, and being in an enlisted rank, compared to being an officer, is associated with a higher risk of suicidal behaviors and that this high risk is present before and after joining the Army.

Finally, Baer et al. [1] evaluated hospitalized military psychiatric patients with and without a history of non-suicidal self-injury, combined with a history of at least one suicide attempt, where they were compared for severity of suicidal ideas. No significant differences were found.

5 Conclusion

The analysis of these articles provides important information on suicide in the armed forces, attending to warnings from the International Labor Organization that has been alerting towards the need to identify psychosocial factors in the workplace.

The articles analyzed provide important information on suicide in these institutions, arguing that it may be more prevalent among military components than in the civilian population due to presence of firearms. It also details on gender issues, the use of chemicals, and issues related to army enlisting, as these factors can influence suicidal thoughts and can lead to death.

No significant responses were found for the prevention of suicide and self-inflicted injuries in the military.

Further studies are important to bring additional empirical data on self-harm and suicide in the army and in work-related police organizations, as well as effective policies to address suicide prevention risks involving public safety workers.

References

1. Baer, M.M., LaCroix, J.M., Browne, J.C., Hassen, H.O., Perera, K.U., Weaver, J., Soumoff, A., Ghahramanlou-Holloway, M.: Non-suicidal self-injury elevates suicide risk among United States Military personnel with lifetime attempted suicide. Arch. Suicide Res. **22**(3), 453–464 (2018)
2. Botega, N.J.: Comportamento suicida: epidemiologia. Psicologia Usp **25**(3), 231–236 (2014)
3. Carlotto, P.A.C., Cruz, R.M., Guilland, R.: Riscos Psicossociais Relacionados ao Trabalho: perspectivas teóricas e conceituais. Revista Interamericana de Psicología Ocupacional **37**(1), 52 (2018)
4. Cohen, G.H., Fink, D.S., Sampson, L., Tamburrino, M., Liberzon, I., Calabrese, J.R., Galea, S.: Coincident alcohol dependence and depression increases risk of suicidal ideation among Army National Guard soldiers. Ann. Epidemiol. **27**(3), 157–163 (2017)
5. Delazar, R., Farahi, H.: Processing of suicidal thoughts and acts of religious ritual in patients with depression. Ardabil Univ. Med. Sci. J. **3**, 224–234 (2009)
6. Ennis, J., Fathi-Ashtiani, A., Soltaninejad, A., Amiri, M.: Prevalence of suicidal thoughts and associated factors among the soldiers. Mil. Med. J. **2**, 7–11 (2006)
7. Giusti, J.S.: Automutilação: características clinicas e comparação com pacientes com transtorno obsessivo-compulsivo. Doctoral dissertation, Universidade de São Paulo (2013)
8. Hajebi, A., Ahmadzeh-Asl, M., Zaman, M., Nasrbkht, M., Mohammad, N., Davwdi, F.: Suicides recorded in the system design. Iran J. Psychiatr. Clin. Psychol. **2**, 106–109 (2011)
9. Herberman Mash, H.B., Fullerton, C.S., Ng, T.H.H., Nock, M.K., Wynn, G.H., Ursano, R.J.: Alcohol use and reasons for drinking as risk factors for suicidal behavior in the US Army. Mil. Med. **181**(8), 811–820 (2016)
10. Herrra, A., Dahlblom, K., Dahlgren, L., Kullgren, G.: Pathways to suicidal behavior among adolescent girls in Nicaragua. Soc. Sci. Med. **62**, 805–814 (2006)
11. International Labour Organization (ILO): Work-Related Stress and Psychosocial Risks. (P. and D. B. (PRODOC) of the I. Document and Publications Production, Ed.), 8th edn. International Labour Office, Geneva (2017)
12. Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P.A., et al.: The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ **339**, b2700 (2009). https://doi.org/10.1136/bmj.b2700
13. Linehana, M., Rizvi, L.: Psychiatric aspects of suicidal behavior: personality disorders. In: Hawton, K., Heeringen, K. (eds.) The International Handbook of Suicide and Attempted Suicide. Wiley, New Jersey (2000)
14. Liu, X., Tein, J.Y., Zhao, Z.: Suicidal and correlates among rural adolescents of china. J. Adolsc. Health. **37**, 443–451 (2005)
15. Mash, H.B.H., Fullerton, C.S., Ramsawh, H.J., Ng, T.H.H., Wang, L., Kessler, R.C., Stein, M.B., Ursano, R.J.: Risk for suicidal behaviors associated with alcohol and energy drink use in the US Army. Soc. Psychiatry Psychiatr. Epidemiol. **49**(9), 1379–1387 (2014)
16. Matarazzo, B.B., Barnes, S.M., Pease, J.L., Russell, L.M., Hanson, J.E., Soberay, K.A., Gutierrez, P.M.: Suicide risk among lesbian, gay, bisexual, and transgender military personnel and veterans: what does the literature tell us? Suicide Life-Threat. Behav. **44**(2), 200–217 (2014)
17. Millner, A.J., Ursano, R.J., Hwang, I., King, A.J., Naifeh, J.A., Sampson, N.A., Zaslavsky, A. M., Stein, M.B., Kessler, R.C., Nock, M.K., STARRS-LS Collaborators: Lifetime suicidal behaviors and career characteristics among US Army soldiers: results from the Army Study to Assess Risk and Resilience in Servicemembers (Army STARRS). Suicide Life-Threat. Behav. **48**(2), 230–250 (2018)
18. Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A.: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst. Rev. **4**(1), 1 (2015)

19. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., The Prisma Group: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLOS Med. **6**(7), e1000097 (2009)
20. Nouri, R., Fathi-Ashtiani, A., Salimi, S.H., Soltani Nejad, A.: Effective factors of suicide in soldiers of a military force. J. Mil. Med. **14**(2), 99–103 (2012)
21. Ribeiro, J.D., Gutierrez, P.M., Joiner, T.E., Kessler, R.C., Petukhova, M.V., Sampson, N.A., Stein, M.B., Ursano, R.J., Nock, M.K.: Health care contact and suicide risk documentation prior to suicide death: results from the Army Study to Assess Risk and Resilience in Servicemembers (Army STARRS). J. Consult. Clin. Psychol. **85**(4), 403 (2017)
22. Santiago, E.S., Ribeiro, L.S.L.: Vivências subjetivas de psicólogos em seu dia a dia de trabalho: O contato com pacientes suicidas. Trabalho, Economia e Educação, Anais VI Seminário do Trabalho (2008)
23. Shakeri, J., Parvizifard, A., Sadeghi, K.H., Moradi, R.: Personality traits, stress, coping and religious attitudes in people with suicidal attempt. Razi Univ. Med. Sci. J. **1**(2), 6–9 (2000)
24. Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A.: Preferred reporting items for systematic review and metaanalysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. **349**, g7647 (2015)
25. Shelef, L., Fruchter, E., Spiegel, D.O., Shoval, G., Mann, J.J., Zalsman, G.: Characteristics of soldiers with self-harm in the Israeli Defense Forces. Arch. Suicide Res. **18**(4), 410–418 (2014)
26. Street, A.E., Gilman, S.E., Rosellini, A.J., Stein, M.B., Bromet, E.J., Cox, K.L., Colpe, L.J., Fullerton, C.S., Gruber, M.J., Heeringa, S.G., Lewandowski-Romps, L., Little, R.J., Naifeh, J. A., Nock, M.K., Sampson, N.A., Schoenbaum, M., Ursano, R.J., Zaslavsky, A.M., Kessler, R.C.: Understanding the elevated suicide risk of female soldiers during deployments. Psychol. Med. **45**(4), 717–726 (2015). https://doi.org/10.1017/S003329171400258X
27. Ursano, R.J., Kessler, R.C., Stein, M.B., Naifeh, J.A., Aliaga, P.A., Fullerton, C.S., Wynn, G. H., Vegella, P.L., Ng, T.H.H., Zhang, B.G., Wryter, C.L., Sampson, N.A., Kao, T.C., Colpe, L.J., Schoenbaum, M., McCarroll, J.E., Cox, K.L., Heeringa, S.G.: Risk factors, methods, and timing of suicide attempts among US Army soldiers. JAMA Psychiatry. **73**(7), 741–749 (2016). https://doi.org/10.1001/jamapsychiatry.2016.0600
28. Ursano, R.J., Kessler, R.C., Stein, M.B., Naifeh, J.A., Nock, M.K., Aliaga, P.A., Fullerton, C. S., Wynn, G.H., Ng, T.H.H., Dinh, H.M., Sampson, N.A., Kao, T.C., Schoenbaum, M., McCarroll, J.E., Cox, K.L., Heeringa, S.G.: Medically documented suicide ideation among US Army soldiers. Suicide Life-Threat. Behav. **47**(5), 612–628 (2017a). https://doi.org/10.1111/sltb.12316
29. Ursano, R.J., Kessler, R.C., Naifeh, J.A., Mash, H.H., Fullerton, C.S., Bliese, P.D., Zaslavsky, A.M., Ng, T.H.H., Aliaga, P.A., Wynn, G.H., Dinh, H.M., McCarroll, J.E., Sampson, N.A., Kao, T.C., Schoenbaum, M., Heeringa, S.G., Stein, M.B.: Risk of suicide attempt among soldiers in army units with a history of suicide attempts. JAMA Psychiatry. **74**(9), 924–931 (2017b). https://doi.org/10.1001/jamapsychiatry.2017.1925
30. World Health Organization: Country reports and charts available. Recuperado de www.who.int, acessado a 03/08/2019 (2014)

Social Workers' Exposure to Psychosocial Risks—A Case Study

Maria Manuel Sá and Rui Azevedo

Abstract Social work is considered a very strenuous work due to the constant exposure to conflicts, dilemmas and calls for help from troubled individuals. Although, an extensive number of papers have been published on psychosocial factors correlating with health outcomes, few have focus on the work performed by social workers. This study aims to identify the prevalence of aspects of the psychosocial environment of social workers that may impose risks to the Health and well-being. Thirty-five social workers of Private Social Solidarity Institutions (IPSS) from the Oporto metropolitan area were subjected to psychosocial risk assessment using the long version of COPSOQ II (validated to Portuguese population). The sample included social workers in the areas of gerontology, childhood, disable persons and Insertion Social Income (RSI) beneficiary. Results showed that social workers registered high values of depressive symptoms, stress and burnout especially for the childhood intervention area. Changes in work organisation increase of workers' autonomy and improvement of interpersonal relationship is required.

Keywords Psychosocial risk · Social worker · Emotional and cognitive demands · Burnout

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1 Introduction

Several economic changes such as growing globalization, different work methods, workers' mobility, the growing feminization of the labour force, new family concept and the progressive ageing of the population increased the need to offer care and support for vulnerable population groups which is usually provided by social workers.

The International Federation of Social Workers (IFSW) [1] define Social work as "a practice-based profession (…) that promotes social change and development, social cohesion, and the empowerment and liberation of people. Principles of social justice, human rights, collective responsibility and respect for diversities are central to social work (…) social work engages people and structures to address life challenges and enhance wellbeing".

High work rhythm, lack of recognition by management, difficulty to express feelings, job insecurity, mutual respect between colleagues, conflict between values, low job satisfaction, stress, lack of social support, lack of appropriate rewards, excessive workload are some of the factors that may induce risk factors [2–4].

Accordingly to the International Labour Organization [5] psychosocial factors can be defined as "interactions between and among work environment, job content, organizational conditions and workers' capacities, needs, culture, personal extra-job considerations that may, through perceptions and experience, influence health, work performance and job satisfaction".

Social workers are particularly exposed to psychosocial risks once their intervention is mainly focused in giving support to socially disadvantaged individuals, victims of domestic violence, homeless, drug addicts, or other specific cases [6] and do not have enough support or mechanisms to fulfil their job properly. Social workers were shown to have 1.5-fold higher risk of work disability due to mental disorders compared to other human service professionals [7, 8], revealing high rates of stress and burnout [6, 9–11]. In a three-year longitudinal study Kim et al. [12] showed that higher levels of burnout in the social workers led to a faster rate of deterioration in physical health.

Burnout is defined as a state of physical, emotional and mental exhaustion [13, 14]. Is also known as a chronic response to interpersonal stressors occurred in a work-related situation [9, 15].

The main objective of this case study is to identify the psychosocial risk factors to which social workers are exposed and to analyse the consequences of this exposure on these professionals.

2 Materials and Methods

The psychosocial work characteristics were measured by the long version of the COPSOQ II [16], the research questionnaire, validated for Portuguese version [17]. There were evaluated eight factors: Demands at work, Work organisation and job contents, Interpersonal relations and leadership, Work-individual interface, Values in the workplace, Health and well-being and Offensive behaviour. Also evaluates 41 dimensions of the psychosocial work environment: quantitative demands, emotional demands, influence, possibilities for development, degree of freedom at work, meaning of work, commitment to the workplace, predictability, quality of leadership, social support, feedback, social community at work, job insecurity, and job satisfaction. For all items, five response categories were used either with intensity (from "to a very large extent" to "to a very small extent") or frequency (from "always" to "never/hardly ever").

For the data collection, questionnaires were sent for 68 Private Social Solidarity Institutions (IPSS) from the Oporto metropolitan area. A total of 35 social workers delivered the questionnaire fully answered.

The relevance and objectives of the study were explained to the participants and requested informed consent. Questionnaires and informed consent were sent by e-mail ensuring the confidentiality and anonymity of respondents.

3 Results

3.1 Social Workers Sample

The sample comprised a total of 35 social workers, 32 (91.4%) females, 1 (2.9%) males and 2 (5.7%) omitted, age range from 27 to 60 years old, mean age of 35.6 years (SD: 8.1). All respondents have higher education, being predominant the college degree or diploma (51.4%), followed by the masters (22.9%), the bachelor degree (14.3%) and the Ph.D. degree (5.9%). In regards to the area of intervention, 11 individuals from the gerontology area replied to the questionnaire, 5 individuals from the childhood area, 7 from the Insertion Social Income (RSI) beneficiary area, 3 from the people with disability area and 9 belonging to non-specified areas.

3.2 COPSOQ II

Figure 1 presents the overall results on the COPSOQ II subscales by dividing the scores into tertiles, The factors that represented major risks to social workers' well-being were: emotional demands (66.7%) work pace (62.5%); cognitive demands (62.5%); burnout (45.7%); job insecurity (43.7%); stress (39.4%); demands for hiding emotions (38.7%), depressive symptoms (30.3%).

Table 1 presents the means and the standard deviations for the dimensions acquired for the sample. The means for the factors: Demands at work, Work organization job contents, Interpersonal relations and leadership, Personality and Offensive behaviour acquired for the sample of social workers show higher values than the reference values for the professional sector "Services and Trade". For the factor Health and well-being only the mean of Self rated health is lower, all other subscales are higher than the reference values.

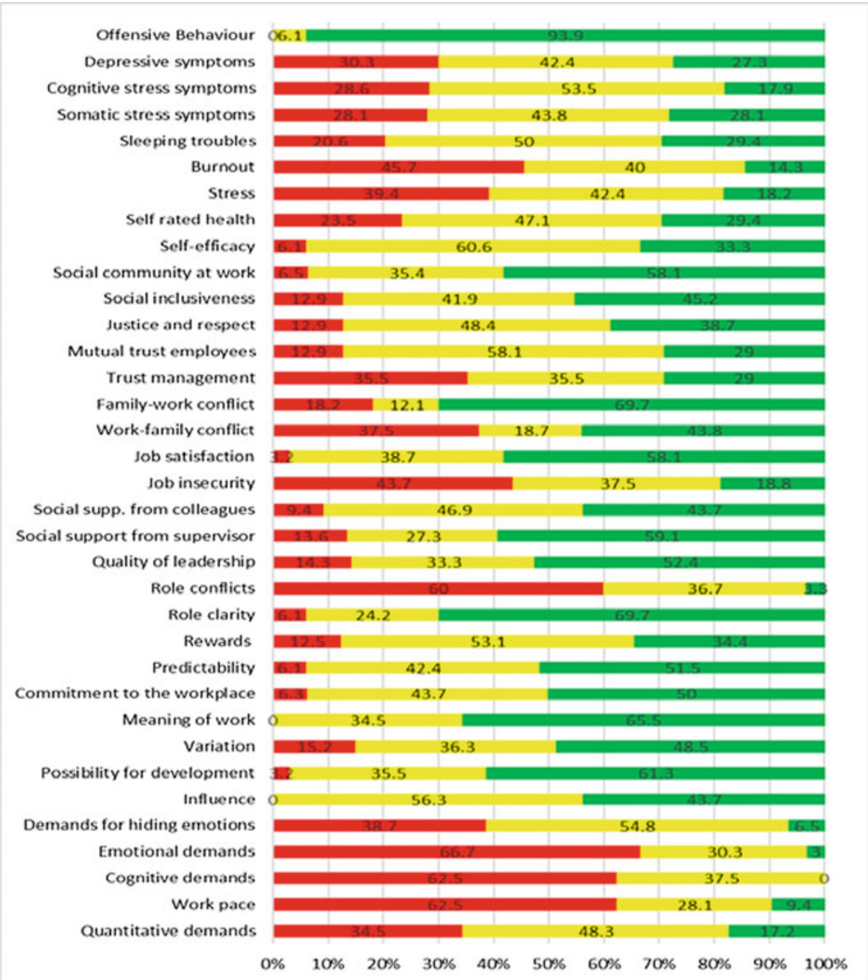

Fig. 1 COPSOQ II subscale tertiles for social workers

Table 1 Mean and standard deviation for the subscales and the T-test and *p*-values

	Social workers		Reference values			
	Mean	SD	Mean	SD	T-test	*P*-value
Demands at work						
Quantitative demands	3.29	0.79	2.31	0.81	6.66	**0.000**
Work pace	3.78	1.13	2.95	1.06	4.17	**0.000**
Cognitive demands	4.02	0.77	3.73	0.73	2.17	**0.037**
Emotional demands	4.05	0.82	3.20	1.19	5.98	**0.000**
Demands for hiding emotions	3.52	0.75	–	–	–	–
Work organisation job contents						
Influence	3.51	0.05	2.71	0.88	7.97	**0.000**
Possibility for development	4.03	0.76	3.69	0.87	2.50	**0.018**
Variation	3.48	1.03	–	–	–	–
Meaning of work	4.08	0.63	4.00	0.74	0.69	0.496
Commitment to the workplace	3.74	0.76	3.38	0.90	2.67	**0.012**
Interpersonal relations and leadership						
Predictability	3.56	0.87	3.09	0.96	3.10	**0.004**
Rewards	3.31	0.85	3.65	0.94	−2.25	**0.032**
Role clarity	3.89	0.70	4.15	0.78	−2.11	**0.043**
Work conflicts	3.54	0.61	2.94	0.71	5.38	**0.000**
Quality of leadership	3.69	1.15	3.38	0.99	1.23	0.232
Social support from supervisor	3.77	1.24	2.98	1.04	2.99	**0.007**
Social supp. from colleagues	3.59	0.89	3.38	0.85	1.36	0.483
Work-individual interface						
Job insecurity	3.14	0.94	3.62	1.39	−2.88	**0.007**
Job satisfaction	3.71	0.75	3.33	0.76	2.82	**0.008**
Work-family conflict	3.29	1.46	2.60	1.04	2.67	**0.012**
Family-work conflict	2.19	1.32	–	–	–	–
Values in the workplace						
Trust management	3.65	0.45	3.65	0.69	−0.06	0.952
Mutual trust employees	3.26	0.75	2.74	0.74	3.83	**0.001**
Justice and respect	3.33	0.96	3.29	0.87	0.24	0.815
Social inclusiveness	3.44	0.86	–	–	–	–
Social community at work	3.79	1.02	3.95	0.86	−0.84	0.407
Personality						
Self-efficacy	3.46	0.69	3.99	0.73	−4.34	0.000
Health and well-being						
Self rated health	2.91	0.90	3.40	0.95	−2.02	0.052
Stress	3.20	0.88	2.68	0.90	3.36	**0.002**
Burnout	3.37	0.89	2.62	0.96	4.97	**0.000**
Sleeping troubles	3.00	0.90	2.44	1.04	3.61	**0.001**

(continued)

Table 1 (continued)

	Social workers		Reference values			
	Mean	SD	Mean	SD	T-test	*P*-value
Somatic stress symptoms	2.87	0.99	–	–	–	**–**
Cognitive stress symptoms	3.05	0.89	–	–	–	**–**
Depressive symptoms	2.92	1.00	2.36	0.91	3.24	**0.003**
Offensive behaviour						
Offensive behaviour	1.29	0.42	1.25	0.49	0.59	0.562

The One Sample t Test was used to test the statistical difference between the sample mean and the mean value for the professional sector "Services and Trade".

4 Discussion and Conclusion

The results showed that social workers that work in Private Social Solidarity Institutions (IPSS) in the Greater Oporto area registered higher values than the reference values from the national services. According to the one sample T-test several of the subscales registered significant statistical differences from the mean reference values for the professional sector (Table 1).

In the "Work Demands" factor, all the subscales registered significantly higher values when compared to the reference values (emotional and quantitative demands and work pace: p-value < 0.01; cognitive demands: p-value < 0.05). The elevated values obtained for "Work Demands" factor can have an impact in the amount of conflicts in the workplace and with the family ("Role Conflicts", "Work-family conflict" with 60 and 37.5% of risk to the health). It is important to highlight that social workers often work over time in order to finish their tasks, decreasing the time spent with their families. The conflict work-family results from an incompatibility between work and family responsibilities [18, 19]. The work overload and the increase of administrative work are often referred as problems in the professional performance of the social workers [20].

What concerns with "Work organisation jobs contents" factor, all the subscales registered higher values, but only three revealed a statistical significance (Influence: p-value < 0.01; Possibility for development: p-value < 0.02; Commitment to the workplace: p-value < 0.02). However, these values are beneficial to the worker's health.

In relation to the "Interpersonal relations and leadership" factor there is a health favourable situation with the increase of the Quality of leadership, Social support from colleagues, Social support from the supervisor and Predictability, these last two with a statistical significance (both with a p-value < 0.01). Nevertheless, the increase in "Role conflicts" (p-value < 0.001) and the decrease of the "Role clarity" and "Rewards" (both with a p-value < 0.05) place a risk to the worker's health. The value registered for the subscale "Mutual trust employees" were higher than the mean reference values (p-value < 0.001). We can conclude that conflicts are related with work demands and not with bad relationship with the leadership or in-between co-workers.

Relationships in the context of service that some professionals develop with clients require a continuous and intense level of personal and emotional contact leading to exhaustion and stress [21]. On the other hand, social workers have the possibility to help others and establish better life conditions to disadvantaged people making this profession challenging and rewarding [22]. The results obtained in this study seem to be in accordance with this reality. In fact, the mean results for "Job satisfaction" are high (58.1%) and higher than the reference values (p-value < 0.001). However, the subscales of "Health and well-being" showed a health risk situation, (45.7% Burnout; 39.4% Stress; 30.3% Depressive Symptoms; 28.6% Cognitive Stress Symptoms; 28.1% Somatic Stress Symptoms and 20.6% Sleeping Troubles). The means of these subscales, when compared to those of the reference, are significantly higher (Stress, Burnout, Sleeping troubles and Depressive Symptoms p-value < 0.001 for all). These results are in agreement with Pines and Aronson [14] who consider burnout as a state of physical, emotional and mental exhaustion caused by long-term involvement in emotionally stressful situations.

The human service professionals place higher expectations with their success to help others. When they fail in achieving this goal, even though their efforts, a feeling of frustration and disability that enhances burnout is created [23]. Travis et al. [19] also considered social workers a profession with high-risk of stress and burnout.

In general, we can conclude that this sample of Portuguese social workers from the Greater Oporto area is exposed to psychosocial risks, in particular stress and burnout.

Further research should be made in order to enlarge the sample and analyse the risk factors related with the task performed by social workers and purpose control measures to improve health and wellbeing of these professionals.

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References

1. IFSW: International Federation of Social Workers. Retrieved from https://www.ifsw.org/what-is-social-work/global-definition-of-social-work/ (2014)
2. Maslach, C., Leiter, M.P.: The Truth About Burnout: How Organizations Cause Personal Stress and What to Do About It. Jossey-Bass, San Francisco, CA (1997)
3. Silva, J., Silva, L., Gontijo, L.A.: Relationship between psychosocial factors and musculoskeletal disorders in footwear industry workers. Production **27**, 1–13 (2017)

4. Afonso, L.: Comparativo da prevalência de sintomas músculo-esqueléticos em trabalhadores de duas empresas da indústria do calçado: setor da costura. Dissertação apresentada para obtenção do grau de Mestre Engenharia de Segurança e Higiene Ocupacionais. Faculdade de Engenharia da Universidade do Porto, Porto (2013)
5. International Labour Organization: Psychosocial Factors at Work: Recognition and Control. ILO-WHO, Ginebra (1984)
6. Hussein, S.: Work engagement, burnout and personal accomplishments among social workers: a comparison between those working in children and adults' services in England. Adm. Policy Ment. Health Ment. Health Serv. Res. **45**(6), 911–923 (2018)
7. Rantonen, O., Alexanderson, K., Pentti, J., Kjeldgård, L., Hämäläinen, J., Mittendorfer-Rutz, E., Kivimäki, M., Vahtera, J., Salo, P.: Trends in work disability with mental diagnoses among social workers in Finland and Sweden in 2005–2012. Epidemiol Psychiatr. Sci. **26**(6), 644–654 (2017)
8. Rantonen, O., Alexanderson, K., Clark, A., Aalto, V., Sónden, A., Brønnum-Hansen, H., Hougaard, C., Rod, N., Mittendorfer-Rutz, E., Kivimäki, M., Oksanen, T., Salo, P.: Antidepressant treatment among social workers, human service professionals, and non-human service professionals: a multi-cohort study in Finland, Sweden and Denmark. J. Affect. Disord. **250**, 153–162 (2019)
9. Maslach, C., Schaufeli, W.B., Leiter, M. P.: Job burnout. Annu. Rev. Psychol. **52**, 397–422 (2001). Retrieved from https://dx.doi.org/10.1146/annurev.psych.52.1.397
10. García, R.G., Sangregorio, M.A., Sánchez, M.L.: Factorial validity of the Maslach Burnout Inventory-human services survey (MBI-HSS) in a sample of Spanish social workers. J. Soc. Serv. Res. **45**(2), 207–219 (2019)
11. Wang, Y., Zhang, H., Lei, J., Yu, Y.: Burnout in Chinese social work: differential predictability of the components of the Maslach Burnout Inventory. Int. J. Soc. Welfare **28**(2), 217–228 (2019)
12. Kim, H., Ji, J., Kao, D.: Burnout and physical health among social workers: a three-year longitudinal study. Social Work **56**(3), 258–268 (2011). https://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,cookie,shib,uid&db=eric&AN=EJ936087&lang=pt-pt&site=eds-live&scope=site. Accessed 22 Oct 2019
13. Pines, A.M.: The burnout measure short version (BMS). Int. J. Stress Manag. **12**, 78–88 (2005)
14. Pines, A.M., Aronson, E.: Career Burnout: Causes and Cures. Free Press, New York, NY (1988)
15. Leiter, M.P., Bakker, A.B., Maslach, C.: Burnout at Work. Taylor & Francis, New York (2014)
16. Kristensen, T., Hannerz, H., Hogh, A., Borg, V.: The Copenhagen psychosocial questionnaire—a tool for the assessment and improvement of the psychosocial work environment. Scand. J. Work Environ. Health **31**(6), 438–449 (2005)
17. Silva, C.F., Cotrim, T.P., Amaral, V., Bem-Haja, P.: Copenhagen Psychosocial Questionnaire – COPSOQ - Portugal e Países Africanos de Língua Oficial Portuguesa. Versão portuguesa do COPSOQ (2011); de Kristensen, T. et al.: "Medição do Índice de Capacidade Humana para o Trabalho em Trabalhadores Portugueses". PTDC/SAU-ESA/66163/2006 - FCT - Fundação para a Ciência e a Tecnologia (2000)
18. Boyas, J., Wind, L.: Employment-based social capital, job stress, and employee burnout: a public child welfare employee structural model. Child. Youth Serv. Rev. **32**(3), 380–388 (2010)
19. Travis, D., Lizano, E., Barak, M.: I´m so stressed!: a longitudinal model of stress, burnout, and engagement among social workers in child welfare Settings. Br. J. Soc. Work **46**, 1–20 (2015)
20. Kim, H., Ji, J.: Factor structure and longitudinal invariance of the Maslach Burnout Inventory. Res. Soc. Work Pract. **9**(3), 325–339 (2009)
21. Maslach, C., Leiter, M.P.: Understanding the burnout experience: recent research and its implications for psychiatry. World Psychiatry **15**(2), 103–111 (2016)

22. Evans, S., Huxley, P., Gately, C., Webber, M., Mears, A., Pajak, S., Medina, J., Kendall, T., Katona, C.: Mental health, burnout, and job satisfaction among mental health social workers in England and Wales. Br. J. Psychiatry **188**, 75–80 (2006)
23. Silva, V., Hewage, C., Fonseka, P.: Burnout: an emerging occupational health problem. Galle Med. J. **14**, 52–55 (2009)

The Invisibility of Occupational Diseases: The Relationship Between Working Conditions and the Diagnosis of Prostate Cancer

Mariana Macedo and Liliana Cunha

Abstract An occupational disease results from exposure to risk factors in the course of work. Although cancer is the main cause of death among occupational diseases, many cases remain unreported, with an impact both on the reparation of victims and on the prevention of the risks that determined its expression. The present study analysed this problem, based on the evidence of 13 cases of prostate cancer in a steel smelting section of a metallurgical industry in northern Portugal. The information was obtained through interviews and the application of the Inquérito Saúde e Trabalho (INSAT), on former workers and actors involved in occupational safety and health (OSH). The results showed that the steel smelting and working conditions—in particular, rotating shifts works, exposure to hazardous substances, electromagnetic fields and radioactivity are risk factors for the health of workers, with a decisive effect on the manifestation of prostate cancer. However, several obstacles prevented the certification of the disease as an occupational disease and the adoption of preventive and compensating measures.

Keywords Prostate cancer · Steel smelting · Working conditions

1 Introduction

Cancer is the main cause of death in the European Union, accounting for 53% of work-related deaths [1]. However, there are still few studies that focus on the role that work can play in the likelihood of developing chronic diseases such as cancer.

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As work is a predominant context of life and, sometimes, of continuous exposure to different professional risks, it is necessary to give visibility to its impact on health, either as a determining or aggravating factor of its health status. Furthermore, as a circumscribed context in space, it has a greater potential for intervention and primary prevention [2]. However, the effects of work are often ignored [3] perpetuating the trend of underreporting occupational cancer [4]. In Portugal, the process of certification of occupational diseases is often hampered by the lack of medical or company action [5]. In addition, there is still a lack of action by the European Union in the field of research on the certification of occupational diseases and the management of occupational risks [4], which would enable these processes to be standardized at European level; and the creation of joint action protocols [1], which is crucial for the consolidation of knowledge on this issue.

This study focused on the specific situation of the emergence of several cases of prostate cancer in a metallurgical industry, based on the testimony of some of the affected workers and some key actors regarding occupational safety and health. A few studies have already shown that some working conditions in this sector can be a determining or aggravating factor on prostate cancer manifestation, such as own steel casting activity [6], exposure to the metal as cadmium [7] or rotating shifts works [8].

2 Objectives

This present study concerns an exploratory study of qualitative nature, with evidence from 13 confirmed cases of prostate cancer, as previously mentioned, in 125 workers in the steel section of a metallurgical industry in northern Portugal in 2013/2014. The request that underpinned the study was formulated by the Union of Workers in the Manufacturing, Energy and Environmental Activities of the North, with the aim of identifying work risk factors associated with a perceived impact on the manifestation of this type of cancer.

Based on the research question "What are the difficulties in building a causal connection between work and prostate cancer?" were formulated five objectives. For the sake of the article's own limitations, we will privileged the following: to describe the working conditions and risk factors of steel working and their impact on workers' health; to assess the effect of occupational exposure of steel working on prostate cancer propensity; to identify the obstacles to certification of this cancer as an occupational disease. It will be transversal in this analysis, the assumption from the point of view of former workers and actors involved who have responsibilities in OSH matters, who know or intervened in this specific reality.

3 Methodology

3.1 Participants and Material

The sample consisted of five former steel casting workers and four actors with areas of expertise in OSH. Despite the fact that the sample had a limited number of participants, given that two workers had already died; it was not possible to establish contact with some of them; and the others refused to participate in the study, a methodological plan was defined for the in-depth analysis of the five cases considered.

Workers were aged between 63 and 70 (M = 66), seniority in the company was between 33 and 42 (M = 37.2), and the diagnosis of prostate cancer was between 58 and 61 (M = 60) (Table 1).

The four actors involved in occupational safety and health—the union leader (P1), the representative of the company's workers' committee (P2), the leader of the union's occupational diseases department (P3), and the urologist responsible for some of the diagnoses (P4) were aged between 40 and 52 years (M = 47.25) (Table 2).

The privileged methods for data collection were the interviews and the INSAT survey [9]. The construction of the interview guides should have been based in a prior analysis of work activity in real context, but the company didn't authorize the visit to its premises. However, the testimony of the former workers and the workers' representatives and the medical opinion of the urologist allowed an in-depth view on the problem analysed. The interview guide covered the following domains: working conditions; company characterization; history of occupational risk exposure; and prostate cancer manifestation. INSAT was used as an instrument of dialogue with the workers [10], about the relationship between work and health.

Table 1 Characterization of former workers

Code	Sex	Age	Seniority in the company	Diagnosis age
T1	Male	70	38	61
T2	Male	66	42	61
T3	Male	63	33	58
T4	Male	65	36	60
T5	Male	66	37	61

Table 2 Characterization of OSH actors

Code	Sex	Age	SST actors—status
P1	Male	49	Union leader
P2	Male	52	Representative of the Company's Workers' Committee
P3	Male	48	Leader of the union's occupational diseases department
P4	Male	40	Medical urologist

3.2 Data Collection and Analysis

Data collection was divided into the following: two collective interviews with former workers and some actors working on OSH; individual and collective completion of the INSAT by the former workers; and an interview with the urologist (Table 3).

With the exception of the latter, an audio recording was made, authorized by the participants (after due informed consent). Throughout this process, the information that was collected was always returned and validated.

The full transcription and floating analysis of the collective interviews were performed, which allowed the categorization of potentially carcinogenic risk factors based on scientific evidence and also the collection of some information on the professional paths of former workers. These results were validated by the participants and restructured. After the application of the INSAT, the answers were analysed and comments were transcribed as they were filled in, with reference to concrete examples, to the debate of some questions raised and also the doubts and reflections that emerged, and they were recorded in audio. The Descending Hierarchical Classification, made by the support software for content analysis IRAMUTEQ, allowed the identification of more prominent contents in collective interviews. Finally, we promoted the articulation of the results obtained by different data collection methods and the comparison with the scientific literature on this

Table 3 Data collection schedule (2019)

Context	Day	Location	Duration	Participants	Aim
1st and 2nd collective interview	03/01	Union premises	2 h 15	P1, P2, T1, T2	– Characterize working conditions and risk factors of the steelworks and the workers' professional paths
	15/02		1 h 57	P1, P2, P3, T1, T2, T3, T4, T5	– Same purposes to the 1st collective interview – Determine perceived association: work performed—cancer
Interview-urologist	14/03	Work psychology atelier-FPCEUP	1 h	P4	– Medical opinion on cases of prostate cancer (anatomy, physiology, diagnosis, treatment, risk factors)
INSAT	14/03	Union premises	2 h 20	T1	– Restitute/validate interviews data – Obtain each worker's view on working conditions—variations during professional path and specific health problems
	02/04		2 h 14	T2, T3	
	15/04		1 h 15	T5	

subject. The data collection and analysis focused on three content categories: occupational risk factors; prostate cancer manifestation and a certification as an occupational disease; and professional path, corroborated by IRAMUTEQ analysis.

4 Results and Discussion

4.1 Risk Factors

In order to organize the risk factors perceived by workers, the first to be presented are those that have a more direct impact on the expression of cancer, including prostate cancer, and then those with a less severe effect on health, but deserving equal attention.

According to the International Agency for Research on Cancer [11], the "Iron and steel casting" activity is classified as carcinogenic to humans, with a higher risk of prostate cancer in workers in this sector [6]—"that is a very harmful industry (…) only those who know it from within know how burdensome it is" (T4).

The production process results in exposure to hazardous substances, in dust, gases and vapours and with various harmful effects on health. This article will present only some elements that have a determining effect on the propensity to cancer, in particular, lead, aluminium, cadmium, silica and asbestos.

According to the workers, lead and aluminium should be removed from steel scrap before casting because they are elements that weaken it. However, this extraction was not stipulated and sometimes the spectrometers were not calibrated to detect these substances. Considering the carcinogenic potential of lead and aluminium [11], the inhalation of these elements by the workers is a risk factor for health, highlighting the effects of lead on the renal and reproductive system [12]—"(…) 40 years ago the company was accused, workers were impotent due to lead" (T1).

Cadmium was one of the elements often added to the smelting process by giving certain specific characteristics to steel. Exposure to this element is associated with a higher propensity to various types of cancer, including prostate cancer [7].

Silica, one of the most frequent dust in the steelmaking, is considered carcinogenic to humans, particularly for lung cancer [11]. Continuous exposure to this substance can cause occupational disease silicosis [13], as one of the workers said: "I have an occupational disease which I caught at the very beginning (…) we worked a lot with silica refractories (…)" (T2).

In the early years of the company, the workers wore asbestos suits and protection plates because of the heat insulating properties—"We had these big plates of pure asbestos, when there was a steel spill on the floor, we would put that asbestos on top so we could go to work, as it smothered the heat (…) the asbestos burned and when we went out, it was dust!" (P2). The carcinogenic nature of asbestos exposure and inhalation [11] is widespread and its potential in the manifestation of various respiratory diseases (e.g. lung cancer), which manifest themselves between 35 and 40 years after exposure [13].

The casting of the steel through the electrodes in electric furnace assumes the formation of electromagnetic fields. Despite the legislation, there was no signing of the area of influence of these fields [14] and no training was given to workers on safety strategies to adopt towards this risk factor. The "extremely low electromagnetic fields" are a possible human carcinogen [11], and one of the main effects of exposure is the warming of some parts of the body [14], such as the eyes—"It was aggravated [the degenerative problem in vision]. Just the intensity of the electrodes melting the scrap metal" (T3) and the testicles—"(…) that heat up there, I had to leave everything because I was already burning here between my legs" (T3).

The cobalt ampoules, used to control the level of steel in the mould where it solidifies, have radioactivity. The damage that cobalt causes to DNA through death or cellular mutation [15], characterizes this element as having a carcinogenic effect on humans [11]. However, the workers were not trained in the handling of the ampoules and the risks of this exposure—"(…) people would carry them by hand … pure and simple, it is their own ignorance" (T1). According to the representative of the workers' committee, although the occupational doctor was aware of the dangerousness of this element, the doctor said that it did not have any harmful effect on workers' health.

Rotating shifts works, alternating between day and night shifts, were also one of the main risk factors highlighted by workers. Several studies have shown an increased propensity to prostate cancer due to changes in the body caused by shift work—loss and sleep disorders; inhibition of genes in charge of circadian rhythm that can affect cell proliferation; and also suppression of melatonin production due to exposure to artificial night light, which increases the sex hormones and the propensity of cancers originated by hormones [8].

Workers also mentioned other working conditions that are risk factors with perceived negative effects on their health and well-being, since these made the work environment more physically demanding. Thus, steel smelting presumes continuous exposure to very high noise levels resulting from the processes of the electric furnace; to very intense rhythm of work associated with the stipulated production targets; and to very high temperatures, which are necessary and inherent to steel smelting.

Finally, according to participants testimony's, the company's performance in terms of security is also a risk factor. Workers mentioned that the company, in order to comply with the exposure limit values, tampered with the monitoring of occupational exposure and did not warn them about the risks of exposure (e.g. through training). At the beginning of the company's labouring, there was a lack of awareness and legislation for the use of protective equipment. In addition, the workers admitted that they sometimes did not use personal protective equipment because it impaired their performance. They consider that the increase in collective protective equipment (e.g. furnace protection) is the result of pressure from the public, political and media in regard to the pollution, and not due to an effective policy of workers protection.

4.2 The Perceived Effect of the Work on General Health and Prostate Cancer

The workers identified the determining and/or aggravating role of work in the health problems they had, considered as less serious (e.g., sleep, hearing, vision and stomach problems, musculoskeletal injuries). Throughout the research, these workers also reinforced the idea of an association between their work activity and the manifestation of prostate cancer, which is considered to be the most serious problem.

Representatives of the trade union and the workers' committee recognize the harmful impact of this work environment on the health of these workers and its translation into the causal link between work and prostate cancer. For the urologist, this work context is aggravating the health state of workers; although he considers it unwise to establish a causal relationship with prostate cancer, he recognizes the possibility of this activity increasing the propensity for pathology.

It is also important to view the positioning of the company in relation to the effect of this work environment on the health of workers, according to the point of view of the participants. Thus, according to the former workers and the representative of the workers' committee, the company, despite the growing implementation of protective equipment, constantly adulterates the process of monitoring of occupational hazards—"And when they do these tests inside they always reduce [the labouring] to a minimum (…) if they come to measure the heat, they will always do it when we are not moving" (T2). Also, the company does not connect them with the clinical process of workers, making it difficult to identify a link between work and health. The representative of the workers council also revealed that the company also refused to carry out a study on prostate cancer cases. Finally, based on the testimony of workers, the occupational physicians did not report the cases to Departamento de Proteção contra os Riscos Profissionais do Instituto da Segurança Social (DPRP—ISS) to confirm the diagnosis, referring them only to an outsider doctor of the company.

4.3 Underreporting Prostate Cancer as an Occupational Disease

This study allowed to identify some of the obstacles that prevented the certification of this pathology as an occupational disease, according to the participants' testimony.

First, the characteristics of prostate cancer—its multifactorial origin, whether individual and/or environmental factors, and the long latency period between exposure and disease manifestation [16], make it difficult to establish a causal link between the steel smelting environment and disease incidence.

The workers' testimony showed that the occupational physicians did not report these cases to DPRP-ISS. The urologist was unaware of the actual incidence of prostate cancer in this section of the company. He also revealed that the focus of his work is not the screening of risk factors, but the treatment and cure of cases that arise.

From the perspective of the representative of the workers and workers' committee, the company did not express interest in developing a study with an urologist to investigate the incidence of the disease; the company failed to comply with legislation on health and safety at work, through the adulterated monitoring of occupational exposure and the lack of articulation with the workers' medical history; the company concealed the data on diseases triggered or aggravated by work; and the company did not transmit to workers the risks to which they were exposed and the possible consequences, preventing the connection with emerging health problems.

5 Conclusions

This research allowed to signal the working conditions of the steel smelting, the working practices, and insufficient action to ensure the safety of workers as harmful to health. Scientific evidence showed the negative and carcinogenic effect of these conditions on health (e.g. exposure to aluminium, lead, electromagnetic fields, radioactivity), in particular in increasing the propensity for develop prostate cancer.

It should be noted that, in addition to the ethical nature—offering visibility to a problem common to several workers, this study allowed them to become aware of the incidence of prostate cancer, the risks to which they were exposed and its effects on health. We assume that awareness of these former workers, even if in itself is not sufficient for the transformation of this work situation, was useful to reveal the malfunctioning of the company and avoid the emergence of similar cases.

In addition to the obstacles referred to in Chapter 3.3, the current situation also hampers the process of certifying occupational diseases. At national level, weaknesses in this field include the scant reporting of suspected cases to the DPRP-ISS and the lack of disclosure of official figures and risk factors [5]. At European level, the lack of standardization of procedures between countries, culminates in a management of professional risk factors based on economic interests (cost–benefit type) [1]. The increase in joint action protocols (e.g. sharing of information on each company at national and European level) [1] would make it possible to better substantiate the processes of certification of occupational diseases and management of occupational risks, emphasizing work as a determining factor [4]. These obstacles prevented the certification of this disease and the consequent intervention at the level of concrete working conditions. That is, as the cases were not reported to the DPRP-ISS, complementary evaluations were not performed to confirm the diagnosis of professional prostate cancer. Therefore, no measures, either curative/compensating or preventive (e.g. changes in working conditions to reduce or eliminate the risks) were taken.

This study is intended to contribute to the efforts of workers' representatives (e.g. trade union) and the local community (e.g. public health physician in the region), namely through the analysis of the work situation of workers currently working in this context (e.g. observation of the actual work, consultation of health indicators), with a sight to avoiding the reproduction of this type of cases.

References

1. Vogel, L.: Cancer at Work: More Needs to be Done to Achieve Better Legislation. HesaMag, 14. European Trade Union Institute (2016)
2. Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work. Official Journal of the European Communities: No. L 183/1
3. Barros-Duarte, C., Lacomblez, M.: Saúde no trabalho e discrição das relações sociais. Laboreal, **II**(2), 82–92 (2006)
4. Takala, J.: Eliminating Occupational Cancer in Europe and Globally. European Trade Union Institute, Brussels (2015)
5. Castro, M., Moreira, S., Santos, S. Doenças Profissionais na Região de Lisboa e Vale do Tejo no ano de 2003: um contributo para o diagnóstico e prevenção. Centro Regional de Saúde Pública de Lisboa e Vale do Tejo (2004)
6. Redmond, C.K., Wieand, H. S., Rockette, H. E., Sass, R., Weinberg, G.: Long-term experience of steelworkers. National Institute for Occupational Safety and Health, Cincinnati, OH. DHHS, NIOSH Publ., pp. 81–120 (1981)
7. Fernandes, L., Mainier, F.: Os riscos da exposição ocupacional ao cádmio. Sistemas e Gestão **9**, 194–199 (2014)
8. Behrens, T., Rabstein, S., Wichert, K., Erbel, R., Eisele, L., Arendt, M., Dragano, N., Brüning, T., Jöckel, K.H.: Shift work and the incidence of prostate cancer: a 10-year follow-up of the German population-based cohort study. Scand. J. Work Environ. Health **43** (6), 560–568 (2017)
9. Barros-Duarte, C., Cunha, L., Lacomblez, M.: INSAT–uma proposta metodológica para análise dos efeitos das condições de trabalho sobre a saúde. Laboreal **3**(2), 54–62 (2007)
10. Cunha, L., Nogueira, S., Lacomblez, M.: Beyond a man's world: methodological contributions of considering gender when studying bus drivers' activity. Work **47**(4), 431–440 (2014)
11. International Agency for Research on Cancer: Agents Classified by the IARC Monographs, Volumes 1–123. Lyon, International Agency for Research on Cancer (2019)
12. Silva, J.: Exposição Profissional a Chumbo: utilização da protoporfirina-zinco (PPZ) na vigilância de saúde de trabalhadores expostos (Doctoral dissertation in Occupational Health). Escola Nacional de Saúde Pública Universidade Nova de Lisboa, Portugal (2002)
13. Decreto Regulamentar nº. 76/2007 de 17 de julho. [Portuguese Regulatory Decree No. 76/2007 of July 17]. Diário da República, 1º série – Nº. 136. Ministério do Trabalho e da Solidariedade Social, Lisboa

14. European Commission: Non-Binding Guide to Good Practice for Implementing Directive 2013/35/EU "Electromagnetic Fields" Volume 1: Practical Guide. Publications Office of the European Union, Luxembourg (2015)
15. United Nations Environment Programme: Radiation: Effects and sources (2016)
16. Direção Geral de Saúde. Informação Técnica 09/2014 da DGS relativa ao "Diagnóstico, conhecimento, prevenção e reparação da doença profissional" (2015)

Type II Violence in Portuguese Nursing Homes: Contributions to its Characterization

Andreia Ribeiro, Isabel Silva and Pedro M. Arezes

Abstract This article aims at contributing to the characterization of the phenomenon of violence practiced by institutionalized elderly people on "non-technical" care providers in Portugal. A cross-sectional, descriptive and quantitative study was carried out involving nine Particular Institutions of Social Solidarity of Braga and Oporto districts, wherein data on Type II Violence was collected via a questionnaire. The study included 156 workers, who did not belong to the technical staff of the institutions (mostly geriatric assistants) and those who, in the exercise of their functions, provided care for the institutionalized elderly. The results indicated that 64.7% reported having suffered from, at least, one type of violent behavior on the part of patients in the last 12 months. Psychological violence was the most reported, with emphasis on the *threat of complaint to superiors* (46.9%), while the most identified physical violence behaviors were *scratching/pinching* (44.4%), *being held* (35%), *kicking* (29.9%), *spitting* (29.6%), and *beating* (26.8%). The professionals who reported the occurrence of violent behaviors to the employer were those who presented a higher perception of severity as compared to those who did not report such behaviors. Although this is a pioneering study in Portugal, the results show that Type II Violence (both physical and psychological) is a common reality in nursing homes in the Northern Region of the country. Similar to Northern European studies, the phenomenon is normalized and underreported, which makes it difficult to implement strategies to prevent and combat this problem.

Keywords Workplace violence · Care sector · Institutionalized elderly

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1 Introduction

Psychosocial risks in the workplace are one of the biggest challenges for workers' health and safety, including violence at work. In fact, the phenomenon of violence at work has aroused growing interest, even though the real size of the problem is fundamentally unknown [1], and there is, on the other hand, great heterogeneity among sectors of activity. Chappell and Di Martino [2] analysis in different occupations and in different countries indicated that "working in contact with the public" or "working with people in stress" constituted important risk factors in terms of exposure to violence at work, constituting the health one of the most exposed sectors. In contrast to the hospital context, the research of violence at work in the context of care delivery in nursing homes is much scarce [3, 4] and a unrecognized phenomenon. However, with the increasing ageing of population, the violence of institutionalized elderly people towards health professionals is a theme that has drawn more attention, especially in Northern European countries [3, 5–7]. Characteristics of institutionalized elderly such as states of dementia, pain or sex are associated with their violence towards care providers; most incidents are occurring during the provision of direct care (hygiene, bathing, dressing, and feeding) [6].

1.1 Perception of Violence at Work in a Geriatric Context

The study of violence in the geriatric context has been conducted considering the elderly as a victim [8, 9], but also from the perspective of caregivers [3, 5], which will be the focus of the present work. Workplace violence can be defined as "any action, incident or behavior that departs from reasonable conduct, in which a person is assaulted, threatened, harmed, injured in the course of, or as a direct result of, his or her work" (p. 4) [10]. It has two types: physical and psychological violence. According to the World Health Organization (WHO), the first type of violence is related to the "use of physical force against another person or group that results in physical, sexual, or psychological harm", while the second type of violence is related to "intentional use of power against another person or group that may result in damage to physical, mental, spiritual, moral, or social development" (p. 4) [11]. The WHO also differentiates the concept of violence at work in three categories, and one of them, designated as type II, refers to violence directed at professionals by clients, patients, students, and inmates among others. The social services and health workers are particularly exposed to this type of violence [12].

Sharipova et al. [3] investigated the exposure to physical violence at work in approximately 10,000 caregivers of Danish elderly, and the results indicated relatively high prevalence values. In fact, in the year preceding the study, about 1/4 caregivers had been exposed to physical violence, with 5.6% of these professionals being exposed to a daily/monthly frequency. In this study, the most frequent behaviors identified were hitting (63%), scratching/pinching (62%), being held

(32%), and kicked (27%). On the other hand, the less frequent behaviors were related to the use of weapons, hitting, or shooting with an object corresponded to 2% of the incidents. In Slovenia [13], nursing teams found that the violence by patients in nursing homes in the last year was mainly verbal (71.1%), followed by physical violence (63.8%), and sexual harassment (35.5%). Joseffson and Ryhamar [7] evaluated the Swedish geriatric context and found that approximately half of the 212 interviewed nurses had been subjected to violence. Specifically, 42% of the professionals had experienced acts of violence by the care recipients, 48% indirect threats, and 40% direct threats of active violence. In the remaining European context, although research is scarce, overall the results obtained are in the same direction. For example, a study conducted in Barcelona [14] evaluated the phenomenon of type II work violence in nursing homes, and observed that 61% of respondents reported having been assaulted by the elderly in the last 12 months. Another type of violence studied has been the vicarious experience, although in a much scarcer way. Studies such as Joseffson and Ryhamar [7] indicate that 45% of the nursing professionals in the sample witnessed violent acts against coworkers in the context of providing care to the elderly. For its part, the study by Eker et al. [15], carried out in the hospital context, indicated that 73% of the professionals had witnessed violence. Nevertheless, despite the scarcity of data of this type of violence, the data presented above indicate “indirect exposure” as an important source of exposure to violence.

Violence in health professionals has varied repercussions: early abandonment of the profession [16], burnout [17], low levels of mental energy, work capacity, participation, decision-making, and high levels of stress [18]. The negative repercussions of violence at work are not exclusive to caregivers and can also be reflected in the services provided [15, 18]. For example, Eker et al. [15] studied the frequency of exposure to violence and aggression of health professionals in Turkish hospitals and its consequences were assessed. The results indicated that 1/3 of the professionals were exposed to violence at least once in the last year, and half of them stated that their behavior towards patients was negatively influenced; 44.7% reported having reduced communication with patients and their families, 22.3% avoided medical risks, 19.1% reduced the care or interest shown to patients, and 13.1% reduced time spent with patients. Negative effects in the post-aggression period were more frequent in staff who suffered from aggression five or more times in the last year, and, in those who evaluated the safety of their hospital as bad or very bad.

The present study aims at contributing to the knowledge of the violence practiced by institutionalized elderly in relation to care providers in Portugal, a country where, as far as we know, there is no research in the area. In this sense, partial results of the study conducted with a Portuguese sample of geriatric auxiliaries, less studied professionals than more qualified professionals are presented. In any case, it should be noted that when the studies specify health professional groups, the results go towards associating a higher risk of violence with lower qualified professionals (nursing auxiliaries and direct caretakers) [14, 19]. These professionals may be almost four times more at risk of suffering from violence in work [19].

2 Methodology

A cross-sectional, descriptive and quantitative study was carried out involving geriatric assistants (and other technical staff) in Portuguese nursing homes. In total, 156 professionals from nine Private Institutions of Social Solidarity (PISS) participated from the northern region of Portugal (districts of Braga and Oporto), all of them in agreement with Social Security Institute. In general, the sample consisted of professionals with experience in the geriatric context, working on average in this context for 12.67 years (SD = 8.22), all women. Approximately 2/3 of the workers are between 36 and 55 years of age, and the predominant educational level (44.1%) corresponds to the 9th grade. Once access to the nine institutions was negotiated, the questionnaires were provided to workers with the following exclusion criteria: alliteracy, age group below 18 years, and caregivers belonging to the technical staff (e.g. psychologists, nurses, or physiotherapists). Thus, "non-technical" workers from nursing homes participated in the study, who provided direct care to institutionalized elderly (mainly geriatric auxiliaries) and whose level of schooling allowed to fill the questionnaire.

In the data collection, the questionnaire with two parts was provided: one part meant for the collection of demographic information, while second part meant for collecting information about the perception of violence at work. In the second part, the following domains were questioned: perception of exposure to violence (physical, psychological, and vicarious) by institutionalized elderly, consequences and professional implications of exposure to violence, perception of the severity of the "worst incident", and reporting or not to the employer of the episode(s) of violence. The different questions were adapted to the Portuguese context from instruments already available in the literature or developed specifically in the scope of the study. Taking into account the results of the Akerstrom empirical investigation [5], it was decided to evaluate the phenomenon avoiding the expression "violence", privileging the presentation of a list of behaviors (violent/aggressive) in order to avoid the underreporting of phenomenon. In the characterization of the physical violence perpetrated by the elderly to their care providers in nursing homes, the measure developed by a Danish [3] team was used. This measure assesses the violence at work among workers in the geriatric sector, integrating a list of ten violent behaviors (e.g. "hitting", "shooting with objects") that the professional could have faced from the elderly in the last year. For each behavior, the worker should indicate whether he had been exposed to it in the reference period and, if so, mark the frequency in one of the four available options (see Table 1). Since the previous measure did not contemplate behaviors of psychological violence and it's a type of violence that is very frequent in the geriatric context [7, 14], it was decided to add four behaviors of this nature (e.g. "insulting purposely") to the list behaviors of physical violence. For the identification of such behaviors, the study by Sousa et al. [20] was taken into account, where type II violence in work in the Portuguese social services was analyzed. At the level of exposure to violence, vicarious violence was also evaluated, wherein the professional was asked if he had

Table 1 Frequency of violent behaviors of institutionalized elderly with their caregivers

In the last 12 months, some elderly persons had these behaviors with you: (N = 156)	Yes		Behavior frequency			
	n	%	All or almost every day	Every week	Every month	Once in a while
Physical violence						
Hitting (n = 149)	40	26.8	7	6	0	27
Scratching, pinching (n = 144)	64	44.4	8	6	0	50
Spitting (n = 142)	42	29.6	3	4	0	35
Hitting with a fist (n = 147)	36	24.5	7	2	2	25
Hitting with a hard object (n = 137)	10	7.3	0	1	0	9
Kicking (n = 147)	44	29.9	5	3	1	35
Biting (n = 143)	28	19.6	3	3	0	22
Being held (n = 140)	49	35.0	8	4	0	37
Throwing a hard object (n = 140)	8	5.7	1	0	0	7
Use of weapon (n = 139)	0	0.0	–	–	–	–
Psychological violence						
Unwanted sexual attention (n = 143)	16	11.2	0	1	0	15
Purposely insulting (n = 142)	50	35.2	11	2	1	36
Threatening (verbal, written form) (n = 141)	53	37.6	6	5	3	39
Threatening to complain to superiors (n = 147)	69	46.9	14	2	2	51

ever witnessed an episode of aggression/violence to coworkers, and he/she could answer "Yes" or "No". After evaluating the exposure to violence behaviors, there were two questions of dichotomous answer ("Yes" or "No") that aimed at assessing whether there were bodily injuries resulting from violent/aggressive acts, and if it was necessary to miss the work for the same reason. If so, the number of days of sick leave or insurance was requested. Another topic evaluated was the "perception of severity of the worst incident suffered", evaluated by a 10-point scale (0-"less severe" to 10-"more severe"). Another evaluated area was the impact of exposure to violence from the point of view of professional practice, namely the relationship with the elderly receiving care. Specifically, it was asked if "there was change in his behavior with the user after the episode of violence" and if so, what kind of changes. For that, five possible changes were listed (e.g. "reduction in communication with users"). The questions developed under this area were based on the questionnaire used in the study by Eker et al. [15]. Finally, the worker was also questioned, dichotomously ("Yes" or "No"), if he/she has reported the "knowledge of violent incidents to the employer". If so, it was questioned how this report had been made and, if not, why he/she did not do so.

Data were analyzed using the Statistical Program for the Social Science, version 22, while the answers to open questions were subjected to content analysis. The research project was submitted to the Ethics Committee of the University of Minho and was approved (CEUM 020/2014).

3 Results

3.1 Perceived Violence at Work

Of the 156 participants, 101 (64.7%) reported suffering from at least one of the listed violent behaviors, while the others did not identify any of the behaviors presented. Table 1 shows the frequency values of the behaviors of the elderly. The most frequent are associated to psychological violence, with special emphasis on "threat of complaint to superiors" (46.9%). Of the 69 participants who reported having been exposed to this behavior in the last year, 14 participants indicated "daily or almost daily" frequency, and 51 participants reported occasional occurrence. The behaviors of "purposely insulting" and "threatening (verbal, written form)" were indicated by about 35% of the workers. Finally, 11.2% of the participants reported being subjected to "unwanted sexual attention". Regarding the physical violence, it can be said that generically three profiles were displayed. Thus, we have the least identified behaviors up to 20%, like the use of weapons (0%), shoot with object (5.7%), hitting with an object (7.3%), and biting (19.6%). On the other hand, we have the behaviors identified by 20–30% of workers, namely hitting with a fist (24.5%), hitting (26.8%), spitting (29.6%), and kicking (29.9%). Finally, we have the behaviors identified by more than 30% of the professionals, which include being held (35%) and scratching/pinching (44.4%). The latter is also the most frequent with 8 workers reporting being scratched/pinched almost every day, 6 weekly and 50 occasionally. The perception of violence in an indirect way was also evaluated, and when questioned if they attended a colleague to be the victim of aggression/violence, about a quarter of the workers (24.8%) responded affirmatively.

3.2 Impacts of Perceived Violence at Work

The percentage of employees who reported having suffered some bodily injury resulting from the presented behaviors was evaluated. Of the 136 workers who responded to the question, 12.5% responded in an affirmative way. None of them, however, lacked work due to such consequences. Regarding the question whether there had been change in behavior towards users after the episode(s) of violence occurred, 6 employees (5.9%) reported having altered their behavior, and each participant could identify more than one alteration. Specifically, six participants reported that they reduced communication with users, one avoided interventions and care that have high risk of complication, and one reduced the communication with relatives and visits of users.

3.3 Seriousness of the Incident and Reporting to the Employer

To the 101 workers who had been exposed to some incident of violence, they were asked to indicate the severity level of the worst incident on a scale ranging from 0 to 10. The mean value of severity perception of the worst incident was 2.73 (SD = 2.34). Of the 88 employees who answered this question, 41 (46.6%) reported incidents to the employer, mainly verbally (n = 25). Of the remaining 47 workers (53.4%) that did not report the incidents, 15 justified the reason for the lack of reporting. The reasons for not complaining to the employer were centered to the devaluation of the incident(s) (n = 10) and the characteristics of the users (n = 5). Statistical analysis of the relationship between "reporting to the entity" and "perception of the severity of the incident" indicated statistically significant differences between the professionals who reported the occurrence of violence to the employer and those who did not report the occurrence of violence to the employer ($t = 3.57$; $gl = 69$; $p = 0.001$). The first category ($M = 3.59$; $SD = 2.07$) presents the perception of higher severity in comparison to the second ($M = 1.67$; $SD = 2.41$).

4 Discussion and Conclusions

The general objective of this study was to contribute to the characterization of the phenomenon of type II violence suffered by nursing home workers in Portugal. Most workers reported having suffered from some kind of violence in the last 12 months, whether physical or psychological. This high value can be justified by the fact that the workers were exposed to a list of behaviors instead of giving a more general question of the type "*suffered from violence?*", as suggested by Akerstrom [5], given that the introduction of the word violence caused a significant difference in the reports by the workers. Psychological violence was more reported by workers as compared to physical violence, which is in line with other studies [7, 14] also conducted in a geriatric context in European countries (e.g. Spain and Sweden). The violent behaviors of a physical nature most reported were scratching/pinching, being held, kicking, spitting and hitting, while the less reported behaviors were using weapons, shooting and hitting with objects, which is similar to the study conducted by Sharipova et al. [3]. Although there are cultural differences, the approximate results of the two countries (Portugal vs. Denmark) can be based on the combination of factors such as the characteristics of users (e.g. dementia, abandonment situations) and the current reality of nursing homes, which increasingly receive more elderly [6, 17]. In addition to physical and psychological violence, vicarious violence was also reported by 1/4 participants.

Regarding the perception of severity of behaviors, although 12.5% affirmed that they suffered from some type of physical injury owing to violent behaviors, the mean severity value was low (2.7), and the greater the perceived severity, the greater the report to the organization. Regarding the lack of reports to the employer, the workers showed a high devaluation of the phenomena (e.g. "*because it was only a pinch, there was no reason to inform the superiors*"), as found by Sharipova et al. [3]. This devaluation of the phenomenon, with the reduced literature in the geriatric context, does not allow many organizations to have an adequate prevention and/or intervention plan to bridge the possible violent behaviors that their workers may suffer. However, factors such as the growing aging of the population [21] and the more dependent elderly as well as more pathologies of the neurological/psychiatric origin [6] make it essential to properly prepare the employees for this reality. Some of the organizational strategies can go through guaranteeing a culture of safety for workers, training them for violent situations at work [13], promoting occupational health and providing additional training [17] besides developing action plans such as conflict management and training supervisors [11].

In terms of limitations, the late response of some contacted institutions culminated in reduced sample for the study objective. In the future, this line of research can be maintained with a larger sample, both participants level and geographical level, to increase its external validity. Another limitation of the study was the lack of control of the health status of the elderly (e.g. diagnosis or suspicion of cognitive impairment), which should be controlled in future studies. It will also be important that in future the investigations should remove the expression "violence" from the documentation underlying the study (such as informed consent or questionnaire) due to the influence it has on the phenomenon reports. In conclusion, the present study allowed us to know a reality that, until now, apparently no Portuguese data has been published, pointing out its results to the fact that physical and psychological violence of the elderly to the care providers is a common reality in nursing homes that are part of the sample studied. With the increase in the ageing population, the reality of this has been changing and several interventions are necessary to accompany it. Like other studies conducted in northern Europe, this phenomenon tends to be normalized and underreported by workers, which makes it difficult to assess their real dimension and outline intervention strategies.

References

1. Spector, P.E., Zhou, Z.E., Che, X.: Nurse exposure to physical and nonphysical violence, bullying, and sexual harassment: a quantitative review. Int. J. Nurs. Stud. **51**(1), 72–84 (2014)
2. Chappell, D., Di Martino, V.: Violence at Work, 3rd edn. International Labour Office, Geneva (2006)

3. Sharipova, M., Borg, V., Hogh, A.: Prevalence, seriousness and reporting of work-related violence in the Danish elderly care. Scand. J. Caring Sci. **22**(4), 574–581 (2008)
4. Viitasara, E., Sverke, M., Menckel, E.: Multiple risk factors for violence to seven occupational groups in the Swedish caring sector. Relat. Ind-Ind Relat. **58**(2), 202–231 (2003)
5. Akerstrom, M.: Slaps, punches, pinches—But not violence: boundary-work in nursing homes for the elderly. Symb. Interact. **25**(4), 515–536 (2002)
6. Banerjee, A., Daly, T., Armstrong, P., Szebehely, M., Armstrong, H., Lafrance, S.: Structural violence in long-term, residential care for older people: comparing Canada and Scandinavia. Soc. Sci. Med. **74**(3), 390–398 (2012)
7. Jofesson, K., Ryhamar, L.: Threats and violence in Swedish community elderly care. Arch. Gerontol. Geriatr. **50**(1), 110–113 (2010)
8. Carvalho, I.: An exploratory study of social workers perceptions of violence against older people in Portugal. Indian J. Gerontol. **28**(3), 414–430 (2014)
9. Santos, A., Ferreira-Alves, J., Penhale, B.: Prevalence of older adults' abuse and neglect in Portugal: an overview. Qual. Ageing Older Adults **12**(3), 162–173 (2011)
10. International Labour Organization (ILO): Code of practice on workplace violence in services sectors and measures to combat this phenomenon. In: Proceedings of the Meeting of Experts to Develop a Code of Practice on Violence and Stress at Work in Services: A Threat to Productivity and Decent Work, 8–15 October, Geneva, Switzerland. International Labour Office, Geneva (2003)
11. Di Martino, V., Hoel, H., Cooper, L.: Preventing violence and harassment in the workplace—European foundation for the improvement of living and working conditions. Office for Official Publications of the European Communities, Luxembourg (2003)
12. Occupational Safety and Health Administration: Guidelines for Preventing Workplace Violence for Health Care & Social Service Workers. Department of Labor, Washington D.C. (2004)
13. Gabrovec, B., Eržen, I.: Prevalence of violence towards nursing staff in Slovenian nursing homes. Zdrav. Var. **55**(3), 212–217 (2016)
14. Vidal-Martí, C., Pérez-Testor, C.: Patient assaults on professionals? Type II workplace violence: a known phenomenon in Barcelona nursing homes. Work **51**(4), 879–886 (2015)
15. Eker, H., Özder, A., Tokaç, M., Topçu, İ., Tabu, A.: Aggression and violence towards health care providers, and effects thereof. Arch. Psych. Psychother. **14**(4), 19–29 (2012)
16. El Ghaziri, M., Zhu, S., Lipscomb, J., Smith, B.: Work schedule and client characteristics associated with workplace violence experience among nurses and midwives in sub-Saharan Africa. J. Assoc. Nurses. AIDS Care **25**(1), S79–S89 (2014)
17. Nienhaus, A., Westermann, C., Kuhnert, S.: Burnout among elderly care staff. a review of its prevalence. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschut **55**(2), 211–222 (2012)
18. Arnetz, J., Arnetz, B.: Violence towards health care staff and possible effects on the quality of patient care. Soc. Sci. Med. **52**(3), 417–427 (2001)
19. Silva, I., Aquino, E., Pinho, I.: Violência no trabalho em saúde: a experiência de servidores estaduais da saúde no Estado da Bahia. Brasil. Cad. Saúde Pública **30**(10), 2112–2122 (2004)
20. Sousa, S., Silva, I.S., Veloso, A., Tzafrir, S., Enosh, G.: Client's violence toward social workers. TÉKHNE—Rev. Appl. Manag. Stud. **12**(1), 69–78 (2014)
21. International Labour Organization (ILO): Emprego e proteção social no novo contexto demográfico [Report IV]. International Labor Conference procedures, 102nd session, 5–20 June, Geneva, Switzerland. International Labour Office, Geneva (2013)

Other Occupational and Emergency Issues

Intervention in OSH for SMEs Employers: Influence in Knowledge and Prevention Activities

André M. Lopes, Rita A. Costa, Artemisa R. Dores and Matilde A. Rodrigues

Abstract Small and Medium-sized Enterprises (SMEs) face several difficulties compared to large enterprises, such as the lack of human, economic and technological resources. This could lead to difficulties in identifying, assessing and controlling occupational risks and, as a consequence, in having a good Occupational Safety and Health (OSH) performance. Employers of SMEs are responsible for the most part of decision making, namely in OSH. OSH interventions are important to change the behaviors and attitudes to the target group and may encourage both employers and employees to be more active and conscious about OSH in their enterprises. This study aims to design and implement a training session that target employers of micro and small-sized enterprises and analyze its effect on employers' OSH knowledge and on the preventions activities carried out. The training session was divided in two parts, the first was more theorical and the second more practical. A questionnaire was developed and applied to assess the intervention effect. One month after the intervention, most of participants increased their participation in OSH activities, but were reluctant to invest financial resources to implement measures that promote OSH. The effect of the intervention in employers' knowledge was limited. This study contribute to the design future OSH interventions in SMEs, suggesting important topics to address and provide information about how to assess its effectiveness.

Keywords Employers · OSH intervention · OSH knowledge · SMEs · Training

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1 Introduction

According to the European Union (EU) recommendation 2003/361, an enterprise is any entity engaged in economic activities. The same recommendation also defines Small and Medium-sized Enterprises (SMEs), and states that they can be classified as micro, small and medium-sized, according to the staff headcount, turnover and balance sheet total: micro enterprises are, then, defined has having less than ten employees and less than two million euros on turnover or total balance sheet; small enterprises are the ones that have less than fifty employees and less than ten million euros on turnover or total balance sheet; medium enterprises are firms that have less than two hundred and fifty employees and less than fifty million euros on turnover or less than forty-three million euros on total balance sheet [1].

SMEs are of paramount importance for the European economy if considering that from all enterprises in EU, 99% are constitute by SMEs, employing in 2015 almost 90 million people [1]. In Portugal, 99% of all enterprises were SMEs, of which 96.2% were micro-sized enterprises, 3.2% small-sized enterprises and 0.5% medium-sized enterprises [2].

Despite their relevance to the worldwide economy, SMEs are in an enormous pressure due to an extremely competitive environment and the need to cope with severe business constraints in order to strive [3]. Besides the competitiveness, SMEs have much more difficulties compared to large enterprises in other domains. According to previous studies, there are several barriers that contribute to this scenario, being the most consensual the lack of resources (e.g., economic, technological and human) [4, 5]. The lack of resources is reflected in the difficulty to identify, assess and control occupational risks [6]. Consequently, SMEs tend to present a poorer OSH management, leading to a higher risk of occupational accidents [7]. In the EU, between 2010 and 2015, most of the reported accidents, both non-fatal and fatal accidents, were related to SMEs [8]. In fact, it is pointed out by several authors that, comparatively to larger enterprises, there is a higher accident rate in smaller sized enterprises [6, 9–11]. This highlights the fragility of the OSH systems in SMEs comparatively to larger enterprises. Additionally, most of the regulations are designed taken into consideration the reality of larger enterprises, with permanent employees; therefore, regulations tend to be inappropriate for the SMEs [11]. As a consequence, to make sure that SMEs can thrive, they start disregarding OSH regulations, increasing the risk of accidents and injuries [6, 12].

Responsibilities concerning an enterprise' OSH management are undertaken by the employers, making them play a central role in this field [11]. In smaller sized enterprises, the employers tend to have multiple responsibilities, including administration, accounting, planning and sometimes they even work together with the employees [13]. As a result, although safety management should also be one of his/her responsibilities, it tends to get overlooked sometimes in favour of other tasks [13, 14].

It is also important to realize that complying with OSH regulations and legislation has been the main concern of SMEs employers for many years, particularly because, as referred above, most of the legislation is written considering large enterprises, defaulting the particularities of smaller enterprises. It also has to do with the fact that the owners most of the times do not know or know little about legislation and think of it as being bureaucratic [15]. The interest that an employer has regarding safety issues is representing the value attached to safety in the organization and this could have an impact on the attitudes and behavior of employees. This is, if the employees feels that employers regard safety has a priority, then is more likely that they also regard safety as a priority [6]. Considering this, it is important that employers be encouraged to focus and maintain comprehensive safety policies and procedures [16].

Because SMEs are more sensitive to occupational risks, effective OSH interventions are of paramount importance, specially OSH interventions that target employers due to their role in OSH performance. They are the ones who usually decide what approach should be made and they are the responsible for OSH prevention activities, such as carrying out risk assessments and store those and any other related documents [17, 18]. To this, seems important to increase employer's knowledge about OSH legislation and about the importance of their participation and involvement in OSH related activities.

Taking this into account, the present study aims to design and implement an intervention that targets the employers of micro and small-sized firms in the field of OSH and analyse its effect in terms of improving employer knowledge regarding OSH and the involvement and participation in OSH management activities. This study will involve micro and small enterprises from the waste management sector.

2 OSH Interventions

An OSH intervention is an attempt to change something to improve the level of OSH [19, 20]. Regarding safety intervention, it is defined as an attempt to change behaviors or procedures in order to improve safety [19]. In this line, OSH interventions are usually implemented to change the behaviors and attitudes of the target group towards the specific context of the intervention [7], by implementing engineering solutions, education and training activities, and safety related policies and/or procedures [21]. However, it is difficult to predict the outcome of this interventions because they tend to be ambiguous. This makes interventions hard to design, because even using the best information available to increase its success, different target groups will have different results [7]. Additionally, OSH practitioners face many difficulties while trying to implement interventions, such as carrying out a sufficient analysis of context and mechanisms while, at the same time, keeping the interventions simple and practical, mostly due to the lack of resources, specially from SMEs [21].

Interventions targeting the employees have been approached by several studies, but scientific evidence about interventions targeting the employers is still scarce.

3 Methodology

3.1 Sample

This study involved a selected group of employers from the waste management sector, with NACE 38. The enterprises and respective employers were chosen considering the following criteria: (1) be a part of the clients database of an OSH consultancy company; (2) be a micro and small-sized enterprise; (3) showed interest in participating in this study.

There were two groups of employers involved in this study: (1) Intervention group, which was composed by 7 employers, aged between 25 and 60 years old; (2) control group, which was composed by 13 employers, aged between 31 and 63 years old.

3.2 Training Session

The planning of the training session was carried out considering the results of a literature review and a focus group (working paper).

The training session was designed as a 2-h session with the employers, divided in 1 h of theoretical training session and 1 h of case study discussion. Before the session, it was explained to the employers the reason why the session was taking place and what was going to be addressed. The first part started with a presentation of occupational accidents statistics, comparing the large enterprises with the small ones. Afterwards, different concepts were presented, such as OSH, risk, hazard, occupational accident and disease/health. In this first part, common risk factors and risks that can exist in the workplaces were also addressed. Additional contents were related to the hierarchy of preventive and control measures and the importance of the OSH external services support. Throughout this first part, the trainers (research team) tried to interact with the trainees by asking questions and making exercises with them.

In the second part of the session, several case studies were presented to the employers. The participants were asked to analyze each case study, independently, together with the research team. There were five case studies analyzed, accordingly to the following topics: risk assessment, occupational accidents and psychosocial risks.

3.3 Assessment of the Intervention Effectiveness

A questionnaire was developed in order to assess the effect of the intervention. In this study, the questionnaire was used to analyze the following variables:

(i) employer knowledge about OSH; and (ii) employer involvement and participation in OSH management activities. The questionnaire was developed taking into account the results from a focus group (working paper) and the contents covered along the intervention.

Regarding the intervention group, the questionnaires were given in three moments, before the training session, after the training session and follow-up (one month after the intervention). Regarding the control group, the questionnaires were given in two moments, at the same time that they were applied in the intervention group: before the training session and follow-up. The questionnaire comprised two parts. The first part contained general questions regarding employers: age; gender; education level; years of business activity; number of employees; type of waste managed in the enterprise; and occupational accidents occurred in the last two years. The second part was related to OSH issues.

In the second part of the questionnaire were included questions to assess different variables related to OSH issues, being presented hereafter the ones that respond to the study aims. Employers were asked about their involvement in OSH activities, through a question with 7 items. The participants chose among one of the following options: “Yes”, “No” and “Do not know”. Additionally, in this part of the questionnaire it was also included a question with 18 items to assess employers’ knowledge about the different topics addressed in the intervention. The participants chose among one of the following options: “True”, “False” and “Do not know”.

The collected data were analyzed by using descriptive statistical analysis, focused in the relative frequency of the answers. The descriptive analysis was conducted using Statistical Packaged for Social Sciences (IBM SPSS, version 25, Inc., Chicago, Illinois).

4 Results and Discussion

4.1 Training Session

The results of the OSH activities developed by the employers in their enterprises are summarized in Table 1 for the intervention group.

According to the obtained results, one month after the training session, the employers seem to be more involved in the OSH management activities of their enterprises, with an increase of the number of activities in which they were involved. Almost 40% of the employers defined an OSH policy after the intervention and 30% the OSH goals. Despite before of the session several employers took over do not comply with legal requirements related to prevention activities (risk assessment, OSH training, employees consultation and medical surveillance), after the session all of them tended to comply with it. However, in what regard to the willingness of the employers to allocate financial resources to OSH matters in their enterprises, the percentages remain the same in both moments. It appears that,

Table 1 OSH activities developed by the employers in the intervention group

Item	Moment	Yes (%)	No (%)	I do not know (%)
My company has an OSH policy	Before training session	42.9	0	57.1
	Follow-up	85.7	14.3	0
I have set OSH goals for my company and promote activities to achieve them	Before training session	42.9	57.2	0
	Follow-up	71.4	14.3	14.3
I have allocated financial resources to implement measures that promote OSH	Before training session	57.1	42.9	0
	Follow-up	57.1	42.9	0
I promote proper medical surveillance of my employees	Before training session	71.4	28.6	0
	Follow-up	100	0	0
I consult my employees at least once a year on OSH issues	Before training session	57.1	42.9	0
	Follow-up	100	0	0
I provide adequate training in the field of safety and health at work to my employees	Before training session	57.1	42.9	0
	Follow-up	85.7	14.3	0
I carry out risk assessment in my company	Before training session	57.1	42.9	0
	Follow-up	100	0	0

although there seems to be a willingness from the employers to improve OSH of their enterprises, they do not allocate the necessary financial resources. This unwillingness to allocate financial resources to OSH matters could be connected to the financial difficulties that SMEs are known to struggle from [4, 5]. In what regards to the control group, the results before and one month after the intervention were the same as expected.

OSH knowledge was previously identified as an important safety performance indicator [22]. As a consequence, the effect of the intervention in this dimension was analysed in both groups, being the results described in Table 2. An increase was verified in the average of correct answers after the training session when compared to the moment before training session. A decrease of the average of “Do not know” answers to zero was also verified, which can be an indicator that the intervention helped in possible knowledge gaps. Although, it was observed a slight increase in the average of incorrect answers in the follow-up. In the follow up moment, when compared to the moment after training session, there was a decrease of the average of correct answers, an increase of the average of incorrect answers and also an increase of “do not know” answers. This seems to mean that there was not a lot of retention of knowledge by employers. Overall, there was an

Table 2 OSH Knowledge in the three moments in intervention and control groups

Group	Moment of evaluation	Correct mean (±*SD*)	Incorrect mean (±*SD*)	Do not know mean (±*SD*)
Control	Before training session	14.10 (±1.370)	1.00 (±0.816)	0.90 (±1.287)
	Follow-up	14.10 (±1.370)	1.00 (±0.816)	0.90 (±1.287)
Intervention	Before training session	12.71 (±2.138)	1.57 (±0.976)	1.71 (±2.289)
	After training session	14.17 (±1.169)	1.83 (±1.169)	–
	Follow-up	12.86 (±0.899)	2.71 (±1.113)	0.43 (±0.77)

improvement in a short period of time, but, after one month the average of correct answers was almost the same as before the intervention. These results were not expected, since previous studies that applied a similar type of intervention had positive outcomes regarding OSH knowledge in follow up sessions, when directed to employees [23].

Employers seem to have difficulties regarding OSH legislation. This was already denoted in previous literature [23]. During the intervention, legal requirements in the field of OSH were taught. One month later there was still a lack of knowledge, suggesting that employers are not completely familiarise with OSH legislation.

The most mistaken statement was related to the following question: “It is preferable to use collective protection equipment (CPE) against personal protective equipment (PPE)”. This conveys that employers may not know the concept of CPE or do not provide the correct importance to this control measure. The percentage of this statement answered as false decreased after the intervention, since in the intervention it was addressed the concepts of CPE and PPE and the prevention principles. However, after one month, there was a higher percentage of incorrect answers to this statement than before the intervention, which could mean that there was no long-term retaining of knowledge.

5 Conclusion

This study proved to be fruitful to understand not only the level of OSH knowledge of employers in micro enterprises from waste management sector, and their level of participation and involvement in OSH management activities, but also the effect of an OSH intervention with this group. It could be concluded that in some areas (e.g., control measures and legislation) there is a lack of knowledge about OSH. However, the intervention does not seem to have helped to improve the employer’s knowledge as expected. Instead, the intervention has proven to contribute to an increase in the participation in OSH activities by the employers.

This study may help into design future OSH interventions in SMEs, by suggesting important topics to address, how to evaluate the effectiveness of the intervention and providing additionally data in this area. However, there were some limitations regarding this study, such as the small sample of employers in both groups; the high rate of incomplete questionnaires, which compromises the analysis, interpretation and generalization of the study results.

References

1. Parlamento Europeu: Pequenas e médias empresas, 1–5 (2008)
2. PORDAT: PORDATA—Pequenas e médias empresas em % do total de empresas: total e por dimensão, 14 Feb 2019 [Online]. Available: https://www.pordata.pt/Portugal/Pequenas+e+médias+empresas+em+percentagem+do+total+de+empresas+total+e+por+dimensão-2859. Accessed: 23 Feb 2019
3. Hasle, P., Limborg, H.J.: A review of the literature on preventive occupational health and safety activities in small enterprises. Ind. Health **44**(1), 6–12 (2006)
4. Masi, D., Cagno, E.: Barriers to OHS interventions in small and medium-sized enterprises. Saf. Sci. **71**, 226–241 (2015)
5. Masi, D., Micheli, G.J.L., Cagno, E.: Developing, implementing and evaluating OSH interventions in SMEs: a pilot, exploratory study. Int. J. Occup. Saf. Ergon. **20**(3), 385–405 (2014)
6. Hadjimanolis, A., Boustras, G., Economides, A., Yiannaki, A., Nicolaides, L.: Work attitudes and safety performance in micro-firms—results from a nationwide survey: (the opinion of the employees). Saf. Sci. **80**, 135–143 (2015)
7. Kvorning, L.V., Hasle, P., Christensen, U.: Motivational factors influencing small construction and auto repair enterprises to participate in occupational health and safety programmes. Saf. Sci. **71**, 253–263 (2015)
8. Eurostat: Accidents at Work—Statistics by Economic Activity—Statistics Explained (2018) [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_-_statistics_by_economic_activity#Analysis_by_enterprise_size_class. Accessed: 14 June 2019.
9. Sørensen, O.H., Hasle, P., Bach, E.: Working in small enterprises—is there a special risk? Saf. Sci. **45**(10), 1044–1059 (2007)
10. Walters, D.: Worker representation and health and safety in small enterprises in Europe. Ind. Relat. J. **35**(2), 169–186 (2004)
11. Fabiano, B., Currò, F., Pastorino, R.: A study of the relationship between occupational injuries and firm size and type in the Italian industry. Saf. Sci. **42**(7), 587–600 (2004)
12. Quinlan, M., Mayhew, C.: Precarious employment and workers' compensation. Int. J. Law Psychiatry **22**(5–6), 491–520 (1999)
13. Ozmec, M.N., Karlsen, I.L., Kines, P., Andersen, L.P.S., Nielsen, K.J.: Negotiating safety practice in small construction companies. Saf. Sci. **71**, 275–281 (2015)
14. Jørgensen, K., Duijm, N.J., Troen, H.: Accident prevention in SME using ORM. Saf. Sci. **48**(8), 1036–1043 (2010)
15. Cagno, E., Micheli, G.J.L., Masi, D., Jacinto, C.: Economic evaluation of OSH and its way to SMEs: a constructive review. Saf. Sci. **53**, 134–152 (2013)
16. Parboteeah, K.P., Kapp, E.A.: Ethical climates and workplace safety behaviors: an empirical investigation. J. Bus. Ethics **80**(3), 515–529 (2008)
17. Isik, S.N., Atasoylu, E., Economides, A., Yiannaki, A., Nicolaides, L.: Occupational safety and health in North Cyprus: evaluation of risk assessment. Saf. Sci. **94**, 17–25 (2017)

18. Kontogianni, S., Moussiopoulos, N.: Investigation of the occupational health and safety conditions in Hellenic solid waste management facilities and assessment of the in-situ hazard level. Saf. Sci. **96**, 192–197 (2017)
19. Robson, L.S., Shannon, H.S., Goldenhar, L.M., Hale, A.R.: Guide to Evaluating the Effectiveness of Strategies for Preventing Work Injuries: How to Show Whether a Safety Intervention Really Works. National Institute for Occupational Safety and Health, USA (2001)
20. Zwerling, C.: A review of a guide to evaluating the effectiveness of strategies for preventing work injuries: how to show whether a safety intervention really works. J. Saf. Res. **32**(4), 501–503 (2002)
21. Masi, D., Cagno, E., Farne, S., Hasle, P.: Design of OSH interventions: a model to improve their actual implementation. Saf. Sci. **115**, 51–65 (2019)
22. Barbosa, C., Azevedo, R., Rodrigues, M.A.: Occupational safety and health performance indicators in SMEs: a literature review. Work **64**(2), 217–227 (2019)
23. Barros, B., Dores, A., Rodrigues, M.A.: Effectiveness of occupational safety and health training methods: a study with metalworking small enterprises. In: Arezes, P.M., Baptista, J. S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., et al. (eds.) Occupational and Environmental Safety and Health, pp. 631–640. Springer, Cham (2019). ISBN: 978-3-030-14729-7

Safe Cargo Lifting

António Teodoro

Abstract Goods from production to final destination, in addition to having to be properly wrapped and tied, have to be moved three-dimensionally, i.e. moving to the same level, for example by truck or ship and different sizes, increasing or reducing dimensions, i.e. by forklifts or cranes. In this way, they use equipment and accessories that allow and assist these movements. Its selection and mode of operation, including positioning and displacement, must be carefully analyzed in accordance with the specific load requirements and working conditions to ensure safe operations. Large loads or unusual forms carried as Loose should be the subject of Lifting Plans, indicating in particular the risk assessment, the Rigging Plan, the equipment and accessories to be used, its positioning and lashing, as well as the positioning of the load in the different phases of movement and static positioning. In turn, human resource involvement requires them to have adequate specific training, depending on the roles they perform technically and behaviorally so that they can work as a cohesive team.

Keywords Lifting · Rigging · Safety

1 Introduction

Cargo handling requires that all resources involved are adequate to properly perform the various operations safely. Material resources include quality, certification and equipment maintenance. In human resources, technical training is required for the execution of adequate mooring and lifting plans, plus solid knowledge in the area of occupational safety and health and complemented by behavioral instruction that is notorious in attitudes and behaviors in the activities they perform.

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2 Pre-lifting Load

Before moving the load, the real concern is the load itself, the structure in which it is stowed and the anchor points where the load will be lifted directly. At the same time, appropriate lashings should be defined to ensure that these fittings are of adequate capacity and made of suitable materials for future safe handling.

The main concerns at this stage are: the determination of the weight and size of the loads, the proper packing of the loads, the center of gravity and the mooring/anchoring points for future movement.

There should also be specific information on: the typology of cargo and signaling (i.e. for hazardous or fragile products); Inspection of conditioners; Structural condition and period of validity of packaging certifications.

If transported as loose the tie down/anchor points must be adequate, explicit, sturdy and properly bonded to the structure.

3 Three-Dimensional Cargo Handling and Lifting Equipment

Using equipment to move loads does not mean that there is no effort or risk to workers. The equipment significantly reduces physical effort in moving loads, but does not prevent the workers involved from being exposed to a number of significant risks that require adequate safety measures to counteract or mitigate the consequences of the activity.

There are risks that can cause serious injury or even death when operators: Not trained or qualified to operate the requested equipment; Overrated their abilities; Overload equipment and accessories, not respecting the limits of resistance; Failure to comply with the rules of movement in your workplace; Operate equipment damaged or in poor working condition and Do not respect recommended speed.

According to the authors E. Gomes; F. Moreira; Joaquim Cavaca; J. Pina, Practical Guide—Safety of Work Machines and Equipment—ACT, 2013 [1], page 3 “Working with work machines and equipment is one of the activities that causes many work accidents.” It is stated that “From a set of 366 fatal accident records, 161 accidents occurred while working with machines or whose injuries were caused by machines” and illustrated in Fig. 1.

Please note that such equipment is logistically efficient, must be suitable for the service they provide, comply with the manufacturer’s maintenance and inspection plan, perform tasks in adequate spaces and must be humanely operated by skilled and qualified workers. Experienced by the manufacturer, following the safety procedures prescribed by the manufacturer and defined in good use practice, as well as being inspected by the competent maintenance and operation personnel to alert and apply the appropriate requirements for the equipment. Always be operational when performing the tasks and the operator performs them safely.

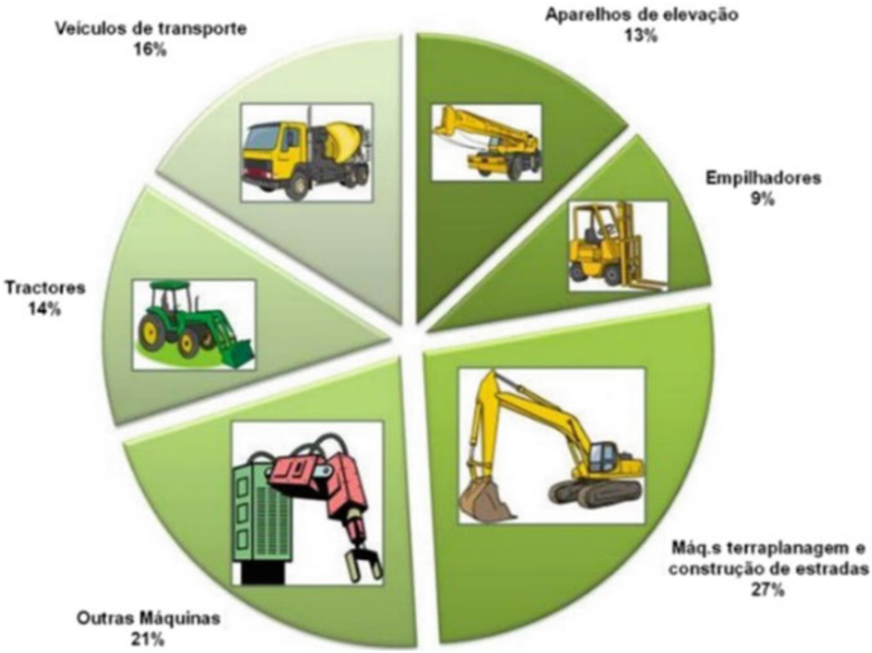

Fig. 1 Deadly work accidents by machine family

Continuing the analysis of a sample of surveys conducted by the Working Conditions Authority Inspectors [2], as indicated at the end of Sect. 3 (page 4), obtained the indicated data (see Fig. 2).

If the team does not function as a whole, with individual and collective commitment there is a clear sign of strong potential for accidents to occur.

When using equipment new duties and responsibilities of entities and people arise, namely: manufacturers; employers; supervisors; differentiated and undifferentiated operators. Everyone is subject to legal responsibilities, especially where there is: absenteeism; recklessness; negligence; inattention; alcoholism or consumption of psychoactive substances.

Equipment must be certified, maintained and suitable for the required functions. Workers should have specialized training for the tasks they perform, but also in the areas of occupational safety and behavioral actions. Thus it will be normal to carry out proper pre-inspections before using the equipment and accessories and performing the activities with safe techniques, individual and collective responsibility.

It is up to the security technician to obtain evidence of what has been exposed and to confirm on the ground the good performance of the activities by creating and using checklists specific to the various situations, but being prepared to see other possible security breaches beyond those indicated, or presented in a generic way.

The two previous figures show the possibility of using the Pareto principle, namely: In Fig. 1 the families of machines that contributed to the fatal accidents:

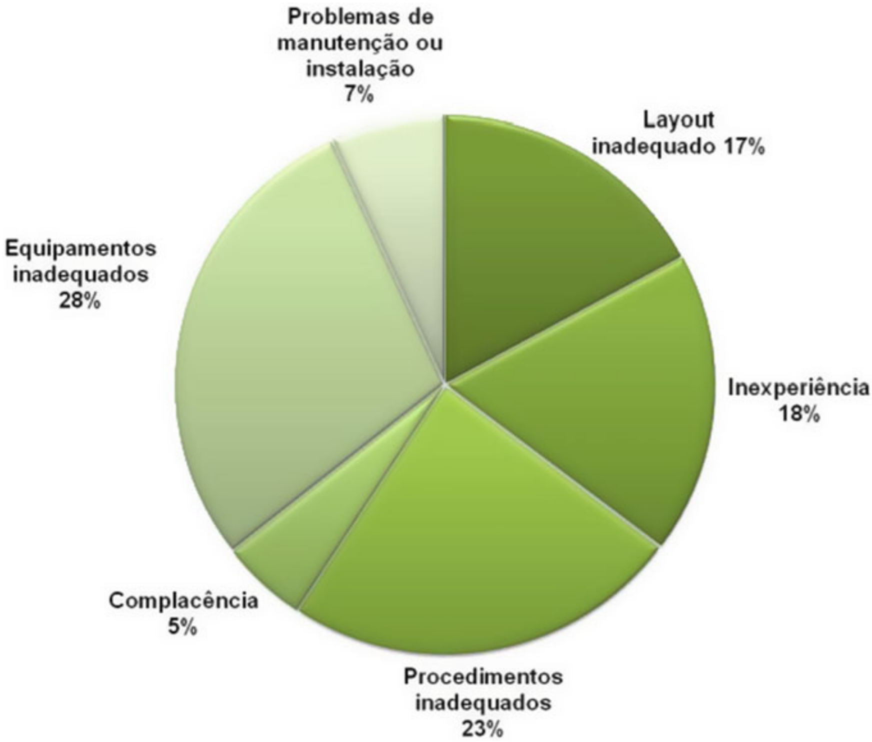

Fig. 2 Influencing factors that contributed to accidents

earthmoving machines, transport vehicles, tractors, appliances elevators and fork-lifts make up 79% of fatal accidents; In Fig. 2 the influencing factors that contributed to the fatal accidents: Inadequate equipment; Inadequate procedures; Inexperience and improper layout account for 86% of fatal accidents.

If the inspections, training, technical-pedagogical support material and even the regulation of laws focused on these evidenced aspects, it would be possible to reduce the significant loss detected.

The availability of human, technical and financial resources needs to be managed efficiently and this principle, as a quality management tool, could help in decision making.

By way of example, it can be seen in Portugal that Ordinance No. 58/20015 of 21 January ended up creating a problem by including in the third paragraph of its preamble that “The professional certification required in this law will be of a no obligation, …”. The consequence was that few entities were concerned about the proper training of their equipment operators.

Subsequently, the National Qualifications System (SNQ) published in Decree-Law No. 396/2007 of 31 December, which had as its fundamental objective, to promote the elevation of the basic formation of the active population, through school progression and as regards the training of machine operators, it refers to the National Qualifications Catalog (CNQ) where in the Training and Education Area 582—Civil Construction and Engineering presents several Short-term Training Units (UFCD), in this area, namely: 3919—Backhoe Loader—Excavation (25H); 3922—Rotary excavator—earthmoving and excavation (50H); 3923—Rotary excavator—demolition, lorry load and transport (50H); 3924—Operations with the mini loader (25H); 3925—Lorry—loading, transporting and unloading of earth (50H) 3926—Moving, handling and operation of the mobile crane (50H); 8391—Handling, operation and operation of car cranes with a load capacity exceeding 130 tonnes (50H); 8386—Handling, operation and operation of front stackers (50H); 8387—Handling, operation and operation of multi-purpose telescopic forklifts (50H); 8384—Handling, operation and operation of tower cranes (50H); 8395—Tower Crane Handling, Operation and Operation—Development (50H).

However, it is rare to find an operator who indicates any UFCD in the training certificate and, as a rule, the syllabus is not as indicated therein and the workload is much lower than that defined therein.

The questions remain: To what extent are training certificates issued by various certified entities, such as training providers, but not fulfilling the requirements of UFCD, valid? It would not be appropriate to indicate that operator certifications would be required to follow the syllabus and workloads defined in the CNQ and these would have to be delivered by entities that were specially certified for these courses, competent and qualified trainers, as well as have to own/rent the appropriate means for theoretical and practical training?

4 Supplementary Rules Specific to Three-Dimensional Safety of Movement

There are international standards that address specific activities and indicate safety factors to be considered in the calculations required to ensure safe handling, such as DNV STANDARD FOR CERTIFICATION No. 2.7-1 OFFSHORE CONTAINERS APRIL 2006 [3] and DNV STANDARD FOR CERTIFICATION No. 2.7-3 PORTABLE OFFSHORE UNITS IN JUNE 2006 [4].

Manufacturers are also subject to standards that guarantee the quality of the products they place on the market and produce useful technical information so that equipment and accessories suitable for the loads/structures to be moved can be selected as shown in the Lifting Guide from Gunnebo Industries, Issue 27, 2016 [5], where on page 6 you refer to the institutions on which it is based: ISO, International Organization for Standardization, develops world standards, cen, European Committee for Standardization, develops European standards. ASTM, American Standardization Organizations.

According to the complexity of the intended movement, it is necessary to have mathematical and physical knowledge that allows, easily or using specialized software, to guarantee perfect moorings and movements and, if effectively fulfilled, to guarantee the safety of the load/structure and the means.

As safe as it may be, if the behavioral attitude is not appropriate, from the risk identification phase to the operability of the movements, several accidents can occur due to multiple factors, namely: Nonexistent, inadequate or incomplete procedures; Equipment and accessories of poor quality, poor condition or unsuitable for the load in question; Incorrect positioning of equipment, badly placed or inadequate attachments, or loads without adequate information to ensure safe handling; Existence of gout objects that when moving can fall and injure/kill those who are hit; Untrained personnel and/or team spirit and safety culture.

It is the security technician's ability to interpret the calculations, with or without further clarification, to provide evidence of all of the above, to monitor the various phases related to these activities, to sensitize all persons involved at all stages and of course there is a team meeting that will move the load moments before its execution, where everyone will know exactly the task assigned to them indicating ways to act and communicate in normal or emergency development. This is the perfect time to motivate the team and pull their professional pride and show that the words "Safety First" so used are not rhetoric or propaganda, but a way of being in life (not only professional). One should also remember and ensure that hurry is not a good advisor and that more important than speed is the effective execution of tasks ahead of each other, because safety is everyone's responsibility.

This is where the Organizational Culture and the Safety Culture of companies enter.

The Dupont-developed Bradley Curve is designed to detect and then help raise companies' job security maturity.

This curve indicates the various stages of maturity and leaves indications of improvements to be made. It is up to each entity, with or without external support, to verify which zone is in this curve and what improvements it needs to implement. Age and leaves indications of improvements to be made (Fig. 3).

5 Special Handling Loads

Loads of unusual size, shape or weight should be carefully studied so that operational teams do not feel any doubt about how they should perform their tasks. In the initial phase, a mooring plan should be designed to ensure that the load is properly bonded for strength and positioning for future movement.

In the next phase, a lifting plan must be prepared to select the appropriate equipment and accessories, as well as the positioning and movements of the load and equipment required for the movement of the load.

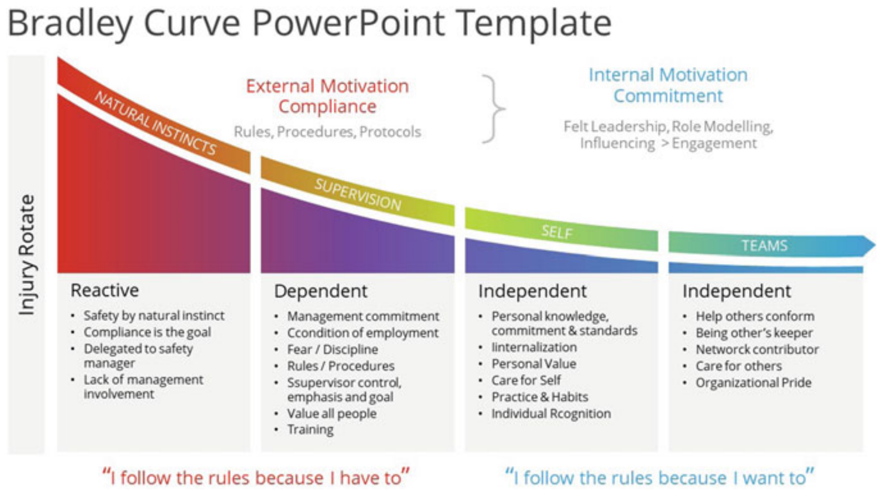

Fig. 3 Bradley curve

5.1 Rigging Plan

The mooring plane indicates the characteristics of the structure to be lifted and moved. It consists of descriptive memory and drawings indicating the elevation points or zones, center of gravity location and maximum load to move.

The risk assessment methodology discriminates mitigating actions which, once applied, ensure that there are no risks above the acceptable level.

In the specification are stated, namely: Tare; Carrying capacity, point location or anchor zones; Packers Certification and Expiration Date.

In the drawn pieces there are specific details of the structure that indicate in detail the indicated points, lengths; stresses at the mooring and lifting points (i.e. crane hook) angles the plant and the elevation and eventually cut and detail in the mooring areas. They must indicate the center of gravity and the lashing accessories and their positioning, indicating at particular lengths, angles and force, so that the riggers have no doubt in their practical application.

Today there is a huge diversity of loads and ways to tie them. Most packers are standardized and it is relatively easy to perform these tasks. However, loads known as loose, in which the cargo to be carried is packed with non-return elements that help create secure or already fixed or removable lifting points attached to the structure in question. In such cases, a mooring plan is essential and needs to have field operators capable of interpreting descriptive memories and drawings, which must exist and be provided for the execution of the task, including the calculations performed and the results obtained from analytical and print shop.

5.2 Lifting Plan

The cargo handling plan should include the full movement of cargo from the place of origin to be picked up to the place where it will be permanently deposited or for a long period, which will require new plans for future travel.

It is the responsibility of a security technician to analyze all elements in question to ensure that operations are performed safely. Although the work of the office is important in defining and analyzing all the steps and calculations necessary to ensure that nothing has been overlooked by the technicians who prepared the cargo handling plan (which can take a very active part), on the other that they have to follow the various steps on the ground and confirm that the plan is strictly adhered to.

The technician must ensure that all data and evidence he needs is obtained in a timely manner to ensure that all that is needed is in order and prepared for the date and time in question. The calculations must be observed very carefully, taking into account the specifics of the machines, equipment and places where the load moves. It is often these small details that cause the load to collapse.

On the ground, checklists based on pertinent safety-related issues should be followed to ensure that you do not forget a basic situation, but keeping in mind that no list is completely exhaustive and you should always be prepared for specific situations, depending on the load, packing structure, means and mooring means, machinery and equipment used, conditions of the place where it will operate, as well as all human resources involved.

Note that manufacturers and operators often make minor changes to the equipment and accessory plan to make it easy to perform with the means at their disposal, and often reducing the resilience, which when with a small margin of safety can lead accidents.

Once the lifting plan has been carried out and approved, it is up to the safety technician to ensure that it is strictly adhered to or that, in the event of a change, it is requested in due time to review any existing restrictions and only after further authorization. Duly substantiated, the new plan or its occasional restructuring may follow.

6 Conclusions

Suspended loads may fall. Moving suspended loads is a high risk activity that should only be performed by properly trained professionals with gradual experience in degree of complexity. Machinery and equipment must be properly certified and must be carefully selected, pre-inspected and applied. The existence of an appropriate lifting plan with written and designed elements clearly presented to all stakeholders according to the degree of need should be ensured.

The behavioral relationship is vitally important given the number and variety of actors and their particular interests. The safety officer should be one of the key (if not the main) elements of party oversight and coordination whose mission is to foster an effective safety culture for Operations. To accomplish, creating well-being and team spirit, but without neglecting the requirement for attitude, the precision of the calculations and the perception that the actors are fully aware of what will be accomplished and which must be proven in a timely manner.

The employer and coordinator of the work should continue to maintain continuous risk assessment and benchmarks of the activities, seeking continuous improvement that enhances the efficiency of the safe activity, using the appropriate quality tools and following the guidelines indicated therein (i.e. Pareto).

The commitment of everyone individually and as a team is essential so motivation should be intrinsic to each and every one of them looking to improve their skills and help the team to improve theirs as a whole (i.e. Bradley curve).

References

1. Gomes, E., Moreira, F., Cavaca, J., Pina, J.: Practical Guide—Safety of Work Machines and Equipment. ACT (2013)
2. Gomes, E.: Machine Work Accidents: Consequences of the Adoption and Implementation of Community Legislation on Safety Integration in Machine Design and Use of Work Equipment. University of Minho, School of Engineering (2008)
3. DNV (Det Norske Veritas): Standard for Certification Nº 2.7-3. Portable Offshore Units (2006)
4. DNV (Det Norske Veritas) Standard for Certification Nº 2.7-1. Offshore Containers (2006)
5. AAVV: Lifting Guide, issue 27. Gunnebo Industrier AB (2016)
6. AAVV: International Manual on Handling and Lifting Loads. NSL—Safety Awareness & Training Materials (1991)
7. Dickie, D.: Crane Handbook, Revised and metricated edn. Butterworth & Co (Publishers) Ltd. (1981)
8. Council Directive of 30 November 1989 on the minimum safety and health requirements for the use of labor selection equipment by operating workers (second individual directive within the meaning of Article 16 (1) of Directive 89/391/EEC)
9. Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery and amendment of Directive 95/16/EC (recast)
10. Lowe, A.: Lifting Gear Examination. Biglift, Loler & Puwer (2013)

Labour Production of Persons with Disabilities in the Construction Industry in Brazil

Bruno Guimarães, Béda Barkokébas Junior and Laura Martins

Abstract The objective was evaluate the labour production of PwD in the construction industry in the metropolitan area of Recife, Pernambuco, Brazil. Study participants were workers with disabilities that performed jobs at the work sites in the construction industry. Participants were interviewed and they answered the sociodemographic questionnaire. The companies provided labour production data of the last 12 months of the persons with disabilities and without disabilities. Twenty-six workers with disabilities participated in the study, of which 30.76% were laborer and 65.38% had physical disabilities. The companies made accommodations for 53.84% of PwD and all of them were the organizational type. The mean labour production of the PwD was 16.50% ± 0.36 (p = 0.016) lower than the production of the persons without disabilities. Persons with physical disabilities and laborer had labour production statistically significantly inferior than workers without disabilities. However, it is important to note that none of the companies performed job tasks analysis to accommodate PwD, which may have influenced the labour production of PwD.

Keywords Workers with disabilities · Labour production · Job accommodation · Construction industry · Work environments

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1 Introduction

Despite the attempts to include people with disabilities (PwD) at work, the number of those receiving job opportunities remains low. Data from several countries show that employment rates of PwD are smaller than the general population [1]. A study showed that in 27 countries, the employment rate for working-age PwD, on average, was 44%, while for persons without disabilities it was 75% [2]. In this sense, several researchers indicate that the main difficulties faced by PwD to gain employment are: the lack of work experience [3], misconceptions about their capacity to perform jobs [4] and the belief that PwD are less productive than workers without disabilities [5]. However, Brazilian policies need to ensure enforcement and compliance of their rights to equal access and opportunities in housing, transportation, work and leisure [6].

Besides, some companies have hired workers with disabilities without prior analysis of accessibility conditions, demands of their jobs or even these people's potential, bringing about problems such as job accommodation, accidents, economic losses, as well as the social conscience and image of the company [7]. The outcome of such a situation is that persons with a disability do not always experience optimal workplace inclusion and must make efforts on their own to advance their careers [8].

Then, to ensure adequate labor inclusion of PWD, Chi [9] mentions that an accurate and detailed evaluation should take place, focusing on two important aspects, one concerning the individual evaluation, which consists in ones interest in the work, ones skills and disabilities; and another one based on the ergonomic aspects, such as job demands and the characteristics of the tasks. Determining reasonable accommodations through the use of ergonomics is an important step in providing an environment of inclusion at the workplace for individuals with physical or mental disabilities [10].

According to Newton and Ormerod [11], PwD in the United Kingdom work in offices rather than construction sites, in most construction companies. Civil construction employers say it is easier to employ PwD in office activities due to the nature of the construction activities, and also because it can be difficult to match the abilities of PwD with the job demands and the environment. Furthermore, the types of disability that they have are not known, neither the relationship between the environment and the disability, nor the impacts of that environment, such as the type of work [11].

Besides, some studies are found in the literature evaluating the labour production of PwD, but most is through a questionnaire to employers and to Human Resources managers [12, 13], and few use labour production data of companies [14]. Therefore, the purpose of the research was to evaluate the labour production of PwD in the construction industry in the metropolitan area of Recife, Pernambuco, Brazil.

2 Methods

The field research was conducted in two stages. The first stage was to identify which companies had PwD in vertical construction sites of the Metropolitan Region of Recife, Brazil, and the jobs that these workers performed. Eighteen companies responded stating that there were PwD in vertical construction sites, but nine companies were excluded because did not authorize the research.

In the second stage, the sites of the nine companies were visited for data collection. The study participants were interviewed and answered a sociodemographic questionnaire about the jobs, origin of the deficiencies, the time to onset the disability, time that the job was exercised, type of disabilities, etc. In addition, the companies provided information about accommodations made in the workplace and quantitative data of the monthly labour production of the last 12 months of each PwD and the largest amount of workers without disabilities who performed the same activities of each PwD. Then, the relative production of PwD was obtained by the ratio between the average monthly labour production of the workers with and without disabilities that performed the same activities of each PwD. From then on, the data were compiled to perform comparative analysis of labour production between workers with and without disabilities.

2.1 Data Analysis

The model to be estimated via the least squares method [15] to identify the variables that correlate with the labour production of workers with disabilities compared to those without disabilities is given by:

$$\mathrm{Yi} = \beta 0 + \beta 1\mathrm{Xi} + \varepsilon \mathrm{i}$$

where Yi is defined as the relative production of workers with disabilities in relation to workers without disabilities (production with disabilities/production without disabilities). Xi takes many variables such as age, education, time exerting the job, time of onset of the disability, carried out of organizational accommodation, among others.

The interpretation of the model above considers, as an example, the relation between labour production and variable age. It is assumed that the model estimation led to β0 Estimated = 0.00 and β1 Estimated = 0.05. Thus:

$$\begin{aligned}\mathrm{E}[\mathrm{Yi}|\mathrm{age} = 0] &= \mathrm{E}[\beta 0 + \beta \mathrm{Xi} + \varepsilon \mathrm{i}|\mathrm{age} = 0] \\ &= \mathrm{E}[\beta 0|\mathrm{age} = 0] + \mathrm{E}[\beta 1\mathrm{Xi}|\mathrm{age} = 0] + \mathrm{E}[\varepsilon \mathrm{i}|\mathrm{age} = 0] \\ &= \beta 0 + \beta 1 * 0 = \beta 0 = 0.00\end{aligned}$$

Considering also that the youngest person in the sample is 20 years old while the oldest is 25, the labour production of the youngest person is:

$$\begin{aligned} E[Yi|age = 20] &= E[\beta 0 + \beta Xi + \varepsilon i|age = 20] \\ &= E[\beta 0|age = 20] + E[\beta 1Xi|age = 20] + E[\varepsilon i|age = 20] \\ &= \beta 0 + \beta 1 * 20 = \beta 1 * 20 = 1.00 \end{aligned}$$

As this number (1.00) represents the relative production between the PwD in relation to a worker without disabilities, it can be interpreted that the two of them are similar in labour production, i.e., production with disabilities/production without disabilities = 1.00. Considering now the 25-year-old person, this person has a relative production of 1.50 (=$\beta 0$ + $\beta 1$ * 20 = 0.00 + 0.05 * 20), or 50% more productive than the worker without disabilities. Thus, the coefficient $\beta 1$ captures the relationship between age and labour production; this being positive, it indicates that there is positive correlation between age and labour production.

Considering another aspect, it is wished to estimate the relationship between education and labour production. It is assumed that Xi is set to 1.00 if the person has not completed high school and 0.00 otherwise. It is assumed that the model estimation led to $\beta 0$ Estimated = 1.30 and $\beta 1$ Estimated = −0.40. Thus, workers with higher education have higher relative production (30% higher), while employees with less education have lower relative production (10% lower):

$$\begin{aligned} E[Yi|Xi = 0] &= E[\beta 0 + \beta Xi + \varepsilon i|Xi = 0] \\ &= E[\beta 0|Xi = 0] + E[\beta 1Xi|Xi = 0] + E[\varepsilon i|Xi = 0] \\ &= \beta 0 = 1.3 \\ E[Yi|Xi = 1] &= E[\beta 0 + \beta Xi + \varepsilon i|Xi = 1] \\ &= E[\beta 0|Xi = 1] + E[\beta 1Xi|Xi = 1] + E[\varepsilon i|Xi = 1] \\ &= \beta 0 + \beta 1 = 0.9 \end{aligned}$$

As usual practice in the literature, it was decided (a) to disclose the standard deviations (SD) robust to heteroscedasticity, since the database contains information about several individuals and (b) by using t tests to assess the significance of the estimated parameters linear regression models [16].

Statistical analysis was performed using Stata software version 9.0. In order to evaluate the statistical significance, it was used the confidence interval of 95% (IC 95%) and the value of 0.05 for the probability associated with the t test (*p*-value).

3 Results

There were 26 workers with disabilities participating in this research, of which 65.38% (n = 17) had physical disabilities, 15.38% (n = 4) partial visual disability (monocular), 11.53% (n = 3) partial hearing disability and 7.69% (n = 2) full hearing disability. All volunteers were male and were distributed in 15 construction sites. The average age of the sample was 41.11 years and standard deviation (SD) of ±9.13, the average time to onset the disability was 25.34 years ago ± 15.34, the average time that the job was exercised was 9.91 years ± 10.44, the average time working in the company was 4.47 years ± 5.56.

It was found that 30.76% (n = 8) of PwD was laborer, 19.23% (n = 5) bricklayer, 11.53% (n = 3) bricklayer assistant, and a worker for each of the following roles: steel fixer, carpenter, electrician, foreman, concrete mixer assistant, stockman assistant, attendance indicator-man, concrete mixer operator, plasterer and painter.

Regarding the origin of the deficiencies, 34.61% (n = 9) were due to acquired disease, 34.61% (n = 9) accidents, while 15.38% (n = 4) had congenital cause and 15.38% (n = 4) occupational accident. Of the cases of disability caused by accidents, 23.07% (n = 6) were domestic accidents, while the four cases that the deficiencies emerged from work-related accidents, three occurred in the construction industry. Also, to 53.84% (n = 14) of PD, companies made accommodations in the workplace, all of the organizational type. The most prevalent adaptations were: not carrying weight and performing light work (n = 9; 64.28%), prohibition to work at height (n = 5; 35.71%). In addition, 100% of PD said it was not necessary to carry out further accommodations at work.

Table 1 presents the results of variables according to the type of disability. The results show that persons with partial hearing loss were, on average, the oldest ones, and also the ones who have spent the longest time working in the companies, besides the longest time performing the same occupation. The time of onset of the disability had a higher average for workers with full hearing disability and the average score of the WLQ summed score was higher for persons with physical disabilities. Moreover, it is observed that 41.17% of workers who have physical disabilities are laborers and organizational accommodations were made for 70.58% of persons with physical disabilities. Besides, all the accommodations made by the companies were of organizational type such perform lighter tasks and not to handle heavy objects and prohibition to work at height.

The relative production of PwD was obtained by the ratio between the average labour production of the workers with and without disabilities that performed the same activities of each PwD. The results showed that the mean labour production of the PwD corresponded to 83.50% and SD of ±0.36 of the labour production of the workers without disabilities, which means 16.50% lower in relation to workers without disabilities. This difference was statistically significant (p = 0.016) by t test.

Furthermore, when analyzing each labour production data of the worker with disability compared to those without disabilities, it was found that 19.23% (n = 5)

Table 1 Descriptive statistics the sample according to the type of disability

	Physical	Partial visual (monocular)	Full hearing	Partial hearing
Mean in years				
Age	40.11 (7.19)	36.75 (10.90)	47.00 (18.38)	48.66 (10.69)
Time in the company	3.30 (3.98)	4.74 (6.25)	6.54 (7.72)	9.38 (10.92)
Time exercising the job	7.24 (8.91)	10.89 (13.00)	12.04 (15.49)	22.33 (7.37)
Time of onset of the deficiency	26.94 (15.53)	14.75 (4.11)	45.00 (15.55)	17.33 (11.67)
%				
Bricklayer	17.64 (0.39)	25.00 (0.50)	0.00 –	33.33 (0.57)
Laborer	41.17 (0.50)	0.00 –	50.00 (0.70)	0.00 –
Laborer of bricklayer	5.88 (0.24)	50.00 (0.57)	0.00 –	0.00 –
Organizational adaptation	70.58 (0.46)	25.00 (0.50)	50.00 (0.70)	33.33 (0.57)
N	17	4	2	3

Note The standard deviation is shown in brackets

of the PwD had higher production, while 19.23% (n = 5) had the same level of production and 61.53% (n = 16) had lower production.

The higher the age and the time that the worker performs the job, the greater labour production of PwD compared to those without disabilities, but the relationship has only been significant for the variable of the time that the worker performs the job ($p = 0.001$). Regarding the level of education, PwD who did not conclude high school showed 18.21% lower production in relation to the workers without disabilities. Whereas PwD who had higher educational level showed 17.17% lower production than workers without disabilities. Moreover, it appears that the shorter the time of onset of the disability, the higher the production in relation to workers without disabilities.

In cases where there were not accommodations, workers with disabilities had 10.03% of higher labour production than those without disabilities. Whereas in the cases where these accommodations were made, the production of PwD was 33.75% ($p = 0.001$) inferior than the production of workers without disabilities. Table 2 presents the relative production of the PwD according to the type of disability, job and origin of disability.

Table 2 Labour production of the workers with disabilities

Variable	Production (%)	*p*
Physical disabilities	−29.86	0.001*
Partial visual disabilities (monocular)	+25.03	0.081
Total hearing disabilities	−14.64	0.589
Partial hearing disabilities	−9.53	0.272
Bricklayer	−0.63	0.977
Laborer	−47.88	0.000*
Laborer of bricklayer	+20.20	0.180
Congenital	−28.49	0.024*
Acquired disease	−25.42	0.061
Accident	−16.57	0.214
Occupational accident	+ 6.59	0.675

Note $^{*}p < 0.05$

4 Discussion

Workers with physical disabilities corresponded to 65.38% of the workers in the research sample, a similar result to other studies in various productive sectors [17]. In this sense, this higher proportion of persons with physical disabilities in the sample may be due to greater access to education, because according to Lancillotti [18], in Brazil, this group of persons has advantages in education over the other types of PwD.

Regarding the jobs that were carried out, 30.76% of the workers were laborers and 11.53% were bricklayer assistants. Thus, most workers performed auxiliary jobs in civil construction, working paired with another professional, which requires lower professional qualification, generating lower wages and lower valuation. This result is similar to that found in the literature, as PwD take low-skilled jobs [19], such as laborer [20], cleaner, janitor, doorman, collector, stockman and general assistant [19].

Companies performed accommodations at work to 53.84% of the PwD. This result was higher to that found in the research carried out by [21], in which accommodations were made to 43.9% and 33.6% of PwD. In this direction, it turns out that it is not always necessary to have work accommodations for the employment of PwD, once they are able to perform various jobs in the labor market. In the cases where accommodations were not made, the labour production of PwD was 10.03% higher than for the workers without disabilities. However, not having accommodations in the workplace can also occur because some companies hire workers whose disabilities do not require adjustments at work [22].

Moreover, it was observed that all the accommodations made by the companies were of organizational type and the most frequent one (64.28%) was for PwD to perform lighter tasks and not to handle heavy objects, i.e., redistributing non-essential tasks to other workers. Other research shows that 64% [23] and 66% [18] of employers redistributed non-essential tasks to other workers. Thus, the redistribution of tasks and requesting help for another employee to perform non-essential tasks is a useful accommodation for the labor inclusion of PwD [20].

When comparing the labour production of each PwD to the labour production of the workers without disabilities, it was found that 39.46% (n = 10) of PwD showed equal or greater production than those without disability, so, 61.53% (n = 16) of them had inferior production. By analyzing the findings in the literature, results found that employers of unidentified economic sectors stated that the labour production of workers with disabilities was equal [12], lower [13] and higher [24] than of those without disabilities.

Furthermore, the study found a statistically significant lower labour production of 16.50%, on average, of workers with disabilities in relation to those without disabilities. This result can be explained by the fact that 65.38% of the sample was made of persons with physical disabilities, who were the ones that had the lowest production. This lower production found in the research is less than the one found in the study of Graffama et al. [14] in various economic sectors of Australia. The authors found that, on average, the 653 of PwD were 27.71% slower and showed a decrease on labor quality of 21.56%, compared to those without disabilities [14].

The workers with physical disabilities were those who had the lowest production compared to workers without disabilities. This may have been caused because persons with physical disabilities were those who had the lowest average time of performing the job, given that the results of this research showed that the longer the time of carrying out the job, the larger the production regarding workers without disabilities.

The labour production of laborers with disabilities was 47.87% inferior than the one compared to those without disabilities, because 87.50% of these workers had physical disabilities, which was the type of disability that had the lowest production.

5 Conclusions

In this research, there were cases in which PwD of the civil construction had higher production, equal and less than those without disabilities. It is important to emphasize that no company carried out an analysis of job tasks to include PwD, which may have influenced the labour production. Thus, it is believed that if these analyzes had been carried out using ergonomics knowledge and if the necessary adaptations to the PwD workplaces had been implemented, more adaptations and different types of adaptations could have been made and the production of PwD would have increased.

This research may contribute on the topic and can be helpful for construction practitioners dealing with employment of the persons with disabilities. Every situation, or every worker with or without disabilities in the workplace is unique, it is not possible to make generalizations about who has higher or lower labour production.

References

1. WHO—World Health Organization: World Report on Disability 2011. World Health Organization, Genebra (2011)
2. OECD—Organization for Economic Co-operation and Development: Sickness, Disability and Work: Breaking the Barriers. A Synthesis of Findings Across OECD Countries. Organization for Economic Co-operation and Development, Paris (2010)
3. Bruyere, S.M.: Disability Employment Policies and Practices in Private and Federal Sector Organizations. Cornell University, School of Industrial and Labor Relations, Program on Employment and Disability, Ithaca, NY (2000)
4. Robinson, J.E.: Access to employment for people with disabilities: findings of a consumer-led project. Disabil. Rehabil. **22**, 246–253 (2000)
5. Gartrell, A.: 'A frog in a well': the exclusion of disabled people from work in Cambodia. Disabil. Soc. **25**, 289–301 (2010)
6. Hammel, J., Magasi, S., Heinemann, A., Whiteneck, G., Bogner, J., Rodriguez, E.: What does participation mean? An insider perspective from people with disabilities. Disabil. Rehabil. **30** (19), 1445–1460 (2008)
7. Simonelli, A.P., Camarotto, J.: Analysis of industrial tasks as a tool for the inclusion of people with disabilities in the work market. Occup. Ther. Int. **15**(3), 150–164 (2008)
8. Kulkarni, M., Gopakumar, K.V.: Career management strategies of people with disabilities. Hum. Resour. Manag. **53**(3), 445–466 (2014)
9. Chi, C.: A study on job placement for handicapped workers using job analysis data. Int. J. Ind. Ergon. **24**, 337–351 (1999)
10. Larson, B.A.: The role of ergonomics in providing reasonable accommodation. Work **14**, 175–177 (2000)
11. Newton, R., Ormerod, M.: Do disabled people have a place in the UK construction industry? Constr. Manag. Econ. **23**, 1071–1081 (2005)
12. Hernandez, B., Mcdonald, K.: Exploring the costs and benefits of workers with disabilities. J. Rehabil. **76**(3), 15–23 (2010)
13. Campos, J.G.F., Vasconcellos, E.P.G., Kruglianskas, G.: Incluindo pessoas com deficiência na empresa: estudo de caso de uma multinacional brasileira. Rev. Administração **48**(3), 560–573 (2013)
14. Graffama, J., Smith, K., Shinkfield, A., Polzina, U.: Employer benefits and costs of employing a person with a disability. J. Vocat. Rehabil. **17**(4), 251–263 (2002)
15. Angrist, J., Pischke, J.S.: Mostly Harmless Econometrics: An Empiricist's Companion. Princeton University Press, Princeton, NJ (2008)
16. Imbens, G.W., Wooldridge, J.M.: Recent developments in the econometrics of program evaluation. J. Econ. Lit. **47**(1), 5–86 (2009)
17. Wiggett-Barnard, C., Swartz, L.: What facilitates the entry of persons with disabilities into South African companies? Disabil. Rehabil. **34**(12), 1016–1023 (2012)
18. Lancillotti, S. S.: Deficiência e trabalho: redimensionando o singular no contexto universal. Autores associados, Campinas (2013)
19. Tanaka, E.D.O., Manzini, J.E.: O que os empregadores pensam sobre o trabalho da pessoa com deficiência? Rev. Bras. Educação Especial **11**, 273–294 (2005)

20. Guimarães, B.M., Martins, L.B., Barkokébas Junior, B.: Workplace adaptation to people with disabilities at construction industry in Brazil. Work **50**(4), 575–584 (2015)
21. Hogan, A., Kyaw-Myint, S.M., Harris, D., Denronden, H.: Workforce participation barriers for people with disability. Int. J. Disabil. Manag. **7**, 1–9 (2012)
22. Monteiro, L.G., Oliveira, S.M.Q., Rodrigues, S.M., Dias, C.A.: Responsabilidade social empresarial: inclusão de pessoas com deficiência no mercado de trabalho. Rev. Bras. Educação Especial **17**(3), 459–480 (2011)
23. Stoddard, S.: Personal assistance services as a workplace accommodation. Work **27**, 363–369 (2006)
24. Raphael, T.: Think twice: disabling some old stereotypes. Workforce Manag. **81**(8), 88 (2002)

Organizational Maturity Models: Trends for the Future

Carolina Ferradaz, Pedro Domingues, Aneta Kucińska-Landwójtowicz, Paulo Sampaio and Pedro M. Arezes

Abstract By adopting a maturity model (MM) an organization aims ascending to a higher maturity level and, simultaneously, preserve the evolution attained thus, for this reason, is mandatory to prospect the trends for future. This article intends to address the organizational maturity concept, evolution shift perspectives and establish the current landscape by performing a bibliometric analysis aiming to detect trends and evidences of convergence. The purpose is the identification of opportunities for further study and to deepen the theoretical-scientific universe of the subject. Throughout a scrutiny of diverse data nucleus (databases), this paper supports the theory that there is increased interest from the academic community (including the occupational health and safety academic community) and entrepreneurial market on organizational maturity models (OMM's) adoption. The pivotal fields are outlined in order to fulfill scholars, practitioners and managers' information needs and expectations, as well the research behavior, which can booster forward-looking insights. Inasmuch, is stressed the urge for development of the safety management and related maturity as a research topic.

Keywords Bibliometric analysis · Industry 4.0 · Management · Maturity · Maturity model · Safety management

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1 Introduction

The business horizon enforces organizations to challenge their strategy and soar from their current position to an excellence level. Considering the global market dynamics and insurgent products requirements, not just technical but including environmental and occupational health and safety (OHS) issues [1], the companies must foster technology, and innovation to distinguish themselves. By setting quality parameters and establishing controls to satisfy beyond technical specifications (also the requirements of the most demanding customers) creates opportunity: a *continuum* of pursuing Quality and the achievement of organizational maturity. Furthermore it is necessary to extrapolate the parameters and to reach more than solely adaptation to the entrepreneur environment, it is necessary create value for customers and Society. Thus, it is essential to plan the organizations' future and embodying innovation perspectives into the organizational mindset. The organizational ripening must occur through and integrated approach and holistically, which captures the complexities of externalities and organizational reality. Albeit the multitude of MM's existing in literature that envisages those parameters it also constitutes a difficulty among the practitioners to select the more operating one for the organizational strategy and objectives [9]. Top management sense concerning the interrelationship of this range of factors is a fence against uncertainty.

The maturity level reflects the actual capability in terms of management. As an organization evolves to safety is assigned a high priority and to turn it into efficient reality must be carry out the harmonization of safety practices through adoption of a common 'language' [2]. The hallmarks of an immature organization are reactivity and improvisation in which the decision to implement improvements is triggered only by emergencies. Those sort of organizations usually display extent chaotic processes with no regulatory requirements. In order to the occurrence of awareness (where the organization evolves from an immature stage to one that seeks to start maturation) must exist proactivity for learning, exploitation of mistakes like lessons learned and improvement opportunities, and also, accept the active participation and enrolment of the whole staff. The cultural shift, thus, must come from top management and should diffuse throughout all organizational levels. It is imperative to point out that evolution happens optimally with commitment. It is top management assignment the dissolution of behavioral and cultural barriers [7], and transmits the goals' significance so employees can understand the relevance of changes either perceive their role in the endeavor.

Hence, this article aims to address the organizational maturity concept and establish the current landscape of the extant literature on the subject OMM's. Therefore the main objectives are: (i) to perform a bibliometric analysis adopting a visual mapping tool to pinpoint correlations and detecting research streams, which includes the identification of trends and evidences of research convergence to new topics (ii) put in classification criterial for models as appropriate its implementation field; (iii) to identify the topics in which opportunities emerge for further study and deepening, which means inferring whether the scientific community provides content in parallel with the scholars, practitioners and managers' needs.

2 Methodological Background

2.1 Bibliometric Analysis

The bibliometric concept encompasses the act of identifying the current prospect of the theoretical-scientific universe of a targeted subject using quantitative methods; hence, it reflects the content behavior and its research structure on present. It is an effective technique for studying in an intellectual field and examining how it evolves [10]. Bibliometric analysis is a useful tool for finding patterns, which provides insights and disruptions. According to Kilubi [5], "an increasing number of academic researchers have dedicated their attention to bibliometric studies to evaluate the advance of management disciplines evolving from their juvenile stages". This paper adopts bibliometric analysis methods aiming at the visual mapping of the extant literature on OMM's by extracting the modal terms. It is intended to establish the terms linkages and to measure the contents' strength being the outcome "gauging the state-of-the-art of its discipline and to frame future requirements and research prospects" [5]. The first step encompasses the development of a network diagram. Thereafter, the second step covers the statistical analysis and discussion of results. The selected publications were identified from the Scopus database by adopting the keywords 'organizational maturity model'. Restrictive filters were applied in order to diminish the publications set to a manageable amount, enabling further individual analysis of the abstracts. The resulting final sample comprised 242 publications embedded in the time horizon from 2004 to 2019.

2.2 Visual Mapping: A Network Diagram

Narrowed the database follows the visual mapping stage of the modal terms at the scope of scientific research. The shape is a theme network that illustrates the intellectual arrangement of the subject (using the abstracts' content) which, inherently, it is a static view and has an ad hoc nature (i.e. provisional). The ensuing appraisal is diametrically opposed: approaches the evolution of research in a *continuum* whereby the production of scientific content undergoes critical revisions continuously.

The software VOSviewer [8] was adopted to develop the network diagram encompassing a body of analysis of 242 abstracts. The diagram points out the recurrent words, where each of these terms has distinct weight and is represented by their label and, by default, also by a circle. Terms with a higher weight are shown more prominently size variation: the higher the weight of an item, the larger the label and the circle of the item [8]. The network visualization also points out the intertwined nature between the terms so the number of links is an attribute of the concepts correlation. The outcome is the demonstration of the strong keywords correlation, which are ‘industry’, ‘technology’, ‘project’, ‘organization’, ‘culture’ and ‘improvement’, amidst others, widely used in the context of OMM’s scientific research within the 2004–2019 time range Fig. 1. It is reasonable to consider if publications and their references reflect the shared research interests and work contents, then bibliometric methods provide a useful approximation to the social environment behind the citation maps [10]. The identified keywords and their connections bring to light topics not solely pertaining to the MMs’ context but also other keywords encompassing the surrounding environment in the macroeconomics, technological, business management and externalities that drive the research. The connections traced are a prospect that underpins future academic endeavors.

2.3 Data Analyses

Starting by the etymological concept of statistics that includes data collection and classification, statistical analyses are performed in order to develop classification and clustering criterial for OMM’s as appropriate its implementation field. Exploiting the set of 242 abstracts follows the distribution chart Fig. 2 of the total publications. It shows a growth of the number of publications year by year (as highlighted by the trend line) where the peak occurs in 2014.

On a different note, a hypothesis is a conjecture about an unknown event, a condition that can properly explain something that is presumed empirically. It is legitimate to accept that the data Fig. 2, in parallel with number of publications

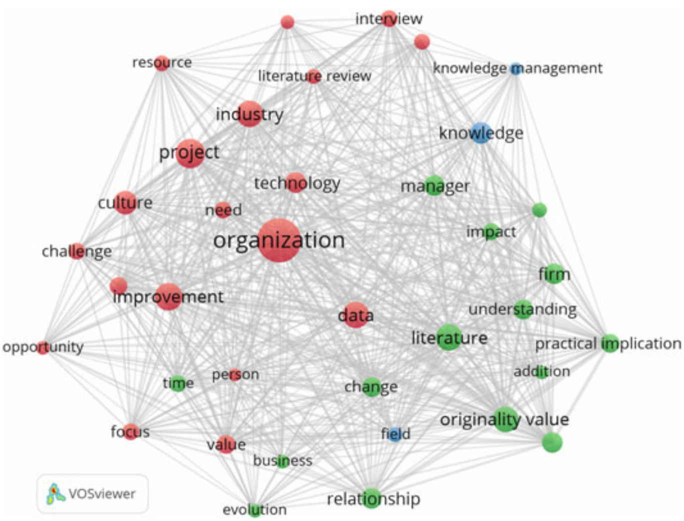

Fig. 1 The network diagram illustration of the sample: an intellectual arrangement

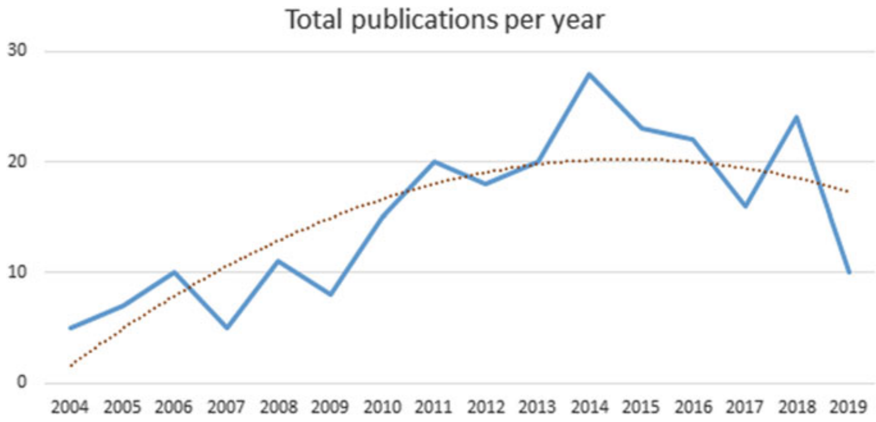

Fig. 2 Total number of publications—breakdown by year

Table 1 Most cited papers under organizational maturity models sample [3]

Author	Publication year	Scope	Citations
Schumacher, A., Erol, S., Sihn, W.	2016	Industry 4.0 advent	119
Grant and Pennypacker	2006	Project management	116
Khosrowshahi and Arayici	2012	Information technology	109

growth, support the assumption that there is an increased interest from the academic community and entrepreneurial market on OMM's. Bibliometric studies usually include a citation analysis, where papers' citations are an influent measure (proxy variable). This proposition rests on the assumption that those papers heavily cited can be considered hors concours at that scope [11]. Thenceforward is possible to stress the most prominent publications Table 1 drawing on the citations number as an attribute indicator.

Considering the distribution chart Fig. 3 of total citations year-by-year (where total amount is 2647 citations) it is reasonable to consider that, taking into account the last four years, less relevant content has been published. The foremost publications take place throughout the 2006–2014 time range (as highlighted by the trend line) and 2012 the year belonging of the pivotal publication, Khosrowshahi and Arayici [4], aforementioned, with 109 citations. This single publication accounts for nearly 30% of the number of citations of the referred year.

3 Results and Discussions

The employed criteria for categorization embraces the assessment of survey field, the main publication purpose and the MM's focal area of adoption. In light of these perspectives, there are publications that earned more than one classification. The

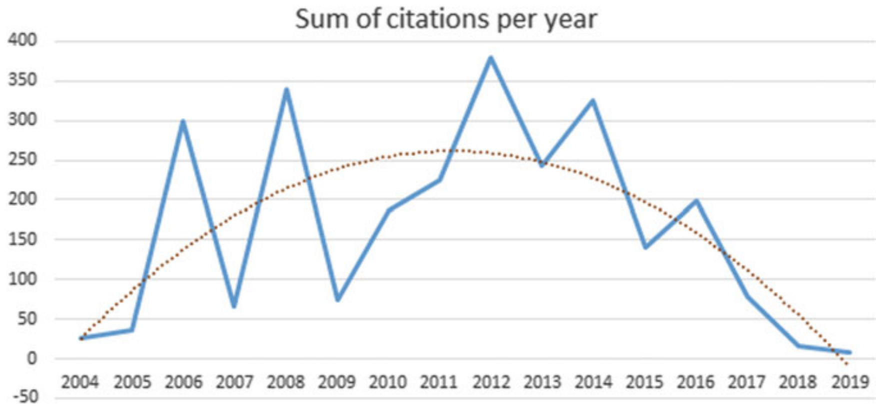

Fig. 3 Sum of sample citations—breakdown by year

Table 2 Results of classification criterial for organizational maturity models

Classification	No	Classification	No
Project management (PM)	34	Human resource, ergonomics, health and safety management (HEHSM)	24
Knowledge management (KM)	32	Process management (PRM)	20
Business management and strategy (BME)	30	Supply chain management (SCM)	15
Information technology (IT)	30	Risk management (RM)	14
Performance management (PFM)	30	Innovation management (IM)	13
Quality management (QM)	30	Industry 4.0 concept (I4.0)	02
Total			274

same criteria were applied to all abstracts. Drawing on, as an attribute indicator, the publications number for each classification; it is possible to stress relevant research fields at the OMM's theoretical-scientific universe Table 2. Listed in ascending order: PM, KM and, with the same publications number, the BMS, IT, PFM and QM.

I4.0 field retains the smallest number of publications (2 papers) accounting for solely 0.7% of the total classification results. Nevertheless, amidst the abstracts appreciated the most cited paper (118 citations) is 'A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises' [6]. It is legitimate to accept that the data obtained do not support the assumption that scientific community provides content in parallel with the practitioners, managers and scholars' needs and expectations in search for OMM's embedded in I4.0 concept. Considering the last four years, less relevant content has been published Fig. 3 whereby foremost publications take place at the 2006–2014 range time. It is legitimate to accept that there is no scenario to support that the scientific community provides content in parallel with the needs. It is also possible to highlight the most

Fig. 4 Total number of citations—breakdown by classification

prominent research fields Fig. 4 drawing on the total citations number (distributed through each classification pertained) as an attribute indicator. Listed in ascending order: IT, PM and PFM. The IT subject spotlight is mainly due for the aforementioned article 'Roadmap for implementation of BIM in the UK Construction Industry' [4], with 109 citations, and therefore, with the impact evaluation approximately 24% on the classification at issue. HEHSM, within the scope of the OHS, is the less relevant research field with an impact about 3% overall, so it is also legitimate to accept that the scientific community is not yet focused on developing this subject.

The network diagram Fig. 1 points out the keywords (also their correlations) embodied into the OMMs' context, also the surrounding environment, and highlights terms such 'industry', 'technology', 'project', 'organization', 'culture' and 'improvement'. Considering the most relevant research fields, namely PM, KM, BMS, IT, PFM, QM and the demand for I4.0 content, it is legitimate to accept the results above discussed constitutes a corollary of this visual mapping outcome.

4 Conclusions

It is imperative to burst the status quo, the immutability. Evolving is a natural process of any organism or organization and safety culture is a critical feature for the corporate maturity. Adaptability and changeover to ripeness are themselves innovation; hence, to leverage the shift it is mandatory prospecting the trends for the future. The data assessed supports the theory that there is an increased interest from the academic community and entrepreneurial market on OMM's. Inasmuch, the pivotal fields are IT, PM, PFM and I4.0. Those entailed in the theoretical-scientific universe of the subject, concluded throughout scrutiny of diverse data nucleus, what brings validity for inferences. The visual mapping diagram stressed the correlations and includes the actual trends, i.e., the evidences of research convergence. Those results are suitable for extrapolation as trends for forthcoming environment in the macroeconomics, technological, business management and externalities that drive the research and the MMs' adoption. The connections outlined are a prospectus distinguishing thereby the power of the cluster analysis method. In practice, IT, PM, PFM, I4.0 and HEHSM domains are opportunities for further research thus catalyzing the organizational maturity and safety improvement in a continuous cycle. Pointing out I4.0, to buffer shortcomings, i.e., fulfillment scholars, practitioners and managers needs for information that interprets the new industrial revolution phenomenon. Moreover, in a *paradoxum* and spite of the increased interest, less relevant content has been published in last four years in the OHS domain. In addition, not only the acknowledged fields are opportunities for deepening but the whole OMMs' is a prospective subject to critical review.

An organizational model is not, itself, feasible or unfeasible. Success arises according the companies' ability to implement and operationalize it. The universalization of models can be ineffective in capturing the organizational reality, therefore, on this paper is encouraged the proper shift administration: considering obstacles, organizational specificities and complexities of externalities. This due confluence bears fruit to sustainable evolution of the organization and a successful effort to maturity.

5 Limitations and Future Research

The sample analyzed was extracted from Scopus database and, thus, bounded to it, which arises a limitation and an opportunity for future research. The same methodology and bibliometric analysis can be adopted throughout samples from distinct databases and performing results: data crossing from various sources can provide insights and either validate, or not, the robustness of the conclusions. To the abstracts content analysis is associated some bias which introduces noise into the results. Another opportunity for future research is the development of a network diagram, i.e. the visual arrangement, for every a pre-fixed period aiming evolutionary gearshifts detection on the subject. The timeline scrutiny of the research behavior can booster forward-looking insights. Also, to develop research avenues concerning the OHS management topic is of utmost importance. From the results a question emerges: why the safety performance and its maturity is a topic not growing concurrently with the industrial development? Further research should address this issue.

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References

1. Domingues, P., Sampaio, P., Arezes, P.M.: Integrated management systems assessment: a maturity model proposal. J. Cleaner Prod. **124**, 164–174 (2016). https://doi.org/10.1016/j.jclepro.2016.02.103
2. Domingues, J.P.T.: Sistemas de gestão integrados: desenvolvimento de um modelo para avaliação do nível de maturidade. Ph.D. thesis, University of Minho, Portugal (2013)
3. Grant, K.P., Pennypacker, J.S.: Project management maturity: an assessment of project management capabilities among and between selected industries. IEEE Trans. Eng. Manag. **53**(1), 59–68 (2006). https://doi.org/10.1109/TEM.2005.861802
4. Khosrowshahi, F., Arayici, Y.: Roadmap for implementation of BIM in the UK construction industry. Eng. Constr. Architectural Manag. **19**(6), 610–635 (2012). https://dx.doi.org/10.1108/09699981211277531.
5. Kilubi, I.: Investigating current paradigms in supply chain risk management—a bibliometric study. Bus. Process Manag. J. **22**(4), 662–692 (2016). https://doi.org/10.1108/BPMJ-05-2015-0060
6. Schumacher, A., Erol, S., Sihn, W.: A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP **52**, 161–166 (2016). https://doi.org/10.1016/j.procir.2016.07.040
7. Sternad, D., Krenn, M., Schmid, S.: Business excellence for SMEs: motives, obstacles, and size-related adaptations. Total Qual. Manag. Bus. Excellence **30**(1–2), 151–168 (2019). https://doi.org/10.1080/14783363.2017.1300054
8. Van Eck, N.J., Waltman, L.: {VOSviewer} manual. Univeristeit Leiden, Leiden (January). Retrieved from https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.1.pdf (2013)
9. Van Looy, A., de Backer, M., Poels, G.: Defining business process maturity. A journey towards excellence. Total Qual. Manag. Bus. Excellence **22**(11), 1119–1137 (2011). https://doi.org/10.1080/14783363.2011.624779.
10. Vogel, R.: The visible colleges of management and organization studies: a bibliometric analysis of academic journals. Organ. Stud. **33**(8), 1015–1043 (2012). https://doi.org/10.1177/0170840612448028
11. Zupic, I., Cater, T.: Bibliometric methods in management and organization. Organ. Res. Methods **18**(3), 429–472 (2015)

Occupational Health and Safety-Sustainable Development and the Changes in Organizations

Cristina Reis, Carlos Oliveira, Paula Braga, J. F. Silva and L. T. Silva

Abstract The paper aims to demonstrate the interconnection between occupational hygiene and health, which is based on three main pillars: economy, environment and society, just as sustainable development is based on three major topics: people, planet and profit. Thus there must be strong OHS policies that encompass sufficient environmental programs to ensure workers are safe and thus ensure sustainability. Sustainable development is an increasingly imminent concern in all countries and organizations today. The United Nations (UN) has played a key role in this context. In 1992 at Rio-92, through Agenda 21, elaborated with the collaboration of 172 countries, they decided to create goals for sustainable development, giving priority to the environment. The document was based on environmental conservation, social

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justice and economic growth. In the meantime, at the beginning of the century, the eight outlined goals that became known as the «8 millennium goals» for the period 2000–2015 were set. At the UN Summit, in New York (USA), a new action agenda, until 2030, was established. This agenda is the result of the joint work of governments and citizens, around the world, to create a new global model for ending poverty, promoting prosperity and well-being, protecting the environment and fighting against climate change. The year of 2015 will be in history as the year of defining the 17 Sustainable Development Goals, known as the 2030 agenda.

Keywords Sustainability · Environment · Prevention · Safety · Occupational health

1 Introduction

1.1 Sustainable Development

Sustainability has played a predominant role in our society over the last few years. During the 2000s, space and urban policy in the United Kingdom became increasingly concerned with the creation of sustainable communities. The urban renaissance's focus on security through design has been replaced by new, more holistic discourses that emphasize "community security" and the ways in which the planning process can be reformulated to achieve this [1].

Sustainability is, in fact, a "process" that seeks to strike a balance between the environment and use of natural resources. Humanity over time has so degraded the planet's natural resources that it is now necessary to carefully seek and plan their consumption to ensure their existence for future generations [1].

According to the UN, sustainable development is a development model that enables the needs of the present to be met without compromising the ability of future generations to meet their own needs [2].

Factors that affect sustainable development and deserve individual and collective reflection are:

– Energy efficiency;
– Sustainable mobility;
– Climate and climate change;
– Sustainable consumption;
– The efficient use of resources;
– Waste recovery or preservation of biodiversity.

The way in which the concept of sustainable development is viewed has evolved in recent decades, due to the new scientific knowledge, but also due to the awareness of society in general, reflected on several international decisions already taken, namely within the UN Organization.

1.2 Occupational Health and Safety

Occupational hygiene is understood as a set of norms and procedures that aim at protecting the physical and mental integrity of the worker, preserving from health risks inherent to the tasks and the physical environment where the work is performed [3].

In turn, Occupational health is the science that encompasses occupational hygiene, safety and medicine by monitoring workers at their work, establishing methods, organizing the work environment and designing programs that promote workers' health [4].

Companies are responsible for providing a safe working environment for their workers. Occupational hygiene and health seeks to reduce work-related hazards by identifying and minimizing factors that may eventually affect employees' environments [5]. Safety at work sensitizes employees and seeks to eliminate unsafe conditions by preventing work accidents [5].

2 Evolution of Organizations on Sustainable Development

2.1 Evolution in Organizations

This development paradigm was embodied in Rio-92, through Agend-21, prepared with the collaboration of 172 countries, which decided to create goals for sustainable development, giving priority to the environment. The document was based on environmental conservation, social justice and economic growth.

These three pillars are still considered essential for the application of this development concept. At the beginning of this century, eight objectives were set internationally, which became known as the «8 millennium goals» for the period of 2000–2015 [6].

In 2015, at the UN Summit in New York (USA), a new action agenda was embodied by 2030. This agenda is the result of the joint effort of governments and citizens around the world to create a new global model for ending poverty, promoting prosperity and well-being, protecting the environment and combating climate change. Thus 2015 will be in history as the year of the 17 Sustainable Development Goals definition [6].

2.2 2030 Agenda

The 2030 agenda set out a new action schedule, by 2030, which was build on the progress and lessons learned from the «8 Millennium Development Goals» between 2000 and 2015. The 17 Sustainable Development Goals are:

- Eradicate poverty;
- Eradicate hunger;
- Quality health;
- Quality education;
- Gender equality;
- Drinking water and sanitation;
- Renewable and affordable energy;
- Decent work and economic growth;
- Industry, innovation and infrastructures;
- Reduce inequalities;
- Sustainable cities and communities;
- Sustainable production and consumption;
- Climate action;
- Protect marine life;
- Protect terrestrial life;
- Peace, justice and effective institutions;
- Partnership for the implementation of the objectives.

The UN launches these goals based on real facts. The need to eradicate poverty is associated with the hunger in the world. For instance, it may be found that in an urban slum in Hanoi, Vietnam (Fig. 1), over 13% of Vietnam's population and a quarter of the world's population—nearly 2 billion people—live on $1.25, or less, a day, according to the World Food Bank.

The Sustainable Development Goals set global priorities and aspirations for 2030 and require global action by governments, businesses and civil society to eradicate poverty and create a life with dignity and opportunity, for all, within the planet limits [8]. The Sustainable Development Goals (SDGs) and the 2030 Agenda, adopted by almost all countries in the world (having been signed by 193 countries) in the UN context, sets the priorities and aspirations for global sustainable development for 2030 and seek to mobilize global efforts around a set of common goals and objectives. There are 17 SDGs in areas that affect the quality of life of all the world's citizens and those yet to come [7].

Fig. 1 Urban slum in Hanoi, Vietnam. *Photo* UN/Kibae Park [7]

The SDGs require global action by governments, businesses and civil society to eradicate poverty and create a life with dignity and opportunity for all within the confines of the planet. For companies, particularly, the SDGs provides an opportunity to create and implement solutions and technologies that address the greatest global challenges, helping to link business strategies and global priorities.

More broadly and comprehensively, an overview of the objectives of sustainable development is presented [7]:

- End poverty in all its forms and everywhere;
- End hunger, achieve food security and improved nutrition, and promote sustainable agriculture;
- Ensure a healthy life and promote well-being for all, at all ages;
- Ensure quality inclusive and equitable education and promote lifelong learning opportunities for all;
- Achieve gender equality and empower all women and girls;
- Ensure the availability and sustainable management of water and sanitation for all;
- Ensure access to reliable, sustainable, modern and affordable energy for all;
- Promote sustainable, inclusive and sustainable economic growth, full and productive employment and decent work for all;
- Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation;
- Reduce inequality within and between countries;
- Make cities and human settlements inclusive, safe, resilient and sustainable;
- Ensure sustainable production and consumption patterns;
- Take urgent action to combat climate change and its impacts;
- Conserve and sustainably use oceans, seas and marine resources for sustainable development;
- Protect, restore and promote sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, halt and reverse land degradation and halt biodiversity loss;
- Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, responsible and inclusive institutions at all levels;
- Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Only 1/5 of the planet's population consumes 70% of the energy, 85% of the wood and 75% of the metals, holding four fifths of world income [9].

The SDGs results from the joint work of governments and citizens around the world to create a new global model for ending poverty, promoting prosperity and well-being for all, protecting the environment and combating climate change [9].

2.3 International Labour Organization

The International Labour Organization (ILO), on the occasion of World Day for Safety and Health at Work, publishes its new report "Safety and Health at the Centre of the Future of Work: Building on 100 Years of Experience", which examines the organization's 100 years of work dedicated to improving occupational health and safety (OSH), and highlights emerging issues in this area in the world of work [10].

1st—Technology—such as digitalization, robotics and nanotechnology—can also affect psychosocial health and introduce new materials with health risks that have not yet been taken into account. Properly applied, it can also contribute to reduce exposure to occupational hazards, facilitating job training and inspection [10].

2nd—Demographic changes are relevant because there are high levels of occupational injuries in the young working population. On the other hand it is also necessary to ensure working methods and equipments that ensure the safety and health of younger workers. Increasing numbers of women at work are more likely to work in atypical forms of employment and are at a greater risk for musculoskeletal injury [10].

3rd—Sustainable development and climate change that open the door to risks such as air contamination, stress from excess heat, emerging diseases, changes in rainfall patterns, which may lead to job losses. But also, new jobs will be created thanks to the green economy [10].

4th—Changes in work organization can give rise to flexibility that allows more people to enter the working world, but also may lead to psychosocial problems (e.g. insecurity, reduced privacy and rest time, or inadequate OSH and social protection) and excessive working hours [10].

Based on these challenges, the ILO report proposes six areas on which policy makers and other relevant partners should be concentrated [10].

- Anticipate new and emerging OSH risks;
- Adopt a multidisciplinary approach;
- Establish a greater relationship with public health;
- Better understanding of OSH related issues;
- Strengthen international labour standards and country legislation;
- Enhance collaboration between governments, employers and employees representatives.

3 Good Examples and Methodology

The methodology followed in this research work was based on a bibliographical research on the subject and the changes in the organizations involved in this matter. In a second phase it was tried to present examples of a program of good practices, for sustainable development, that has been implemented.

3.1 Eco-Schools Program

At a national level, in this area of sustainable development, several actions have been promoted at primary, secondary and higher education level, with the action program being designated Eco-schools. This program aims to alert children and adolescents to environmental issues, to promote good practices. The early awareness of these issues begins to reverse years of environmental unconsciousness [11].

3.2 Eco-Campus Program

At a national level, as regards higher education, the sustainable Eco-Campus has been promoted. Its purpose is to reduce the energy load of universities by promoting the use of clean energy sources, placing solar panels, replacing traditional lamps with LED lamps. Other measures include promoting the reduction of plastic use, food waste, physical exercise for a healthier life, the use of sustainable transportation, such as the use of electric bicycles, running bike paths, among others [11].

4 Interface Between Occupational Health and Sustainable Development

After giving a brief presentation of the concepts, and an analysis of the organizations regarding sustainable development and occupational health, it is possible to outline the objective and motivation that led to the elaboration of this work. It aims to show how occupational health is interconnected with the sustainable development paradigm. According to major international references such as the World Health Organization: Healthy Environments for Healthy People and the International Labor Organization which says, "decent work: the key to sustainable development", occupational health is considered to be the important driver for achievement of three main objectives of sustainable development [12]. Fulfilling, in this way, the 3 objectives of the 2030 agenda:

- Goal 3: Quality Health;
- Goal 8: Decent Work and Economic Growth;
- Goal 12: Sustainable Consumption and Production.

Also, another approach is that occupational health is at the center of sustainable development in the following ways [13]:

(a) The prevention of accidents, injuries and illness at work, and the protection of workers from physical and psychological overload require a parsimonious use of resources, minimizing unnecessary loss of human and material resources.

(b) The goal of healthy and safe work environments requires the use of safer, lower energy, low emission and low waste (green) and in many countries occupational health legislation requires the use of the best available production technology.
(c) The occupational health approach has been shown to facilitate undisturbed production that increases product quality, productivity and process management, thereby helping to avoid unnecessary energy and material losses, and to avoid unwanted impacts on the environment.
(d) Many environmental risks and burdens are derived from occupational environments, industry, farming or transportation practices and services. Occupational health specialists, and other safety officers, are well informed of the processes and agents that can be hazardous to the environment. Often this information is available to them at a very early stage of the problem, thus allowing prevention that is no longer possible when the hazardous substances are released into the environment. The impact of occupational health on protecting the environment from problems arising from production systems is likely to be effective and economical. In many industrialized countries, measures exist to approximate links between occupational health and environmental health approaches.
(e) Occupational health services aim to ensure the health, safe, capacity and well-being of the working population. A healthy, productive and well-motivated workforce is the main agent for socioeconomic development. In addition, high quality and productivity work can ensure healthy production of materials, goods and services, and the consideration and practical implementation of sustainable development principles.
(f) Most of the environmental health risks that were later found to affect the health of the general population were first detected in the workplace and/or working population. Thus, the occupational environment provides an early warning system for certain environmental health risks, as well as provides effective models for preventive action.
(g) For more than half of the adults, the work environment is the most demanding environment in terms of physical, chemical, ergonomic or psychological stress and physical workload. The requirement of the Rio Declaration, on healthy and productive living, is particularly relevant to the work environment and calls for occupational health.
(h) The state of the general environment and ecosystem has an impact on workers' health, indirectly or directly on various occupations, like agriculture, mining, fishing and manufacturing. Therefore, there is a two-way relationship between occupational health and safety, on the one hand, and environmentally sound sustainable development, on the other.

Equally important to the personal well-being, and socio-economic development of communities and countries, is an employment policy that guarantees access to work for all and enables individuals to support themselves and their families through their own work. Potential employment is also a key factor in the safe, stable and sustainable social development of countries, while high unemployment rates and other associated problems put this development at risk [13].

5 Conclusion

From this research work it may be concluded that occupational health and safety policies are critical for sustainable development. According to Kwesi Amponsah-Tawiah, occupational health and safety should bring benefits from improved environmental and social performance, more employment, worker satisfaction and commitment, greater innovation and creativity [14].

There is a positive correlation between protecting workers against work-related injuries, illness, physical and psychological overload and prudent use of resources, minimizing unnecessary loss of human and material resources. Occupational health and safety emphasizes best practices in the use of production technologies that ensure low energy consumption, low emission and low waste technology, key elements in maintaining the environment [15].

As a major reflection on sustainable development, it should be noted that only 1/5 of the planet's population consumes 70% of energy, 85% of wood and 75% of metals, accounting for four fifths of the world income [16].

The SDGs results from the joint work of governments and citizens, around the world, to create a new global model for ending poverty, promoting prosperity and well-being for all, protecting the environment and combating climate change [9].

There is still a lack of environmental sensitivity, especially in underdeveloped countries, where investing in such actions is considered as an added cost. On the other hand, the application of good practices will depend not only on the organizations that run them, but also on the leaders who are governing the countries. If they are not focused on investing in this matter, to have the return of these policies adopted in the future this will not be possible. Often governments have only a short-term economic view and do not worry about the consequences this will have in the future.

According to Apolpia et al. [17] the term, urban regeneration, is synonymous of rehabilitation or urban renewal. Whatever the mode of expression this is based on, on a set of action principles, aiming at the sustainable development of cities. The problem of urban growth can be tackled effectively through the rehabilitation of historic centers. The rehabilitation of historic centers allows new life to be given to the cities that are already dead, but in turn it is an added value for traffic control, as it will avoid the movement of vehicles from the surroundings to the urban center. Urban rehabilitation of historic centres largely contributes to the application of sustainable developments, as it encourages the use of public transportation, physical exercise and CO_2 emissions, as no car is needed to go to work.

The use of a mobile environmental monitoring station to evaluate the urban environment, for instance, would also be a technological aid, by developing a platform where the population could be informed about the quality of the urban environment (air and noise) on the city they live [18].

From this analysis it may be concluded that there is a strong relationship between sustainable development and occupational health. For a healthy work environment, safety is essential, and for that, the sustainability of the environment must be taken into account.

References

1. Reis, C., Carpinteiro, E., Sanches Fernandes, L.F., Paula, S., Oliveira, C.: Sustainable safety measures applied in construction. Arezes PM et al (eds), Occupational and Environmental Safety and Health. Studies in Systems, Decision and Control. Springer Nature Switzerland AG (2019). Book ISBN: 978-3-030-14729-7 Book ID: 478838_1_En. https://doi.org/10.1007/978-3-030-14730-3_14
2. Maletas da sustentabilidade, Objetivos da sustentabilidade, https://www.maletas.ena.com.pt/?cix=1017&curr=802&lang=1. Last accessed 10 April 2019
3. Princípios da Higiene Ocupacional, https://pt.scribd.com/doc/106826299/PRINCIPIOS-DA-HIGIENE-OCUPACIONAL. Last accessed 26 Dec 2019
4. Info Escola, https://www.infoescola.com/trabalho/higiene-no-trabalho/. Last accessed 23 Dec 2019
5. Vendus, O que é higiene e segurança no trabalho, https://www.vendus.pt/blog/higiene-seguranca-trabalho/. Last accessed 22 Dec 2019
6. ONU, 17 objetivos sustentáveis, https://www.unric.org/pt/17-objetivos-de-desenvolvimento-sustentavel. Last accessed 10 May 2019
7. ONU, https://www.unric.org/pt/ods-link-menu/31955-goal-1-end-poverty-in-all-its-forms-everywhere. Last accessed 8 Feb 2019
8. Conselho empresarial para o desenvolvimento sustentável, https://www.ods.pt/ods/. Last accessed 8 Feb 2019
9. ºSopcom, Associação Portuguesa de Ciências da Comunicação, https://bocc.ufp.pt/pag/cruz-ana-mudanca-organizacoes-portuguesas.pdf. Last accessed 14 Feb 2019
10. ACT, OIT tirando partido de 100 anos de experiência, https://www.act.gov.pt/(pt-PT)/Itens/Noticias/Paginas/OITdivulgarelat%C3%B3rioSeguran%C3%A7aesa%C3%BAdenocentrodofuturodotrabalhoTirandopartidode100anosdeexperi%C3%AAncia.aspx. Last accessed 2 May 2019
11. Eco-Escolas, https://ecoescolas.abae.pt/. Last accessed 2 May 2019
12. Programa de saúde ocupacional, Extensão 2018–2020, https://www.dgs.pt/saude-ocupacional/documentos-so/pnsoc_extensao-pdf.aspx. last accessed 23 Dec 2019
13. Joint ILO/WHO Committee. Definition of Occupational and Safety. 12th Session of Joint ILO/WHO. Committee on Occupational Health (1995). [Online] Available: www.ilo.org/safework. ISBN 95 1-802-071-X
14. Amponsah-Tawiah, K.: Occupational health and safety and sustainable development in Ghana. Int. J. Bus. Adm. **4**(2), 74–78 (2013). https://doi.org/10.5430/ijba.v4n2p74. ISSN 1923-4007
15. Organização Mundial de Saúde: Global strategy on occupational health for all: The way to health at work. Geneva, https://www.who.int/occupational_health/en/oehstrategy.pdf. Last accessed 22 Oct 2019

16. Dicionário do desenvolvimento sustentável, https://ddesenvolvimento.com/portfolio/desenvolvimento-sustentavel/. Last accessed 14 March 2019
17. Alpopia, C., Manolea, C.: Importance of urban rehabilitation. Procedia Econ. Finance **6**, 178–185 (2013). 2212–5671 © 2013. https://doi.org/10.1016/S2212-5671(13)00130-5
18. Silva, L.T., Mendes, B., Oliveira, C., Reis, C., Silva, P., Silva, J.F.: Contribution of an environmental monitoring system to evaluate the potential effect of urban air pollution. In: First International Symposium on Risk and Safety of Complex Structures and Components, pp. 2452–3216, Porto, Portugal (2019)

Cost-Benefit Analysis of Occupational Health and Safety: A Case Study

Delfina Ramos, Paulo Afonso and Rosa Costa

Abstract Top management generally considers occupational safety and health as an extra cost instead of a benefit. The current work presents a case study in a company that produces and installs temporary structures for events, involving two sectors: warehouse and production (assembly and disassembly). The Analysis of the Return on Investment of Preventive Measures clearly proved that the Benefit-Cost (B/C) Ratio is a very valuable instrument for decision making in the context of occupational safety and health. A sensitivity analysis of the B/C ratio was also performed. The proposed measures were proved as efficient for both sectors, with a positive Net Present Value and a B/C ratio higher than 1 in both sectors. Furthermore, the results obtained from the sensitivity analysis allowed us to understand the importance of validating the preventive measures under different situations. Indeed, by varying the scenarios with the introduction of different factors and the level of efficiency of the measures, it became much clearer the conditions of viability of the different preventive measures.

Keywords Cost-Benefit Analysis (CBA) · Sensitivity analysis · Occupational Health and Safety (OHS)

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1 Introduction

Political, social and economic activities focus on the protection of human resources involved with the economic sectors. Experience shows that economic growth and industrial development depend on several factors. In this context, the damages caused by work accidents and the direct and indirect costs related to them, show the importance of the safety management system in organizations. In addition, obtaining a health, safety and environmental certificate and awarding safety performance is required to be in a competitive market, according to Toutounchian et al. [1].

Cost-benefit analysis (CBA) aims to specify the economically optimal strategies for mitigating risks change through minimizing the sum of costs from mitigation action and ensuing damages. Future mitigation costs entail epistemic uncertainty on what might be physically achievable, but also depend strongly on how much the society invests in developing and deploying new technologies, and therefore this uncertainty cannot be separated from the mitigation action considered in a cost-benefit model [2–5].

In a health and safety benefit-cost analysis, benefits are calculated as the (expected) reduced risk of morbidity or mortality for a population multiplied by the value people place on those reduced risks. People value each unit of risk reduced and those values can be estimated [6].

Sensitivity analysis is an important tool for a systematic evaluation of mathematical models. Sensitivity analysis can be used for various purposes, including model validation, evaluating model behavior, estimating model uncertainties, decision-making using uncertain models, and determining potential areas of research [7].

According to ISO 31000 [8], the goal of risk management is the creation and protection of value. It should allow an organization to manage the effects of uncertainty on its objectives.

Risk management decisions can be based on different factors, such as the need to protect a highly exposed or sensitive group of people or a legal requirement. Because different legal requirements and values affect risk management decision-making, different thresholds may need to be considered in benefit-cost determinations [6].

A case study will be presented in this paper involving two types of sectors in a Portuguese production and installation of temporary event structures company.

2 Materials and Methods

2.1 Case Study

The Production and Installation of Temporary Event Structures company focuses on the rental and assembly of multi-standard structures, namely tents, stands, stages, furniture and a wide range of accessories needed to hold an event. This company has an average of 100 employees. In the present case study were studied the Warehouse and Production sectors (assembling and disassembling), and the respective professional categories.

In total, in both sectors, they work 77 employees, of which 12 are women and 65 men. In the warehouse sector there are a total of 24 workers (men and women), women are distributed by professional categories of service assistant, cleaning and handling maids, service support maids, head of service and in the warehouse. The 12 men are distributed across all professional categories except the driver category. In this sector of the warehouse there are three fixed shifts. One shift works from 8:00 a.m. to 5:30 p.m., a second shift from 2:00 p.m. to 11:00 p.m. and the third night shift works from 11:00 pm to 8:00 a.m. The women all work in the first shift and the men are spread over the three shifts. In the production sector there are 53 employees, all men, distributed in all categories.

The study analyzed accidents due to falls, cuts, excessive efforts and other types of accidents that occurred in the company in 2017.

2.2 Model

In this case study it was applied the Occupational Safety and Health Cost-Benefit Analysis (ACBSSO) Model developed by Ramos et al. [3].

At the beginning of 2017, the events company undertook a restructuring in the process of registration, investigation and analysis of occupational accidents.

Accident analysis and related costs were carried out, followed by a risk assessment. Following this, the respective preventive measures and their costs were planned and the expected benefits were estimated. Subsequently, a financial and economic cost-benefit analysis was performed and the benefit-cost ratio was calculated. Finally, a sensitivity analysis of the B/C ratio was performed and its results were discussed.

Ramos et al. [3] developed an Occupational Safety and Health Cost-Benefit Analysis (ACBSSO) model that includes not only financial aspects related to the business perspective, but also economic aspects (from the viewpoint of all stakeholders, with special emphasis on workers and society).

Figure 1 presents the schematic representation of the Benefit-Cost ratio [3].

The ACBSSO model was applied to a company that produces and installs temporary event structures in the Braga region.

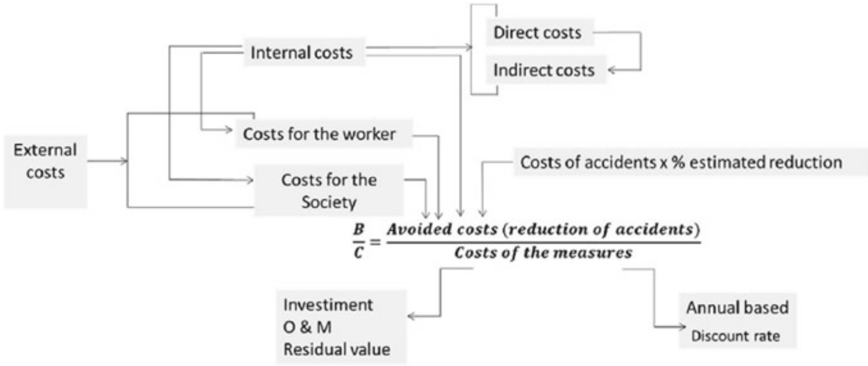

Fig. 1 Benefit-cost ratio [3]

2.3 *Sensitivity Analysis of the B/C Ratio*

The B/C ratio proposed here allows to quantify the benefits of preventive measures on OSH for all the stakeholders. It can be an important support tool to validate, understand and analyze the implementation of preventive measures. The analysis of the B/C ratio will permit to show which preventive measures defined in the risk assessment process are cost effective and should be implemented. Nevertheless, as it is mentioned by Ramos et al. [3], the quality and availability of health-related data is still a major limitation to link OSH and business performance.

The B/C Ratio is a valuable tool for decision-making related to occupational safety and health (OSH). However, it is important to emphasize that it is important for the manager to understand that the behavior of the B/C ratio depends on the assumptions made and the contribution of several variables to the result obtained by Ramos et al. [3].

3 Results and Discussion

Given the company's record of events, objectives were strategically defined with respect to reducing workplace accidents. Thus, by analyzing the nature of occupational accidents and the expected outcome of the preventive measures to reduce them, the following reduction of occupational accidents was considered, assuming the implementation of all measures: 40% reduction in the case of fall accidents, 30% for cutting accidents, 40% for overexertion accidents and 20% for other types of accidents. These objectives were because prevention measures are more targeted at accidents with higher costs, such as falls and overexertion.

Table 1 presents the global analysis of all proposed preventive measures to prevent accidents caused by falls, cuts, excessive efforts and accidents of other nature, in both sectors studied.

Table 1 NPV and financial B/C ratio of prevention measures by sector

Sector	Benefit	Cost	NPV	B/C ratio
Warehouse	7625.00	4881.17	2743.83	1.56
Production	36,190.00	15,178.80	21,011.20	2.38
Total	48,815.00	20,059.97	23,755.03	2.18

The second column of Table 1 shows the value of the estimated benefits, using the indicated criteria and objectives (40%, 30%, 40% and 20% reduction in accidents due to falls, cuts, efforts and other accidents, respectively).

This overall analysis leads us to conclude that the proposed measures are efficient for both sectors with positive Net Present Value (NPV) and a B/C ratio > 1 in both sectors.

For calculating the efficiency presented in Tables 2 and 3, only direct costs were considered. The direct costs of accidents have a high degree of reliability and represent the minimum level of costs to consider for the computation of the B/C ratio.

The B/C ratio at efficiency levels of 20%, 30%, 40% and 50% is presented in both sectors under study and for the different types of injuries in Tables 2 and 3.

Thus, Tables 2 and 3 present the results obtained for the B/C Ratio considering different levels of efficiency for the proposed preventive measures, in the Warehouse and Production sector respectively and for each type of injury under study, Falls, Cuts, Efforts and Others.

It can be seen that preventive measures can only be justified from a pure financial perspective (i.e., when B/C > 1) in the Warehouse, for Cuts and Other accidents, for efficiency levels above 30%. For accidents due to falls and efforts it is not expected, even in optimistic scenarios, that preventive measures can be justified.

Table 3 also shows that preventive measures are only justified (B/C > 1) in Production, for Cuts accidents in more optimistic scenarios, for efficiency above 40%, and for accidents of Other Nature, for efficiency levels above 30%. For accidents due to falls and efforts, it is still not expected, even in optimistic scenarios, that preventive measures are viable.

Table 2 B/C Ratio in the warehouse for different levels of efficiency of preventive measures

Efficiency	Falls	Cuts	Efforts	Others
50	0.07	**2.13**	0.13	**1.99**
40	0.05	**1.70**	0.11	**1.59**
30	0.04	**1.28**	0.08	**1.20**
20	0.03	0.85	0.05	0.80

Table 3 B/C Ratio in the production for different levels of efficiency of preventive measures

Efficiency	Falls	Cuts	Efforts	Others
50	0.51	**1.01**	0.63	**1.27**
40	0.41	0.81	0.51	**1.01**
30	0.30	0.61	0.38	0.76
20	0.20	0.41	0.25	0.51

Nevertheless, in most situations, and with regard to occupational risk, the organization's perspective is more holistic than departmental. Therefore, the analysis of the overall impact of preventive measures is especially important, but in these cases these measures are not justified whatever the nature of the injury (the overall B/C ratio is less than 1). However, it may be relevant to prioritize different measures or areas of application to prioritize investments in sectors where expected results may be more significant or, on the other hand, to give priority to those representing a smaller investment effort among other reasons that may influence decision-making.

The ACBSSO model has the advantage of allowing the cost-benefit comparison of occupational safety preventive measures, employing the same unit of measure, which facilitates and makes the decision-making process more evident. Limitations include the need of very detailed information, the complexity of estimating external benefits, particularly those related to society, given their intangible nature, and may not adequately consider the risks affecting future generations, if future economic flows have little impact on the computation of the B/C ratio [3, 9].

4 Conclusions

It is particularly important to be aware of the conditions of validity of preventive measures and the degree of certainty of different possible scenarios, so that the B/C Ratio can be assumed as an effective support tool for OHS decision making.

Thus, in the first phase, in relation to the studied sectors, warehouse and production, it was found that it is in production that accidents that lead to higher costs occur.

The results that were obtained were expected considering that in the production sector there are more workers and considering the type of work they perform, and the intrinsic tasks in this sector and the seriousness of the risks they carry.

This study also demonstrated that falls injuries and excessive efforts are more relevant in the costs of work accidents. In this sense, the value of investing in preventive measures to reduce the occurrence of occupational accidents in 2017 was estimated.

A cost-benefit financial analysis of prevention measures was performed using the ACBSSO Model. Since the financial analysis only takes into account the employer's perspective, it was found that, in overall, all the proposed measures are efficient for both sectors, warehouse and production, with a positive NPV and a B/C ratio > 1 in both sectors. However, it is noted that in the detailed study by nature of injury, in the case of falls and excessive efforts in the warehouse sector, it was found that there are no financial advantages in implementing the preventive measures in this sector as the NPV was negative and the B/C ratio < 1.

References

1. Toutounchian, S., Abbaspour, M., Dana, T., Abedi, Z.: Design of a safety cost estimation parametric model in oil and gas engineering, procurement and construction contracts. Saf. Sci. **106**, 35–46 (2018)
2. Ekholm, T.: Climatic cost-benefit analysis under uncertainty and learning on climate sensitivity and damages. Ecol. Econ. **154**, 99–106 (2018)
3. Ramos, D., Arezes, P., Afonso, P.: Analysis of the return on preventive measures in musculoskeletal disorders through the benefit-cost ratio: a case study in a hospital. Int. J. Ind. Ergon. **60**, 14–25 (2017)
4. Ramos, D., Arezes, P., Afonso, P.: Application of the Delphi Method for the inclusion of externalities in occupational safety and health analysis. Int. J. DYNA **83**(199), 14–20 (2016). https://doi.org/10.15446/dyna.v83n196.56603
5. Ramos, D., Arezes, P.M., Afonso, P.: Economic evaluation of occupational safety preventive measures in a hospital. J. Prev. Assess. Rehabil. Work **51**, 495–504 (2015). https://dx.doi.org/10.3233/WOR-141884
6. Williams, R.A.: Economic benefit-cost implications of the LNT model. Chem. Biol. Interact. **301**, 141–145 (2019)
7. Lehr, W.J., Calhoun, D., Jones, R., Lewandowski, A., Overstreet, R.: Model sensitivity analysis in environmental emergency management: a case study in oil spill modeling. In: Conference: Simulation Conference Proceedings, 1994. Winter (1994)
8. ISO 31000. Risk Management—Principles and Guidelines, 2nd edn (2018)
9. Costa, R.: Analysis model of return on investment in preventive measures in occupational safety: conception, application and discussion. Master’s thesis. Published in April (2019)

Hand Tools Characteristics in Slave and Modern Slave Labour

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Abstract The Brazilian economy was founded on slave labour until the late nineteenth century. Based on an analysis of historical descriptive studies, this work aimed to make an objective investigation of the slaves' safety conditions, concerning the use of manual tools, associated with mechanical risks. The research was conduct in selected databases without language restrictions. The tools' safety conditions, as well as the work performed by them, were evaluated. The search initially provided 36,355 references. After applying the screening and eligibility criteria, this number was reduced to 20 with high-quality standards and a specific focus on the subject: 8 articles, three books and nine rare books. The tools used by the slaves ranged from simple wooden rods to cutting hand tools such as hoes, axes, and scythes, made of metal alloys. Compared with the hand tools used in the twenty-first century, those considered ideal in the nineteenth century tended to have higher mass and longer wooden cables. The shapes and dimensions of the metal tools did not change significantly since then. The evaluated studies pointed to the existence of similar devices in all Brazilian regions, suggesting that injury accidents also occurred similarly among slaves throughout Brazil. The same can be assumed for workers who currently use identical tools. The more ergonomic cable shape is the only apparent improvement in occupational safety.

Keywords Hand tools · Slavery · Modern slavery · Neo-slavery · Brazil

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1 Introduction

In the colonial and imperial time, the historical period when slavery was legal in Brazil, the Brazilian economy was mostly based on agriculture supported by the work of the captive population [1].

In this period the most of their tasks, like deforestation, excavations, plantations, weeding and harvest, used manual tools only, like axes and sickles. Even the machines in use on those times were Human or animal-powered [2].

Slaves were considered an asset. Thus the capital invested in their acquisition should not only be recovered but also generate profit to ensure the economic return to their owner. To ensure that return, slaves were forced to work for long periods in adverse conditions. Often with poor quality and insufficient food.

Irrespective of other circumstances, these working conditions put the health and safety conditions of these workers at serious risk [3–5]. However, this general framework remains a reality in the early 21st century. The International Labour Organization (ILO), a United Nations (UN) agency, estimates in 40 million the number of people subject to work similar to slavery around the world [6].

The generality of the national governments endorses the disapproval for the slave work, signing several international treaties as the "Declaration on Fundamental Principles and Rights at Work of ILO", grounded in ILO regulations (conventions 29, 87, 98, 105, 138 and 182). However, modern slaves continue to exist and keep suffering from daily accidents or developing occupational diseases without any control of Occupational Health and Safety (OHS) authorities.

According to Brazilian law, conditions analogous to slavery may be characterised by at least one of the following factors: (i) being subjected to forced labour; (ii) being subjected to long working hours; (iii) being subjected to poor working conditions; (iv) movement restrictions, by any means, due to debt towards the employer or representative.

From these four characteristics, the poor working conditions and the long working hours are directly associated with the OHS conditions. Those conditions are described in the Brazilian Health and Safety Regulation as the minimally required. However, for this same reason, those conditions are not considered a crime but only as an infraction punishable with a simple fine. Therefore, in many of these situations, the penal code is not applied, but instead, the general labour laws are used. Considering this framework, the "employers" that use neo-slave labour can escape the expected penalties for these situations [7].

However, no scientific and technical support can be used as a reference to identify current neo-slave labour. This allows, as mentioned, legal support for this practice to be considered as a mere violation of labour laws.

So, this paper aims to contribute to a better understanding of the OSH conditions of slave labour in Brazil when it was legal. It is expected to contribute to raising evidence and methodologies for the approach and identification of new forms of slavery in different parts of the world where these practices are still a reality.

2 Materials and Methods

This study was designed as a review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [8]. In this first phase, the most recent historiographical research was selected from the following databases: Science Direct, Scopus, Web of Science, Criminal Justice, EBSCO, Business Source Complete, within the time frame following 2014. In all of them, the same combination of keywords was used: slavery and work. No language restrictions were imposed, and duplicate references were excluded. In the second phase, the potentially relevant articles were selected based on the analysis of titles and abstracts. The research papers without references to official or environmental reports of slave labour activities were also excluded. As inclusion criteria were established: (i) the existence of direct descriptions of the themes related to this study, (ii) dealing with Brazilian slavery of the nineteenth century, and (iii) being recognised as a reliable source. Thus, there were only included works that, after analysing the full-texts, allowed the extraction of relevant information using, for that, a standardised form (complete references, country region, used tools and machines).

After completing the second phase, all bibliographic references of all the selected articles were analysed (without distinction on the publication type). That allowed the analysis of thesis, dissertations, books and rare books (original publications dating from the eighteenth and nineteenth centuries). It should be noted that the primary sources (rare books) were the richest in the detailed description of working conditions in nineteenth-century agricultural farms.

In the last phase, data were collected on the tools and machines used by captive workers. At this stage, device-related conversions of measurement units were performed to improve understanding and comparison with current unit systems. Subsequently, historical data were compared with those of poor but free workers from the same period. This comparison allowed highlighting the everyday exposure situations related only to slave workers. Finally, historical data were compared with elements of modern slavery.

3 Results

After the research, 36,355 records were identified, from which, nine were selected for full-text screening after applying the exclusion criteria. Due to date, 28,498 records were excluded, and 4312 were withdrawn after the publication requirement in journals was used. Finally, 3444 records were excluded because they were out of scope, and 92 after reading its abstracts, which did not indicate a possible positive result for the presence of relevant reports to the research. To the nine articles included, another 19 papers cited in their references or obtained from other sources were added, in a total of 28 papers selected for full-text reading. After analysing these articles, eight were excluded because they did not meet the defined inclusion criteria. In the end, 20 works were included in the systematic review: 8 articles, three books, and nine rare books.

From these 20 works, Albuquerque [1] refers to the problem of crushing hands and arms in sugarcane mills; Assunção [9] analyses how axes and pylons cause mutilations in work accidents; de Carvalho Cabral [10], describes tools such as hoes, axes, and scythes; de Lima [3] underlines that 46.4% of slaves have work-related injuries; Debret [11] presents the axe as the cause of injuries; do Alferes and Werneck [12] refers the risk of crushing accidents with hoes, axes and scythes; Rugendas [13] describes in detail the type of axe used; Eugenio [14] refers to the mining pick, as well as the injuries and burial deaths in excavation; Imbert [15] describes hand-tool injuries, namely by knife and sickle; Lima, de Oliveira, and dos Santos [5] reinforce the analysis that 46.4% of slaves present traumatic injuries related to work; Magalhães [16] describes the wooden stick used for navigation; Marques [17] describes hoes, axes, scythes, and saws; Pinsky [18] describes the role of the hoe and pestle in the deaths by the employee's violence and injuries due to occupational accidents; Rodrigues [4] develops a study in which it is demonstrated that more than 40% of the illnesses are caused by traumatic injuries and many deaths are caused by mistreatment; Rodrigues [19] describes the hoes, axes, and sickles used by the slaves; Schwartz [20] presents the hoes, axes, scythes, and picks as being in the origin of accidents and mutilations in mills and accidents due to extreme fatigue; Spix [21] describes hoes, scythes, knives, and axes; Taunay [2] describe shovels, plows and axes; Vieira Junior and Martins [22] describes the scythe and the axe in their most common version; and finally, Viveiros [23] also presents a detailed description of axes, scythes, shovels, and spades.

4 Discussion

Manual cutting tools such as hoes, axes, and scythes had high relevance, and their extensive use in rural properties was described by several authors [10, 18, 20, 22]. The concern for acquiring better and modern tools was widespread among farmers. As an example of concern with the modernisation of tools as a way of increasing productivity, the introduction, in the first half of the nineteenth century, of the American woodcutter axe, which was broader and thinner than the Portuguese axe can be pointed out [2]. Its higher productivity led to its consolidation as the type of axe most sought after by farmers at the time despite costing three times more than those used at the time [23].

However, the importance of these tools to the productivity and profitability of a farm was not always understood by the farmers. Sometimes, they purchased tools that were unsuitable for service or did not pay proper attention to maintenance and sharpening [12]. Aswell, cables were made of round wood (branches) taken from nearby forests, without well-defined criteria beyond their length.

The widespread use of hand tools (hoes, axes and sickles) by slaves has also made them the primary source of mechanical hazards [15]. Due to the low mechanisation at the time, injuries caused by hand tools were more common than those caused by machines without protection to moving parts.

In Tables 1 and 2, for the moment of inertia (Nm) calculation, the wood cord and the points of an adequate handle on the cable by the workers were disregarded. The calculation of the Moment of inertia (Nm) has the sole purpose of demonstrating the existence of a significant difference in a physical effort by tool stroke when comparing the two historical periods.

$$\boldsymbol{M} = \boldsymbol{F}.\boldsymbol{d} \tag{1}$$

F—Newton (N); d—meter (m); M—Newton $\times$ meter—Nm.

Compared to the used hand-tools in the twenty-first century, those considered ideal in the nineteenth century [12] tended to have higher mass and longer wooden cables (Tables 1 and 2). However, the shapes and dimensions of the tools' metallic structures did not change significantly during the same period. Regarding energy expenditure, these values are smaller with the tools of the XXI Century, due to the decrease of the mass and the length of the cable (lower moment values—Nm). This should not be seen as an improvement for the worker, but as an indicator of better productivity due to the use of better tools.

The decrease in the mass of the tools used in 21st-century was mainly due to the evolution of the mechanical processes used in manufacturing. With a particular focus in stamping and cold forging occurring below the recrystallisation temperature of the metal, providing higher resistance to the parts, due to the hardening in the material during its conformation [25, 26].

The decrease in the size of wood cables seems to be, mainly due to the adoption of industry design support based on ergonomic studies. However, it is not perfectly

Table 1 19th-century standard tool[a]—Measures of mass, cable size, and momentum (Nm)

Tool	Mass (kg)	Grip (m)	P (Nm)
Long hoe	Approx. 1.80	1.43	25.24
Woodcutter axe[b]	1.35–2.25	1.10	14.56–24.27
Big sickle	0.80–1.60	1.32	10.36–20.71

[a][2, 12]; [b]American woodcutter axe

Table 2 21th-century standard tool[a]—Measures of mass, cable size, and momentum (Nm)

Tool	Mass (kg)	Grip (m)	P (Nm)
Long hoe	0.80–1.25	1.30–1.45	10.20–17.77
Woodcutter axe	1.50–2.00	0.90	13.24–17.65
Big sickle	0.57–0.8	1.10	6.15–8.63

[a][24]

proportional to the tool mass decrease. Hypothesis corroborated by the apparent counter-sense between the reduction in cable length and the average increase in people's height in the last century.

Tools have kept a similar shape and blade edge, and the decreased energy per stroke does not mean that the total physical effort has been lighter. The only safety improvement is in the ergonomic shape of the cable, which provides better grip, contributing to fewer errors and consequently accidents. Nevertheless, modern slaves do not always receive ergonomic cables, and there is no evidence that they receive training in hand tools operation [27].

5 Conclusions

The analysed working conditions, as well as the tools and machines used in slave labour, are similar in all regions of Brazil at the 19th-century.

When comparing the tools of the 19th-century with those of the 21st-century, it can be observed a significant decrease in size and mass, which led to a reduction in a physical effort by tool-stroke for twenty-first-century workers. However, the changes within the use of better equipment in slave labour are mainly the ability to produce more and generate more significant economic gains. The Brazilian Farmer's Handbook [2], relevant at the time, explains that only the activities performed with the "use of all the forces of the body" were regarded as work. No matter the type of tool, enslaved workers' power is always extracted to the maximum since this is only considered as one of the production factors.

Generally, in modern rural slavery, hand tools are predominant in daily activities. So, exposure to mechanical risks as well as associated injuries occur similarly to 19th-century slave labourers, and the only apparent safety improvement is in the ergonomic shape of the cable.

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References

1. Albuquerque, W.R.: Uma história do negro no Brasil, p. 320. Fundação Cultural Pal-mares, Brasília (2006). I.S.B.N.: 85-88070-022
2. Taunay, C.A.: Manual do agricultor brasileiro, 2 edn. Typographia Imperial e Constitucional de J. Villeneuve e Comp., Rio de Janeiro. https://pt.scribd.com/document/359086871/TAUNAY-1839-Manual-do-agricultor-brasileiro-pdf (1839)
3. Lima, C.A.M.: Frontier, sugarcane and trafficking: slavery, disease and death in Capivari, São Paulo, 1821–1869. Hist. Cienc. Saude—Manguinhos **22**, 899–919 (2015). https://dx.doi.org/10.1590/S0104-59702015000300014; https://www.scopus.com/inward/record.uri?eid=2-s2.

0-84940512655&doi=.1590%2fS0104-59702015000300014&partnerID=40& md5=9236126 07d094877ef83e20251b4ed25
4. Rodrigues, K.: Manuais de fazendeiros e saúde escrava em Vassouras, 1830–1870. Simpósio Nacional de História, 25. https://encontro2014.rj.anpuh.org/resources/anais/anpuhnacional/S.25/ANPUH.S25.0745.pdf (2009)
5. de Lima, P.V.S.F., de Oliveira, K.A., dos Santos, D.L.R.: Aspectos gerais da saúde dos escravos no Brasil: revisão de literatura. Gestão e Saúde **7**, 471–489 (2016). https://doi.org/10.18673/gs.v7i1.22093
6. OIT: O.I.d.T.-. Trabalho Forçado no Brasil. Availabe online https://www.ilo.org/brasilia/temas/trabalho-escravo/lang–pt/index.htm. Accessed on 02 Nov 2017
7. Ramos Filho, W.: Trabalho degradante e jornadas exaustivas: crime e castigo nas relações de trabalho neo-escravistas. Revista Direitos Fundamentais & Democracia, 4. https://revistaeletronicardfd.unibrasil.com.br/index.php/rdfd/article/view/213 (2008)
8. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Group, P.: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. **6**, e1000097 (2009). https://doi.org/10.1371/journal.pmed1000097
9. Assunção, M.R.: De caboclos a bem-ti-vis: formação do campesinato numa socie-dade escravagista: Maranhão, 1800–1850, p. 474. ANNABLUME, São Paulo (2015). I.S.B.N.: 978-85-391-0660-3
10. de Carvalho Cabral, D.: Into the bowels of tropical earth: leaf-cutting ants and the colonial making of agrarian Brazil. J. Hist. Geogr. **50**, 92–105 (2015). https://doi.org/10.1016/j.jhg.2015.06.014; https://www.sciencedirect.com/science/article/pii/S0305748815000997
11. Debret, J.B.: Voyage pittoresque et historique au Brésil, vol. 2. Firmin Didot Frères, Paris, 1834–1839 (1839). I.S.B.N.: https://digitalcollections.nypl.org/items/510d47df-7993-a3d9-e040-e00a18064a99; https://digitalcollections.nypl.org/items/510d47df-7988-a3d9-e040-e00a18064a99
12. do Alferes, P., Werneck, F.P.L.: Memoria sobre a fundacao e costeio de uma fazenda na provincia do rio de janeiro (1878). I.S.B.N.: http://dedalus.usp.br/F/VYFY3EMFAYJN4MQ; KIREDYEI8GCJG9HP9K5LHT1XAVKXDBEGLYX-47495?func=full-set-set&set_number=014943&set_entry=000001&format=999
13. Rugendas, M.: Voyage pittoresque dans le Brésil. Engelmann (1835). I.S.B.N.: https://200.159.250.2:10358/handle/acervo/9881
14. Eugenio, A.: Luis Gomes Ferreira reports on the health of slaves in his work entitled Erärio mineral (1735). Hist. Cienc. Saude—Manguinhos **22**, 881–897 (2015). https://doi.org/10.1590/S0104-59702015000300013; https://www.scopus.com/inward/record.uri?eid=2-s2.0-84940567236&doi=10.1590%2fS0104-59702015000300013&partnerID=40&md5=48631bc7e980bb6e2050fe7fd414cfcb
15. Imbert, J.-B.A.: Manual do fazendeiro, ou tratado doméstico sobre as enfermi-dades dos negros, 2nd edn. Typographia Nacional, Rio de Janeiro (1839). I.S.B.N.: https://archive.org/details/DELTA539211FA
16. Magalhães, D.J.G.d.: A Revolução da Provincia do Maranhão: 1839–1840. Ty-pographia Progresso, São Luís (1858). I.S.B.N.: https://digital.bbm.usp.br/handle/bbm/4156
17. Marques, C.A.: Diccionário histórico-geográphico da provincia do Maranhão. Typ. do Frias, Maranhão (1870). I.S.B.N.: https://www2.senado.leg.br/bdsf/item/id/221726
18. Pinsky, J.: Escravidão no Brasil, 7th edn. Contexto, São Paulo (1988). I.S.B.N.: 978-8506071571
19. Rodrigues, K.: Os manuais de fazendeiros, o governo dos escravos e medicina no século XIX. In: Proceedings of XIV Encontro Regional da ANPUH-Rio Memória e Patrimônio, Rio de Janeiro, pp. 1–9 (2010)
20. Schwartz, S.B.: Segredos Internos: Engenhos e escravos na sociedade colonial 1550–1835. Companhia das Letras, São Paulo (1988). I.S.B.N.: 85-7164-012-2
21. Spix, J.B.v.M., von Phil C.F.: Travels in Brazil, in the years 1817–1820. Long-man, Hurst, Rees, Orme, Brown, and Green, Londres (1824)

22. Vieira Junior, A.O., Martins, R.S.: Measles epidemic and slave work in Grão-Pará (1748–1778). Revista Brasileira de Estudos de Populacao, 32, 293–312 (2015). https://doi.org/10.1590/S0102-30982015000000017; https://www.scopus.com/inward/record.uri?eid=2-s2.0-84942429241&doi=10.1590%2fS0102-30982015000000017&partnerID=40&md5=d57 d725b86e139bc41397170d059d18e
23. Viveiros, J.d.: História do Comércio do Maranhão, 1612–1895. Associação Comercial do Maranhão, São Luís (1954). I.S.B.N.: https://memoria.org.br/pub/meb000000461/histcomvol2mar/histcomvol2mar.pdf
24. Tramontina: Ferramentas para Agricultura e Horticultura. Availabe online https://www.tramontina.com.br/233-jardim-e-agricultura/236-ferramentas-para-agricultura-e-horticultura. Accessed on 20 Oct 2018
25. Helman, H., Cetlin, P. R.: Fundamentos da conformação mecânica dos metais. Universidade Federal de Minas Gerais, Escola de Engenharia, Fundação Christiano Ottoni, Brazil (1993)
26. Rodrigues, J., Martins, P.: Tecnologia mecânica: Tecnologia da deformação plástica (2005). I.S.B.N.: 9725921844
27. Trabalho, S.d.I.d.: Relatório de fiscalização. Ministério do Trabalho, Brasil, 2007–2017

Best Methods and Means of Raising Awareness of Road Safety in the Opinion of Drivers

Hamou Boudrifa, Rabah Boudebaba and Abdelkarime Guellati

Abstract Despite the efforts made over the past years in the context of awareness, traffic accidents did not decrease. Which requires the search for the most effective methods and means of raising awareness of the Algerian drivers so that its effectiveness can be guaranteed. Thus to achieve the desired goal from the knowledge of the extent to which the users of the road respond to the various media messages and programs to raise awareness of the dangers of traffic accidents in order to identify and strengthen the best of them. To do so, a national study was carried out at the level of 12 districts among the 48 ones in Algeria. A questionnaire was applied on a sample of 5761 drivers. Friedman ranking means test was used to order the best methods and means of road awareness in the opinion of drivers. The results show that the means and rankings averages for the Friedman test are generally very high, suggesting that these different methods and means are suitable for use in traffic awareness campaigns in general. However, the careful examination of these results shows that some of them are issued for the first ranks, which can be considered as a strong indicator of their importance and effectiveness as well as the urgent need to rely on them in traffic awareness campaigns as reflecting the reality and identify the weaknesses in the traffic process.

Keywords Awareness · Behavior · Traffic accidents · Preventive culture

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1 Introduction

Despite the efforts made during the past years in the context of awareness, road accidents did not decrease, as well as the number of injuries or deaths, not to mention the increase of unsafe and illegal behaviors. So it became necessary to review the strategies on which these large and costly efforts were made to try to find scientific explanations in view of the Algerian reality together with recent developments of modern methods and media outlets that are capable of creating a qualitative arrangement in the behavior of road users. In addition to directing them towards traffic education and a preventive culture that would reduce traffic accidents and everything that results from them by threating the security of society and the waste of human and economic wealth directly, not to mention the indirect waste and consequences.

Perhaps what imposes the urgency of carrying out targeted and constructive awareness campaigns is that although some accidents are fatal or material to some extent outside the human domain, statistics and studies show that the human factor contributes more than 80% to the occurrence of traffic accidents. Which required the necessity of diagnosing the various human factors leading to the growth of risks and possibilities of traffic accidents so that these factors or variables with their various interactions can be employed in the service of preventive campaigns and awareness raising aims at reducing the risks of road accidents. This matter requires searching for the most effective and appropriate methods and media outlets to the Algerian individual in order to ensure their effectiveness in achieving the desired goal. Hence, knowing the extent of the way users respond to what is presented by the various visual, audio and print media (television, radio, newspapers, Magazines, flyers, posters, school days, media days) of messages and programs to raise awareness about the dangers of traffic accidents.

Prevention is usually launched from the principle of strengthening the individual's ability to be aware of the dangers threatening his life, including convincing him to bear the difficulties that preventive behavior requires and pushing him to exert more effort required to change improper habits and patience and inducing oneself to restrain his impulsion or ambitions in the wrong directions and other requirements of preventive behavior. Perhaps the first step in this direction is to educate the individual about the potential for self-exposure so that he can adopt proper preventive behavior. Studies have shown that the individual's awareness of the possibility of being exposed to a risk that postpones his injury, based on his personal vision of the threat posed by the risk and his appreciation of the price and the desired benefit of prevention. This is because it was found that people might not follow a proper preventive behavior until they realize the seriousness of the threat.

In addition, to identify the factors and motives behind these behaviors, appropriate methods and means of awareness are identified. It is usually limited to providing knowledge and information on the one hand, and raising fear on the other hand. A strategy has been proven ineffective in many cases. This is because despite the widespread use of advertising by threatening and intimidating, some studies have found a positive relationship between intimidation and persuasion [4, 5, 7].

However, other studies have shown adverse results in the use of intimidation in the process of persuasion [4–7]. This may require strengthening it with other alternative educational strategies that are searched for by finding the best ways and means to communicate messages or information to the Algerian individual. Hence, trying to convince him to change his behavior from not only the stage of will and the expression of good intentions, but the need to transform the latter to actions until he reaches the stage of its implementation. Therefore, the question is what are these modern methods and means that can contribute effectively to the process of alerting and educating the Algerian individual about the dangers of road accidents. Will it be valid for all social groups? What are the appropriate times and the most effective media channels in communicating information to these various social groups in Algeria? Are there national, artistic, media, political, and other personalities who can play appropriate roles in awareness campaigns?

2 Methods

2.1 Study Tool

After carrying a series of interviews and preliminary studies, a questionnaire was pre-pared in order to answer the following six awareness strategic goals:

1. Do you believe that the best methods of road awareness consist of:
2. Do you believe that the best means for road awareness are:
3. Do you believe that it is possible to promote road thinking in the individual by:
4. Is it possible to change negative road attitudes among road users through the following ways?
5. Do you believe that it is possible to promote behavioral values among road users by:
6. Do you believe that it is possible to transform road awareness into preventive behavior through the following ways:

Different numbers of items followed each of the above questions. Subjects were asked to mark the frequency of each item on a scale of five points (never, rarely, sometimes, most times, always). Only the first two questions are treated in this paper. This study tool was applied on a sample of 5761 drivers in twelve out of forty-eight districts in Algeria. Some of their individuals' characteristics are shown in Table 1.

2.2 Procedure

Twelve out of forty-eight districts in Algeria were chosen according to their order based on percentages of corporal accidents committed to the number of vehicles in each district. The geographical distribution was also taken into consideration by

Table 1 Some individuals characteristics of the study sample

Characteristics	Sex		Age							Status			
Categories	Male	Female	18–20	21–30	31–40	41–50	51–60	61–70	>71	Single	Married	Divorced	Widower
Frequency	4602	1159	105	2095	2060	1041	374	76	10	2202	3316	166	77
Percentage	79.9%	20.1%	1.8%	36.4%	35.8%	18.1%	6.5%	1.3%	0.2%	38.2%	57.6%	2.9%	1.3%

Characteristics	Job											Educational level			
Categories	Unemployed	Professional worker	Qualified worker	Official	Official	High official	Chauffeur	Retired	Liberal profession	Student	No level	Primary	College	Secondary	University
Frequency	514	664	279	2014	110	90	602	107	942	439	161	417	1149	1699	2335
Percentage	8.9%	11.5%	4.8%	35.0%	1.9%	1.6%	10.4%	1.9%	16.4%	7.6%	2.8%	7.2%	19.9%	29.5%	40.5%

selecting each first three districts from the east, middle, west and south of Algeria. In order to have a distribution representing these different regions, districts that do not share the same border were chosen to obtain a representative distribution of each region. The whole sample of the study was limited to 7000 drivers distributed over the twelve districts chosen as mentioned above. The number of individuals of the sample for each district was sorted out by dividing the number of the whole sample by the whole number of corporals accidents multiplied by the number of accidents committed in each district. Their distribution was carried out mainly by postgraduate and under graduate students studying in psychology or sociology under the supervision of assistant professors. They were paid for this task. These applicants scattered in places where drivers are expected to have free time to answer the questionnaires; mainly bus and taxis stations, insurance companies, vehicles' technical control stations and workshops for maintenance. Means, standards deviations and Friedman ranking means were calculated.

3 Results

The results in Table 1 show that the means and rankings averages are generally very high, suggesting that these different methods are suitable for use in traffic awareness campaigns. However, careful examination of these results shows that some of them are issued for the first ranks, which can be seen as a strong indicator of their importance and effectiveness as well as the urgent need to rely on them in traffic awareness campaigns. Strengthening the training programs with the principles of prevention and traffic safety that occupied the first rank is conclusive evidence of the drivers need to fill this gap in the training programs. This is in line with what was reached by Boudrifa et al. [2] who applied the technique of factor analysis to the phrases of the question regarding the objectives of training to drive on a sample of 7058 drivers, and it showed the various basic axes of it distributed on five basic factors:

1. Acquisition of traffic culture and education: This factor has explained by 34.81%.
2. Technical and economic use of the vehicle. This factor has explained 6.30%.
3. Control of the car and awareness of risk, this factor has explained 4.53%.
4. Learn the rules and principles of driving. This factor has explained 3.70%.
5. Obtaining the license, has interpreted 3.51%.

The results in Table 2 also showed that the use of cameras to detect violators of the Highway Code, ranked second as a method of traffic awareness. This is in line with what has been relied on in many countries. It is a logical approach in the context of dealing with traffic safety cameras as a modern means of control in exchange with traditional means. It also goes with the context of the broad safety strategy to support and improve road security results and reduce the number of victims and injured. It has been proven how effective the use of cameras in reducing

Table 2 The best methods of road awareness

The best methods of road awareness			
Do you believe that the best methods of road awareness consist of:	Mean	SD	Rank
1. Reinforcement of the driving training program by principles of prevention and road safety	3.99	1.045	14.30
2. The use of cameras to detect violators of the Highway Code	3.99	1.048	14.23
3. Promoting the level of education and road culture among family members	3.96	1.058	14.00
4. The installation of signs and advertising supports in public places, popular markets, means of and transport stations and on the roadsides	3.93	1.059	13.92
5. The mobilization of traffic officers for the rigorous application of the Highway Code to all road users at all times and places	3.92	1.111	13.86
6. The contribution of religious organizations (the mosque) in the realization of the principles and moral values related to the behavior of road users	3.90	1.063	13.73
7. Radio broadcasting of commercials spots, emissions and programs open to the public on road safety	3.89	.980	13.55
8. Radio broadcasts for publicity announcements and open-access programs for the public on traffic safety	3.88	1.010	13.50
9. Continuing traffic awareness among schoolchildren through brochures, plays and stories	3.87	1.055	13.43
10. Conduct regular medical check-ups by the Ministry of Health to monitor and educate drivers	3.84	1.105	13.38
11. Providing incentive discounts from maintenance workshops to encourage drivers to maintain their vehicles	3.82	1.123	13.17
12. Hosting disabled people, parents and children as victims of a traffic accident, to present them through the media with live testimony about their suffering	3.83	1.066	13.13
13. The media host people who have committed serious traffic accidents to express their sorrow and profound regret	3.80	1.092	13.04
14. Linking the vehicle insurance pricing to the number of traffic violations committed	3.78	1.160	13.00
15. Publishing articles, advertisements, interviews, investigations and photos about traffic safety in the specialized newspapers and magazines	3.80	1.055	12.91
16. Involving associations and civil society organizations in diffusing and implementing the principles of traffic safety	3.76	1.077	12.70
17. Getting volunteered Islamic Scouts to distribute brochures and posters on traffic safety awareness	3.76	1.066	12.67
18. Training community members on how to provide first aid by member of the civil protection	3.75	1.159	12.61
19. Engaging vehicles manufacturers and sellers in prevention campaigns about traffic accident	3.74	1.116	12.57
20. Organizing informational days, seminars, lectures, photo galleries, and showing films about traffic accident prevention	3.73	1.055	12.38
21. Presenting advertisement flashes by famous media figures (religious, political, sports, art)	3.66	1.114	12.07

(continued)

Table 2 (continued)

The best methods of road awareness			
Do you believe that the best methods of road awareness consist of:	Mean	SD	Rank
22. Using electronic communication (internet, e-mail, fax, and mobile phone) in traffic awareness	3.62	1.156	11.85
23. The use of widely consumed products (food, toys, school tools, clothes, cleaning materials) in traffic awareness	3.60	1.193	11.82
24. Exposing shows and videos on traffic safety through cultural organizations (theater, cultural centers, and cinema)	3.61	1.112	11.71
25. Use mail messages to send advertisements about traffic accident prevention	3.56	1.179	11.48

traffic accidents. Nowadays cameras, whether fixed or mobile are used in the crossroads, tunnels, highways, and even in residential areas. The use of safety cameras may be more effective than regular security. It has the ability to monitor around the clock, and it can reduce the presence of traffic men, and traffic violation. Cameras or what is called "traffic control cameras" are considered as a modern technique introduced by many countries in order to monitor traffic and reduce the outcome of road accidents. This action is based on their advantages and effectiveness in deterring violators and reducing traffic accidents, human and material losses, as well as reducing friction between drivers and security men [9].

From the point of view of the official bodies behind this procedure, speed cameras are effective in slowing down and also contributing significantly in reducing injuries and serious accidents, Many reports over the years have confirmed the importance of using photographic enhancements technology through statistics that prove effective in reducing accidents and risks. For example, the Scottish government report in 2010 showed an analysis of a ten-year period (from 2000 to the end of 2009), after using Speed cameras, that during this period, deaths and serious injuries decreased by 56% in places where cameras are placed [8]. For its part, Philadelphia State statistics in the United States showed that, during the year following the installation of red light cameras, incidents of crossroads equipped with cameras decreased by 87–100%. It was also found that the installation of safety cameras in more than 4000 locations across Britain in 2004 resulted in rescuing about 1000 people from death or serious injury. In addition to the prevention of about 3600 accidents with human losses, and in the case of expanding these Operation across Britain will result in approximately 800 other people being saved from death or serious injury [1].

The high and very close means and rankings averages for the rest of the methods of road awareness shown in Table 2, are also very important. They present more alternatives and different ways of awareness that can be used to change not only drivers' behavior in order to reduce accidents but also the rest of the road users in order to promote the road safety. Boudrifa et al. [3] used a checklist of 150 items to measure unsafe behaviors of road users. They concluded that the frequencies and dangers of unsafe behaviors are not limited to the driver only, but expanded to cover all road users.

Table 3 The best means for road awareness

Do you believe that the best means for road awareness are:	Mean	SD	Rank
1. Continuity in raising the traffic problem on a daily basis and not only talking about it when incidents or accidents occur	3.92	1.036	8.97
2. Relying on those with expertise and experience in designing traffic awareness programs	3.91	1.042	8.95
3. Promote the method of dialogue and accept criticism and other opinion from users of the road	3.87	1.013	8.74
4. Encourage and honor efficient drivers by the institutions working for them	3.85	1.067	8.73
5. Provide knowledge and intellectual information related to the prevention of traffic accidents	3.85	1.072	8.65
6. Organizing driving competitions to honor the best drivers	3.82	1.121	8.60
7. Renewing the content of the traffic ads, as well as developing and improving its display techniques	3.83	1.057	8.58
8. Relying on the language of numbers, statistical significance, and the influence of images in communicating the traffic prevention message	3.81	1.058	8.50
9. Submit scientific and documentary tapes for proper vehicle maintenance and use	3.80	1.051	8.44
10. The use of Influential pictures of the disabled and the mutilated people due to traffic accidents	3.78	1.125	8.43
11. Convince drivers to put stickers on the backs of their vehicles with emblems calling for the prevention of traffic accidents	3.79	1.094	8.40
12. Set aside space in newspapers to display color pictures of serious traffic accidents	3.78	1.116	8.39
13. The increase in the areas and times allocated to traffic safety in the various media	3.79	1.055	8.36
14. Convincing drivers to volunteer to visit and provide social services and assistance to victims of traffic accidents	3.76	1.100	8.24
15. Organizing motivational competitions on radio and television about gaining knowledge in the field of driving and traffic law	3.73	1.073	8.08
16. Organizing motivational competitions for children on the best expressive drawing on the topic of traffic accident prevention	3.70	1.083	7.94

It can be noticed from the results shown in Table 3, that there are various different means for road awareness. Their means and Freedman rankings averages are very high, suggesting that these different methods are suitable for use in traffic awareness campaigns. It can be seen that: Continuity in raising the traffic problem on a daily basis and not only talking about it when incidents or accidents occur is classified first with a mean of 3.92. This principle emphasizes on one the main manners as a very necessary tool to keep on raising awareness over the year and not occasionally when incidents or accidents happen. Similarly, the other items are also suggesting so many manners of implementation of raising road awareness. It looks as though they are different from those methods shown in Table 2. Most of them are trying to involve different resources in the society in order to be involved by participating in the promotion of the highway safety and making the culture prevention the highest priority. Encouraging different members and associations in the society to change their ways of thinking and behave by sharing their experiences and addressing common problems can do this.

4 Discussion

Despite the fact that the different methods and means of raising awareness shown in Tables 2, 3, are ranked significantly in descending order, all of them still have quiet high means and ranking. The convergence of these results may show the importance of the various methods and means mentioned in Tables 2 and 3, and therefore the need to rely on all them of in raising the level of awareness and prevent traffic accidents. The convergence of these results may show the importance of the various methods and methods mentioned in Tables 2 and 3, and therefore the necessity of relying on them all to raise the level of awareness to prevent traffic accidents. This can be explained on the basis that what works for them in one place or time may not do so in another place or time, and what may be appropriate for a category of society or a region of the country may not be suitable for other groups or other areas of Motherland.

For example, despite the spread of television and its control over many areas of the media, radio is still considered as one of the most important means of effective mass communication, which has been playing an important role in the field of communication. This is mainly due to the speed of transfer of media material to the target groups and what the extent of its spread, both in terms of ease of access to the listener in different places or times. It also raises the listener's thinking and imagination, not to mention the low costs and flexibility in presenting programs. The listener does not need to stop what he is doing, such as moving through the vehicle, for example driving. Accordingly, the radio can contribute to dealing with many issues related to traffic safety, especially as it accompanies most of the drivers during their transportation after most vehicles have become equipped with a radio and can even carry out immediate traffic tasks via direct broadcast.

In the same context, Hind Al-Thawadi [10] concluded that the radio is the largest means that the study sample is exposed to in the morning period (6–10 am), and that the most exposed means in the evening period is television (27.5%), and newspapers are 19.1%, And radio, by 18.9%. Which implies the necessity of relying on the concept of time management and its exploitation in the context of broadcasting advertisements on awareness and traffic education at appropriate times for specific groups and through appropriate mass communication means.

Hence, it can be concluded that it is possible for all these various methods and means to raise awareness for road safety especially when they are chosen in the opinion of drivers from different regions and different individuals characteristics.

References

1. Allsop, R.E., The Effectiveness of Speed Cameras: A Review of Evidence. RAC Foundation (Nov 2010)
2. Boudrifa, H., Tir, R., Boukabous, A.: Evaluation du systeme de la formation à la conduite en Algerie. Projet d'étude au profit du Centre National de Prevention et la Sécurité de la route, Laboratoire de Prévention et d'Ergonomie, l'Université d'Alger (2007)
3. Boudrifa, H., Bouhafs, A., Touill, M., Tabtroukia, F.: Measurements of unsafe behavior of road users. In: 15th International Conference Road Safety on Four Continents, Abu Dhabi, United Arab Emirates, 28–30 Mar 2010
4. Higbee, K.: Fifteen years of fear arousal: research on threat appeals. Psychol. Bull. **72**(6), 426–444 (1969)
5. Insko, C., Arkoff, A., Insko, V.: Effects of high and low fear-arousing communications upon opinions toward smoking. J. Exp. Soc. Psychol. **1**, 256–266 (1965)
6. LaTour, M.S., Rotfeld, H.J.: There are threats and (maybe) fear-caused arousal: theory and confusions of appeals to fear and fear arousal itself. J. Advert. **26**(3), 45–59 (1997)
7. Leventhal, H., Watts, J.: Sources of resistance to fear-arousing communications on smoking and lung cancer. J. Pers. **34**, 155–175 (1966)
8. Reported Road Casualties Great Britain 2010.: Department for Transport (2011)
9. The National Safety Camera Program.: Four-year Evaluation Report by University College London & PA Consulting. Published by Department for Transport (Dec 2005)
10. Hind Al-Thawadi.: Planning social marketing campaigns by applying to traffic culture management campaigns. Magister thesis, University of Bahrain (2012).

Data Digitalisation in the Open-Pit Mining: Preliminary Results

J. Duarte, M. Fernanda Rodrigues and J. Santos Baptista

Abstract The new technological era has been shaping all industries and its impact on Mining activity lead to the emergence of the Mining 4.0 concept. Even though cutting edge technology is currently being used, this keeps being one of the most hazardous sectors. Therefore the importance of using such tools to improve, not only the productive agendas but also the environmental and occupational safety. The purpose of this study is to provide the preliminary results regarding the types of digitalisation tools and their main intents. In order to do so, the PRISMA guidelines extension for Scoping Reviews was used to filter the results. In this first investigation phase, from the 6775 identified articles, only 24 met the expected inclusion criteria, providing rationale for the digitalisation methodologies and tools. It was verified that the most used tools have in its core geographic information systems, despite the growing trend regarding photogrammetry tools. Regardless of the usage, the studies were mostly trying to solve engineering issues related to slope stability (which can also be linked to safety) and environmental monitorisation, thus showing the importance of creating models to design these project components to perform adequate managing actions. With this study, the needed background to carry this project is launched and further studies will be added to try to determine which tools and what information is needed to execute a design project.

Keywords Mining 4.0 · Photogrammetry · Geographic information systems

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1 Introduction

1.1 Background

Despite the recent slower and weaker market trends, the mining industry still plays an important role in the economy, being part of the supply chain of several other sectors namely construction, production and banking [1]. Surface mining is one of the most common forms of ore extraction, posing as the key economic activity for many countries worldwide [2], especially in developing countries such as India [1]. However, due to its engineering challenges, this field is still seen as a high-risk occupation. Hence, using these technological tools, it is important not only to increase production rates but also to improve safety conditions [3]. The new development in the light of Mining 4.0 [4] is helping to study and monitor the quarrying areas, but also raising awareness to other subjects such as management and even risk assessment [2]. It is known that safety in mining is mainly influenced by the technical and natural characteristics of the bedrock at the localities of interest. Landslides, most of the times, have its origin in insensitive exploitation combined with inadequate geological examination [5]. The stability of the excavated surface is crucial, not only for production matters but as for the economy and safety of the operations [6]. Therefore, it is important to develop models that can help plan, model and predict such events. Three-dimensional modelling serves as an exploration tool and can be used to foresee the feasibility of the exploitation at any level [7].

1.2 Objectives

The digitalisation of information in the mining industry includes databases with geological, geophysical, geochemical and other collected information, mainly, through remote sensing techniques [8]. The purpose of this study is to provide the preliminary results regarding the digitalisation tools used in open-pit mining, providing rationale related to its main intents. This paper will be the motto for an extended scoping review on Mining 4.0 tools.

2 Methodology

The applied methodology to conduct this research was based on the scoping review protocol proposed by Duarte et al. [9], where the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [10] were used, with the proper adjustments to scoping reviews [11].

The keywords defined to conduct the search were "digitalisation"/"digitalization" and "modelling"/"modeling", which were combined with "open pit" and "open cast". The selected databases and journals were Scopus, Web of Science, Current Contents, Academic Search Ultimate, Inspec, Cambridge Journals Online, Emerald, Taylor and Francis, Ingenta, SAGE, Science Direct, ACM Digital Library and Geological Society of America. The set of exclusion criteria applied to the papers was: (1) date—despite the protocol refers 2018, the research was carried out in late 2019, therefore, the range considered was between 2015 and 2019-, (2) document type—only articles and articles in press were considered, (3) source type—articles published journals or trade publications, and (4) language—only English written articles were considered. Despite these exclusion criteria, in the second phase of research, the criteria will be expanded to consider any other relevant publications from conferences and grey literature, as well as other works from reference authors. To be included, the articles had to report digitalisation tools or rationale for the digitalisation of information in the open-pit mining context. Additional attention was paid to the type of digitalised information and its application.

3 Results and Discussion

On the screening phase, a total of 6775 articles were identified. The application of the exclusion criteria lead to the following results: (1) date—3864 papers were excluded, (2) "type of paper"—642 papers were excluded, (3) paper source—5 papers were excluded, (4) manuscripts not written in English—140 texts. Duplicates (43 articles) and works without full-text access (after trying to reach the authors), a total of 9 papers, were removed. On the eligibility phase, all of the articles' title and abstracts were screened, where 2007 articles were rejected as they were not in accordance with the proposed objective. After this process, only 65 papers were considered eligible and were full-text screened, so to determine evidence related to the digitalisation of information or modelling (as long as they provided rationale regarding the digitalisation component). After the selection process, 24 articles were included for qualitative analysis. All of the articles fall in the category "digitalisation and modelling" and are related to open-pit mining (which was one of the inclusion criteria). Table 1 displays all of the articles' characteristics in relation to the main digitalisation and modelling tools, when provided.

Some of the studies (nine) used photogrammetry as the main resource so to extract the needed data for each project: two studies used terrestrial photography [17, 30] and the other seven used aerial photography [2, 15, 16, 23, 25, 27, 31]. Photogrammetry techniques are accepted and widely recognized as suitable to perform analysis in hard rock environments [33], being also used to produce high-resolution topographic data [34]. Two of the biggest advantages of aerial photogrammetry (in comparison with the remaining methodologies and, even,

Table 1 Summary of the studies' characteristics

Author, year	Digitalisation tool	Modelling tool
Barakat et al., 2015 [12]	ArcView (GIS)	Not mentioned
Francioni et al., 2015 [2]	ERDAS™ IMAGINE software, Leica™ Cyclone software	Rocscience
Kulatilake & Shu, 2015 [13]	3DEC	3DEC
Muzik et al., 2015 [14]	Not mentioned	Not mentioned
Shahbazi et al., 2015 [15]	Pix4D software	Pix4D software
Tong et al., 2015 [16]	Leica photogrammetry suite	ArcGIS 9.2
Wajs, 2015 [17]	Bentley Microstation V8i software	Bentley InRoads software
Wężyk et al., 2015 [18]	Terrasolid, FUSION, LASTools	ArcGIS ESRI
Cardozo et al., 2016 [19]	Move (GIS)	Move (GIS)
Horner et al., 2016 [20]	FieldMove (GIS)	Leapfrog Geo/ Leapfrog Mining
Basson et al., 2017 [21]	ArcView (GIS)	Micromine
Caudal et al., 2017 [22]	Optech parsing software	Not mentioned
Esposito et al., 2017 [23]	CloudCompare, AgisoftTM PhotoScan Professional, ESRITM ArcGIS v.10.3	AgisoftTM Photoscan
Lindqvist et al., 2017 [6]	Hyperdata software TM, Analyst Mine Mapping Suite TM	Move, GEOVIA Surpac
Jayanthu & Karthik, 2018 [24]	Not mentioned	Oasys and FLAC SLOPE software
Kondela et al., 2018 [5]	ReflexW Sandmeier scientific software, Surfer13	Petrel Software
Sayab et al., 2018 [25]	Agisoft Photoscan Pro, CloudCompare and ArcGIS	CloudCompare
Sengupta et al., 2018 [26]	ArcGIS 10.1	CARTOSAT, ArcGIS 10.1
Xiang et al., 2018 [27]	Agisoft PhotoScan, CloudCompare	Not mentioned
Creus et al., 2019 [28]	Sirovision	Micromine, Leapfrog Geo
Morales et al., 2019 [29]	GIS, ArcMap	Leapfrog Geo
Morales et al., 2019 [30]	Dips, Sirovision, ArcGIS	Leapfrog Geo

(continued)

Table 1 (continued)

Author, year	Digitalisation tool	Modelling tool
Padró et al., 2019 [31]	Agisoft PhotoScan, MiraMon RS&GIS software	Agisoft PhotoScan
Vanneschi et al., 2019 [32]	Dips 7.0, Rhinocheros 5.0	3DEC

terrestrial photogrammetry) are its low cost and the capture of high-resolution images of inaccessible areas [23]. The invention of the unmanned aerial vehicles (UAVs) and increasing dissemination due to its close-range and high-resolution technology turned the digital photogrammetry into a popular technique for mapping [25]. These systems are simple and require two components: a platform and compatible navigation sensors which are able to acquire images to feed the remote sensing and photogrammetric applications [15, 16]. The unmanned aerial imagery has been applied in several fields such as civil engineering, mining, spatial ecology and resource management [15]. In mining, more specifically in open pit mining, the necessary framework to build this methodology can be divided into four parts: configuration of the network and flight route design, image acquisition (and matching), image accuracy improvement (through geo-positioning), and land covers classification [16]. Esposito et al. [23], Sayab et al. [25], Xiang et al. [27], Padró et al. [31] used, in their projects, AgiSoft PhotoSchan as the main digitalization tool, which, in the case of Esposito et al. [23] and Padró et al. [31] was also the preferred tool for the modelling part of the studies. On the studies of Francioni et al. [2], Shahbazi et al. [15], and Tong et al. [16], other image softwares were used to digitalise the information, such as Leica's Software and Pi4D. As for terrestrial photogrammetry, Bentley's Microstation was used.

Seven articles [12, 19–21, 26, 29, 30] have in its core Geographic Information Systems (GIS), which are computer-based applications which models the real world into separate spatial layers (for example, geological facies, structures, hydrographic networks) used widely to suite several purposes, namely, management in open pit mining. The digitalisation attached to this methodology consists of describing the boundaries of the spatial objects, decomposing them into their elementary constituents (polygons, lines or points) [12]. This process then leads to the creation of new 2D or 3D spatial information [18]. Another potentiality of this technology is the capacity to provide visual displays, integrating real data (such as surface topography) with interpolations (cokriging estimations, for example) [35].

From the remaining nine papers [5, 6, 13, 14, 18, 22, 24, 28, 32], seven used specific software (Table 1) to perform the digitalisation of the data, which included locations, geology, fractures' dip/dip direction, maps, displacement, geometrical data, and point clouds. Two of the selected papers [14, 24] refer how they digitalized the information (linear dimensions and displacements), however, did not provide any reasoning for tools.

Figure 1 summarises the overall purpose of each article, interpreted from the studies' objectives and applied methodologies. The leading theme was engineering

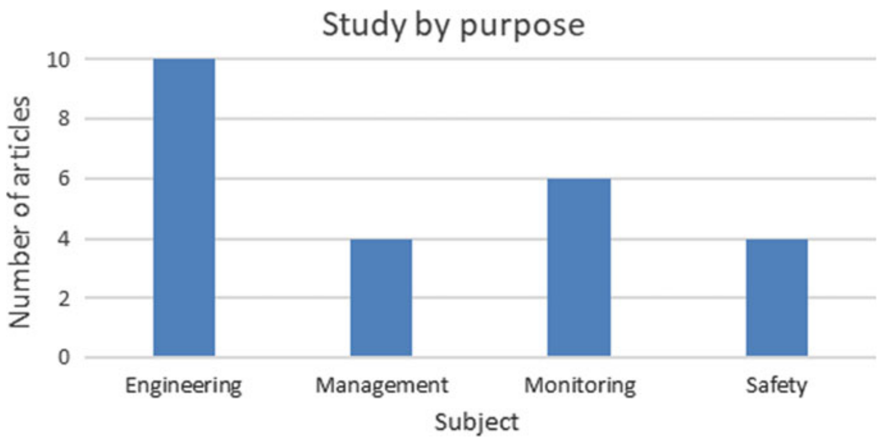

Fig. 1 Studies divided by the main field

[6, 15, 19–21, 25, 28, 30, 32, 34], where new methodologies were developed, old methodologies were optimised and most papers focused in structural analysis regarding slopes. Monitoring mining areas with relation to landscape and environmental impacts were also addressed [16, 18, 22, 23, 27, 31]. Management including planning and production, volumes estimations and quarry census were the main topics [12–14, 17]. Safety matters were related to slope stability analysis [2, 5, 24, 26], as slope stability accidents are in the list of leading causes of accidents in the open-pit mining context [24].

4 Conclusions and Future Work

Despite the recent trends in technology regarding Mining 4.0 development, the mining industry continues to be on the top list of hazardous activities. Therefore, the importance of understanding how these tools can help solving production quotas but also other management and safety requirements. The aim of this study is to provide the preliminary results concerning the digitalisation tools currently in use and to act as bottom line for extended research on this matter. From it, can be concluded that the digital photogrammetry is becoming a trend methodology especially for mapping (and consequent model development), with the help of the unmanned aerial vehicles [2, 15, 16, 23, 25, 27, 31]. One of the biggest advantages of UAVs is the possibility of collecting high-resolution information from inaccessible places [25]. Nonetheless, the Geographic Information Systems (GIS) applications are, from far, the most disseminated applications to deal with the digitalisation of information and even modelling. It was observed that most papers focused on engineering issues with relation to slope stability even though this issue can be more easily linked to safety conditions. However, there are other elements that need to be considered for the design of safe and efficient structures such as geological structure, water condition and rock mass characteristics [24]. Another common solving issue was environmental monitorisation, especially with regard to landscape monitorisation. Future work will include further studies on the digitalisation and modelling, especially on the methodologies matter, to improve environmental and safety design in future projects.

References

1. Soleimani, H.: A new sustainable closed-loop supply chain model for mining industry considering fixed-charged transportation: a case study in a travertine quarry. Resour. Policy, pp. 1–11 (2018). https://doi.org/10.1016/j.resourpol.2018.07.006
2. Francioni, M., Salvini, R., Stead, D., Giovannini, R., Riccucci, S., Vanneschi, C., Gulli, D.: An integrated remote sensing-GIS approach for the analysis of an open pit in the Carrara marble district, Italy: Slope stability assessment through kinematic and numerical methods. Comput. Geotech. **67**, 46–63 (2015)
3. Verma, S., Chaudhari, S.: Safety of workers in Indian mines: study, analysis, and prediction. Saf. Health Work. **8**, 267–275 (2017). https://doi.org/10.1016/j.shaw.2017.01.001
4. Bartnitzki, T.: Mining 4.0—importance of industry 4.0 for the raw materials sector. Min. Rep. **153**, 25–31 (2017)
5. Kondela, J., Prekopová, M., Budinský, V., Pandula, B., Ďuriška, I.: The importance of seismic methods application for geological reconstruction of rockslide threatened open pit. J. Appl. Geophys. **159**, 304–311 (2018). https://doi.org/10.1016/j.jappgeo.2018.09.005
6. Lindqvist, T., Skyttä, P., Koivisto, E., Häkkinen, T., Somervuori, P.: Delineating the network of brittle structures with geotechnical, structural and reflection seismic data, Kevitsa open pit, northern Finland. GeoResJ **13**, 159–174 (2017). https://doi.org/10.1016/j.grj.2017.04.004
7. Lepine, I., Farrow, D.: 3D geological modelling of the Renard 2 kimberlite pipe, Quebec, Canada: from exploration to extraction. Mineral. Petrol. **112**, 411–419 (2018). https://doi.org/10.1007/s00710-018-0567-x
8. Zelko, M., Spišák, J.: Changing the raw material industry through digitalization and informatization. In: Information Technology Human Values, Innovation and Economy, pp. 251–258 (2013)
9. Duarte, J., Rodrigues, F., Santos Baptista, J.: Data digitalisation in the mining industry—a scoping review protocol. Int. J. Occup. Environ. Saf. **3**, 64–67 (2019). https://doi.org/10.24840/2184-0954_003.001_0006
10. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Altman, D., Antes, G., Atkins, D., Barbour, V., Barrowman, N., Berlin, J.A., Clark, J., Clarke, M., Cook, D., D'Amico, R., Deeks, J.J., Devereaux, P.J., Dickersin, K., Egger, M., Ernst, E., Gøtzsche, P.C., Grimshaw, J., Guyatt, G., Higgins, J., Ioannidis, J.P.A., Kleijnen, J., Lang, T., Magrini, N., McNamee, D., Moja, L., Mulrow, C., Napoli, M., Oxman, A., Pham, B., Rennie, D., Sampson, M., Schulz, K.F., Shekelle, P.G., Tovey, D., Tugwell, P.: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. **6** (2009). https://doi.org/10.1371/journal.pmed.1000097
11. Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., Moher, D., Peters, M.D.J., Horsley, T., Weeks, L., Hempel, S., Akl, E.A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M.G., Garritty, C., Lewin, S., Godfrey, C.M., Macdonald, M.T., Langlois, E. V, Soares-Weiser, K., Moriarty, J., Clifford, T., Tuncalp, O., Straus, S.E.: PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann. Intern. Med. **169**, 467–473 (2018). https://doi.org/10.7326/M18-0850

12. Barakat, A., Baghdadi, M.E., Rais, J.: A GIS-based inventory of ornamental stone and aggregate operations in the Beni-Mellal Region (Morocco). Arab. J. Sci. Eng. **40**, 2021–2031 (2015). https://doi.org/10.1007/s13369-015-1672-3
13. Kulatilake, P.H.S.W.: Biao Shu: prediction of rock mass deformations in three dimensions for a part of an Open Pit Mine and comparison with field deformation monitoring data. Geotech. Geol. Eng. **33**, 1551–1568 (2015)
14. Muzik, J., Vondráčková, T., Sitányiová, D., Plachý, J., Musílek, J.: Limestone quarry reserve estimation by laser scanning and GIS tools. Procedia Earth Planet. Sci. **15**, 382–388 (2015). https://doi.org/10.1016/j.proeps.2015.08.008
15. Shahbazi, M., Sohn, G., Théau, J., Menard, P., Theau, J., Menard, P.: Development and evaluation of a UAV-photogrammetry system for precise 3D environmental modeling. Sensors (Switzerland) **15**, 27493–27524 (2015). https://doi.org/10.3390/s151127493
16. Tong, X., Liu, X., Chen, P., Liu, S., Luan, K., Li, L., Liu, S., Liu, X., Xie, H., Jin, Y., Hong, Z.: Integration of UAV-based photogrammetry and terrestrial laser scanning for the three-dimensional mapping and monitoring of Open-Pit mine areas. Remote Sens. **7**, 6635–6662 (2015)
17. Wajs, J.: Research on surveying technology applied for DTM modelling and volume computation in open pit mines. Min. Sci. **22**, 75–83 (2015). https://doi.org/10.5277/msc152207
18. Wężyk, P., Szostak, M., Krzaklewski, W., Pająk, M., Pierzchalski, M., Szwed, P., Hawryło, P., Ratajczak, M.: Landscape monitoring of post-industrial areas using LiDAR and GIS technology. Geod. Cartogr. **64**, 125–137 (2015). https://doi.org/10.1515/geocart-2015-0010
19. Cardozo, N., Montes, C., Marín, D., Gutierrez, I., Palencia, A.: Structural analysis of the Tabaco anticline, Cerrejón open-cast coal mine, Colombia. South Am. J. Struct. Geol. **87**, 115–133 (2016). https://doi.org/10.1016/j.jsg.2016.04.010
20. Horner, J., Naranjo, A., Weil, J.: Digital data acquisition and 3D structural modelling for mining and civil engineering—the La Colosa gold mining project, Colombia. Geomech. und Tunnelbau. **9**, 52–57 (2016). https://doi.org/10.1002/geot.201500046
21. Basson, I., Lourens, P., Paetzold, H.-D., Thomas, S., Brazier, R., Molabe, P.: Structural analysis and 3D modelling of major mineralizing structures at the Phalaborwa copper deposit. Ore Geol. Rev. **83**, 30–42 (2017). https://doi.org/10.1016/j.oregeorev.2016.12.002
22. Caudal, P., Grenon, M., Turmel, D., Locat, J.: Analysis of a large rock slope failure on the east wall of the LAB Chrysotile Mine in Canada: LiDAR monitoring and displacement analyses. Rock Mech. Rock Eng. **50**, 807–824 (2017). https://doi.org/10.1007/s00603-016-1145-3
23. Esposito, G., Mastrorocco, G., Salvini, R., Oliveti, M., Starita, P.: Application of UAV photogrammetry for the multi-temporal estimation of surface extent and volumetric excavation in the Sa Pigada Bianca open-pit mine, Sardinia, Italy. Environ. Earth Sci. **76**, 103 (16 pp.) (2017)
24. Jayanthu, S., Karthik, G.: Evaluation of stability of cutslopes in open cast metal mines using numerical modelling and field monitoring. Adv. Model. Anal. A. **79**, 12–15 (2018)
25. Sayab, M., Aerden, D., Paananen, M., Saarela, P.: Virtual structural analysis of Jokisivu open pit using "structure-from-motion" Unmanned Aerial Vehicles (UAV) photogrammetry: implications for structurally-controlled gold deposits in Southwest Finland. Remote Sens. **10** (2018). https://doi.org/10.3390/rs10081296
26. Sengupta, S., Krishna, A.P., Roy, I.: Slope failure susceptibility zonation using integrated remote sensing and GIS techniques: A case study over Jhingurdah open pit coal mine, Singrauli coalfield, India. J. Earth Syst. Sci. **127** (2008). https://doi.org/10.1007/s12040-018-0982-8
27. Xiang, J., Chen, J., Sofia, G., Tian, Y., Tarolli, P.: Open-pit mine geomorphic changes analysis using multi-temporal UAV survey. Environ. Earth Sci. **77**, 220 (18 pp.) (2018)
28. Creus, P.K., Basson, I.J., Koegelenberg, C.K., Ekkerd, J., de Graaf, P.J.H.H., Bester, M., Mokele, T.: 3D Fabric analysis of Venetia Mine, South Africa: using structural measurements and implicitly-modelled surfaces for improved pit slope design and risk management. J. African Earth Sci. **155**, 137–150 (2019). https://doi.org/10.1016/j.jafrearsci.2019.04.009

29. Morales, M., Panthi, K.K., Botsialas, K.: Slope stability assessment of an open pit mine using three-dimensional rock mass modeling. Bull. Eng. Geol. Environ. **78**, 1249–1264 (2019). https://doi.org/10.1007/s10064-017-1175-4
30. Morales, M., Panthi, K.K., Botsialas, K., Holmøy, K.H.: Development of a 3D structural model of a mine by consolidating different data sources. Bull. Eng. Geol. Environ. **78**, 35–53 (2019). https://doi.org/10.1007/s10064-017-1068-6
31. Padró, J.-C.J.C.J.-C.J.C., Carabassa, V., Balagué, J., Brotons, L., Alcañiz, J.M., Pons, X.: Monitoring opencast mine restorations using Unmanned Aerial System (UAS) imagery. Sci. Total Environ. **657**, 1602–1614 (2019). https://doi.org/10.1016/j.scitotenv.2018.12.156
32. Vanneschi, C., Eyre, M., Venn, A., Coggan, J.S.: Investigation and modeling of direct toppling using a three-dimensional distinct element approach with incorporation of point cloud geometry. Landslides (2019). https://doi.org/10.1007/s10346-019-01192-w
33. Riquelme, A.J., Abellán, A., Tomás, R.: Discontinuity spacing analysis in rock masses using 3D point clouds. Eng. Geol. **195**, 185–195 (2015). https://doi.org/10.1016/j.enggeo.2015.06.009
34. Passalacqua, P., Belmont, P., Staley, D.M., Simley, J.D., Arrowsmith, J.R., Bode, C.A., Crosby, C., DeLong, S.B., Glenn, N.F., Kelly, S.A., Lague, D., Sangireddy, H., Schaffrath, K., Tarboton, D.G., Wasklewicz, T., Wheaton, J.M.: Analyzing high resolution topography for advancing the understanding of mass and energy transfer through landscapes: a review. Earth-Sci. Rev. **148**, 174–193 (2015). https://doi.org/10.1016/j.earscirev.2015.05.012
35. Uygucgil, H., Konuk, A.: Reserve estimation in multivariate mineral deposits using geostatistics and GIS. J. Min. Sci. **51**, 993–1000 (2015). https://doi.org/10.1134/S1062739115050186

Methodological Proposal for Quality Assessment of Urban Pedestrian Galleries

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Abstract The urban space is formed by elements which adopt established norms to implement them so that these guidelines are elaborated aiming the functionality and effectiveness of designed properties. Thus, as important as compliance with the rules, it verifies the performance of urbanistic component elements from the users' perspective. In this sense, when it comes to galleries evaluation methods the bibliography is absent. Thus, affording the relevance of public opinion to the daily life elements, there is the need to create measures to judge the operation of galleries. Therefore, this paper aims to present a tool capable of qualitatively assessing galleries. In order to do so, evaluation methods were used for measurements (Pedestrian Movement Estimation Model Used in Space Syntax, Performance Measurements, and Artificial Neural Networks), have adapted to the object of study (pedestrian galleries); thus two questionnaires were applied (for professionals and users), intending evaluated the performance characteristics quantitatively, comparing to the performance measures. Through results obtained analysis, it would conclude that the quality of the studied urban galleries, presents in Juiz de Fora, mostly are considered a poor service level. Stressing the need to maintain and improve the level of service provided by each gallery.

Keywords Assessment · Galleries · Performance measures

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1 Introduction

The accelerated urban growth brought considerable transformations in the issues related to the ambience of the physical spaces, consequently, resignifying experiences and collective memory of these places. Thereby, Gehl and Gemzøe [1] state that urban public spaces have precious characteristics in the memory of the population, being liable to lose their essence when they are resignified, whether there are urbanistic processes for example.

For this, it is necessary to use tools that assess the quality of pedestrian roads, measuring their performance and the way they influence user comfort [2–5]. To this objective, the study target of this article is the galleries located in the central region of the city of Juiz de Fora, strategic elements used for the urban planning of the city in the mid-1950s [10]. Therefore, creating an evaluative method for galleries, including professionals' opinion able to judge the performance criteria as well as the consensus of the users, in order to verify the practical functionality of the analyzed route, is needed. The objective of this paper is to present a tool capable of evaluating and qualifying both existing galleries and those that will be built still.

2 Methodology

Considering the analyzed bibliographies, regarding the use and quality assessments of sidewalks and the importance of weighting the other urban elements, the study of galleries' evaluation was made through the parallel between the qualitative criteria of these two urban elements; taking advantage of some of those already presented for sidewalks, and adding other viable ones to galleries' evaluation.

The object of study of this article were sixteen galleries located in the central region of Juiz de Fora (see Fig. 1). These were chosen in order to obtain a considerable variety of features present in these spaces.

Therefore, for the elaboration of the new method, the sidewalk evaluation tool made by Zampieri [5] was a reference, whose analysis material is the spatial syntax and the performance measurement of sidewalks. Despite the existence of other evaluation methods, and it is not the purpose of this paper to discuss them, according to Castañon et al. [6], Zampieri's methodology is more appropriate for the necessary adaptations of galleries' evaluation, since it presents malleability of the tool structure, allowing insertion, adaptation and exclusion of attributes.

As already reported, the need for a method for galleries evaluation leads to an adaptation of the methodology used to evaluate an urbanistic element, similar in certain way, which includes the removal of some performance measures and the insertion of other so that the tool is appropriate. The model chosen as the basis was the Estimating Model of Pedestrian Movement Based on Spatial Syntax, Performance Measures and Artificial Neural Networks [5].

Fig. 1 Location of the analyzed galleries. *Source* Adapted Google Maps (2019)

2.1 Presentation of the Estimating Model of Pedestrian Movement Based on Spatial Syntax, Performance Measures and Artificial Neural Networks

Zampieri's proposal [5] presents a final model with well-specified performance measures in order to show criteria for sidewalks' evaluation, as well as a research on pedestrian movement and artificial neural networks, an innovative technology with much potential in urban modeling area. Thus, his research consisted of a data collection, starting with the selection of sidewalks, which were enumerated for the study. Subsequently, a pedestrian flow was counted at each one of them at different times of the day for a few days in order to classify them regarding the movement.

Therefore, Zampieri [5] comes to the performance measures for the evaluation of sidewalks. It is noteworthy that some changes were defined during the elaboration of the evaluation sheets, being chosen as ideal the one that has the criteria arranged separately, in which each of these is divided into characteristics as:

- Attractiveness: This criterion encompasses the visual and social characteristics of the studied space, beyond the visual characteristics of the surroundings. There is, then, a concern with the aesthetics and the socialization of pedestrians;
- Comfort: In this parameter there are the characteristics of the circulation range, the access to people with physical and motor needs and the arrangement of street furniture;
- Maintenance: This performance measure shows concern with the characteristics of paving adequacy, as well as its physical condition and its cleanliness;
- Safety: This is the possibility of conflict between pedestrians and vehicles, the characteristics of crossings from one sidewalk to another through the safety lane and traffic lights;

Table 1 Table with the quality indicators and their respective values

Quality indicator	F	E	D	C	B	A
Gallery note	0 a 0,9	1 a 1,9	2 a 2,9	3 a 3,9	4 a 4,9	5

- Public Safety: Issues related to local policing, local co-presence and visibility among different points of the sidewalk are addressed in this assessment. There is, then, a concern with the sense of security that the place conveys to users, either by the presence of a responsible authority or the presence of other people.

Finally, these measures were arranged in questionnaires, one of them designed for technical judgment, answered by urbanism professionals, in which scores were given for each performance measure ranging from 0 to 5. In addition to this technical questionnaire, another one was elaborated with the objective of creating a criteria weighting factor, assessing which of the measures are most important for pedestrians. For this purpose, this questionnaire was answered by pedestrians, always relating the evaluation criteria to each other. Finally, the weighting can be calculated from the scores received in the technical questionnaire and weighted by the coefficient of each performance measure awarded by pedestrians.

In possession of the questionnaires, according to Zampieri [5], it is convenient to represent the basis of sidewalk quality indicators, as follows (Table 1).

2.2 *Adaptation of the Method Proposed by Zampieri [5]*

In order to make the method more effective in its application to galleries, some adaptations were made in the methodology proposed by Zampieri [5].

In the attractiveness criterion, the item that evaluates the visual characteristics of the surroundings, which observes the buildings around the sidewalks, was removed, since the elements evaluated in this subdivision of the performance measure do not apply to the galleries [7–9].

Still, in the comfort criterion were added, besides the care with pedestrians that have physical-motor disabilities, the evaluation question regarding the existence of tactile floor for the visually impaired.

The safety criterion, which assesses the possibility of conflict between pedestrians and vehicles, safety lane and the presence or absence of traffic lights, was removed from the present method due to the fact that in galleries there is no presence of these items.

Finally, in the public safety criterion, the question that considers local policing was removed, considering that in some galleries there is presence of security guards, and this other weighting factor was added to the evaluation. Thus, this criterion was evaluated as follows:

- Presence of security guards in the spot: 1,1
- Absence of security guards in the spot: 1.

The other criteria evaluated in this performance measure were maintained.

To determine the sample of questionnaires to be applied, a statistical calculation was made considering the number of inhabitants of the city, which led to the result of 384 questionnaires [4, 5, 7, 8].

Both technical and personal questionnaires were applied according to the methodology proposed by Zampieri [5].

3 Results and Discussions

With the personal questionnaires answered, the weighting coefficient was obtained. For this, the values of each performance measure were summed separately and the result was divided by their total sum (Table 2).

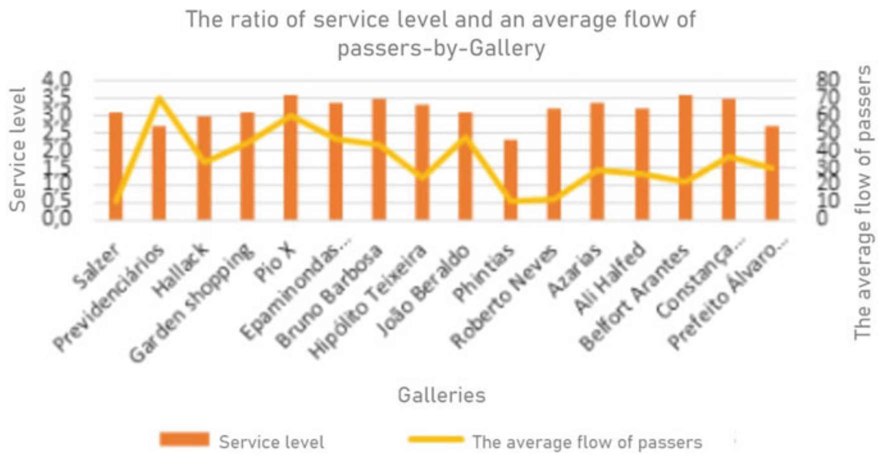
Through the analysis of the two questionnaires, the final result was the performance level of each gallery analyzed, which are listed in Table 3.

Table 2 Table with the weighting factors obtained for each performance measure analyzed

Performance measures	Weighting factor
Attractiveness	0.245
Comfort	0.209
Maintenance	0.209
Public safety	0.337

Table 3 Service level and quality indicator of the galleries analyzed in Juiz de Fora

Gallery	Service level	Quality indicator
Salzer	3,1	C
Previdenciários	2,7	D
Hallack	3,0	C
Garden shopping	3,1	C
Pio X	3,6	C
Epaminondas Braga	3,4	C
Bruno Barbosa	3,5	C
Hipólito Teixeira	3,3	C
João Beraldo	3,1	C
Phintias	2,3	D
Roberto Neves	3,2	C
Azarias	3,4	C
Ali Halfed	3,2	C
Belfort Arantes	3,6	C
Constança Valadares	3,5	C
Prefeito Álvaro Braga	2,7	D



Graph 1. Relationship of the service level and flow of passers of each gallery

Through the analysis of the obtained results it can be concluded that the quality of the urban galleries present in the city center of Juiz de Fora is mostly C, which is a poor service level. Thus, it is emphasized that the maintenance and improvement of the level of service provided by each gallery are necessary. Analyzing the pedestrian flow in each gallery along with their level of service, the following graph was obtained (Graph 1).

From this, it can be observed that in some galleries, such as the Previdenciários gallery, there is a high flow of pedestrians, due to the service provided in the site. Thus, there is a need for studies related to improvements that should be made in the gallery for the best quality of service provided to users.

At the end of the research, it can be said that the objective was achieved, considering that the method proved to be sufficient to evaluate the quality of the galleries.

4 Conclusion

Through results obtained analysis, it would conclude that the quality of urban galleries presents in the downtown of Juiz de Fora, mostly are C, which is considering a poor service level. Thus, stands out the need to maintain and improve the level of service provided by each gallery. Finally, the research achieved their objective, considering the method that showed sufficient for the galleries quality evaluation.

References

1. Gehl, J., Gemzøe, L.: New City Spaces. Danish Architectural Press, Copenhagen (2000)
2. Ferreira, M.A.G., da Sanches, S.P.: Índice de qualidade das calçadas - IQC. Revista dos Transportes Públicos - ANTP, 47–60, maio/ago. 2001. Trimestral
3. Khisty, C.J.: Evaluation of pedestrian facilities: beyond the level-of-service concept. In: Transportation Research Record 1438. Illinois Institute of Technology, Chicago (1994)
4. Sarkar, S.: Qualitative evaluation of comfort needs in urban walkways in major activities centers. Transp. Quart. **57**(4) (2003) (Eno Transportation Foundation, Washington, DC)
5. Zampieri, F.L.L.: Modelo estimativo de movimento de pedestres baseado em sintaxe espacial, medidas de desempenho e redes neurais artificiais. Dissertation (Master)—Postgraduate Program in Urban and Regional Planning, Porto Alegre. UFRGS (2006)
6. Castañon, J.B., Luchini, B.C., Almeida, D.P., Andrade, R.A.: Avaliação da qualidade de galerias: Uma análise das ferramentas existentes. Primeiro Congresso Internacional de Ergonomia aplicada (2016)
7. de Cambra, P.J.M.: Pedestrian Accessibility and Attractiveness Indicators for Walkability Assessment. Lisboa (2012)
8. ABERGO: O que é ergonomia. Desenvolvido pela Associação Brasileira de Ergonomia. Available in: https://www.abergo.org.br/internas.php?pg=o_que_e_ergonomia. Accessed on: 11 May 2016
9. Vasconcelos, E.A.: Transporte urbano, espaço e equidade: análise das políticas públicas. Annablume, São Paulo (2001)
10. Corrêa, V.M., Boletti, R.R.: Ergonomia: Fundamentos e Aplicações. 1, vol. 1. Bookman, Porto Alegre (2015)

Prospective Analysis of Blockchain Applications Within the Occupational Health and Safety Management and Wearable-Related Ergonomics in Manufacturing Industry

Juan Antonio Torrecilla-García, María Del Carmen Pardo-Ferreira and Juan Carlos Rubio-Romero

Abstract The Blockchain technology is becoming gradually one of the most important variables of the transformation in many industries. However, not sufficiently studied from the empirical point of view, the potential foreseen of the distributed ledgers is considerable. The objective of this research has been to trace the initial path of how Blockchain technology can be used to solve practical Health and Safety problems faced by manufacturing organizations. The present state-of-the-art analysis on industrial uses of Blockchain, although with limited scope, is also still conceptual and proposal-oriented. Some applications within the manufacturing industry ecosystems have been analyzed. The emergent trend of Industry 4.0 takes the relevant role within the development of applied grounds for the Blockchain technology spread in different areas of the manufacturing industry. In this paper, according to the performed scoping review of the potential of Blockchain for the Occupational Health and Safety Management, the applications in traceability, supply chains transparency, production events recording have been considered as able to become extrapolated or adapted to the Ergonomics Management. During the literature review, the preliminary framework of Wearable-based Ergonomics Management through the Blockchain platforms has been proposed.

Keywords Blockchain · Ergonomics · Wearable · Manufacturing industry · Occupational health and safety

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1 Introduction

Blockchain technology, more than a decade old, is widely becoming the object of consideration for multiple industries [1–4], including the manufacturing industry [5, 6], due to its attractiveness to enhance the real-time transparency of processes and to reduce firm costs [4, 7]. Initially considered as a digital ledger of economic transactions updated continually by many different users, Blochchain's technical aspects have been studied by many scholars [5]. On that basis, other studies have emerged on the different role of Blockchain as activator of the value creation across different industries [8, 9]. Many authors recognize vast field to apply the Blockchain [10], as well as the different organizational aspects can be affected by [8]. It is considered the technology could potentially be used in trading applications, consumer information records, smart contracts, decentralized patient/user records management, customized marketing, identity verification, fraud detection, etc. [11]. New focus of the Blockchain applications is moving towards more complex platform-based solution for specific requirements of the industries and branches [12, 13].

Even considering the majority of Blockchain applications still lay in the financial industry, the interest and potential role of this technology in manufacturing industry is growing [14]. Blockchain can increase the operability and efficiency of a range of activities in the manufacturing companies [15]. Although the distributed legers can solve manufacturing challenges in particular within the supply chain management [16], especially if taking into account, the efficiency the tracking during the shipping process or supply information recording [17, 18]. Present industrial supply chains are closely related to wide array of contractual and functional interrelations across the more and more complex and multiple channels in dynamic environment [19]. This complexity of the supply chain affects the productivity and growth opportunities of the manufacturing companies focused on continues improvement of the productive processes but still not able to harness all digital processes [20]. Blockchain technology fulfills necessary conditions to become the transformation trigger to make the manufacturing industry ecosystem orderly and efficient as well as based on simplicity, visibility and automation [16]. Korpela et al. [21] display the possibilities of the digitalization of supply chain system through Blockchain technology as the technology provides the capability if digitally modeling of real-world relationships across the supply chain ecosystem [13].

On the other hand, Blockchain technology has been suggested as a facilitator of the sustainability in the manufacturing industry owing to its real-time transparency and cost savings [3, 22]. Recent research [23] analyzes how the cost savings can be enabled by Blockchain technology's mechanism classifying the Blockchain-based cost reduction effects into verification costs and networking costs. On the other part, a few authors [24, 25] provide new point of view on the use of Blockchain platforms to secure the traceability and quality of products in the manufacturing industry.

Additionally Blockchain may become the game changing factor when Industry 4.0 is considered [26]. The wide range of emergent technologies of Industry 4.0, such as Internet of things (IoT), big data analytics, cloud manufacturing, digital twin, etc. [27], has the potential to change the actual paradigms of manufacturing industry by bringing the opportunities defined by [15]: self-awareness, self-prediction, self-comparison, self-reconfiguration, and self-maintenance [28]. However, the preliminary transformation is required to move towards more flexible, efficient, transparent and resilient systems [29] as to harness the full potential of Blockchain within the manufacturing industry solutions [26]. As manufacturing industry is still dependent to the centralized industrial networks and trust-based operations with third-parties [30], the paradigm change will be required to exploit the internal processes potentialities of Blockchain [31].

As the bottom line for the distributed ledger system, the Blockchain technology could make the strategic and operative advantages for Workplace Safety Management possible. This ledger is decentralized and distributed over a network of computational nodes [3, 19, 32], where each node contains a copy of the entire ledger. In this paper, the initial scoping review on possibility of application of Blockchain technology for the Occupational Health and Safety is presented.

2 Foreseeable Applications of Blockchain Technology Within the Wearable-Related Ergonomics

Workplace Safety Management concerns more than just identifying, analyzing and controlling hazards in work environment [33]. The modern Occupational Health and Safety in manufacturing industries are also a managerial strategic and prospective process in which the initial conditions and expectations must be settled and the whole system must be able to self-adjust if required [34]. Therefore, most manufacturing companies have OHS processes based on the implication of supervisory activities and the collaboration of employees within the measurable environment [4]. This trinomial of supervisory/control, users/employees implication and data deriving from the environment can become the founding stone for the Blockchain application in the Occupational Safety Management [35]. This prospective analysis pretends to align the opportunities of distributed OHS Management in complex, often Cyber-Physical Systems, manufacturing ecosystems, use of networks of Wearable Ergonomics Devices and Blockchain platforms [35–37].

2.1 Distributed Occupational Health and Safety Management

Recent OHS approaches [38] intend to enhance the effective Safety Management in manufacturing environments by improving both occupational and industrial safety indicators on more decentralized and participative basis [39]. According to the Gaining Distributed Safety method (GDS) [40] applied in several companies, the six axes define the culture of safety in an organization: commitment, coherence, objectivity, tolerance, communication and supports. This approach implies the necessity not only of compliance with the OHS agreement terms but also the almost real-time surveillance of the safety conditions. The more distributed scope of the OSH Management can benefit manufacturing firms in terms of the quality of Health and Safety Prevention [41], as well as by providing the safety risk assessment and early warning mechanisms [42]. These warning and prevention mechanisms are compulsorily related to the distributed machine learning algorithms. Hence, under these conditions the distributed OHS Management may turn into the scope of the Blockchain's intensive use [43, 44]. A distributed system of Blockchain-based nodes, indirectly connected assures faster calculation, lower maintenance costs, better stability, and easier upgrades [2]. Being the internally executed, the risk assessment and early warning systems under Blockchain technology are in general exempt of external public manipulation. Although, the benefits of real-time transparency of the distributed system, prevail [42].

2.2 Wearable-Related Ergonomics

Networks of wearable, measuring devices and sensors are rapidly becoming the core of Ergonomics in the manufacturing environments [45, 46]. The increased attention that wearable technologies are gaining in many industries elevates their status to an efficient solution for the OHS optimization [47–49]. Nevertheless, there are still come challenges to effective adoption of wearable and smart device for environment risk measuring aligned to the human workplace mobility or working postures in manufacturing factories [50]. While the wearable-related Ergonomics is clearly gaining ground over the more human perception based techniques [51], the full potential of data obtained from the real occupational context of these devices still lag behind. The distributed data processing platforms are required to make the wearable-related Ergonomics more strategic and less centralized [52]. The Blockchain technology can provide integrated distributed platform solutions both for the traditional factories but also for Industry 4.0 where human workers interact with the robots or advanced machines able to become the sensors o measuring devices themselves [45, 49].

2.3 Blockchain Technology Within the Wearable-Based Ergonomics in Manufacturing Industry

The future of Ergonomics in the manufacturing complex ecosystems involves the potential of distributed nodes interactions among the human workers, cybernetic systems and digital processing [53]. Hence, the required consensus about the distributed, participative OHS management is achieved, the manufacturing organization can benefit from the traceability, real-time processing and machine learning scalability of Blockchain platforms [52]. As a result of the conceptual and context review of the potential of Blockchain for the Ergonomics and more generally for the Occupational Safety and Health Management, the following framework is proposed (Fig. 1).

Distributed legers make possible the adequate structuring of a Blockchain system in the mode the real-time transparency and peer upgrading of detected work conditions can be analyzed. When a new block with new information on condition, ergonomics and workers performance is uploaded to the Blockchain system, all parties concerned, can access, review or even process the information through the shared digital ledger. Thus, the supervisors and plant workers can both check real-time conditions to act on that assumption and upgrade their measuring devices or sensors due to the adjustments based on every step and action data registration.

The opportunities of Blockchain use in manufacturing Ergonomics processes seem to be quite promising. The valuation and visualization of data received from the sensors, and in particular from wearable, can become the key points for controlling the external risks as well as for the health and safety assessment. Even if the applied uses of

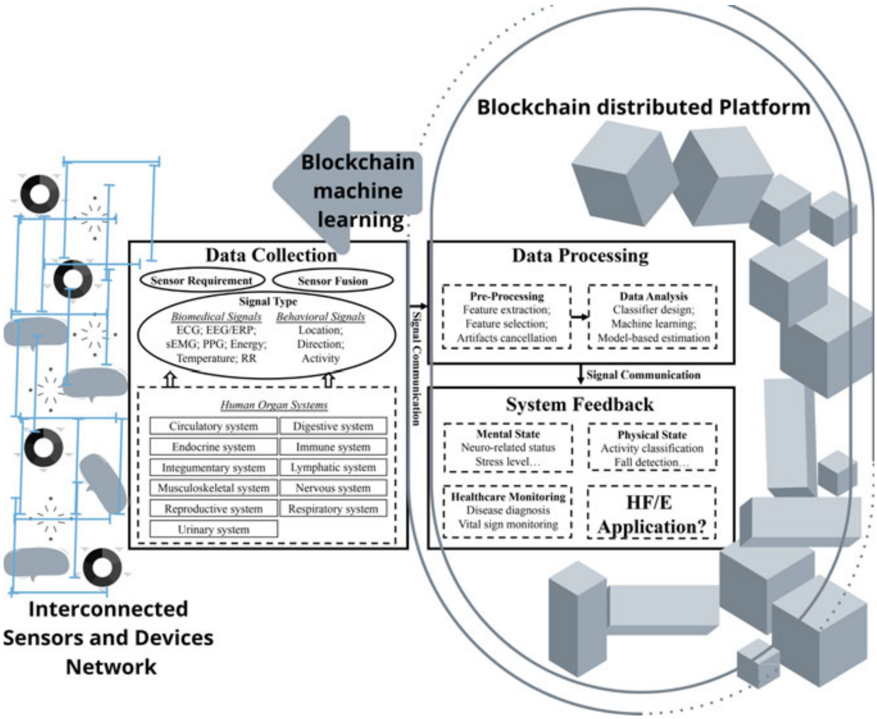

Fig. 1 A proposal of the Blockchain-based ergonomics system including the wearable, devices and sensors network. Partially sourced on: Tsao et al. 2018 [46]

Blockchain in manufacturing OHS systems are still to come [54]. Additionally, the challenges have arisen due to the lack of the integrative and truly preventive OHS framework in manufacturing industry. All of them linked to the unclear legal and regulatory framework of the limits of human interaction monitoring, as well as some technical issues required for adequate Blockchain platform development.

3 Conclusions

In this paper, the authors reviewed the state-of-art of the present and foreseeable applications of Blockchain technology in the manufacturing industry. This review has concluded in the wide range of uses to be explored within different organizational and functional areas in manufacturing firms. The gradual spread of this technology will depend on the advances in the decentralization of the industrial strategies. Altogether, Blockchain technology is able to support manufacturing organizations sustainability in the manufacturing industry through real-time transparency and cost savings. As well as, it will evolve according to the pace of Industry 4.0 transformation. It's easy to glimpse that Blockchain has the potential of enable emergent business and organization solution based on transparent, tamper-proof and secure systems in manufacturing industry.

The Occupational Health and Safety can become one of the most relevant areas of application of Blockchain in the manufacturing industry structures. In particular, when Ergonomics and wearable sensors-based distributed systems considered, the Blockchain seems to be a safe bet for the future. Subsequently, the authors summarized the current progress of prospective analysis of new applications of Blockchain in a preliminary framework of Blockchain-based Ergonomics System including the Wearable, Devices and Sensors Network. This proposed framework, although with many shortcomings, consists of the scheme of data collection, data analysis, and system feedback; all with specific focus on the participative Ergonomics optimization in the manufacturing environments.

References

1. Risius, M., Spohrer, K.: A Blockchain research framework. Bus. Inf. Syst. Eng. **59**, 385–409 (2017). https://doi.org/10.1007/s12599-017-0506-0
2. Drescher, D.: Blockchain Basics. Apress, New York, NY, USA (2017)
3. Mougayar, W.: The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology. Wiley, Hoboken, NJ, USA (2016)
4. McPhee, C., Ljutic, A.: Blockchain. Technol. Innov. Manag. Rev. **7**(10), 3–5 (2017)
5. Pilkington, M.: Blockchain technology: Principles and applications. In: Xavier Olleros, F., Zhegu, M. (eds.) Research Hanbook on Digital Transformations, pp. 225–253. Edward Elgar, Chetenham, UK (2016)

6. Tanner, H., Valtanen, K.: Blockchain technology in the manufacturing industry. In: Towards a new era in manufacturing: Final report of VTT's For Industry spearhead programme, vol. 288, pp. 149–153. VTT Technical Research Centre of Finland (2017)
7. Notheisen, B., Cholewa, J.B., Shanmugam, A.P.: Trading real-world assets on Blockhain. Bus. Inf. Syst. Eng. **59**, 425–440 (2017). https://doi.org/10.1007/s12599-017-0499-8
8. Tapscott, D., Tapscott, A.: How Blockchain will change organizations. MIT Sloan Manag. Rev. **58**, 10 (2017)
9. Lakhani, K.R., Iansity, M.: The truth about Blockchain. Harvard Bus. Rev. **95**(1), 119–127 (2017)
10. Bae, J.: Blockchain as a myth of the decentralized processing system. Rev. Fair Econ. **3**, 1–13 (2018)
11. Beck, R., Avital, M., Rossi, M., Thatcher, J.B.: Blockchain technology in business and information systems research. Bus. Inf. Syst. Eng. **59**, 381–384 (2017). https://doi.org/10.1007/s12599-017-0505-1
12. McKinsey & Company: Blockchain technology in the insurance sector. In: Quarterly Meeting of the Federal Advisory Committee on insurance (FACI) (2018)
13. Seebacher, S., Schüritz, R.: Blockchain technology as an enabler of service systems: A structured literature review. In: Lecture Notes in Business Information Processing, pp.12–23. Springer, Cham (2017)
14. Subramanian, H.: Decentralized Blockchain-based electronic marketplaces. Commun. ACM. **61**, 78–84 (2017). https://doi.org/10.1145/3158333
15. Li, Z., Wang, W.M., Liu, G., Liu, L., He, J., Huang, G.Q.: Toward open manufacturing a cross-enterprises knowledge and services exchange framework based on Blockchain and edge computing. Ind. Manag. Data Syst. **118**, 303–320 (2018). https://doi.org/10.1108/IMDS-04-2017-0142
16. Somapa, S., Cools, M., Dullaert, W.: Characterizing supply chain visibility—a literature review. Int. J. Logistics Manag. **29**(1), 308–339 (2018)
17. Hald, K.S., Kinra, A.: How the Blockchain enables and constrains supply chain performance. Int. J. Phys. Distrib. Logistics Manag. **49**(4), 376–397 (2019)
18. Kim, H.M., Laskowski, M.: Toward an ontology-driven Blockchain design for supply-chain provenance. Intell. Syst. Accounting, Financ. Manag. **25**, 18–27 (2018)
19. Abeyratne, S.A., Monfared, R.P.: Blockchain ready manufacturing supply chain using distributed ledger. Int. J. Res. Eng. Technol. **5**, 1–10 (2016)
20. Notheisen, B., Cholewa, J.B., Shanmugam, A.P.: Trading real-world assets on Blockchain. Bus. Inf. Syst. Eng. **59**, 425–440 (2017). https://doi.org/10.1007/s12599-017-0499-8
21. Korpela, K., Hallikas, J., Dahlberg, T.: Digital supply chain transformation toward Blockchain integration. In: Proceedings of the 50th Hawaii International Conference on System Sciences, Hilton Waikoloa Village, HI, USA (2017)
22. Duma, C., Shahmehri, N., Caronni, G.: Dynamic trust metrics for peer-to-peer systems. In: Proceedings of the Sixteenth International Workshop on Database and Expert Systems Applications, pp. 776–781. Copenhagen, Denmark (2005)
23. Catalini, C., Gans, J.S.: Some Simple Economics of the Blockchain. National Bureau of Economic Research (2016)
24. Yermack, D.: Corporate governance and Blockchains. Rev. Financ. **21**, 7–31 (2017)
25. Mondragon, A.E.C., Mondragon, C.E.C., Coronado, E.S.: Exploring the applicability of Blockchain technology to enhance manufacturing supply chains in the composite materials industry. In: IEEE International Conference on Applied System Invention (ICASI), pp. 1300–1303, Chiba (2018)
26. Wang, S., Wan, J., Zhang, D., Li, D., Zhang, C.: Towards smart factory for Industry 4.0: a self-organized multi-agent system with big data based feedback and coordination. Comput. Networks. **101**, 158–168 (2015). https://doi.org/10.1016/j.comnet.2015.12.017
27. Sun, J., Yan, J., Zhang, K.Z.K.: Blockchain-based sharing services: What Blockchain technology can contribute to smart cities. Financ. Innov. **2**, 26 (2016)

28. Li, Z., Barenji, A.V., Huang, G.Q.: Toward a Blockchain cloud manufacturing system as a peer to peer distributed network platform. Robot. Comp.-Integr. Manuf. **54**, 133–144 (2018)
29. Viriyasitavat, W., Da Xu, L., Bi, Z., Sapsomboon, A.: Blockchain-based business process management (BPM) framework for service composition in industry 4.0. J. Intell. Manuf., 1–12 (2018)
30. Lee, J., Azamfar, M., Singh, J.: A Blockchain enabled cyber-physical System architecture for Industry 4.0 manufacturing systems. Manuf. Lett. **20**, 34–39 (2019)
31. Panarello, A., Tapas, N., Merlino, G., Longo, F., Puliafito, A.: Blockchain and IoT integration: a systematic survey. Sensors **18**(8), 2575 (2018)
32. Vatankhah Barenji, A., Li, Z., Wang, W.M.: Blockchain cloud manufacturing: shop floor and machine level. Smart SysTech, 1–6 (2018)
33. Rost, K.A., Alvero, A.M.: Participatory approaches to workplace safety management: bridging the gap between behavioral safety and participatory ergonomics. Int. J. Occup. Safety Ergon., 1–10 (2018)
34. Ladewski, B.J., Al-Bayati, A.J.: Quality and safety management practices: the theory of quality management approach. J. Saf. Res. **69**, 193–200 (2019)
35. Nabuco, R.B., Ribeiro, A.O., Pereira, L.: Health-centered care Based on co-designed cyber-physical system. In: Research into design for a connected world, pp. 691–701. Springer, Singapore (2019)
36. Aste, T., Tasca, P., Di Matteo, T.: Blockchain Technologies: The Foreseeable Impact on Society and Industry. Computer **50**(9), 18–28 (2017)
37. Afanasev, M.Y., Fedosov, Y.V., Krylova, A.A., Shorokhov, S.A.: An application of Blockchain and smart contracts for machine-to-machine communications in cyber-physical production systems. In: IEEE Industrial Cyber-Physical Systems (ICPS), pp. 13–19, St. Petersburg, Russia (2018)
38. Amaya, N., Rovira, M.D., Del Cerro, S., Grillo, M., Nomen, R., Sempere, J.: Distributed Safety Management as a tool for creating a safety culture in university students and future professionals. J. Loss Prev. Process Ind. **57**, 114–119 (2019)
39. Swuste, P., Theunissen, J., Schmitz, P., Reniers, G., Blokland, P.: Process safety indicators, a review of literature. J. Loss Prev. Process Ind. **40**, 162–173 (2016)
40. Sheffick, R., Crespo, A., Sempere, J.: El enfoque de la seguridad desde la conducta humana. Asepeyo, Barcelona (2007)
41. Găureanu, A., Draghici, A., Weinschrott, H.: Increasing the quality of occupational safety and health implementations through awareness training for those involved in implementing the Safety Observation Report. Calitatea **20**(1), 141 (2019)
42. Liu, H., Tian, G.: Building engineering safety risk assessment and early warning mechanism construction based on distributed machine learning algorithm. Saf. Sci. **120**, 764–771 (2019)
43. Hulusi, U., Gül, S., Yılmaz, H.: A multiple attribute decision model to compare the firms' occupational health and safety management perspectives. Saf. Sci. **91**, 221–231 (2017)
44. Gopang, M.A., Nebhwani, M., Khatri, A., Marri, H.B.: An assessment of occupational health and safety measures and performance of SMEs: an empirical investigation. Saf. Sci. **93**, 127–133 (2017)
45. Li, J., Ma, Q., Chan, A.H., Man, S.S.: Health monitoring through wearable technologies for older adults: smart wearables acceptance model. Appl. Ergon. **75**, 162–169 (2019)
46. Tsao, L., Li, L., Ma, L.: Human work and status evaluation based on wearable sensors in human factors and ergonomics: a review. IEEE Trans. Hum.-Mach. Syst. **49**(1), 72–84 (2018)
47. Barata, J., da Cunha, P.R.: Safety is the new black: the increasing role of wearables in occupational health and safety in construction. In: International Conference on Business Information Systems, pp. 526–537. Springer, Cham (2019)
48. Conradi, J., Westhoven, M., Alexander, T.: Interaction options for wearables and smart-devices while walking. In: Congress of the International Ergonomics Association, pp. 559–568. Springer, Cham (2018)
49. Teizer, J.: Wearable, wireless identification sensing platform: self-monitoring alert and reporting technology for hazard avoidance and training (SmartHat). J. Inf. Technol. Constr. **20**, 295–312 (2015)

50. Choi, B., Hwang, S., Lee, S.H.: What drives construction workers' acceptance of wearable technologies in the workplace? Indoor localization and wearable health devices for occupational safety and health. Autom. Constr. **84**, 31–41 (2017)
51. Alberdi, A., Aztiria, A., Basarab, A.: Towards an automatic early stress recognition system for office environments based on multimodal measurements: a review. J. Biomed. Inform. **59**, 49–75 (2016)
52. Vega-Barbas, M., Diaz-Olivares, J.A., Lu, K., Forsman, M., Seoane, F., Abtahi, F.: P-ergonomics platform: toward precise, pervasive, and personalized ergonomics using wearable sensors and edge computing. Sensors **19**(5), 1225 (2019)
53. Badri, A., Boudreau-Trudel, B., Saâdeddine, A.: Occupational health and safety in the industry 4.0 era: a cause for major concern? Saf. Sci. **109**, 403–411 (2018)
54. Thomas, G., Sousan, S., Tatum, M., Liu, X., Zuidema, C., Fitzpatrick, M., Koehler, K.A., Peters, T.M.: Low-cost, distributed environmental monitors for factory worker health. Sensors **18**, 1411 (2018)

How the Environment Affects the Residential Property Values?

L. T. Silva, C. Reis, C. Oliveira and J. F. Silva

Abstract The growth of the World's population has been followed by the reinforcement of the population living in urban areas, which very often results in additional stress over space, ecosystems, infrastructures, facilities and the way of life. Domestic and industrial sources, and mainly motorized traffic are responsible for pollutant emissions and noise which decisively affects the living in today's cities. Besides the impact caused to the quality of life of the urban citizens and public health, the urban noise and the air pollution contribute negatively to the values of the properties that, due to the location, are more affected by this kind of urban pollution. How we can assess the environmental impacts on residential property values? High noise levels and fair air quality is negatively correlated with health issues risk and housing price. Saying so, it is expectable the establishment of a correlation between the noise and the air pollution and the market value of the residential property. The main objective of this paper is to reflect on the implications of urban environmental quality on people's quality of life and consequently on the quality of places. This theoretical discussion, based on applied case studies,

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aims to contribute to a better understanding of an important question: How much is a family willing to spend on the various environmental attributes of a residential property?

Keywords Quality of life · Property value · Urban pollution · Hedonic pricing method

1 Urban Pollution

The urban environment assumes currently an extreme level of relevance for the governments and the society in general, due to the exponential increase of people living in cities and the consequent associated degradation of quality of life. This growth is continuously applying pressures over resources, infrastructures and facilities, affecting negatively the urban environmental quality in cities.

The atmospheric pollutants are emitted from existent sources and, subsequently, transported and dispersed in the atmosphere, reaching several receivers through wet deposition (through rainout and washout of the rain and snow) or dry deposition (through the adsorption of particles). In urban environment, the typical anthropogenic sources are mainly the road traffic and, when existing, the industrial activity. Emissions from mobile sources contribute to primary and secondary air pollution that can threaten human health, damage ecosystems and influence climate [1]. The compounds from the exhaustion gases of the road vehicles released to the atmosphere create impacts in a different geographical scales and time [1, 2]. Certain compounds possess an immediate and located effect. For instance, a plume of black smoke is instantly unpleasant for people observing it, while at a longtime scale repeated exhibitions to the black smoke of the exhaustion of vehicles can cause, through deposition of particles on the surface of the buildings, the darkening of their facades.

The combustion of hydrocarbon fuel in the air generates mainly carbon dioxide (CO_2) and water (H_2O). However, the combustion engines are not totally efficient, which means that the fuel is not totally burned. In this process the product of the combustion is more complex and could be constituted by hydrocarbons and others organic compounds, carbon monoxide (CO) and particles (PM) that contain carbon and other pollutants. On the other hand, the combustion conditions—high pressures and temperatures—originate partial oxidation of the nitrogen present in the air and in the fuel, forming oxides of nitrogen (mainly nitric oxide and some nitrogen dioxides), conventionally designated by NOx.

Environmental noise is understood as a significant factor of impact on personal well-being. One of the main challenges of urban planning is the creation of urban spaces capable of providing its residents a high quality of life. Although the exposure of communities to environmental noise is a worldwide concern, most cities are still subjected to noise levels that are a disturbance to human activities. The health effects of environmental noise are well-documented. Traffic noise can cause numerous health problems such as sleep disturbance, high blood pressure and psycho-physiological symptoms [1]. Environmental noise can be regarded as one of the agents of deterioration in the quality of life of people in an urban ambient. In Europe, noise achieves a significant level, being considered an environmental problem of major proportions and impacts. The WHO estimates that the DALYs—Disability-Adjusted Life Years—lost due to environmental noise are "6000 years for ischemic heart disease, 45,000 years for cognitive impairment of children, 903,000 years for sleep disturbance, 21,000 years for tinnitus and 587,000 years for annoyance" [3]. In addition, the noise exposure is actually increasing in Europe. Noise caused by road traffic is the most often cited nuisance by roadside residents [4–6].

It is known that, besides the impact caused to the quality of life of the urban citizens and public health, the urban pollution contributes negatively to the property value that, due to the location, they are more affected by this kind of phenomenon. The environmental factors are one of the major issues that people would consider before buying a house and are reflected in the property prices. On the other hand, such factors are among the main reasons for the placement for sale of the houses that are more exposed to road pollution.

2 Real Estate Depreciation and Urban Pollution

Due to the discomfort it produces on its inhabitants, it is expected that noise affects the houses values. This statement has not been completely consensual, as reported by several studies. Saulnier [7] concluded that noise was not revealed significant in Grenoble, France and Cavailhès [8] found that in the majority of the French urban centres noise is not significant.

On the other hand, Nelson [9] considers an average drop in house prices of 0.58% per additional decibel (dB), with greater noise sensitivity in Canada. According Nelson [9] Noise Depreciation Index (NDI) has a median value of 0.74% per dB for aircraft noise and 0.54% for traffic noise. Andersson et al. [10] show a negative effect of road noise of 1.2% in property price, and of aircraft noise of 0.4% per additional dB, in Lerum, Sweden. According the same author, this depreciation rises to noise levels above 55 dB, being of 1.7 and 0.7% for road an air traffic noise, respectively. In addition, apartments in the quieter neighborhoods of Paris, have on average a higher value about 1.5% [11]. Brècard et al. [12] shows that noise exposure reduces the price of apartments in 2006 and 2008. For a noise exposure of 55 to 60 dB, their results suggest a lower price of 0.28% per additional decibel.

On the other hand, due to the health issues that it produces on its inhabitants, it should be also expected that air pollution affects the houses values. But also this statement has not been completely consensual. Since 1967, Ridker and Henning investigates the association between air pollution and housing values, and recognized a negative impact of sulfur pollution [13]. Later, in 2003 Kim et al. find that a permanent 4% improvement in air quality, through lower sulfur dioxide pollution (SO_2) is valued at 1.43% of mean house price in Seoul. However, he shows that pollution with NOx does not affect housing values [14]. Saulnier [7] shows a not significant link between air pollution and housing values, and Cavailhès [8] found that in the majority of the French urban centers, air pollution is not significant to renting values. Concerning the potential influence of air quality on the price of apartments in Nantes Métropole, Brècard et al. [12] do not find any positive relationship between air quality and the price.

3 How Calculate the Environmental Effects on Residential Property Values?

Residential properties prices appear to be related to environmental qualities. Some of those qualities affect the prices in a positive way, otherwise some others, like air pollution and traffic noise, affect the prices in a negative way. The marginal depreciation due to urban pollution is usually estimated using the Hedonic Pricing Method [15]. This method assumes that the price of a house is related to the characteristics of the house and the property itself, the characteristics of the neighborhood and community, and environmental characteristics.

Thus, if non-environmental factors are controlled for, then the remaining differences in price can be attributed to differences in environmental quality. Applying the Hedonic Pricing Method usually involves the collect of cross-section data on the residential properties values and characteristics for a well-defined market area that includes homes with different environmental qualities, and then relates the changes in those environmental qualities to the changes in price through a regression analysis.

However, because Hedonic Pricing Method requires large amounts of reliable data on property sales and characteristics, this method is difficult to apply in countries where such data are not easily available. This is what happens in Portugal, where property records are not reliable regarding the sale price all over the country, so this data must be obtained specifically for this purpose. Thus, an approach that requires less amount of data, based on the increase/decrease rate of the market values over time, should be developed in order to estimate the marginal depreciation due to urban pollution.

The relationship between the property depreciation and urban pollution will require adequate methods for the valuation of the property, and on the other hand, as said before, a proper environmental assessment, namely regarding parameters that imply with the human senses (such as noise annoyance, odour, a cloud of smog). It is known that any of the compound are harmful to the man's health, but the ones that cause larger annoyance is undoubtedly those that are captured by the human senses, that means, those that are visible and those that have odor.

Different approaches can be used in order to achieve an adequate valuation of the property. Market based valuation approaches allow to estimate the market value of the property, this being the amount for which a property should exchange on the date of valuation between a buyer and a seller. Market based valuation approaches include three analytical methodologies that are generally accepted for this purpose, as referred by the International Valuation Standards (IVS) [16]: Sales Comparison Approach, Income Capitalization Approach and Cost Approach. For ordinary residential properties located in urban areas, the Sales Comparison Approach is in common use as it offers reliable valuations.

4 Final Notes

As final considerations, scientific evidences prove that air pollution and noise affects human health, and can be regarded as major agents of deterioration of people's quality of life in an urban environment [1]. In fact, there is a relatively large body of literature concerning the impacts on health regarding exposure to environmental noise and air pollution. However, can we state that noise and air pollution affect the houses values? This statement has not been completely consensual as reported by several studies above described. This general absence of relationship could reflect that real estate capitalization is better explained by subjective perceptions of environmental attributes rather than objective data.

First of all, two points should be underlined: Excessive noise, mainly due to urban traffic, is generally considered annoying by the inhabitants and may be the cause of several health issues. But the largely invisible and intangible nature of air quality, generally makes objective measures non influent, except in the case when the pollution is odorous or visible. On the other hand, as stated by Le Boennec and Salladarré [17], air pollution is seen as transitory, although its health effects are real.

On the other hand, more monitoring stations in city centers may provide up-to-date and geo-referenced information on the quality of the urban environment, which will be useful and will maintain the population aware for the air quality issues [18]. Will a more informed people become a more demanding population? Will the link between urban pollution, risk of health issues and property value become stronger?

At last, this subject leads to another issue, regarding fiscal equity. Since the taxation of a property is directly related to its valuation, which in turn depends on its market value, it seems reasonable to introduce the variable Quality of the Urban Environment in the calculation of property taxation, by applying a coefficient of reduction to the value of the properties with worst environmental location. And if the variable Quality of the Urban Environmental is considered, this could lead to the adoption of more clean policies?

References

1. Silva, L.T., Mendes, J.F.G.: City noise-air: an environmental quality index for cities. Sustain. Cities Soc. **4**, 1–11 (2012)
2. Silva, L.T., Mendes, J.F.G., Ramos R.A.R.: Urban air dispersion model of a mid-sized city. Validation methodology. WSEAS Trans. Environ. Develop. **1**(6), 1–10 (2010)
3. WHO: Homepage. https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf. Last accessed 20 Oct 2019
4. OECD: Roadside Noise Abatement. Organisation for Economic Co-operation and Development Publications, Paris, France (1995)
5. Oliveira, M.F., Silva, L.T.: The influence of urban form on facades noise levels. WSEAS Trans. Environ. Develop. **5**(7), 125–135 (2011)
6. Silva, L.T., Oliveira, M., Silva, J.F.: Urban form indicators as proxy on the noise exposure of buildings. Appl. Acoust. **76**, 366–376 (2014)
7. Saulnier, J.: Une application des prix hédonistes: influence de la qualité de l'air sur le prix des logements? Revue d'économie politique **114**(5), 613–636 (2004)
8. Cavailhès, J.: Le prix des attributs du logement. Economie et Statistique, pp. 91–123 (2005)
9. Nelson, J.P.: Hedonic property value studies of transportation noise: aircraft and road traffic. In: Baranzini, A., Ramirez, J., Schaerer, C., Thalmann, P. (eds.) Hedonic Methods in Housing Markets. Springer, New York (2008)
10. Andersson, H., Jonsson, L., Ögren, M.: Property prices and exposure to multiple noise sources: hedonic regression with road and railway noise. Environ. Resour. Econ. **45**(1), 73–89 (2010)
11. Bureau, B., Glachant, M.: Évaluation de l'impact des politiques Quartiers verts et Quartiers tranquilles sur les prix de l'immobilier à Paris. Economie & prévision **192**(1), 27–44 (2010)
12. Brécard, D., Le Boennec, R., Salladarré, F.: Accessibility, local pollution and housing prices. Evidence from Nantes Métropole, France Economie et Statistique/Economics and Statistics, pp. 501–502 (2018)
13. Ridker, R.G., Henning, J.A.: The determinants of residential property values with special reference to air pollution. The Review of Economics and Statistics, pp. 246–257 (1967)
14. Kim, C.W., Phipps, T.T., Anselin, L.: Measuring the benefits of air quality improvement: a spatial hedonic approach. J. Environ. Econ. Manag. **45**(1), 24–39 (2003)
15. Hui, E.C.M., Chau, C.K., Pun, L., Law, M.Y.: Measuring the neighbouring and environmental effects on residential property value: using spatial weighting matrix. Build. Environ. **42**, 2333–2343 (2007) (Elsevier)
16. International Valuation Standards Committee (IVSC): International Valuation Standards 2007, 8th edn. IVSC, London, UK (2007)
17. Le Boennec, R., Salladarré, F.: The impact of air pollution and noise on the real estate market. The case of the 2013 European green capital: Nantes, France. Ecol. Econ. **138**, 82–89 (2017)
18. Silva, L.T., Mendes, B., Rodrigues, D.S., Ribeiro, P., Mendes J.F.G.: A Mobile Environmental Monitoring Station for Sustainable Cities, pp. 1–10. WIT Press (2016)

The Impact of Implementing Hygiene and Safety Measures on Absenteeism—A Case Study in a Small Metallurgical Company

M. Brito, M. A. Gonçalves, N. Caravana, M. Esperança and H. Teixeira

Abstract The absenteeism related to health and safety at work is a serious issue in the manufacturing process, and some industries can be dangerous work fields with a high level of accidents. It is important to understand what causes the accident and, if possible, apply standard procedures to minimize the risk of accidents and subsequent absenteeism. This study aims to assess the impact of the implementation of occupational health and safety procedures on company absenteeism. In the company where the study took place, most work accidents and absenteeism happened in the production area, with workers who directly handle raw materials and machines. As a result, an HSE manager was hired in order to reduce accidents by putting in place several hygiene and security measures and procedures. The results of these measures as well as absenteeism data were studied and conclusions regarding company performance were drawn.

Keywords Health · Safety · Absenteeism · Case study · Work accidents

1 Introduction

Nowadays, productivity is an essential factor in business success, and one of the main reasons for concern that directly affects production in an industry is absenteeism [1]. High rates of absence amongst employees are putting company profitability at risk, while in others they endanger the enterprise's own survival [2].

Some of the negative results of absenteeism are high costs, such as direct compensation costs or replacement costs, and a drop-in productivity [3].

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Absenteeism is a short-term absence from work (temporary withdrawal from a company) which is caused by problems such as illness, death in the family, or other personal matters [1]. Two types of absence metrics are considered: time lost and absence frequency. Time lost measures represent absenteeism as a sum of units of time (e.g., hours or days) far from work [4]; absence frequency, on the other hand, is the sum total of absences in a specific period of time regardless of duration [5].

The importance of studying absenteeism lies in the fact that a more detailed understanding of absence behavior can result in its successful management [1]. A lot of what is done by managers to combat absence in their organizations is done in total ignorance of the motives for absence. Most managers neither understand, nor have investigated the causes of their absence problem. In its place, personal hunches, prejudices and rules of the thumb are the basis on which remedial action is chosen. Management's failure to effectively deal with the absence issues comes, to a large extent, from a lack of proper understanding of the challenges connected with absence [2].

This study was conducted in a small company and aims to identify the absenteeism causes and its impact on the company's performance before and after the implementation of hygiene and security measures.

2 Methodology

This study was conducted as a case study. According to [6], this method consists of an analysis of the phenomenon in its natural context, collecting all the necessary data, analyzing the data and finally getting a result and the conclusion of the investigation. The study was developed in a small metallurgical company (Centrimpor). It is a metalworking company whose activity involves the purchase, transformation and sale of various stainless steel products. This steel has hygienic and aesthetic properties that make it a very attractive material to satisfy many types of applications. The company building is made up of three warehouses and several offices, in which there are twenty-two employees, eleven of whom are assigned to the warehouses. In the warehouses, the company has three forklifts, a crane, two grinding machines and a cutting machine which all help with the transformation of stainless steels into coils, plates, bars, angles, poles and square and round tubes. Through partnerships with two Italian companies, Bravo Inox and Ronda, Centrimpor is also able to provide doors, drawers, sinks, washers and food preparation stands.

The first step was to collect data from the last two years, before and after the implementation of occupational hygiene and safety measures. Then the data were analyzed and conclusions were taken. These conclusions were then analyzed in a meeting with the company managers.

3 Results

In 2018, there were 73 cumulative days of absenteeism at Centrimpor. Considering that the year in question had 252 working days, accumulated absenteeism impacted about 29% of the analyzed working days, or the equivalent of 584 accumulated working hours. Figure 1 depicts these results.

Of these 73 days, 63 had absenteeism due to occupational accidents, and the other 10 were due to other reasons, not relevant to the theme of this study. Thus, 86.3 of the days with absenteeism at Centrimpor were related to occupational accidents (Fig. 2). Centrimpor has 22 employees, 11 of whom exclusively dedicated to manufacturing. There were 4 occupational accidents in 2018, which affected 4 different factory employees, meaning that the accidents resulted solely from the factory production activity, which is equivalent to about 36% of the universe of the employees in question (Fig. 2).

The 4 occupational accidents resulted in 3 different types of injuries and impacts on each of the employees involved in the respective accidents. Two employees had muscle injuries which came from manually displacing stainless steel bars between 10 and 14 kg. One of the employees had injuries to the dorsal and lumbar muscles and was absent from work activities for 16 days. In the case of the other employee, there were injuries to the cervical muscles and an impediment to work for 27 days. Both employees underwent physical therapy and muscle rehabilitation in the time between the accident and the return to their duties. A traumatic injury also occurred to a third employee, in the form of an ankle sprain, caused by the sliding of two 9 kg stainless steel tubes from a wall-mounted platform. This occupational accident led the employee to be absent for 7 working days and to be accompanied by a physical therapist during this time period. A fourth employee suffered a cut in his right hand due to the handling of a stainless-steel plate without protective gloves on. This accident forced the employee to stop for 13 working days, as well as undergo

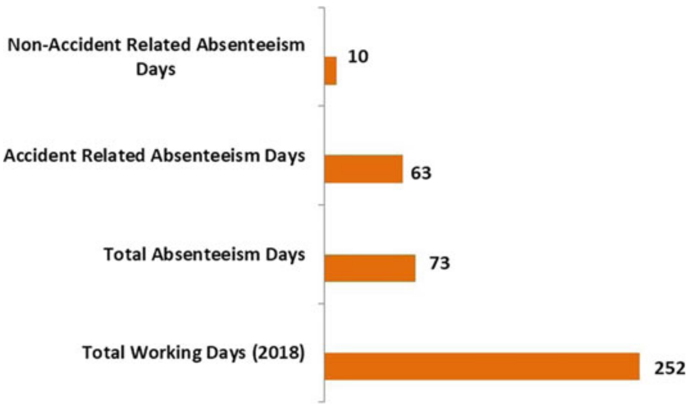

Fig. 1 Absenteeism data during the year 2018

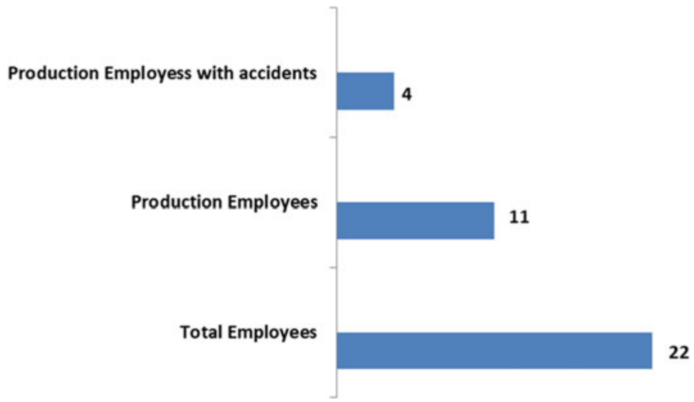

Fig. 2 Total number of employees in the company, working in the production area, and number of employees who work in the production area and suffered a work accident

an operation and subsequent recovery before returning to his job. Figure 3 depicts these numbers.

In the year 2019, until the end of October, there were no work accidents at Centrimpor and, consequently, no related absenteeism. After obtaining the data and results of the study conducted at Centrimpor, it can be inferred that it is a small size company in which the focus of activity is on the manufacturing process, where it has allocated 11 employees, about half of the entire workforce. Thus, the fact that all work-related accidents occurred in the manufacturing process had a huge impact on the company's performance in 2018. This impact has several results: firstly, that they worked with one less element for 25% of the working days available in 2018 and, secondly, the fact that 86% of absenteeism had to do with accidents at work. These accidents also had other impacts on the company’s activity, as it was

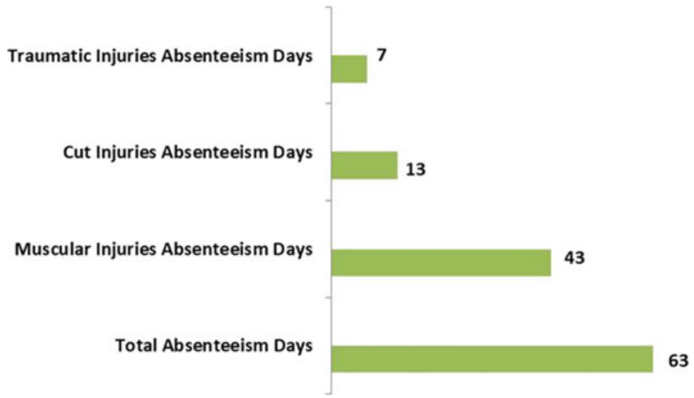

Fig. 3 Total absenteeism days on injury type

necessary to assign employees to the service that the injured worker could no longer do with the natural result of increased time to perform the tasks. There was work overload and financial effort (need to resort to temporary work) for the company. There was an increase in task completion time and customer order fulfillment, as well as lost sales due to inability to place an order. It is important to note, however, that no workplace injury has affected the company in this year 2019 due to the introduction of a superior occupational health and safety technician. Ever since the company started its business, there has always been a briefing session on handling and operating machines and materials on the entry of new employees. However, accidents had always taken place. With the introduction of an occupational health and safety technician and the consequent implementation of new rules, work-related accidents causing absenteeism were reduced by 100% regarding the same period last year. The establishment of better visible guides for forklifts, better maintenance of safety equipment and a reduction in the distance between manually transported materials and machines, all these combined with a better training conducted by the occupational health and safety technician contributed to a drastic reduction in work accidents.

4 Conclusions

The impact of implementing occupational hygiene and safety measures has proved to be central in combating work-related accidents and absenteeism.

Considering the results obtained in this study, it is possible to directly correlate the size of a company with the impact of the level of absenteeism and the number of work accidents. The smaller the company size, the greater the impact that implementing HST measures has on reducing work-related injuries and absenteeism related to such accidents. The fact that in 11 employees 4 had an accident at work in 2018 and in contrast to the fact that in 2019 there were no accidents with the same 11 employees, clearly underlines the importance that the measures taken by the HST methods had on the company's performance.

However, the study was conducted in a one small company and more studies are needed to support these conclusions.

References

1. Cikes, V., Ribaric, H.M., Crnjar, K.: The Determinants and outcomes of absence behaviour: a systematic literature review. Soc. Sci. **7**(8), 120 (2018)
2. Ramdass, K.: Absenteeism—a major inhibitor of productivity in South Africa: a clothing industry perspective. In: 2017 Proceedings of PICMET 17: Technology Management for Interconnected World, United States, pp. 1–7 (2017)
3. Mathis, R.L., Jackson, J.H.: Human Resource Management, 12th edn, International Student Edition. Thomson South-Western, Mason (2004)

4. Steel, R.P.: Methodological and operational issues in the construction of absence variables. Human Resour. Manag. Rev. **13**, 243–251 (2003)
5. Chadwick-Jones, J.K., Colin, A.B., Nicholson, N., Sheppard, C.: Absence measures: their reliability and stability in an industrial setting. Pers. Psychol. **24**, 463–470 (1971)
6. Yin, R.K.: Case study research: design and methods, 3rd edn. SAGE (2003)

OSH Empowerment of Portuguese Agri-food MSMEs Through the Application of Computational Tools of Risks Assessment

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Abstract The Agri-food Industry is the largest Portuguese Industry, constituted mainly by micro, small and medium enterprises (MSMEs). Occupational Safety and Health (OSH) conditions in an agri-food MSME have its own characteristics depending on the specific food sector. This condition makes the prevention strategies implementation difficult and heightens the problematic of work accidents. In this chapter are described online and offline free computational tools developed to perform OSH risks assessment in the dairy, meat processing, bakery and horticultural subsectors. The tools provide a simple and expedite diagnostic of occupational hazards and risks. Depending on the input data, the tools output identifies successful practices and easy-to-implement solutions for occupational risk prevention. These computational tools aim to empower Portuguese agri-food SMEs to implement innovative OSH management practices in order to prevent work accidents.

Keywords Agri-food industry · Occupational health and safety · MSMEs · Computational tools · OiRA tool

1 Introduction

The European Commission [1] states that micro, small and medium-sized enterprises (MSMEs) accounted for 99.8% of all non-financial business sector enterprises in the European Union 28 member states (EU-28. In terms of employment, the MSMEs are responsible for 66.4% of EU-28 labor market. The Portuguese business fabric is also

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mostly composed by this type of enterprises (99.5%), which employ 97.8% of the country's workers [2]. One of the sectors that has gained paramount importance to the country's growth strategy is the agri-food industry, which in 2018 contributed more than 11% of total exports [3]. In 2018, the agri-food industries represented 20% of Portuguese manufacturing industry, mainly MSMEs, employing about 114,000 workers [4]. These numbers justify by themselves the importance to implement an effective occupational health and safety (OHS) management systems in the MSMEs. Since the MSME, generally have sparse financial, technical and human resources so usually they just allocate the minimum resources needed to comply with legal obligations. This kind of strategy has implications in the quality and accuracy of the risks evaluation that is performed and consequently in the preventive measures that are implemented. Since the hazards that are easily identified through direct observation area analyzed and evaluated, and all of those that are not so obvious are often overlooked. Despite the importance of the agri-food industry to the Portuguese economy, this sector does not have a specific OSH risk assessment tools. The availability of such tools gains more relevance due to sector's wideness.

This chapter describes online free computational tools developed to perform OSH risks assessment in agri-food MSMEs of subsectors of dairy, meat, bread/pastry and horticultural products. The tools provide a simple and expedite diagnostic of occupational hazards and risks. Depending on the input data, the tools output identifies successful practices and easy-to-implement solutions to occupational risk prevention.

2 Materials and Methods

The development of risk assessment tools required OSH audits in agri-food MSMEs. The audits started with a survey of the OSH conditions in the workplace. An inquiry guide was applied to the sixty companies that were analyzed, to identify the main risks. The audits aimed to evaluate the main improvement actions that could be implemented. Also, several measurements were performed namely, noise, illumination and thermal environment. Both OSH audits and computational tools development were activities of +AGRO project—Organizational Management, Energy Efficiency and Occupational Safety and Health in Agrifood Industry (https://maisagro.pt/). Gaspar et al. [5], Lourenço et al. [6], Gaspar et al. [7] provide details of the data collected in these audits.

3 Online Risk Assessment Computational Tool—OiRA

The online risk assessment computational tool to be developed must be validated by the competent authorities. Thus, the path followed to its development was performed in close cooperation with the Portuguese Authority for Work Conditions

(ACT), as national Focal Point of the European Agency for Safety and Health at Work (EU-OSHA), with the social partners Portuguese Enterprise Confederation (CIP), Federation of Portuguese Agro-Food Industries (FIPA), Food Industry Workers Union and the General Union of Workers (UGT).

In this sense, the computational tool was developed in the web platform OiRA (Online interactive Risk Assessment) that enables the creation of sectoral risk assessment tools in any language in an easy and standardized way. The OiRA platform is developed and maintained by the EU-OSHA (https://oiraproject.eu). The main objective of OiRA is to ease carrying out risk assessments in MSMEs, which may lack the resources or the OSH know-how to do so effectively, facing several difficulties to comply with this legal duty that can be quite challenging. The European OiRA objective is to increase the number of MSMEs in Europe assessing and managing their occupational risks, and through corrective procedure to reduce the number of occupational accidents and diseases. This objective may lead MSEs to improve their working conditions and simultaneously to become more competitive by the cost reduction with occupational accidents and illness.

At a Portuguese and sectoral levels, the OiRA tools aim to disseminate and promote online risk assessment tools and to contribute nationally to reduce the number of occupational diseases and accidents. For the MSME, the OiRA aims to be a practical tool to ensure the OSH of workers, thus improving companies' performance. The OiRA tools were developed for each of the food processing subsectors in study, namely *meat products*, *dairy products*, *horticultural products* and *bread/pastry products* (a link to tool is embedded in the subsector's name).

4 Computational Tool Modules

The computational tools referred to in the previous chapter address issues associated with emergencies, psychosocial and stress risks, as well as structural, environmental and OSH management hazards/risks. It allows an assessment of existing risks, suggest measures to control those risks and also produce an action plan to be implemented.

The evaluation process comprises four main steps: (a) Preparation: Overview of the assessment to be performed and fitting it into the specificities of a company; (b) Identification: OiRA shows sequentially the health and safety hazards. By answering "yes" or "no" to risk statements, an indication is provided whether these hazards or risks exist; (c) Assessment: At this stage, the risk level corresponding to each identified statement, requiring intervention is determined; (d) Action Plan: In the fourth step of the assessment process, measures must be defined to limit or reduce the risks assessed. The resources required must be also described. The tool can automatically prepare a risk assessment report.

In general, each tool is composed by a set of questions divided into the several modules: Management of OSH; Common risk factors; Reception and storage of raw materials; Specific risks of each sector: Horticultural, Meat, Dairy, Bread/pastry; Primary packaging; Secondary packaging; Storage of finished product; Emergencies; Other risks (added by user).

4.1 OSH Management

Safety and health at work are fundamental to guarantee the physical, psychological and health of workers while ensuring the productivity of enterprises. The 13 questions included in this subject aim to evaluate: (a) General principles of prevention; (b) Employer and employee general obligations; (c) Workers consultation, information and training; (d) Work organization and OSH services activities; and (e) Workplace accidents.

4.2 Common Risk Factors

There are risk factors that cut across different workplaces and are therefore common, such as: (a) Risks associated with buildings; (b) Environmental risks (thermal environment and ventilation, lighting, noise, vibration, chemicals and biological agents); (c) Psychosocial risks and stress; (d) Ergonomic risks; (e) Electrical risks (f) Safety management of machinery and work equipment; (g) Personal Protective Equipment (PPE); (h) Containers with fluids under pressure; (i) Organization and cleaning.

4.3 Reception and Storage of Raw Materials

In the reception and storage of a agri-food processing company takes place the first contact with raw materials and subsidiaries to be used throughout the production process Orders are placed and checked at this stage and technical requirements are evaluated (e.g. weight, quantity, batch, expiration date, packaging condition, certificates of analysis, etc.) to ensure that all raw and subsidiary materials are capable of being temporarily stored prior to their entry into the manufacturing process. Some food products are stored at room temperature, such as sugar, salt, pulses and spices, but other foods are stored cold (positive or negative). Normally, some fruits and vegetables that will not be cooked right away are stored in negative cold rooms, at freezing temperature.

Other fresh foods, such as fruits and vegetables, meat, dairy, bread is stored in positive cold rooms. The organization of this space is very important, in order to avoid food waste due to reaching expiration date. In addition, if the space is well organized, it will make it easier to plan the required quantities while maximizing existing food resources.

With regard to workers, the main hazards encountered at this stage of the production flow are associated with storage in: (a) Shelves and pallet racks; (b) Refrigeration chambers. The main hazards that may be encountered at this stage of the production flow are associated with the transportation and storage of materials on shelves or in cold chambers (manual handling of loads, falling materials, falling people, discomfort or thermal stress). These two aspects are described below.

Stands and Shelves
Storage systems on stands or shelves are widely used in the agri-food industry. However, there may be quite different situations, in terms of height and load capacity. The height and load capacity determine the equipment used, namely stairs/ladders or mechanical equipment, such as manual or electric pallet truck, stacker, among others. The main hazards are associated with the transportation and storage of materials, with special attention to the structures used, the manual handling of loads, fall of materials and workers falls.

Refrigeration Chambers
When moving the materials/products from and to cold chambers, workers are subjected to very low temperatures, especially in the negative cold chambers where the temperature can drop to −30 °C. As the extremities of the body cool faster than the rest of the body, fingers (hands and feet), as well as the head (nose, chin and ears), are the body parts that suffer most from cold exposure. So, the supply and use of protective clothing appropriate to the cold must be ensured. Simultaneously, abrupt temperature changes can cause different diseases, both respiratory, joint and muscular. Another situation that could lead to serious consequences is the possible imprisonment of the worker inside the cold room. As with other machines, there are moving parts, such as the fan blades of the refrigeration systems. If those parts are not protected can cause damage to the worker, although they are usually attached to the ceiling. The main hazards are associated to the transportation and storage of the materials, with special attention to the manual handling of loads, to the fall of materials and workers falls, and to the discomfort or thermal stress.

4.4 Specific Risks of Each Sector

Horticultural and Meat Products
The design and organization of the manufacturing area in terms of surfaces and workplaces must comply with principles that eliminate or minimize risks. Effectively, an adequate, non-slip flooring, regular and with no level differences, provides safe travel. However, the absence of containers to receive enough waste and placed in convenient places (so that packaging or meat waste can be eliminated immediately), along with the lack of periodic cleaning routines, will quickly transform them into insecure floors. Likewise, the lack of space organization, placing materials or work equipment in places of passage, will increase the risk of

workers falling. The organization is therefore decisive, and the workspace must be organized so that everything has a place (a place for each thing and everything in its place). At the same time, close attention must be paid to workplaces to avoid dangerous postures and movements, which reduce productivity and cause accidents. Thus, it is important to analyze the main risk factors associated with work surfaces and plans, contributing to the adoption of behaviors and measures to improve working conditions. The use of cutting tools (e.g. knives) takes particular care in view of their danger, which is reflected in the number of accidents involving its use. According to accident statistics, one of the main causes of accidents in this sector is the use of knives and other cutting tools. These accidents mainly hit the hands of the user himself. It is therefore crucial that workers are aware of the risks involved in using these tools as well as the rules for safe use. In some agri-food processing enterprises (horticultural: canned, sweets and jams, dough and sauces; meat), hot or very hot liquids may be used for the food products processing. The possible presence of flame and surfaces at high temperature (from the stove), has associated hazards of thermal burn. Preventive measures should be taken to avoid accidents involving contact with liquids and hot surfaces due to the seriousness of injuries. The proper organization of the workspace allows space between the different work areas or equipment, reducing the risk of contact with liquids or hot surfaces. Additionally, knowledge and compliance with elementary safety rules allow reducing these risks. Personal protective equipment may play an important role in eliminating residual risk. It is therefore essential that workers know how to identify risk situations and know the rules and measures to be taken for safe work.

Dairy Products
The main raw material of the dairy industry is milk. Normally, the milk arrives to the companies through trucks to be stored in vats/tanks until its use. It is only after quality control that milk enters the production process through piping systems or hoses. In this space there can be only one tank/several tanks, depending on the size of the enterprise. If the milk does not enter the production process on the day it is received, it is stored in cooling tanks between 4 and 6 °C. The main hazards encountered at this stage of the production flow are associated with the transportation and storage of the materials on the shelves or the manual handling of loads (milk discharge hoses), falling of materials, falling of people, discomfort or thermal stress), as well as the biological risks resulting from contact with potentially contaminated milk. In the manufacturing area, milk can be pasteurized at a temperature above 72 °C and then cooled. During the manufacturing process of dairy products (cheese, yogurt) changes in temperature occur, which can lead to the emergence of different diseases, whether respiratory, joint or muscle. The main hazards encountered at this stage of the production flow, are associated with the contact with hot surfaces, the transportation and storage of materials, with special attention to the manual handling of loads, the fall of materials and people, and the thermal discomfort.

Bread/Pastry Products
In this sector the reception and storage of primary materials, such as flour, is done in silos. These enclosed and confined spaces present danger related to explosions resulting from the existence of excessive accumulated dust. In addition to the explosion hazards, other may be described: (a) dust that can cause eye injury or breathing difficulties; (b) access to its interior (confined space) and manual handling of loads (silo feed); (c) the lack of grounding of the motors; (d) inadequate lighting; (e) presence of static electricity; (f) presence of released gases; and (g) falls due to faults occurring in the fall equipment inside. Bread/Pastry enterprises have long diversified their offer, offering products other than traditional ones (bread, dry cakes and fresh pastry), such as fried salted and salted from soft dough and puff pastry, and still, regional confectionery and pre-made meals. Thus, during processing, several activities can present hazards to workers' health and safety due to the equipment and utensils used and physical effort required. The main hazards can arise from: (a) Weighing of ingredients and eliminating packaging; (b) preparing the dough (mix, leavening/fermenting, dividing/rolling, tendering, laminating, shaping/cutting); (c) preparing the ingredients for the various fillings (cut, bake, cook, forming/shaping). They may be associated with: (a) Skin allergic reactions; (b) Respiratory problems and asthma; (c) Musculoskeletal pain (in the neck, spine, shoulders, and carpal tunnel syndrome); (e) Injuries to tendons; (f) Burns.

4.5 Primary Packaging

In the case of automated processes, the food products may be sent directly to the filling system and are packed in the market packages. In the case of manual filling, it is carried out in its own workbenches, where the packaging is located. In all of these steps, cross-risk factors such as exposure to hot vapors and contact with hot surfaces, work plane height, standing static work, repetitive twisting movements of the hand and manual movement of loads are identified.

4.6 Secondary Packaging

In this area of the production process, the products are packaged, which can be essentially manual or by using machines, such as the wrapping machine, the labeler or the palletizer. In enterprises with predominantly manual processes, the existing hazards are fundamentally associated with the ergonomic conditions of workplaces, such as the height of workplaces, static work carried out on foot or manual handling of loads (bending weight and frequency of movement). In case the packaging process is eminently carried out using machines, the hazards are associated with the ergonomic conditions of the works described above, but also with the operation of machines (such as cutting, entrapment or crushing).

4.7 Storage of Finished Products

The storage may be carried out on shelves or on pallet racks, and the packaging should be done by hand or with equipment for this purpose. Thus, according how storage is carried out, there are different hazards to which the worker will be subject. The details concerning the storage on stands and shelves as already described. Taking into account that assumptions, there are several hazards that can result for the employee in: (a) Musculoskeletal pain and lesions; (b) Crushing; and (c) Light and severe injuries.

4.8 Emergencies

Fires and explosions are examples of emergency situations with great destructive power, both in terms of lives and material losses. First of all, enterprises must assess risks and implement measures that, on the one hand, reduce it and, on the other hand, be prepared to answer in the most appropriate way in an emergency, preserving lives and property. In a first phase, enterprises should identify the potential emergency situations that may occur in their facilities (e.g. fire, explosion), and then adapt themselves in terms of human and material resources to deal with such emergency situations. Undoubtedly, the training and continuous information of workers have a key role. This module covers fire prevention and fire safety, as well as assesses the level of response to emergency situations.

5 Conclusions

The conclusions of this study indicate that risks may be better managed in this group of companies, where good OSH conditions are associated with business success. A well-implemented OSH service guarantees the reduction of accidents, occupational diseases, absenteeism and consequently improves the quality of work, resulting in an increase in productivity and greater competitiveness of the company. But however important an OSH program may be, and the better the tools it provides for the diagnosis and resolution of work risks, if there is no willingness, participation and commitment of all involved in these actions, especially employers and workers, the results will be limited, both qualitatively and quantitatively.

There are still opportunities for a more detailed investigation, provided by greater sample of companies in each subsector, as well as the measurements in all workstations, reflecting a deeper comparative analysis, with stricter quantitative data with international benchmarking. It would be advantageous to include also ergonomics and psychosocial risk evaluations. Given the increasing importance of

OSH related topics, the increasing scope of the agri-food industry and its companies' dimension, i.e., MSMEs, there is still a long research ahead to improve the management and prevention of work accidents.

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References

1. Muller, P., Mattes, A., Klitou, D., Lonkeu, O., Ramada, P., Ruiz, F.A., Devnani, S., Farrenkopf, J., Makowska, A., Mankovska, N., Robin, N., Steigertahl, I.: Annual report on European SMEs 2017/2018. The 10th Anniversary of the Small Business Act. European Commission (2018)
2. Pordata: homepage: https://www.pordata.pt/. Last accessed 25 Oct 2019
3. AICEP: Fileira agroalimentar portuguesa um sucesso fora de portas. AICEP Portugal Global, vol. 119 (2019)
4. FIPA. Homepage: https://www.fipa.pt. Last accessed 25 Oct 2019
5. Gaspar, P.D., Elias, M., Pereira, C.D., Andrade, L.P., Pinheiro, R., Paiva, T., Soares, C., Gândara, J., Henriques, M., Laranjo, M., Potes, M.E., Santos, A.C.A., Santos, F.C., Silva, P.D., Nunes, J., Coutinho, P., Carneiro, J., Várzea, J.P., Vaz-Velho, M., Araújo, M.A., Ribeiro, M., Santos, J., Matias, J.: Caracterização e Análise das Condições de Segurança e Saúde no Trabalho em empresas Agroalimentares. +AGRO—Qualificação Organizacional, Energética e de Segurança e Saúde no Trabalho da Indústria Agroalimentar. In: Gaspar, P.D., Elias, M. (eds.) Universidade da Beira Interior, Covilhã, Portugal (2018)
6. Lourenço, M., Lima, T.M., Gaspar, P.D., Charrua Santos, F.: Assessment and improvement opportunities for occupational health and safety in the portuguese food processing industry. In: Occupational and Environmental Safety and Health. Studies in Systems, Decision and Control, vol. 202. Springer (2019). https://doi.org/10.1007/978-3-030-14730-3_76
7. Gaspar, P.D., Lima, T.M., Lourenço, M.: Relevant occupational health and safety risks in the portuguese food processing industry. Int. J. Occup. Environ. Saf. **3**(3), 23–33 (2019). https://doi.org/10.24840/2184-0954_003.003_0003

Emerging Risks in Contact Center Sector: A Review

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Abstract Contact Center sector has experienced significant growth in recent decades. This growth has implicated new technologies, increasing workloads and new forms of employment. All of them can lead to ergonomic and psychosocial risks. The aim of this study is to review literature about ergonomic and psychosocial risk factors, as well as the preventive measures advised in the Contact Center sector. The review found that more than half of the workers show high prevalence in musculoskeletal disorders. In addition, there is dissatisfaction regarding lighting conditions, temperature and noise. Regarding psychosocial factors, there is a high prevalence of lack of autonomy and social support, high psychological demands, job insecurity and monitoring. In most cases women are in worse conditions that men. However, no major differences were found between workers in internal and external Contact Centers.

Keywords Contact center · Emerging risks · Ergonomic factors · Psychosocial factors · Good practices

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1 Introduction

Contact Center is a center specialized in managing remote communications with customers, using different channels via telephone, e-mail, etc.

Contact Centers can be classified as Internal Contact Centers, represented by departments within a company with a business line, and external Contact Centers that are companies independent, which provide services to other companies that subcontract them to man-age customer service [1].

Additionally, technological advances and rapid globalization have generated a series of changes in the work of professionals, but new technologies have also led to the emergence of so-called "emerging risks" [2].

This type of risks [3] can be generated by the use of new technologies and production processes, new working conditions such as intense due to workforce reductions or higher workloads, and new forms of employment, such as temporary contracts. Among these emerging risks are the so-called ergonomic and psychosocial risks. Workers in Contact Centers are affected by the characteristics and working conditions in this area, so that professionals are exposed to a series of ergonomic and psychosocial risks that can have a negative effect on their health [4].

The objective of this study is the identification, in the technical literature, of those emerging risk factors studied in the sector.

2 Methodology

The scientific literature search was conducted between January and February 2019 and was carried out through the Web of Science based on the PRISMA method [5]. Keywords used were: *call center, contact center, ergonomic best practices, ergonomic risk, prevention, psychosocial best practices, psychosocial risk, health care occupations, professional diseases, psychosocial preventive measure, psychosocial risk management, psychosocial assessment, musculoskeletal disorders, psychosocial interventions, ergonomic risk assessment*.

The inclusion criteria of the scientific articles have been the following: (a) research whose object of study was the Contact Center sector or related positions, (b) studies that include measurements or prevalence's on ergonomic and psychosocial risk factors, (c) research with evaluations of preventive measures or identification of good ergonomic and psychosocial practices. On the other hand, the exclusion criteria have been: (a) studies that do not include in the title Contact Centers or related positions, (b) studies that do not include in the abstract Contact Centers or related positions, (c) lack of full text availability.

3 Results and Discussion

With the searching strategy defined, 649 articles were found, and 58 of them were selected after applying the inclusion and exclusion criteria.

3.1 Ergonomic Risk Factors in the Contact Center Position

According to the bibliography, workers in this sector were dissatisfied with the noise, lighting and temperature/ambient conditions of their work position [6].

Noise was one of the ergonomic risk factors that generated greater discomfort. In one of the studies, 70.4% of the workers were affected by the noise generated by their colleagues' conversations with customers [7]. On the other hand, in other study it was detected that 95.5% of a sample of 201 workers declared that their workplace was noisy [8].

In reference to the lighting conditions, it was found in one of the studies that 40% of the employees considered that they were inadequate [4]. Likewise, in other of the studies 56% of those evaluated indicated discomfort regarding the temperature of the workplace [9].

Regarding the job positions conditions, the main problems encountered were related to the height of the chairs, the lack of support in them, and the lack of swivel chairs [10, 11]. Regarding the characteristics of the tables, some dissatisfaction was found with the height and lack of legroom [12]. On the other hand, other authors [4] claimed that most of the operators, 88%, reported the presence of reflections on the screen. Therefore, high-quality furniture, with the possibility of an optimal fit and adequate training for it, would help reduce the appearance of musculoskeletal disorders [11].

3.2 Ergonomic Risks

Musculoskeletal Disorders (MSD). According to one of the studies [4], 78.5% of Contact Center workers had MSD, without specifying specific body regions, derived from their job. At the same time, other authors [7] reported that the most affected areas in the workers were the neck, shoulders and back. In addition, a significant association was observed between accumulation of musculoskeletal symptoms and the duration of computer use [13].

On the other hand, [12] showed that 39% of respondents had MSD in wrist-hand, reporting that factors such as inadequate postures, mismatches in the height of the tables, and attending a high volume of answering daily calls, were associated with a higher risk of developing this disorder.

One study found significant associations between the characteristics of the workspace with MSD development in the neck and shoulders, or the appearance of discomfort in the wrist [14]. Other authors reported that the workers surveyed spent more than 80% of their shift sitting [15].

Other symptoms. Visual disturbances appeared among professionals, such as visual fatigue, 73.9%, "weight" in the eyes, 68.2%, and weakening of vision, 43.5% [16]. The regular use of screens, during their tasks, could be related to the development of visual disturbances. These discomforts may also appear due to insufficient lighting, inadequate distance from the worker with respect to the screen, lack of filter of the monitor, poor visual breaks, among others [7].

On the other hand, voice alterations were observed in almost half of the Contact Center staff [4, 17]. These workers carry out their work activity talking most of the day, and usually they increase the volume of their voice due to excessive noise in the workplace.

Likewise, it was observed that 33.8% of the workers suffered from alterations in the ears [18]. These alterations would be related to the acoustic shocks that these workers suffer through the headphones and that generate discomfort in ears, tinnitus, vestibular alterations and even increased sensitivity to noise [8].

3.3 Psychosocial Factors

In the study developed by [12], almost 25% of employees said they were not satisfied with the social support of their colleagues. In addition, two investigations showed that more than 70% of workers referred low social support of their supervisors, 78.4% [14] and 70.80% [17]. Social support from superiors is essential in such employment, since opportunities for contact with colleagues are limited. In addition, the lack of recognition for the work performed by operators [17] can further increase the perception of lack of social support from superiors.

Regarding autonomy, it was low both at the decision level in the execution of tasks [19], and at a temporary level [4]. In this last article, 84% of those evaluated said that they could not decide when to pause. Likewise, it was observed that the operators, compared with other employee computer users, had a higher prevalence in lack of autonomy [20]. Professionals have a low capacity to make decisions because their functions are established by organizations through protocols. In addition, the use of standardized scripts, when talking with clients, is frequent in this type of company [19].

Likewise, 95% of employees claimed to be exposed to a high workload [21]. This factor is associated with the high rate of calls that employees must attend by organization demands. In addition, employees must adapt to the situation presented by each client [14].

On the other hand, these positions were associated with high psychological demands [16, 22]. One study found that the activity that generated the greatest psychological demand was the exchange of information during the call. The workers had difficulties to face the diversity of demands that the call attention required, such as the volume of data to be processed, the speed of information exchange, and use of different types of technology [13]. All this, together with the constant need for attention, generates an important cognitive requirement. Likewise, emotional demands increase physical and mental fatigue in Contact Centers employees [23].

Regarding training, in a study, almost 20% workers said that they had not received specific job training when hired, while 40% of them did not receive refresher courses [24].

Furthermore, low job satisfaction was also present among the Contact Centers workers. An investigation found that 76% were dissatisfied with their employment in the sector [4]. In addition, 52% of the participants in another study expressed their desire to leave that sector [9]. In relation to lack of job security, in one article, 51% of employees claimed to present it [14].

Another of the psychosocial factors present was monitoring/supervision. According to [6], at 84% of those evaluated, the calls were registered by the supervisors. Similarly, monitoring was presented in 54% of workers. As these authors affirm, there was a perception of feeling controlled, which caused the worker to develop his functions under conditions of stress.

On the other hand, according to [25] the relationship with customers was considered an added stressor. In a study, 53.7% of the employees of a company claimed to have received negative comments from customers [17]. In addition, 26.9% of the sample indicated that were exposed to verbal violence by clients, often or very often, [9].

In addition, these companies had high turnover rates, which cause a large number of workers that have temporary contracts. Furthermore, many young workers consider this job as temporary, until they find a position related to their qualification [26].

Shifts can be fixed or rotating, so the operator would be subject to periodic changes. According to a study, 39% of Contact Center employees were dissatisfied with their work schedule [6].

3.4 Differences in the Prevalence of Risk Factors According to Gender

In relation to MSD, women have higher prevalence than men workers, 65.7% and 34.4% respectively [27]. These authors reported a longer working time in women compared to their male colleagues, which could explain their differences in prevalence. Similarly, it was observed a higher prevalence of wrist-hand symptoms in women than in men [14]. Likewise, it was detected that women remained sitting longer uninterruptedly and made fewer postural changes than men [15]. In addition, the duration of computer use was positively associated with MSD in the neck and shoulders in women.

Regarding psychosocial factors, the perception of low social support by co-workers was slightly higher in women than in men, 25% in women versus 23% in men. However, this difference is higher if social support came from superiors, 30% women versus 15% men [12]. Likewise, these authors reported that women occupied positions of lesser responsibility, which can predict that the lack of perceived social support from superiors is greater than in the case of men and, therefore, the opportunities for promotion are reduced.

Regarding the autonomy in the position, the employees reported limitations to influence their work, this prevalence being slightly higher in women, 78%, than in men, 75% [20]. Also, this difference could be due to a lower presence of women in positions of responsibility.

Besides, the number of women with a high workload was greater than that of men. In a study, 69% of women reported that they developed high-intensity work, while in men the prevalence was 61%. Also, it was more women (14%) than men (11%) who reported high psychological demands [20]. According to [12], women are responsible for tasks aimed at customer service, while men are responsible for functions related to the sale of banking products. However, in the relationship with clients, more men than women stated that the relationships were not good, 15% versus 12% [12].

3.5 Differences in the Prevalence of Risk Factors in Internal and External Contact Centers

Regarding the conditions of the job, significant differences were observed in the chairs of workplace in between both centers. 20% of the External Contact Center Workers (ECCW) did not have support for the upper back, versus 7% of the Internal Contact Centers Workers (ICCW). On the other hand, 22% of ECCW did not have rotating chairs, compared with ICCW where only 3% did not have them [11]. The characteristics of the tables, as the previous study identified, were also more unfavorable in the external than in the internal. In addition, 33% of ECCW had inadequate legroom, compared to 5% of ICCW, and 47% of them reported that the table was not adjustable, compared to no ICCW. These authors indicated that 56% of the ECCW had an inadequate position of their keyboard with respect to the edge of the table, without allowing the rest of the forearms and wrists, compared to 43% of the ICCW.

On the other hand, one study observed that discomfort in the neck-shoulder area was higher among ECCW than in ICCW, 67% versus 64% [1]. Nevertheless, [11] they found that the pain in the neck was slightly higher among the ICCW, 46.4%, compared to the ECCW, 43.3%, while the presence of back discomfort was more in ECCW, 28.9% versus 24.6%. In general terms, [28] indicated that ICCW showed slightly greater musculoskeletal discomfort than ECCW, 88% versus 85%. Therefore, discrepancies were detected in the studies, related to the appearance of MSD between both types of Contact Center, without distinguishing a clear trend.

On the other hand, according to the alterations in the voice, significant differences were found in hoarseness and sore throat between internal (85%) and external (70%) Contact Center workers [28]. These results are contrary to those expected, since ECCW would receive a greater number of calls and longer than ICCW [6]. Therefore, the risk of developing alterations and discomfort in the voice should be greater in the external ones.

In the previous paper [28] was observed too, that 84% of ICCW had complaints of visual fatigue, while these discomforts were manifested by 79% of ECCW.

In relation to psychosocial factors, low support was significantly associated with MSD with neck-shoulders in 31% of ICCW, and in 23% of ECCW. If social support came from peers, significant associations with these symptoms appeared in 25% of ICCW and 24% of ECCW [1]. These authors showed significant associations between low flexibility to make decisions and MSD in neck-shoulders in 25% of the ECCW and high psychological demands with MSD in neck-shoulders, in 28% of ICCW. In this study, it was shown that call logging and monitoring were significantly more common in external than in internal.

This difference could be since the external Contact Centers, being subcontracted by other companies, would try to satisfy the client's demand with the minimum resources, thus giving a more economical service. This would imply hiring the least number of workers with high objectives and demands for them. Therefore, being in tension at work, due to low social support and lack of autonomy, it finally translates into physiological problems in form of MSD.

4 Conclusions

The employees of the sector, greatly, are dissatisfied with the lighting conditions, temperature/environment and noise. In addition, employees claim that the characteristics of chairs and tables are, in most cases, inadequate.

Visual, auditory and voice alterations in the Contact Center workers is identified. In addition, MSDs, in general, without specifying specific body areas, appear in approximately half of the workers. The most affected areas in employees are neck, shoulders and back.

Regarding the psychosocial factors that appear among the employees of the sector, the following stand out: lack of autonomy, social support and training; high workloads and psychological demands; low job satisfaction; and presence of monitoring/supervision.

The profile with the highest exposure to risk is that of women workers from external Contact Centers.

References

1. Norman, K., Floredus, B., Hagman, M., Toomingas, A., Tornqvist, E.W.: Musculoskeletal symptoms in relation to work exposures at call centre companies in Sweden. Work **30**, 201–214 (2008)
2. Organización Internacional del Trabajo. Riesgos emergentes y nuevos modelos de prevención en un mundo de trabajo en transformación, Ginebra (2010)
3. European agency for safety and health at work. New and emerging risks in occupational safety and health. Office for Official Publications of the European Communities, Luxembourg (2009)
4. Gilardi, L., Fubini, L., d'Errico, A., Falcone, U., Mamo, C., Migliardi, A., Quarta, D., Coffano, M.E.: Working conditions and health problems among call-centre operators: a study on self-reported data in the Piedmont Region (Italy). Medicina del Lavoro **99**(6), 415–423 (2008)
5. Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., PRISMA-P Group: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst. Rev. **4**(1), 1–9 (2015)
6. Norman, K., Tornqvist, E.W., Toomingas, A.: Working conditions in a selected sample of call centre companies in Sweden. Int. J. Occup. Saf. Ergon. **14**(2), 177–194 (2008)
7. Chi, C.F., Lin, Y.H.: An ergonomic evaluation of a call center performed by disabled agents. Percept. Mot. Skills **107**, 55–64 (2008)
8. Gür, K., Pinar, R., Erol, S.: Health related quality of life and related factors among bank call center employees. Nobel Medicus **12**, 79–86 (2016)
9. Chevalier, A., Dessery, M., Boursier, M.F., Grizon, M.C., Jayet, C., Reymond, C., Thiebot, M., Zeme-Ramirez, M., Calvez, T.: Working conditions and psychosocial risk factors of employees in French electricity and gas company customer support departments. Int. Arch. Occup. Environ. Health **84**, 7–18 (2011)
10. Poochada, W., Chaiklieng, S.: Ergonomic risk assessments among call center workers. Procedia Manufac. **3**, 4613–4620 (2015)
11. Toomingas, A., Gavhed, D.: Workstation layout and work postures at call centres in Sweden in relation to national law, EU-directives and ISO-standards, and to operators' comfort and symptoms. Int. J. Ind. Ergon. **38**, 1051–1061 (2008)
12. Rocha, L.E., Glina, D.M.R., de Marinho, M.F., Nakasato, D.: Risk factors for musculoskeletal symptoms among call center operators of a bank in Sao Paulo, Brazil. Ind. Health **43**, 637–646 (2005)
13. Haldford, V., Cohen, H.H.: Technology use and psychosocial factors in the self-reporting of musculoskeletal disorder symptoms in call center workers. J. Saf. Res. 167–173 (2003)
14. D'Errico, A., Caputo, P., Falcone, U., Fubini, L., Gilardi, L., Mamo, C., Migliardi, A., Quarta, D., Coffano, E.: Risk factors for upper extremity musculoskeletal symptoms among call center employees. J. Occup. Health **52**(2), 115–124 (2010)
15. Toomingas, A., Forsman, M., Mathiassen, S.E., Heiden, M., Nilsson, T.: Variation between seated and standing/walking postures among male and female call centre operators. BMC Public Health **12**, 154 (2012)
16. Costa Saa, E., Ferreira Junior, M., Rocha, L.E.: Risk factors for computer visual syndrome (CVS) among operators of two call centers in São Paulo, Brazil. Work **41**, 3568–3574 (2012)
17. Charbotel, B., Croidieu, S., Vohito, M., Guerin, A.C., Renaud, L., Jaussaud, J., Bourboul, C., Imbard, I., Ardiet, D., Bergeret, A.: Working conditions in call-centers, the impact on employee health: a transversal study. Part II. Int. Arch. Occup. Environ. Health **82**, 747–756 (2009)
18. Saruhanoğlu, A., Gökçen-Röhlig, B., Saruhanoğlu, C., Öngül, D., Koray, M.: Frequency of temporomandibular disorder signs and symptoms among call center employees. CRANIO **4** (35), 244–249 (2017)

19. Fenety, A., Putman, C., Loppie, C.: Self-reported health determinants in female call centre tele-operators: a qualitative analysis. de Advances in occupational ergonomics and safety, Orlando (1999)
20. Norman, K., Nilsson, T., Hagberg, M., Tornqvist, E.W., Toomingas, A.: Working conditions and health among female and male employees at a call center in Sweden. Am. J. Ind. Med. **46**, 55–62 (2004)
21. Neisa, C., Colorado, P.: Factores de riesgo psicosocial asociados al cargo de teleoperador. Cuadernos Hispanoamericanos de Psicología **10**(2), 33–44 (2010)
22. Sprigg, C.A., Stride, C.B., Wall, T.D., Smith, P.R.: Work characteristics, musculoskeletal disorders, and the mediating role of psychological strain: a study of call center employees. J. Appl. Psychol. **92**(5), 1456–1466 (2007)
23. Ribert-Van de Weerdt, C.: Working pressure and emotional regulation strategies in call centre. Travail Humain **74**, 32–1339
24. Croidieu, S., Charbotel, B., Vohito, M., Renaud, L., Jaussaud, J., Bourboul, C., Ardiet, D., Imbard, I., Guerin, A.C., Bergeret, A.: Call-handlers' working conditions and their subjective experience of work: a transversal study. Int. Arch. Occup. Environ. Health **82**, 67–77 (2008)
25. Lourel, M.: The relations to work, control and health in call center-consumer service. Psychologie du travail et des organisations **12**, 39–51 (2006)
26. Observatorio de Riesgos Psicosociales UGT. Prevención de Riesgos Psicosociales en el sector Teleoperadores. Comisión Ejecutiva Confederal de UGT, Madrid (2007)
27. Odebiyi, D., Akanle, O., Akinbo, S., Balogun, S.: Prevalence and impact of work-related musculoskeletal disorders on job performance of call center operators in Nigeria. Int. J. Occup. Environ. Med. **7**(2), 98–106 (2016)
28. Lin, Y.H., Chen, C.Y., Hong, W.H., Lin, Y.C.: Perceived job stress and health complaints at a bank call center: comparison between inbound and outbound services. Ind. Health **48**, 349–356 (2010)

Strategies for an OSH Intervention in SMEs: An Exploratory Study Focused on the Role of Employer

Rita A. Costa, André M. Lopes, Artemisa R. Dores and Matilde A. Rodrigues

Abstract Small and Medium-sized Enterprises (SMEs) are known to face several difficulties in what regards to Occupational Safety & Health (OSH) management. In these enterprises, the employer plays an important role, being the responsible for decision making in this area. OSH interventions that target employers are of particular interest; however, there is a knowledge gap about how to design such interventions. The present study aims to identify the key points to considerer in the design of an OSH intervention for SMEs employers. Issues related to what employers want in an intervention, key difficulties that they face in what regards to OSH management, and strategies to improve it were identified through an exploratory approach. A focus group with six OSH practitioners, with experience in risk management and with knowledge about the waste management sector was carried out. For the dynamization of the session, open-ended questions were developed to stimulate the discussion among the participants. The focus group was designed to identify the key topics to consider in a training program, including: knowledge limitations in the field of OSH; main risk factors of the sector; difficulties experienced by the employers in the field and what employers want or give more importance in a training program. Results denoted that employers of smaller waste management enterprises have a lot of peculiarities about a training session, specifically, duration, the method in which the information is presented, being in group with other employers or not, and the topics to discuss. It was highlighted the need to address issues related to legislation, the support from external service enterprises and the main risks of the sector.

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Keywords Micro-sized enterprises · Occupational safety and health · Owners · Risk management · Training session · Waste management firms

1 Introduction

In Europe, up to 99% of all enterprises are Small and Medium-sized Enterprises (SMEs), representing particular importance for the countries' economy [1–3]. Although this importance, SMEs face many difficulties compared to larger companies, not only because of the extreme competitive environment that they deal with, but also due to limited amount of human, economic or technological resources [4–6]. These difficulties contribute to the poor Occupational Safety & Health (OSH) management that is usually found in this type of enterprises [4, 5, 7–12].

The employer plays an important role in what regards to OSH management in SMEs, being frequently the responsible for the risk prevention activities [12, 13, 16]. However, he/she face several difficulties into manage it. The literature emphasizes the lack of time to deal with OSH issues, the lack of technical support and knowledge about OSH, prioritizing production over safety and lack of communication with the employees [5, 13–15]. Taking all of this into account, interventions that can counter SMEs poor OSH performance, with a special focus on the employers, are of paramount importance.

An intervention in the matter of OSH can be defined as an attempt to improve safety by changing how matters are done [2]. An OSH intervention is important to tackle flaws, to eliminate hazards and mitigate risks, as well as to improve OSH conditions [16]. However, is often difficult for practitioners to implement the interventions in particular when they target the employers and, as a consequence, it not works as expected [2]. In view of this, is important to know how to design an intervention for this group.

Literature on this topic is still scarce, so there is a need to find out more information about how to well-design an intervention to improve the employers' understanding of the importance of OSH in their enterprises. With this in mind, the study aims to identify the key difficulties that employers from micro and small-sized waste management firms face in what regards to OSH management, and to identify strategies to improve it through an exploratory approach. The final aim was to collect information in order to design a training program that target employers from SMEs.

2 Methodology

To achieve the proposed objectives, a focus group was carried out. It is a type of interview with a group of subjects with the necessary knowledge to discuss a certain theme, that is applied to collect data for a specific research, taking advantage of different views, insights and recommendations [17]. In this study, six OSH practitioners, with knowledge and experience in the field of risk management in the mentioned sector participated in the focus group. The participation was entirely voluntary. Before the study, it was given an informed consent to all participants. It was explained that the focus group would be recorded, and that the data collected would not be disclosed.

The focus group was designed to identify the key topics to consider in a training program that target the employers from micro and small-sized enterprises of the waste management sector, including: knowledge limitations in the field of OSH; main risk factors of the sector; difficulties experienced by the employers in the field of OSH. For the dynamization of the session, open-ended questions were introduced to stimulate the discussion among the participants.

Two researchers dynamized the session: (1) a facilitator, whose the job was to guide the group through the discussion and keep the group focused on the topics in discussion; (2) a note taker, who was only an observer and did not interacted with the group—the notes included a sense of what practitioners said, the important comments and records of when transitions occurred from one topic to another.

In an initial interaction it was explained the purpose of the focus group to the participants in order to better guide the conversation to the intended purpose. It was applied an interview guide to help conduct the conversation, and to ensure that the intended topics were addressed. The questions used to conduct the focus group were: (1) "In your point of view, what are the difficulties that SMEs, in particularly the waste management enterprises, face?": (2) "Taking into account the role of the employer, what are, in your opinion, the critical aspects that influence OSH performance in an enterprise?": (3) "What is the role of OSH external services regarding risk management in these enterprises? How can they contribute to improve employer's engagement/commitment to OSH?" (4) "Which risk factors are most common in the sector?: (5) What topics/strategies would you consider important to promote knowledge and improve employer's involvement/commitment regarding OSH?".

The recordings were later transcribed, and the answers analyzed in order to retrieve the necessary information to develop a training session.

3 Results and Discussion

From the qualitative analysis, four major themes were addressed regarding OSH in micro and small-sized waste management enterprises: (1) employer's influence and main obstacles that affect OSH performance; (2) the influence of OSH consultancy services; (3) the main risk factors of the sector and (4) the main aspects considering on a training session.

In what regards to the employer' influence and main obstacles that affect OSH performance, the participants provided important insights, including the lack of training by the employers, lack of risk perception, lack of knowledge about the applied legislation and the focus on production.

> Employers do not have the necessary training. This is common in the sector. They do not see the importance of OSH.

> Subjects with several years of experience in this sector never realize the need of occupational safety and do not understand the reason why it is required. For them, it is just a legal requirement and an additionally cost.

> The legislation is applied without taking into consideration the size of the enterprise. Smaller-sized enterprises say that they do not have the necessary resources to apply and maintain legal requirements.

> Occupational safety is the last thing that they invest; the goal is on production.

> There is a lack of risk perception and investment.

> Employers have the wrong perception regarding OSH consultancy services.

These results were expected, since previous studies have already identified these issues to be related to low safety performance in SMEs [10]. The lack of employers' training in OSH maters was found to be common in the waste management sector. This can influence their ability to understand the importance of OSH and the benefits in the long term in what regards to safety improvement and cost reduction.

Results also denoted that the OSH legislation was designed without consider the particularities of the smaller sized enterprises, in particular lack of resources. In fact, it is known that legislation tend to be unsuitable for these enterprises [18]. This makes it difficult for SMEs fulfil with legal requirements. These statements enforce what was already found in literature, were barriers to OSH performance includes the lack of resources and legislation oriented towards large enterprises [5, 6, 10]. Interventions should address important legal requirements in the field of OSH in order to explain to the employers how to fulfill them and its importance to promote safer and healthy workplaces.

Results also showed that employers tend to favor production. The preference to production rather than safety is frequently pointed in the literature as a barriers to SMEs safety performance [5, 6, 13–15]. The firms need to produce in order to stay competitive in the market [18, 19]. As a consequence, employers from SMEs, which deal with limited resources, tend to consider the investment in OSH as an extra cost, making OSH the last view point to consider in investing, being forced to ignore OSH regulations [18, 19]. However, OSH is a competitive opportunity and should be presented during interventions to the employers in that way in order to direct their attention to this topic in the enterprise.

The misperceptions found about the role of OSH consultancy services may lead to a resistance by the employers to the OSH practitioners work, making more difficult to implement control measures or understanding the importance of OSH consultancy services. However, from the OSH practitioners' point of view, these enterprises have an important impact in SMEs OSH performance; but, they also face some constraints that can jeopardize the quality of their work. According to the expert's own words:

> The OSH consultancy services impose visits to numerous enterprises in a day of work, leaving less time to spend in each one.

> Poor organization of OSH consultancy services.

> It is important for employers to know the role of OSH consultancy services and opt for an enterprise that provides a good follow-up.

It is important for OSH consultancy services to spend the necessary time in each client to provide the correct service and interaction. Usually this is not the case because these enterprises attend to several clients each day. Besides this, it is important to note that, although there is a need of improvement in the consultancy services provided to SMEs, most of the times the employers also tends to hire the minimal services, making hard to provide a good support [20, 21]. According, the importance of a service with quality provided by the OSH consultancy services enterprises should be emphasized to the employers. They need to understand the importance of the support provided by the OSH practitioners.

In what regards to the risk factors in the waste management sector, several were identified in the study, varying from the type of material handled to the physical environment and machinery used.

> Ergonomic risk factors, such as manual material handling, thermal environment (too hot or too cold), and other biological, mechanic, physical (noise) and psychosocial risk factors.

> Small waste management enterprises have several risk factors, but some are more predominant than others.

The statements showed that employees from the waste management sector are exposed to the several risk factors, some of them more predominant than others, depending of the type of activity or the material being handled. Because of the use of different machinery, the existence of noise and mechanic risk factors are unavoidable in this sector. For other side, manual material handling is related to ergonomic and biological risk factors, as is the case of car seats. These statements are in agreement with previous studies [22]. When an intervention for the employers is being designed, these aspects are of the utmost importance. It is necessary to emphasize the different risk factors that are present in the workplaces and how they can lead to occupational accidents or diseases [23].

In order to create a training session specifically to the employers from micro and small-sized waste management firms, it is important to know the aspects that are most relevant for the employers. The practitioners emphasized some of these aspects.

> Short training sessions, practical situations that employers can relate with their reality, videos, graphs and appeal to the financial side.

> It is important to refer legislation, concepts, employers' obligations, risk factors, real life situations, practical exercises and involve different employers.

From the statements it is possible to realize that employers are not interested in long training sessions, with a lot of theoretical material, but a short and practical one, with relatable scenarios that they can voice their opinion and have an open discussion. In terms of the what to approach, it is important to refer and teach legislation, important OSH concepts, obligations and common risk factors. According to the literature, legislation seems to be of great concern for these enterprises; however, most of the legislation applicable to SMEs was written without taking into account the particularities of smaller enterprises [24]. Additionally, employers from SMEs have limited knowledge about OSH legislation and consider its application too bureaucratic [24]. This denote the need of approaching the theme of legislation during training sessions with the employers.

The practitioners, besides emphasizing the need for a short and practical approach for the intervention, also stated that the employers are more influenced for what other employers do not do, than for what they do.

> For these employers it cannot take too much time.
>
> It has to be something very surgical, at most it can take half an hour.
>
> They are more influenced for what other employers do not do, than for what they do.
>
> Yes, they say: if he/she does not do that, then I do not need to do it either.

From the statements of the practitioners, it is possible to infer that the employers seem to want to do less than what they already do and when compared to other enterprises they focus more on the poorer aspects of these. Usually, they do not see ways to improve their own enterprise OSH performance using other enterprises experience.

Throughout the session there seemed to have been a bit of a disagreement between the practitioners about whether to put some employers together and make a training session or not.

> I think it would be best if we could put them all together and make a small training session.
>
> I cannot imagine that those people would make themselves available for that.
>
> If they were together, I think it would be more advantageous for them to have a discussion about each other's doubts.

With these statements from the practitioners, it is possible to realize that not all of them agree in a training session with a group of employers. Taking into account what was mentioned above about the negative influence that these employers have on each other, and the fact that the employers do not seem to be interested enough in a training session, it seems natural that some of the practitioners would think that a training session with several employers together would not have a positive outcome. However, as mentioned by one of the practitioners, there could be a possibility that the employers could take advantage of a common training session. Besides, with this approach, employers have a chance to discuss their doubts and compare them to of others. This could help increase the employer's interest in the subject and in the training session. One study regarding an intervention to owners/managers of small restaurants or food service programs had found that one of the most value aspect of the intervention was the opportunity that owners/managers had to discuss their problems solutions with each other's [25].

> One of themes to be approached should be the costs of the accidents.

All the practitioners seemed to agree with this. For employers to pay more attention to the training session, the trainers should appeal to the fact that if the employers take more caution and be more zealous about OSH management, they would be able to reduce the number of accidents, and this way reduce the costs that come with those.

4 Conclusion

OSH training for employers is crucial to improve OSH in workplaces. It is necessary that the training sessions be designed keeping in mind the target audience, in order to obtain the higher impact. Throughout the focus group it was possible to realize that employers of micro and small-sized waste management firms have a several peculiarities about the training session: duration, the method in which the information is presented, being in group or not, as well as, the topics to be discussed. Additionally, several problems related to OSH management in these firms were emphasized, such as the limited time and knowledge of the employers to deal with OSH, and the limited support by consultancy enterprises.

Future research should address the implementation of a training session for employers, considering the findings of this study.

References

1. Parlamento Europeu: Pequenas e médias empresas. pp. 1–5 (2008)
2. Rosbon, S.L., Shannon, S.H., Goldenhar, M.L., Hale, R.A.: Guide to Evaluating the Effectiveness of Strategies for Preventing Work Injuries—How to Show Whether a Safety Intervention Really Works. NIOSH (2001)
3. PORDAT: PORDATA—Pequenas e médias empresas em % do total de empresas: total e por dimensão, 14 Feb 2019. Available: https://www.pordata.pt/Portugal/Pequenas+e+médias+empresas+em+percentagem+do+total+de+empresas+total+e+por+dimensão-2859 (2019). Accessed 23 Feb 2019
4. Hasle, P., Limborg, H.J.: A review of the literature on preventive occupational health and safety activities in small enterprises. Ind. Health **44**(1), 6–12 (2006)
5. Masi, D., Cagno, E.: Barriers to OHS interventions in small and medium-sized enterprises. Saf. Sci. **71**, 226–241 (2015)
6. Masi, D., Micheli, G.J.L., Cagno, E.: Developing, implementing and evaluating OSH interventions in SMEs: a pilot, exploratory study. Int. J. Occup. Saf. Ergon. **20**(3), 385–405 (2014)
7. Champoux, D., Brun, J.P.: Occupational health and safety management in small size enterprises: an overview of the situation and avenues for intervention and research. Saf. Sci. **41**(4), 301–318 (2003)
8. Hasle, P., Kines, P., Andersen, L.P.: Small enterprise owners' accident causation attribution and prevention. Saf. Sci. **47**(1), 9–19 (2009)
9. Matlay, H.: Employee relations in small firms: a micro-business perspective. Empl. Relat. **21**(3), 285–295 (1999)

10. Micheli, G.J.L., Cagno, E.: Dealing with SMEs as a whole in OHS issues: warnings from empirical evidence. Saf. Sci. **48**(6), 729–733 (2010)
11. Micheli, G.J.L., Gnoni, M.G., Merich, D., Sala, G., Rosso, A., Tornese, F., Piga, G., Malorgio, B.: Barriers, drivers and impact of a simplified occupational safety and health management system in micro and small enterprises. Adv. Intell. Syst. Comput. **791**, 81–90 (2019)
12. Boustras, G., Hadjimanolis, G.: Management of health and safety in micro-firms in Cyprus—results from a Nationwide Survey. Saf. Sci. **79**(1), 305–313 (2015)
13. Isik, S.N., Atasoylu, E., Economides, A., Yiannaki, A., Nicolaides, L.: Occupational safety and health in North Cyprus: evaluation of risk assessment. Saf. Sci. **94**, 17–25 (2017)
14. Nielsen, K.J., Kines, P., Pedersen, L.M., Andersen, L.P., Andersen, D.R.: A multi-case study of the implementation of an integrated approach to safety in small enterprises. Saf. Sci. **71**, 142–150 (2015)
15. Nordlöf, H., Wiitavaara, B., Högberg, H., Westerling, R.: A cross-sectional study of factors influencing occupational health and safety management practices in companies. Saf. Sci. **95**, 92–103 (2017)
16. Masi, D., Cagno, E., Farne, S., Hasle, P.: Design of OSH interventions: a model to improve their actual implementation. Saf. Sci. **115**, 51–65 (2019)
17. Davies, M., Houghton, P., Morga, A.M., Saunders, L.: What is a Focus Group ? Eval. Capacit. Build. Widening Particip. Pract. **10**, 1–4 (2008)
18. Hadjimanolis, A., Boustras, G., Economides, A., Yiannaki, A., Nicolaides, L.: Work attitudes and safety performance in micro-firms—results from a nationwide survey: (the opinion of the employees). Saf. Sci. **80**, 135–143 (2015)
19. Quinlan, M., Mayhew, C.: Precarious employment and workers' compensation. Int. J. Law Psychiatry **22**(5–6), 491–520 (1999)
20. Sá, A.S.S.P.: Determinantes para o desempenho de segurança e saúde no trabalho em micro e pequenas empresas do setor de operação de gestão de resíduos. Master thesis in Higiene and Safety at Organizations. School of Health of Polythecnic Instititut of Porto (2018)
21. Barbosa, C., Azevedo, R., Rodrigues, M.A.: Occupational safety and health performance indicators in SMEs: a literature review. Work **64**(2), 217–227 (2019)
22. Kontogianni, S., Moussiopoulos, N.: Investigation of the occupational health and safety conditions in Hellenic solid waste management facilities and assessment of the in-situ hazard level. Saf. Sci. **96**, 192–197 (2017)
23. Kvorning, L.V., Hasle, P., Christensen, U.: Motivational factors influencing small construction and auto repair enterprises to participate in occupational health and safety programmes. Saf. Sci. **71**, 253–263 (2015)
24. Cagno, E., Micheli, G.J.L., Masi, D., Jacinto, C.: Economic evaluation of OSH and its way to SMEs: a constructive review. Saf. Sci. **53**, 134–152 (2013)
25. Bush, D., Paleo, L., Baker, R., Dewey, R., Toktogonova, N., Cornelio, D.: Restaurant supervisor safety training: evaluating a small business training intervention. Pub. Health Rep. **124**, 152–159 (2009)

Maintenance and Fire Safety Regulation in Spain and Portugal

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Abstract Published studies focused on analyse the development of European regulations regarding maintenance and fire protection, their differences, requirements, strategies and implementation, are really scarce. For this reason, the present study aims to develop a comparative analysis of the Regulation on Fire Safety Installations in Spain and Portugal. For this, differences related to content and levels of requirements are studied. Both regulations, leading in Europe, place special emphasis on the participation of maintenance and installation companies, as well as in the intervention of the Engineer as a competent technician in the field. As a result, it could be concluded that programs that encourage the analysis of the degree of effectiveness of fire protection regulations and their difficulties in their implementation and adaptation to new technologies should be developed. Similarly, the harmonization of requirements regarding regulation in fire protection within European countries is considered very necessary, as well as the competencies of engineers for the project writing with this scope.

Keywords Fire safety regulations · Europe · RIPCI 2017 · SCIE · Occupational health and safety

1 Introduction

The conservation of citizens' health and safety in a built environment is the basic objective of the legislation. In this regard, in terms of fire safety, this remains a fundamental problem in Europe [1].

Research focused on the international field on the issue of regulation in fire protection is certainly scarce. In this sense, in Europe there is the Economic

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Commission for Europe (1985) [2], the Institute of Building Control (1997) [3] and the Consortium of European Building Control (2006) [4].

The evolution of both the technique and the European regulatory framework regarding construction materials, product marketing, fire safety and standardized norms has been very intense in recent decades. Fire safety regulation is changing as adherence to prescriptive requirements is being replaced or complemented by an approach based on performance-based design [5]. Therefore, strategic decision-making of a regulatory nature is extremely important, being able to distinguish between strategic errors, failures and even fiasco [6].

In Spain, Royal Decree 513/2017 of May 22 [7], which approves the new Fire Protection Facilities Regulation, intends to establish the conditions that must have the design, execution, commissioning and the maintenance of said facilities (as well as their components, materials and equipment), to comply with the corresponding national and community regulations.

This new regulation presents the legal provisions, necessary human resources and, through a list of UNE (acronym of a Spanish standardized norm), comprises the requirements related to the design, installation and maintenance of fire protection systems.

The first objective of any building must be the design and construction regulated to prevent the production of accidents such as fires. However, despite the fact that currently in Spain there is a vast regulation that aims to achieve this objective, according to the data provided by the MAPFRE (Spanish insurance company) Foundation and the Professional Association of Firefighters, in 2018 there have been about 21.7% more deaths from fire than in the previous year. At home, estimates of the number of fires in 2018 amounted to more than 23,000, representing an average of 63 daily fires, which killed 144 people, 8.7% more than in 2017 [8].

Therefore, it's difficult to predict when a fire will occur but, once it happens, is essential to have adequate means to prevent its spread and proceed to its rapid extinction.

Unfortunately, in its beginnings, fire regulations in Spain emerged as a necessity as a result of major catastrophes such as those of the Carreteras Cinemas in Madrid, that of the Maternal and Child Hospital of Seville or the fire of the Hotel Corona de Aragón, in which 83 people died. So these events are remembered as some of the events with the greatest social impact of the Spanish political Transition [9].

Finally, in 2017 and with more than 25 years since the Fire Protection Facilities Regulation (known by its acronym in Spanish as RIPCI) of November 1993 [10], the new Fire Protection Regulation (Royal Decree 513/2017, of 22 May) which seeks to guarantee the conditions and requirements for the design, installation, maintenance and inspection of the equipment, systems and components that make up the active fire protection facilities.

Since the first fire protection regulation was drafted in 1974, until today, after the approval of the new Regulation on Fire Protection Installations, Spain is among the leading countries in this area in the European Union. Thus some notable European regulations are:

– **United Kingdom**: Fire Safety, Building regulation in England covering fire safety matters within and around buildings, 7 December 2010.
– **France**: Règlement de sécurité contre les risques d'incendie et de panique dans les établissements recevant du public (ERP), du 25 Juin 1980.
– **Portugal**: Segurança contra incêndio em edificios, de 12 de Novembro de 2008. Regulamento técnico de Segurança contra incendio em edificios, de 29 de Dezembro de 2008.
– **Italy**: Il Regolamento di Prevenzione Incendi, dal 1 de Agosto de 2012.

However, published scientific studies that have dealt with the analysis of the development of these regulations in Europe and their differences in requirements, strategies and implementation are really scarce [1, 11, 12].

Based on this, the present study aim to develop the analysis and comparative study of the Regulation on Fire Protection Installations in Spain and Portugal. The purpose is to obtain a series of results that can be used to improve the current regulations or help to improve the regulations of neighbouring countries.

2 Methodology

In order to achieve the stated objective, the analysis of fire protection regulations in Spain and Portugal was carried out based on differences in content and levels of requirements. The choice of these two countries for the analysis of the technical regulations that they have in fire protection has been based on the considerable similarities between the two states, in terms of institutional, cultural, historical and, of course, geographical relations in the case of countries that share the Iberian Peninsula.

Therefore, a comparison of both technical regulations is developed, ending with a series of conclusions.

3 Results

3.1 European Regulations on Fire Protection

As for the European regulations on Fire Protection, it is certainly difficult to establish bases for evaluation due to differences in the description and application of the requirements. Thus, the mandatory regulations regarding fire protection are different in the several member countries of the European Union. As for some very basic regulations, such as the Construction Products Directive, the Occupational Health and Safety Directive, etc., there is a consensus among the different EU member countries, but as regards the level of actual implementation of the fire safety in industrial and commercial establishments there is no unanimous criterion.

The European Standardization Committee, founded in 1961, is responsible for issuing the EN-UNE standardization regulations, which are only mandatory if they are ratified by a regulation within each member country. These regulations cover various fields and what is intended with them is to promote free trade, worker and consumer safety, environmental protection, compatibility of networks and research and development programs.

With regard to fire protection, the EN-UNE regulations issued refer to requirements and test or manufacturing methods for the components of these facilities. In general, they define the manufacturing of the different elements that make up the installation and in some cases, they also define how they should be installed.

On the other hand, at European level there are also associations and organizations, not official, for the preservation of human lives and property, which have developed technical regulations. This is the case of the European Committee of Insurers, the National Association for Damage and Loss Prevention or Tecnifuego-Aespi in Spain. In this sense, it is common for insurance companies to impose compliance with the technical regulations issued by any of these associations.

Likewise, when a fire protection installation designed by an engineer proceed to legalize, the European regulation dictates that it is the property that presents a certificate of these facilities by an entity of the different countries of the European Union.

3.2 Spain—Reglamento de Instalaciones de Protección Contra Incendios (RIPCI_2017)

In the seventies, with the end of the dictatorship and the beginning of the transition, and before the watchful eye of the neighbouring countries, Spain was one of the "developed" countries where there were no regulations on protection fire protection. A building could not break any rule simply because it didn't exist.

There wasn't single national regulation, but several ordinances in the different autonomous communities. In addition, these regulations didn't usually support each other, since there were important differences between them.

That is why in 1974 the Ministry of Housing approved the Technological Regulation on Fire Protection Installations. Thus, it was a first step to present a unique regulation in Spain, which ended with the great lack of coordination and differences that were between the communities.

However, four years later there were several fires in public buildings, such as the Hospital Materno-Infantil Virgen del Rocío in Seville in 1977 or the Hotel Corona de Aragón in Zaragoza in 1979, which caused the appearance of regulations in fire protection for this type of buildings and not for others with a different function.

Due to the seriousness of the situation, it is for this reason that in 1981 an interministerial commission was constituted by the Minister of Public Works and

Urban Planning in which the Basic Fire Protection Regulation (known by its acronym in Spanish as NBE-CPI-81) was approved, where they established general conditions and particular conditions, in the form of annexes, for each type of building. However, due to the simplicity of the regulation with type buildings, it was difficult to apply.

Therefore, in the following year the Basic Fire Protection Regulation (known by its acronym in Spanish as NBE-CPI-82) was approved, maintaining the general conditions and making modifications to the particular ones, a greater number of UNE regulations were taken into account, achieving a higher prestige and validity. Despite this, this wasn't considered a Regulation that provided practical and technically viable solutions.

It took almost a decade, and with the entry of Spain into the European Union, for the 1991 Basic Regulation to be published, providing a more real vision of the problem and managing to provide different solutions to the same case. This Regulation was adapted to the required levels of the technical and economic reality of the country and was harmonized with that of other countries of the European Community. Even the Spanish Association for Standardization and Certification was represented in this Standard.

Ten years later, the Building Planning Law (known by its acronym in Spanish as LOE) caused the Royal Decree 314/06 [13] to be issued on March 17, 2006, approving the Technical Building Code (known by its acronym in Spanish as CTE) and, within it, the Basic Documents DB-SI (Fire Safety) and DB-SU (Safety of use), which together, constitute the legal body of fire protection in Spain, coming to match European regulations, adopting its symbology and importance to the problem of fire.

However, despite the many basic building regulations, there was no document that established the technical conditions that the fire protection installations and their subsequent maintenance should meet. That is why in 1993 the Regulation of Fire Protection Installations (RIPCI) [10] was approved, which had a series of modifications due to the lack of coordination produced in the industrial sector.

Finally, on May 22, 2017, through RD 513/2017 [7], the Fire Protection Facilities Regulation is approved, which establishes the conditions that must have the equipment and systems that make up the facilities for make its operation effective. A complete document was made, with more than 140 technical regulations that establish quality and safety requirements in the equipment, systems and components of the facilities. This Regulation shows the effective collaboration between regulation and legislation, where the Public Administrations use the UNE regulations in their legal texts to simplify their content and also to adapt to the technological state in which we are.

Thanks to the good work done for the development of the updated and new RIPCI and together with the CTE, Spain has become a leading country in the European Union in the field of Fire Protection.

3.3 Portugal—Regulamento da Segurança Contra Incendio em Edificios (SCIE)

The regulatory efforts made by the Portuguese State in the field of security and fire protection have been clear evident since 1975 [14].

In Portugal since 2008 and after the approval of the legal regime for fire safety in buildings (known by its acronym in Portuguese as SCIE), it became possible to centralize all obligations in this area that, initially, were divided into different laws.

The current legislation in Portugal, through Decree Law 220/2008 [15], of November 12, which establishes the Legal Regime for Fire Safety and its modification with Decree Law 224/2015 [16], of October 9 and Ordinance 1532/2008 [17], of December 29, which approves the Technical Regulations for Fire Safety in Buildings, has established the obligation in each of the buildings in the territories of the neighbouring country, regardless of its use and environment.

Specifically, the Portuguese Technical Regulations for Fire Safety in Buildings (Portaria No. 1532/2008) [17], is a very broad regulation that presents a total of eight Titles, each of them subdivided into different chapters and articles, up to a total of 309, and 1 Annex.

Among the 8 titles include Title III which analyzes the general conditions of behaviour before fire, insulation and protection, Title IV that deals with general evacuation conditions and Title V on the general conditions of numerous technical facilities, such as of electrical energy, heating, evacuation of fuels, ventilation, elevators and combustible liquids.

Regarding the conditions that must achieve by fire protection facilities, Title VI is very remarkable. It treats elements such as emergency lighting, detection and alarm, smoke control, intervention measures, fixed automatic fire extinguishing systems, water curtain systems and gas detection.

The regulation continues with three more titles and an Annex dedicated to definitions.

3.4 Analysis of Main Differences

After the analysis and study of the regulations on fire protection in Spain and Portugal, a series of differences are identified that present both in structure, specific points of the regulations or bodies responsible for them (see Table 1).

Initially it is estimated that comparing regulations on fire protection in different European countries is not easy. The absence of harmonization regarding regulatory strategies in fire safety is shown as the main impediment [1]. For this, it's necessary to understand the competences of the different delegated government systems, the legal systems and the various approaches of the public and private sector.

It is also considered that the structure between documents is completely different between the countries mentioned, which presents a difficulty in understanding and

Table 1 Main differences found between both regulations

Differences	**Spain** Reglamento de Instalaciones de Proteccion Contra Incendios (RIPCI)	**Portugal** Regulamento Tecnico de Segurança contra Incêndio em Edifícios (SCIE)
Complementary technical documents	Royal degree 2267/2004 Royal degree 314/2006	Decree law 220/2008
Application area	Installation companies and/or maintenance companies	Not collected
Fire protection systems	15 systems (annex I)	7 systems (title VI)
Competent technician	University technician degree	Architect or engineer
Structure	Three chapters, 23 articles, 3 annexes	Eight titles, 309 articles and 1 annex

studying the regulations. In addition, if there is the possibility of carrying out a fire protection project in another country, the national regulations cannot be taken as a basis, since all are different from the point of view of the format and structure. Even so, we understand that this study can be very useful for both designers and installers who aim to work in both neighbouring countries.

Spanish regulations place a special emphasis on participation in terms of knowledge and competencies acquired by university technical graduates. In the case of Portugal, also established at the national level, the responsibility for the development of projects must be assumed exclusively by an architect recognized by the Order of Architects (OA) or an engineer, recognized by the Order of Engineers (OE), or by a technical engineer, recognized by the National Association of Technical Engineers (ANET), with a certificate of specialization.

For Spain, the documents that regulate fire safety are the Technical Building Code, the fire safety document and the Fire Protection Facilities Regulations. The competent technician has to demonstrate that the design presented complies with the previous documents. This doesn't happen when a project has reached a detailed design, and has to obtain approval from the relevant college.

In the Spanish Fire Protection Regulation, its application area is subject to both installation and maintenance companies. This aspect is not reflected in the Portuguese regulations as well as in any of the different regulations of the other countries of the Union [11].

4 Conclusions

This study concludes that the regulations of one country cannot be considered better than another, because they are obviously different. However, but it's considered that each country, under the current situation and experience in this matter, must keep updated each of the regulations for the defence of human lives and their own well-being. Similarly and confirming what was stated by Sierra et al. [18]; Cobin [12] or Goncalves [19], programs should be developed that encourage the analysis of the degree of effectiveness of fire protection regulations, their difficulties in their implementation and their adaptation to new technologies.

In short, as Spinardi defends [5], it's considered very necessary to harmonize the requirements regarding regulation in fire protection within European countries, as well as the competencies of engineers to make projects with this scope. In this sense, the best legal instrument would be to have a European Framework Directive, which promotes the concept of fire protection management in an integrated way.

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References

1. Visscher, H.E.N.K., Sheridan, L.I.N.D.A., Meijer, F.R.I.T.S., Wen, P.H., MH–Young, A., Bielek, B., Tesar, A.: The formulation of building regulations in eight European countries. Build. Res. J. **53**(4), 193–205 (2005)
2. Economic Commission for Europe.: Building regulations in EC countries, Geneva (1985)
3. Institute of Building Control.: Review of European Building Regulations and Technical Provisions, Epsom Surrey (1997)
4. Constortium of European Building Control.: Building Control Systems in Europe (2006)
5. Spinardi, G.: Fire safety regulation: prescription, performance, and professionalism. Fire Saf. J. **80**, 83–88 (2016)
6. Le Coze, J.C.: Safety as strategy: mistakes, failures and fiascos in high-risk systems. Saf. Sci. **116**, 259–274 (2019)
7. Real Decreto 513/2017, de 22 de mayo, por el que se aprueba el Reglamento de instalaciones de protección contra incendios. Boletín Oficial del Estado, 12 de junio de 2017, núm. 139, pp. 48349 a 48386
8. Monclus, J.: Estudio de Victimas de Incendios en España en 2017, Asociación Profesional de Técnicos de Bomberos y Fundación MAPFRE. P. 2. Available at https://www.aptb.org/images/Estudio_Victimas en España (2018)
9. Hernández, B.: Protección contra incendios. La revista de la Ingeniería Técnica Industrial, TI 281. Available at http://www.tecnicaindustrial.es/tifrontal/a-2653-proteccion-incendios.aspx (2009)
10. Real Decreto 1942/1993, de 5 de noviembre, por el que se aprueba el Reglamento de instalaciones de protección contra incendios. Boletín Oficial del Estado, 14 de diciembre de 1993, núm. 298, pp. 35159 a 35168

11. Visscher, H., Meijer, F., Sheridan, L.: Fire safety regulations for housing in Europe compared. Buil. Res. J. **56**(4), 215–227 (2008)
12. Cobin, J.M.: Theory review: does fire safety regulation work? Lessons from Turin, Italy. Planning Theory **13**(2), 189–209 (2014)
13. Real Decreto de 17/03/2006, por el que se aprueba el Código Técnico de la Edificación
14. Almeida, J.E., Coelho, A.L., Rodrigues, J.P.C.: As medidas de auto-protecção e aregulamentação portuguesa de segurança contra incêndio. (2009)
15. Decreto-Lei n 220/2008—Legislação sobre segurança contra incêndio em edificios
16. Decreto-Lei n 224/2015—Procede à primeira alteração ao Decreto-Lei n 220/2008, de 12 de novembro, que estabelece o regime jurídico da segurança contra incêndio em edificios
17. Regulamento técnico de Segurança contra incendio em edificios, de 29 de diciembre de (2008)
18. Sierra, F.J.M., Rubio-Romero, J.C., Gámez, M.C.R.: Status of facilities for fire safety in hotels. Saf. Sci. **50**(2012), 1490–1494 (2012)
19. Goncalves.: Managing the implementation of fire self-protection measures in buildings. In: Sho 2015: III International Symposium on Occupational Safety and Hygiene, Guimaraes Portugal

A Diagnostic Analysis of Absenteeism—A Case Study in a Portuguese Cork Industry

Alfredo Silva, Ana Luísa Ramos, Marlene Brito and António Ramos

Abstract Absenteeism is defined as the absence of a worker from his or her workplace during a normal day's work schedule and is seen as a problem which companies face every day. The absence of an employee can result in a significant drop in productivity and the company's daily revenue can be negatively impacted by it, which when multiplied by the absence of multiple workers in different days can have a harmful impact on the company's production. However, most managers neither understand nor have looked into the causes of their absence issue. This study took place at a company which produces cork stoppers, which deals with a problem of high absenteeism that costs around 1,200,000 € per year to the company. The main goal of this study is to identify the sectors which have the highest percentage of absenteeism, quantify its impact on related outcomes and diagnose its causes. The results show that, most absenteeism occurs in production areas and the causes are related to musculoskeletal problems. The consequences involve various costs to the society, some of them difficult to quantify. The methodology used in this study was the action research.

Keywords Absenteeism · Cork industry · Musculoskeletal problems · Productivity · Workplace design · Worker's well-being

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1 Introduction

The human element is essential to any organization. Employees and human resource management are key factors for of service quality, customer satisfaction and loyalty, competitive advantage, organizational performance, and business achievement [1–3].

One of the most important matters that human resource managers are being faced with is managing their staff's absence behavior, i.e., absenteeism [4]. Absenteeism has a negative impact on productive work especially in the manufacturing industry [5]. Absenteeism is a short-term absence from work (temporary withdrawal from an organization) which is caused by issues such as illness, death in the family, or other personal matters [6]. It is also seen as an employee's intentional or habitual absence from work [7]. According to the literature, there are multiple types of absenteeism. The most common is sick leave [8]. Some authors consider vacation, maternity leave, military duty, education absence, etc. as forms of absenteeism as well [4]. Some authors make a distinction between involuntary absenteeism (e.g., certified sickness, funeral attendance) and voluntary absenteeism (e.g., vacation, uncertified sickness) [9] separating authorized and unauthorized absenteeism, while [10] and [11] split absenteeism into organizationally excused and organizationally unexcused groups, with types such as sickness, jury duty, religious holidays, funeral leave, and transportation issues placed in the category of excused forms of absence.

Absenteeism is not difficult to measure [4], and two kinds of absence metrics are considered: time lost and absence frequency. Time-lost measures show absenteeism as a sum of units of time (e.g., hours or days) away from work [12]; absence frequency, on the other hand, is the number of absences in a specific period of time irrespective of duration [13].

Excessive absenteeism might lead to serious consequences for any company [4]. High levels of absence amongst employees are putting company profitability at risk, while in others they endanger the very survival of the enterprise [5].

The significance of this impact is the subject of widespread debate. Some of the negative outcomes of absenteeism are high costs, such as direct compensation costs or replacement costs, and a decrease in productivity [6].

Evidently, absenteeism is a problem with costly and pervasive implications for the effective operation and productivity as well as for relationships among the people in a company, and more formally, for labor relations [5].

Due to its disruptive effects, a high level of absenteeism opposes the interests not only of the employer, but also of workers and their trade unions [5].

The significance of studying absenteeism lies in the fact that a more comprehensive understanding of absence behavior can result in its successful management [4]. Much of what is done by managers to fight absence in their organizations is done in total ignorance of the reasons for absence. Most managers do not understand or analyze the causes of absence problems. Instead, personal hunches, prejudices and rules of the thumb are the basis on which remedial action is decided. Management's failure to effectively handle the absence issues comes, to a large extent, from a lack of proper understanding of the challenges associated with absence [5].

Portugal is the world's leading cork producer—responsible for more than half the world's supply. The cork industry is a labour intensive industry that uses a lot of machinery operated by workers to produce cork articles. This study took place at a cork stoppers producer company, which deals with the problem of high absenteeism rates daily. The main objective of this study is to identify the most critical sectors inside this company which have the highest percentage of absenteeism, quantify its impact on related outcomes and identify its causes.

2 Methodology

The methodology used in this study was the action research. This methodology can be defined as "an approach in which the action researcher and a client collaborate in the diagnosis of the problem and in the development of a solution based on the diagnosis" [14]. In other words, it involves an action researcher and community or organization members who are seeking to improve their situation.

This study was conducted at a large cork company, with 350 workers. Absenteeism was measured by time lost, i.e., the total number of hours away from work. This work also used the absenteeism rate, which was calculated by sum up the total hours away from work and dividing the result by the sum total of total hours available to work (total number of workers × number of each employee's working hours).

The first step was to analyze the company's overall absenteeism rate and compare it with the national average. Then, the critical sectors—the ones with the highest absenteeism rate—, were identified along with the absenteeism causes for these sectors. To do this study some indicators of the company were analyzed, such as production and absenteeism from October 2018 to September 2019. Finally, costs related to absenteeism were calculated taking into account several factors, such as non-quality costs and productivity.

3 Results

The average absenteeism rate of the company studied, from October 2018 to September 2019, was around 11%, higher than the national average, which sits at around 6%, according to national statistics institute (INE).

The evolution of the absenteeism rate over the 12 months of the year was also analyzed. No major differences were detected over the months (Fig. 1).

The company are divide by operations sectors, the sectors more affected by absenteeism (Fig. 2), the ones with an average absenteeism rate over 11%, were the

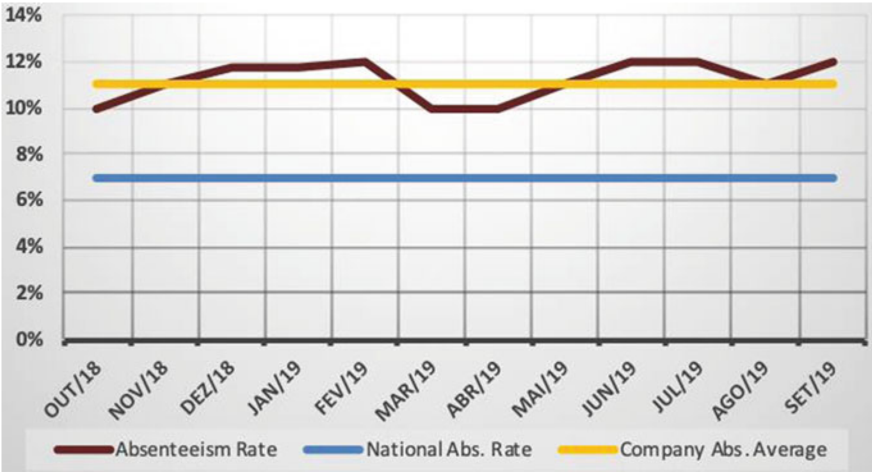

Fig. 1 Absenteeism rate by month compared with the national absenteeism rate and the company's average absenteeism rate

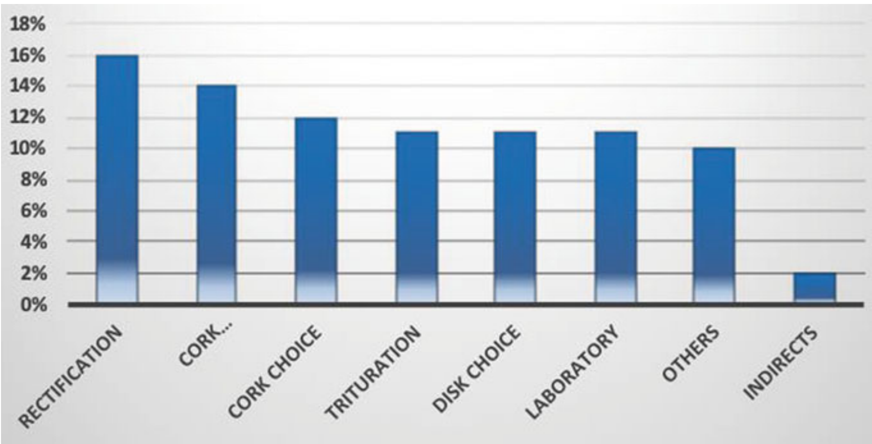

Fig. 2 Average absenteeism rate by sector

rectification sector, with a 16% absenteeism rate, the cork preparation sector (14%) and the cork choice sector (12%).

The next step was the identification of the absenteeism causes (Fig. 3), and the main cause represents 47% related with occupational diseases, such as musculoskeletal problems and breathing problems, 39% are related to natural diseases and the remaining 14% are come from personal matters such as taking care of children or going to medical appointments.

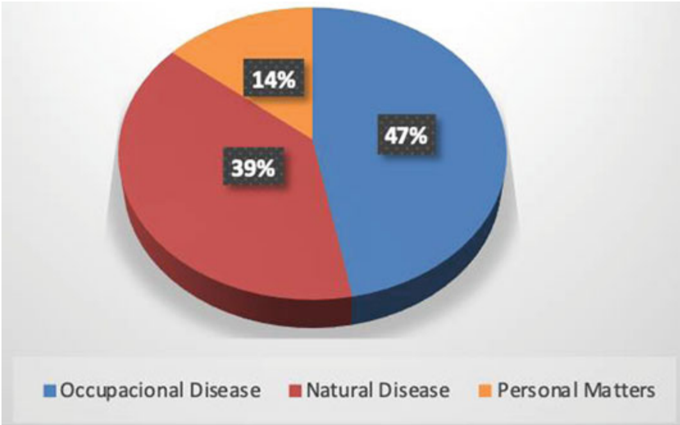

Fig. 3 Absenteeism causes

Trying to understand why the number of occupational diseases is so high, the workplaces and the tasks in the critical sectors, the ones with higher absenteeism rates, were analyzed. The rectification sector is composed of workers who stand up all day and whose main task is to supply the machines by pushing and pulling containers and unlock them every time they stop. These tasks require the adoption of incorrect postures leading to complaints due to muscle aches in the lower back. This sector is also affected by a high level of cork particles in the work environment. The second and third sectors with the highest absenteeism rate were cork preparation and cork choice. Both of these sectors have the same type of problems: repetitive tasks and incorrect postures for performing them, for example as trunk and neck rotation.

It should be noted that most absenteeism occurs in the production areas, which should be the priority areas to act in.

The high absenteeism rate results in several costs for the company, some of them difficult to obtain. In the sector with the highest absenteeism rate (rectification), for each absent worker there is a productivity drop in 15% and an 5% increase in reprocessing due to quality issues (these indicators are daily measured by the numbers of cork stoppers processed per hour). These numbers are caused by the inexperienced workers who replace the absent ones. Overall, it is estimated that the company loses around 1,200,000 € per year due to the absenteeism problem.

4 Conclusions

Despite improving working conditions over the years, and all the incentive policies, absenteeism due to occupational diseases remains one of the biggest problems facing companies. The causes must be investigated and analyzed so that preventive actions can be introduced.

This study was developed in a company which produces cork stoppers. In recent years there has been a great improvement in working conditions in this type of production company as many manual tasks have been automated. However, absenteeism continues to be higher than the national average, leading to large costs for the company. The main causes of the absenteeism found in this study are related to occupational diseases, such as musculoskeletal and breathing problems. To reduce the level of absenteeism in this company, a deeper analysis of workplace design, work environment and organization would be important to understand key issues and implement the most appropriate improvement solutions.

It is important to talk in the same language as managers, which means determining the costs of absenteeism to justify the investment in improving working conditions. If they reduce absenteeism by improving working conditions, companies will have better results and workers will be more satisfied. Everyone wins.

The conclusion of this results is limited to this study. Further studies should be conducted to sustain these results or better understand this phenomenon.

References

1. Bitner, M.J., Bernard, H.B., Tetreault, M.S.: The service encounter: diagnosing favorable and unfavorable incidents. J. Mark. **54**, 71–84 (1990)
2. Nickson, D., Tom, B., Erwin, L., Morrison, A.: Skills, Organisational Performance and Economic Activity in the Hospitality Industry: A Literature Review. Economic and Social Research Council Centre for Skills, Knowledge, and Organizational Performance (SKOPE). University of Oxford and Warwick, Oxford (2002)
3. Schneider, B., Godfrey, E.G., Hayes, S.H., Huang, M., Lim, M., Nishii, L.H., Raver, J.L., Ziegert, J.C.: The human side of strategy: employee experiences of strategic alignment in a service organization. Organ. Dyn. **32**, 122–141 (2003)
4. Cikes, V., Ribaric, H.M., Crnjar, K.: The determinants and outcomes of absence behavior: a systematic literature review. Soc. Sci. **7**(8), 120 (2018)
5. Ramdass, K.: Absenteeism—a major inhibitor of productivity in South Africa: a clothing industry perspective. In: 2017 Proceedings of PICMET 17: Technology Management for Interconnected World, United States, pp. 1–7 (2017)
6. Mathis, R.L., Jackson, J.H.: Human Resource Management, 12th edn. International Student Edition, Mason, Thomson South-Western (2004)
7. Cucchiella, F., Gastaldi, M., Ranieri, L.: Managing Absenteeism in the workplace: the case of an Italian multiutility company. Proc.-Soc. Behav. Sci. **150**, 1157–1166 (2014)
8. Pizam, A., Thornburg, S.W.: Absenteeism and voluntary turnover in central Florida hotels: a pilot study. Int. J. Hospitality Manag. **19**, 211–217 (2000)
9. March, J.G., Herbert, A.S.: Organizations, 2nd edn. Wiley, New York (1958)

10. Blau, G.J.: Relationship of extrinsic, intrinsic, and demographic predictors to various types of withdrawal behaviors. J. Appl. Psychol. **70**, 442–450 (1985)
11. Cheloha, R.S., Farr, J.L.: Absenteeism, job involvement, and job satisfaction in an organizational setting. J. Appl. Psychol. **65**, 467–473 (1980)
12. Steel, R.P.: Methodological and operational issues in the construction of absence variables. Hum. Resour. Manage. Rev. **13**, 243–251 (2003)
13. Chadwick-Jones, J.K., Colin, A.B., Nicholson, N., Sheppard, C.: Absence measures: their reliability and stability in an industrial setting. Pers. Psychol. **24**, 463–470 (1971)
14. MacDonald, C.: Understanding participatory action research: a qualitative research methodology option. Can. J. Action Res. **13**(2), 34–50 (2012)

An Analysis of Aptness and Comfort in Healthcare Units and Patient Safety in the Scope of Occupational Health and Safety

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Abstract Through data collected from the Portuguese National System of Health Quality Assessment (SINAS) for the dimensions Patient Safety and Aptness and Comfort in Healthcare Units a comparison was established between quality evaluation issues in Portuguese healthcare units and how these issues could affect healthcare workers' health and safety, at the same time is presented a methodology that enables to rank healthcare units for the dimension Patient Safety. The methodology proposed shows that, globally, the units need to improve their marks in that dimension. The main adverse events responsible for poor outcomes regarding Patient Safety are also presented. The work done points out a misty relation between the two quality dimensions assessed, showing the need of clearing some aspects related with the evaluation of the dimension Aptness and Comfort in Healthcare Units, though it was found that the most critical events related with healthcare workers' health and safety issues are linked with surgical processes.

Keywords Healthcare units · Health and safety · Quality

1 Introduction

Human errors and adverse events were pointed out as the main factors in patient safety in the last years. Organizational factors like fatigue and sleepiness in healthcare units affect patient safety [1]. The inverse relation is also true. Deficiencies in patient safety results also have a negative impact on healthcare

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workers. Work management, physical work environment, and the quality of health care services have effects on workers' performance, attitudes, job satisfaction, and health and well-being [2–4]. Accordingly to some researchers, healthcare systems must deviate from a "blame and shame" culture to a paradigm that facilitates learning from error [5]. The design of the healthcare system can impact patients and employees. Healthcare workers suffer several consequences from poor system design, such as job dissatisfaction, burnout, intentions to quit, reduced mental health, and injuries [6]. Healthcare workers' perception of being overwhelmed is a consequence of the number of emergency admissions, deaths on the ward and load of tasks performed. Risks of healthcare workers occupationally acquired infections from several fonts of exposure are object of many studies, and there are studies about the relationship between incidents like absenteeism, back injuries and needlestick, and patient incidents [2]. Research already developed in the area of patient safety, in particular, and in healthcare units' quality, in general, doesn't link those aspects to those related to health and safety in the healthcare sector.

The present work searches the relation between quality evaluation issues in healthcare systems in Portugal and how those issues are related to healthcare workers' health and safety. It is also presented a methodology that enables finding the main adverse events responsible for poor quality in patient safety outcomes and designing a scale to rank each healthcare unit for patient safety.

2 Data and Methodology

In Portugal, the promotion of an evaluation system for the global classification of healthcare units is done by the Portuguese Healthcare Regulation Authority (Entidade Reguladora da Saúde—ERS). The National System of Health Quality Assessment (Sistema Nacional de Avaliação em Saúde—SINAS) is a system created by the ERS which aims to assess health care providers in terms of global quality of services [7]. The dimensions of quality evaluate by this system are: Clinical Excellence, Patient Safety, Aptness and Comfort in Healthcare Units; Emphasis on the User and User Satisfaction [8]. Each healthcare unit is liable for the information provided, with periodically audition exerted by ERS.

In the scope of this work, data were collected from the SINAS@Hospitais web page (https://www.sns.gov.pt/home/sistema-nacional-de-avaliacao-em-saude-sinas/) regarding the dimensions Patient Safety [dimPatSafe] and Aptness and Comfort in Healthcare Units [dimACHU]

The evaluation process in the dimPatSafe is carried out by assessing adverse events through a set of indicators that reveal their evidence. The indicators are: Death in Low Mortality Diagnosis Related Groups; Pressure Ulcers from Stage III and IV; Nosocomial Infection (infection that is associated to central catheter insertion); Hip Fracture in post-surgical procedure; Haemorrhage or Hematoma in post chirurgical procedures with necessity of re-exploration; Nosocomial Infection (post-surgical sepsis); Wound Dehiscence and Perforation or Accidental Laceration [8].

The analysis of the global level of quality in these indicators (on a scale from I to III and for all the healthcare units that submit information) will make it possible to select those indicators which are more critical and to advise their consequences in health and safety of healthcare workers. Furthermore, each healthcare unit can get a ranking of quality (from I to III) in the dimPatSafe based on the individual level of quality of the referred indicators.

The dimension Aptness and Comfort is evaluated by SINAS through a check-list submitted online by each healthcare unit and under their responsibility. In the framework of Aptness, the check-list evaluates passageways and mobility; maintenance (equipment, flow nets, residuals management); fire safety auto protection measures, no clinical risks (entrances and departures control, surveillance and warnings). In the scope of Comfort are evaluated the internment areas, complementary zones (coffee shop, restaurants, toilets), thermic, acoustic and visual comfort, water and indoor air quality [8]. The subjects related to safety and hygiene at work are evaluated in this dimension, which is ranked by SINAS on a scale from I to III, based on a ratio of achievement of the requirements. In this dimension is only released a global ranking. There is not a public disclosure of the individual requirements just mentioned.

From the site SINAS@Hospitais, data were retrieved in the dimensions already referred that were submitted in the last evaluation process by 45 public Health Facilities with the status of EPE (Entidade Pública Empresarial—Public Enterprise). Only the units with answers in all the indicators of the dimPatSafe and with rating in the dimension Aptness and Comfort in Healthcare Units were studied. For those units, a database was constructed for the quality evaluation level (from I to III) in each of the eight indicators of the dimPatSafe and with the global evaluation level (also from I to III) in the dimACHU.

In a second stage, and for each indicator of the dimPatSafe, it was computed a ratio of quality (Quality Degree Ranking—QDR) that enables to measure the degree of quality in a parameter for all the healthcare units. This ratio of quality was obtained dividing the sum of the number of quality level found for the indicator, and for all the units, by the maximum quality level that the indicator might get (if all the units were evaluated with III). Thus, the degree of quality varies from 0 to 1, making it possible to rank the indicators in the dimPatSafe from the worst outcomes to excellent outcomes. However, this degree of quality by itself doesn't manage to detect smear deficiencies that can be revealed, for example, by parameters evaluated only with a quality level of two by all Health Facilities. Therefore, five criteria were used in the selection of critical indicators (or adverse effects), as those that can have a greater impact in Patient Safety issues in healthcare units as a whole: quality degree ranking, mode equal to I or II, more than 50% of ones and none three in global evaluation.

Since SINAS classification is for the individual adverse effects in each Health Facility and not for the full Patient Safety dimension, in a third stage, it was computed a QDR for each of the 45 evaluated Health Facilities and each one was evaluated from I to III in the dimPatSafe using the accumulated QDR value (ordered in a percentile scale) and the values of the mode and the mean computed with the evaluation levels of the indicators relative to Patient Safety got in SINAS.

In the last stage it was tried to establish a relationship between the rankings obtain for each Health Facility in the dimPatSafe and the dimACHU and, at the same time, identify the critical indicators (adverse events) in the dimPatSafe that, as a whole, are responsible for a poor evaluation in that dimension, with negative implications in healthcare workers' health and safety.

3 Results

Table 1 presents the results of the Quality Degree Ranking (QDR), modes, and number of I, II and III in the global evaluation of the 45 Health Facilities for the eight indicators included in the dimPatSafe.

As it can be observed in Table 1, the indicator with the worst result is Wound Dehiscence. Attending to the defined criteria to highlight and grade the most critical indicators concerning patient safety, the adverse conditions with a higher level of deficit in terms of quality evaluation (QDR < 50%), in an ordered form are: (i) Wound Dehiscence; (ii) Haemorrhage or hematoma in post-surgical procedures with necessity of re-exploration; (iii) Death in Low Mortality Diagnosis Related Groups (DRG); (iv) Nosocomial Infection (post-surgical sepsis); (v) Hip Fracture in post-surgical procedure.

Excluding "Death in Low Mortality Diagnosis Groups" these indicators are in their majority linked to surgical process.

Wound Dehiscence presents a mechanical failure of wound healing of surgical incisions. One of the causes of Wound Dehiscence is infection [9].

Diagnosis related groups are a system of classification of hospitalized patients that group patients in clinically coherent groups. Among these groups are defined

Table 1 Quality degree ranking and other statistics for adverse events

Adverse events	QDR	Mode	Counts of level I	Counts of level II	Counts of level III
Death in low mortality diagnosis related groups	0.43	I	33	13	0
Pressure ulcers from stage III and IV	0.98	III	1	1	44
Nosocomial infection (infection that is associated to central catheter)	0.98	III	0	3	43
Hip fracture in post chirurgical procedure	0.67	II	0	45	0
Haemorrhage or hematoma in post chirurgical procedures with necessity of re-exploration	0.39	I	38	7	0
Nosocomial infection (post chirurgical sepsis)	0.47	I	27	18	0
Wound dehiscence	0.33	I	45	0	0
Perforation or accidental laceration	0.99	III	0	1	45

conditions with a low mortality incidence, less than 0.5%, that are codified in a system of about 220 codes. These conditions have great variability, from bronchitis and asthma to syncope and collapse [10, 11]. A poor evaluation in this indicator is somewhat critical as it could point a noticeable number of misdiagnosis events.

Nosocomial Infections are ranked in fourth place (QDR ratio equal to 0.47). These are hospital-acquired infections that occur within 48 h of hospital admission, three days of discharge or 30 days of an operation. On average, a hospital-acquired infection results in patients staying 2.5 times longer in hospital. Gram-positive antibiotic-resistant bacteria are the more common cause of Nosocomial Infections [12].

In accordance to some authors, the strongest links between patient and worker health consequences are found in nosocomial transmission of infections via health care worker-related incidents (lack of handwashing, lapses in aseptic protocols). It was also found a strong relationship between the degree of stress and the occurrence of patient incidents, perhaps responsible for misdiagnosis events [2, 4]. Patients' Hip Fracture in post-surgical procedure increases the risk of worker lower back injuries and healthcare worker risk of infection and needlestick injury can be enhanced by Wound Dehiscence occurrences. Globally, as the majority of adverse events are linked to surgical practices, risk factors related to poor outcomes in patient safety that could be expected are infections and cuts.

Table 2 presents the evaluation (from I to III) computed for each of the 45 studied Health Facilities (comprehending: CH—Regional Health Centre, H—Central

Table 2 Evaluation of the dimensions patient safety and aptness and comfort in healthcare units for each healthcare facility

Healthcare facility	Mean	Mode	QDR	dimPatSafe Ranking	dimACHU Ranking
CH 1	2	I	0.667	I	II
CH 2	1.875	I	0.625	I	II
CH 3	1.875	I	0.625	I	III
CH 4	1.875	I	0.625	I	III
CH 5	2	I	0.667	I	III
CH 6	2	III	0.667	II	II
CH 7	2	III	0.667	II	II
CH 8	2	I	0.667	I	II
CH 9	1.875	I	0.625	I	III
CH 10	2	III	0.667	II	III
CH 11	2.125	III	0.708	III	II
CH 12	2.125	III	0.708	III	II
CH 13	2	III	0.667	II	III
CH 14	1.875	I	0.625	I	III
CH 15	1.875	I	0.625	I	III
CH 16	1.875	I	0.625	I	III

(continued)

Table 2 (continued)

Healthcare facility	Mean	Mode	QDR	dimPatSafe Ranking	dimACHU Ranking
CH 17	2	I	0.667	I	II
CH 18	1.75	II	0.583	I	III
CH 19	1.875	I	0.625	I	III
CH 20	1.875	I	0.625	I	III
CH 21	1.875	I	0.625	I	III
CH 22	1.875	I	0.625	I	III
CH 23	1.875	I	0.625	I	III
CH 24	1.875	I	0.625	I	III
CH 25	1.875	I	0.625	I	III
CH 26	2	III	0.667	II	III
CH 27	2	III	0.667	II	III
CH 28	1.875	I	0.625	I	II
CH 29	1.875	I	0.625	I	II
CH 30	1.875	I	0.625	I	II
H 1	2	I	0.667	I	III
H 2	2.125	II	0.708	III	III
H 3	2	I	0.667	I	III
H 4	1.875	I	0.625	I	III
IPO 1	2	II	0.667	II	III
IPO 2	1.875	II	0.625	I	III
IPO 3	1.875	II	0.625	I	III
ULS 1	2	I	0.667	I	III
ULS 2	2.25	II	0.75	III	III
ULS 3	2	I	0.667	I	I
ULS 4	2	I	0.667	I	I
ULS 5	2	II	0.667	II	III
ULS 6	2.125	III	0.708	III	III
ULS 7	2.125	III	0.708	III	III
ULS 8	2.125	III	0.708	III	III

Hospital, IPO—Portuguese Oncology Institute, ULS—Local Health Unit) in the dimPatSafe, using the mentioned methodology, as well as the mode and the mean of the evaluated indicators in each Health Facility and the rankings retrieve from SINAS for the dimACHU. The names of the Healthcare Facilities were omitted.

Among the 45 Healthcare Facilities studied and using the multi-criteria methodology proposed, 7 of them (15.6%) have an evaluation of III in the dimPatSafe and the majority of the studied Facilities (66.7%) has a poor evaluation (level I) in that dimension.

The correlation coefficient computed for dimPatSafe and dimACHU evaluation levels in Table 2 has a value of 0.07, meaning that it cannot be established a relationship between the rankings of those quality dimensions.

Examining the ranking values for dimACHU, it can be state that the majority (71.1%) of the studied Health Facilities has a ranking of III, meaning that the evaluation introduced by most Health Facilities in SINAS for this dimension is with intuit of fulfilling conformity in the respective evaluated indicators, where healthcare workers safety is included.

Whereas the majority of Health Facilities has poor outcomes in dimPatSafe they have good outcomes in dimACHU. This result is somewhat unexpected taking into account that the relationship between workers' safety and patient's safety results may be bidirectional [4]. However, he global nature of rankings disclosure in dimACHU doesn't show the individual evaluation for each of the involved parameters, namely, passageways and mobility, auto protection measures, complementary zones and thermic, acoustic and visual comfort, that may specifically lead to poor outcomes in dimPatSafe.

4 Final Remarks

The evaluation process of the Healthcare Facilities was carried out only in those units where information exists in the Diagnosis Related Groups Data Base, given by the Portuguese Health System Central Administration—Health Ministry (ACSS—Administração Central do Sistema de Saúde). ACSS provides anonymous data from exploration, omitting administrative data that enable the identification of the patient. Thus, the results obtained in ranking critical parameters related with patient safety don´t consider biographical data like age, gender, or primary health conditions, which could affect the ranked outcomes. However, adverse events like Wound Dehiscence and Hip Fracture can be connected with the age of the patient. Aged people are more prone to some sort of health conditions. Death in Low Mortality Diagnosis Related Groups is linked with a great diversity of medical conditions, and so, their consequences in healthcare workers' health and safety are much vague. Overall, the occurrence of critical adverse events parameters doesn't create new conditions for workers' health and safety besides those that are already known in healthcare sector, but they harsh some of them. To improve the study of the relationship between patient safety outcomes and healthcare workers' occupational risks, it would be necessary to construct and apply a survey to verify the consequences on workers of adverse events (that could be considered secondary injuries within the healthcare system) in the scope of patient safety.

Considering the evaluation of the dimPatSafe in each Health Facility according to the proposed methodology it may be referred that for the same QDR evaluation (0.667) there are some Health Facilities with mean II and mode I in the evaluation of adverse events and some Health Facilities with mean II and mode II or III in the evaluation of adverse events. For the first group, the evaluation level attributed was

I, while for the second group the assigned level was II. These criteria produced a greater number of I than of II (underrated) that could, somehow, also explain the lack of numerical relation between the evaluated dimPatSafe and dimACHU ranked by SINAS. Other possible explanation for the lack of numerical relation between the two above mentioned dimensions could be related with the way in which the factors involved in the last dimension are evaluated and perceive in the check-list (overvalued). As a matter of fact validation of evaluation constructs is a challenging subject.

As referred, and summing up, Patient Safety indicators with poor evaluation are related to surgical practices. Wound Dehiscence has the worst result, followed by Haemorrhage or Hematoma in post-surgical procedures with necessity of re-exploration and Mortality in DRG. Risks for healthcare workers related to poor results in those adverse events are infections. Surgical practices, treatment of wounds and contact with blood are the main activities that have a negative impact on healthcare workers' health and safety. Mortality in DRG can improve the degree of healthcare workers' stress. The majority of the Healthcare Facilities evaluated in this work (66.7%) has a poor outcome for the dimPatSafe (level I), having a great number of adverse events weakly evaluated. These last results are not directly related with the rankings in the dimACHU, because for this dimension, that includes subjects as maintenance and physical comfort, linked with workers' safety, the majority of the studied healthcare units have a ranking of III. Apparently, there is no relation between the adverse events in the dimension Patient Safety and the accomplishment of the items related with the dimension Aptness and Comfort in Healthcare Facilities. This result needs to be re-explored to know more details about the way in which the different facilities evaluate this last dimension. While events related with Patient Safety are well documented in ACSS, matters related with Units Aptness and Comfort have a more subjective evaluation, that vary with organizations safety culture and respondent perception, being an issue that requires further development and validation.

References

1. Brasaite, I., Kaunonen, M., Martinkenas, A., Suominen, T.: Health care professionals' attitudes regarding patient safety: cross-sectional survey. BMC Research Notes, pp. 9–177 (2016)
2. Lundstrom, T., Pugliese, G., Bartley, J., Cox, J., Guither, C.: Organizational and environmental factors that affect worker health and safety and patient outcomes. Am. J. Infect. Control **30**, 93–106 (2002)
3. Laschinger, H.K.S., Leiter, M.P.: The impact of nursing work environments on patient safety outcomes: the mediating role of burnout/engagement. J. Nurs. Adm. **36**(5), 259–267 (2006)
4. The Joint Commission: Improving Patient and Worker Safety: Opportunities for Synergy, Collaboration and Innovation. Oakbrook Terrace, IL. Retrieved from http://www.jointcommission.org/ (2012)
5. Nieva, V.F., Sorra, J.: Safety culture assessment: a tool for improving patient safety in healthcare organizations. Qual. Saf. Health Care **12**(Suppl II), ii17–ii23 (2003)

6. Carayon, P., Schoofs Hundt, A., Karsh, B.T., Gurses, A.P., Alvarado, C.J., Smith, M., Brennan, P.F.: Work system design for patient safety: the SEIPS model. Qual. Saf. Health Care **15**(Suppl I), i50–i58 (2006)
7. Entidade Reguladora da Saúde Homepage. https://www.ers.pt. Last accessed 23 Aug 2019
8. Serviço Nacional de Saúde. Sistema Nacional de Avaliação em Saúde Homepage. https://www.sns.gov.pt/home/sistema-nacional-de-avaliacao-em-saude-sinas/. Last accessed 20 Sep 2019
9. Spiliotis, J., Tsiveriotis, K., Datsis, A.D., Vaxevanidou, A., Zacharis, G., Giafis, K., Kekelos, S., Rogdakis, A.: Wound dehiscence: is still a problem in the 21st century: a retrospective study. World J. Emerg. Surg. **4**(12), 1–5 (2009)
10. Agency for Healthcare Research and Quality. Death Rate in Low-Mortality Diagnosis Related Groups (DRGs). Technical Specifications. Patient Safety Indicators #2 (PSI #2). AHRQ Quality Indicators, Version 4.5. Retrieved from https://www.qualityindicators.ahrq.gov/ (2013)
11. Administração Central do Sistema de Saúde. CIDES. Grupos de Diagnósticos Homogéneos. Retrieved from http://portalcodgdh.min-saude.pt/index.php/GDH (2011)
12. Inweregbu, K., Dave, J., Pittard, A.: Nosocomial infections. Continuing Educ. Anaesth. Crit. Care Pain **5**(1), 14–17 (2005)

Importance of the 5S Methodology to Occupational Safety and Health: A Case Study in a Branch of the Asia Commercial Bank in Vietnam

Trần Trúc Ngân Cao, Susana Costa and Paula Carneiro

Abstract Modern management in companies comprises not only the quality management system based on the ISO series 9000:2000 standards, but also the adoption of the Total Quality Management (TQM). In the implementation of the TQM, the concept of 5S is more and more common. The 5S methodology has become the topic of research in the recent times. Implementation of 5S results in immense benefits to the company. This goal of this research was to evaluate the importance of 5S methodology to occupational safety and health through a case study in Cu Chi Branch—Asia Commercial Bank in Vietnam. The bank has applied ISO 9001:2000 and the 5S methodology in the management process. Insight is provided into how the 5S has been implemented in ACB and the key factors on its successful 5S program in workplace occupational safety and health are revealed. It is the authors belief that implementation of 5S may be useful for organizations in creating a well-organized, safe and healthy workplace.

Keywords 5S · Workplace · Safety · Health

1 Introduction

The organization chosen for this study is a branch of Asia Commercial Bank (ACB) in Vietnam, located in Cu Chi District, Ho Chi Minh City. ACB is one of the biggest banks in Vietnam. The bank achieves sustainable competitive advantage through increased customer satisfaction and improved organizational performance.

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In recent years, ACB has received many awards from organizations inside and outside Vietnam, among of them was the Best domestic bank 2017 award from Asiamoney Magazine.

Modern management in companies comprises not only the quality management system based on the ISO series 9000:2000 standards, but also the adoption of the Total Quality Management (TQM). In the implementation of the TQM, the concept of 5S is more and more common. The 5S methodology first emerged following World War II, as part of the quality movement in Japan; the goal was to eliminate obstacles to efficient production [1]. The framework of 5S which the name comes from five Japanese words: Seiri (sort), Seiton (set), Seiso (shine), Seiketsu (standardize) and Shitsuke (sustain) was first formalized by Takashi Osada in 1980s and then developed by Hiroyuki Hirano in 1990s. The general concept of the 5S is that they are intended to eliminate waste. In literature review, the 5S practice was initiated in manufacturing and then extended to other industries and services. The Toyota Production System provides a well-known example of 5S principles in practice. Most Japanese 5S practitioners consider the 5S useful not just for improving their physical environment but for improving their TQM processes as well. Many everyday problems could be solved through applying this practice [2]. There are many examples of successful implementation of some principles of the 5S, especially in the service sector organizations, such as fast-food restaurants, supermarkets, hotels, libraries and leisure centers. The 5S has become the way of doing business, not only to impress the customers but to establish effective quality processes as preconditions for good products and services [3].

The 5S methodology has become the topic of research in the recent times. Implementation of 5S results in immense benefits to the company. Hirano [4] proposed that six main benefits can be obtained when 5S is successfully implemented: (1) product diversification; (2) high quality; (3) lower costs; (4) reliable deliveries; (5) improvement safety; and (6) higher availability rate. The contribution of strategic 5S program toward improving organizational climate and safety has been highlighted [1, 5]. Other researchers have proposed adding safety as a sixth "S" to the 5S methodology, thus creating 6S. Their reasoning is to create a dedicated step to safety to ensure it is not overlooked [6]. However, 5S process involves focusing on what can be done to eliminate risks, improving safety in work processes by arranging objects in certain ways. As a result, the 5S workplace is high in quality and productivity, keeps costs down, ensures delivery on time, is safer for people to work and is high in morale [3]. When performing the 5S appropriately, the outcome is a safe and healthy workplace. The successful 5S implementation requires commitment and involvement from both the top management and everyone in the organization and an efficiency guideline (regulation) to do 5S [7].

Below is a breakdown of each 'S' [4, 5, 8]:

Sort (Seiri): This is a process of sorting and clarifying all the tools, machinery and other materials in the work area and keeping only essential items. Items that do not belong to the area, damaged, broken or expired may be stored or discarded. It leads to fewer hazards and increasing safety and health by reducing the use of improper items or less clutter.

Set in order (Seiton): Keep needed items in the correct place to allow for easy and immediate search [4]. There must be a place for everything, and everything must be in its place. Tools, equipment, and materials must be systematically arranged for easy access, thus improving ergonomics, health for employees and decreasing safety hazards such as fire hazard or electric hazard.

Shine (Seiso): Clean up the workplace and make it “shine”. At a clean worksite without garbage, dirt and dust, problems can be more easily identified (leaks, spills, excess, damaged machines, etc.) It includes cleaning and caring for equipment and facilities and inspecting them for abnormalities. At the end of each day, the work area is cleaned up and everything is restored to its place. Create a good housekeeping routine will inevitably resolve safety concerns, reduce hazards and bring a healthy environment.

Standardize (Seiketsu): Set up standards for a neat, clean and healthy workplace by developing procedures to maintain and monitor the first three S. By revising the previous three S, one can evaluate how well they are being maintained as well as their effectiveness. It is perhaps the most effective step in enhancing a proactive safety program and healthy environment at the workstation.

Sustain (shitsuke): This last step is about “discipline”. Make a habit of maintaining established procedures. It helps keeping a clean, healthy and safe workplace in a long term, increasing employee morale and creating an organizational culture.

This paper is aimed at revealing the importance of 5S methodology to occupational safety and health through a case study in Cu Chi Branch—Asia Commercial Bank in Vietnam. The bank has applied ISO 9001:2000 (and, more recently, ISO 9001:2015) and the 5S methodology in the management process. This paper will provide the insight into how the 5S has been implemented in ACB and reveal the key factors on its successful 5S program in workplace occupational safety and health. It is the author’s belief that implementation of 5S may be useful for organizations in creating a well-organized, safe and healthy workplace.

2 Methodology

The methodology used in this study was qualitative research in which the method of data collection was based on participant observation and interview with a case study in a Branch of ACB—Cu Chi Branch from December 2018 to January 2019.

The observation in this study was carried out at the workstation with photographic record collection provided by the staff of Cu Chi branch to evidence the organizational performance.

Document analysis was used to evaluate the regulation about the 5S program and its contribution in applying 5S. The chosen document was “WI-01/5S Instruction for implementing the 5S program”, issued on 29 March 2017 by ACB.

The case study was also based on semi-structured interviews. The interviews were set up over the telephone with Vice-Director who is responsible for 5S program in the branch and six employees chosen randomly from difference departments. The main topics in the interview with the Vice-Director were: the time applied 5S in the branch; how the manager's concern in 5S; how 5S applied; training programs and documents; main obstacles in applying 5S and factors determine the successful 5S program based on their point of view. In the interviews with employees, the main topics were: their seniority; whether they were trained 5S or not; the frequency of doing 5S; their opinion about the 5S regulation, obstacles and benefits in doing 5S based on their point of view. The interviews were conducted with recording at the end of the working-day for about three to five minutes each, giving the respondents freedom and comfort to speech.

3 Results and Discussion

The observation of the photographic records presented the 5S performance in the Cu Chi branch. Although the branch is being repaired to update to a new brand image of ACB, the branch is still in a good working condition, maintaining cleanness and a healthy environment.

Figure 1 shows an individual desk at the end of working day.

Figure 2 shows file cabinets. The necessary and unnecessary materials available in the workplace were sorted and classified (the first S—sort). Paper files and items were set in order and labeled systematically (the second S—set in order). The desk was clean, without dirt and garbage (the third S—shine). By doing the three first S, occupational health was improved. All items in order with easy access reduced walking and searching. Workers did not have to spend extra time finding objects with less clutter.

Figure 3 was taken under an individual desk. At every worksite, cables and wires were tied neatly; there was not any unnecessary item near the sockets (the second S—set in order). It helped to improve organizational safety by preventing electrical hazards, which can cause serious injury for employees and customers.

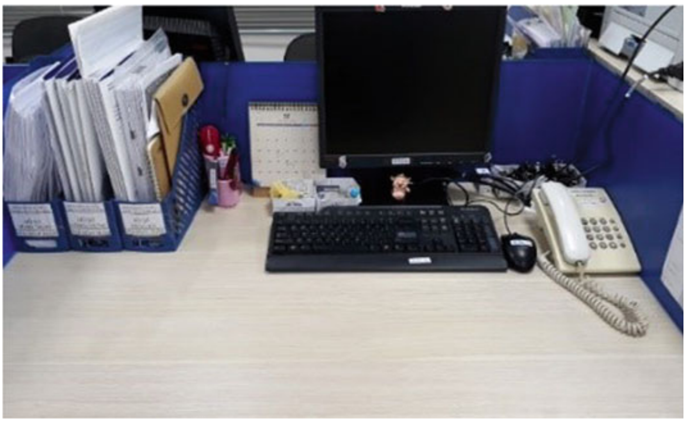

Fig. 1 Individual desk

Fig. 2 File cabinets

Fig. 3 Under an individual desk

Figure 4 shows the Customer Service's room which was airy and cleaned up without garbage, dirt and chairs in line (the second S—set in order and the third S—shine). It led to ensure workplace hygiene, eliminate tripping and falling hazards, which result from an unordered floor with garbage, water or other objects.

Document analysis focused on the regulation "WI-01/5S Instruction for implementing the 5S program," [9] issued on 29 March 2017, the only document related to 5S. This document establishes standards and regulations of the 5S program, which enhances a proactive safety program and illustrates for the fourth S—standardize. It proven to be very efficient, clear and easy to understand. In the interview, the Vice-Director assumed that this document was easy to apply because it set up a detailed and specific guideline to help employees know how to create a healthy environment and prevent safety hazards. In the branch, the document was used to guide employees in doing 5S. Five employees in the interview thought it was clear

Fig. 4 The customer service's room

and easy to understand while one presumed need to read carefully to practice sufficiently. The employees know exactly what to do and their responsibilities. The regulation contributed a procedure to implement and maintain the 5S program in its branch and department involving the responsibility of directors. It ensured the involvement of both managers and employees, which is a key factor in a successful 5S implementation. This is evidenced in part four of the WI-01/5S: "the duration for directors implements the 5S program at their branch is one month after the branch was formed or relocated"; "Directors assign a control team responsible for 5S to maintain 5S practice; Director and the control team guide employees through 5S procedure at the workstation based on the instruction in WI-01/5S; Director and the control team build a 5S work assignment covering all employees and all the workplace in a branch." The instruction was set specifically in each step of 5S: sort, set in order, shine, standardize and sustain. Besides efficiency and productivity at the workplace, steps of 5S also aim at building a healthy and safe workplace. This is evidenced in the Guideline for practicing 5S at worksite and in organization of the WI-01/5S. In the first S—sort: "classify documents, folders, newspapers…; label damaged machines…" it could increase safety by preventing the use of damaged machines which can cause electrical hazards. In the second S—set in order: "arrange working zone neatly, in order; tie neatly wires, cables; ban putting articles, paper files near machines, plugs; ban putting unnecessary materials in a server room…" it led to improve health and safety. Tools, material and documents will be easily accessible, avoiding unnecessary movements and actions, thus reducing fatigue and stress. Electrical hazards which may result in fire also could be prevented with frequent checks for wires, portable electrical tools and a server room. In case of incident or accident, in an ordered workplace, employees could identify quicker access to alarm or rescue equipment such as fire-fighting equipment and clear escape routes. In the third S—shine: "ensure a cleanness workplace without garbage, spill, leak…, maintain clean and hygienic toilets…”, it led to identifying hazards and prevent slips, trips and falls in the workplace and creating an airy, clean environment. There was also a 5S control team in the headquarter together with one inside a branch responsible for the routine inspections of usage of the 5S rule, regulated at part 4 and 5 in the WI-01/5S. Accordingly, the inspection was executed by resorting to a check list and evaluation was carried out by score frame in part 5 of the WI-01/5S. The control team inside the branch executed the inspection at least once a month, and the one in the headquarters did at least one inspection per trimester. It ensures each branch complies with the standards and maintains a clean, safe and healthy workplace as well as increased the awareness of employees.

The results of the manager’s interview showed that the Cu Chi branch had been applying 5S for over ten years. The managers paid concern to implementing the 5S program: the Vice-Director is mainly responsible for the implementation of 5S, whilst he supervises the employees’ performance on 5S in person, and guides newcomers in implementing 5S. The manager played an important role in a successful 5S program. All employees were trained at ACB’s training center, through an e-learning program or by the Vice-Director. The Vice-Director assumed 5S brought many benefits to the entity, especially in achieving a clean and healthy environment for employees and customers and eliminating fire hazards. Bank officers usually deal with many customers, with a significant workload every day. By implementation of 5S, a free-clutter workplace was created which helped employees reduce walk and search, through easy to get access with the needed items. Proper equipment was used which helped to reduce the downtime due to malfunction, accordingly reduce pressure and stress for employees in peak time. Better hygienic conditions in a clean environment led to improved health for employees. With frequent check in potential hazards namely fire or explosion resulting from portable electrical equipment, safety could be enhanced. The manager presumed that the obstacles in implementing 5S are training employees and making their habit in maintaining 5S. According to her, the main factor for a successful 5S program is the employees’ perception and the manager’s commitment.

The interview with employees was made with six subjects from different departments. They have different seniority from six months to eleven years. Results of the question on whether they are trained at 5S practicing shows that there were two juniors trained at the ACB’s training center in apprenticeship and four seniors trained through an e-learning program. All the interviewees appreciated the benefits of 5S in keeping a clean workplace and increasing efficiency. Three of them perceived the importance of doing 5S in creating a safe workplace and eliminating safety hazards while one interviewee’s answer did not converge in this aspect. In daily tasks, an ordered workplace helped them reduce the loss of material and downtime due to search of objectives and equipment malfunction, avoid unnecessary movements and actions. Rather, a clean environment led to improved heath. Accordingly, fatigue was reduced and employers felt more comfortable and less stressed. Finally, although four of them still had some difficulties, at first, in sorting and arranging, all of them perceived the need of practicing 5S to maintain a high standard workplace. They were satisfied with the outcomes of 5S and considered doing 5S daily as their habit, which is the fifth S—Sustain in 5S.

4 Conclusions

In sum, the authors conclude that the 5S methodology has an importance in occupational safety and health. Tools, equipment, and materials are systematically arranged for easy access lead to improve ergonomics, reduce fatigue due to search of items and equipment malfunction. Frequent checks of portable electrical facilities eliminate fire and explosion hazards. A workstation without garbage, dirt, water, spill, leak and free-clutter decrease trip and fall hazard, helps employees identify quicker access to alarms, communication signals, rescue equipment and clear escape routes in case of accident. The 5S methodology can be easily applied in all organizations due to its simplicity and easy recognition. Although the results of the application were obtained rapidly, it sustained implementation requires increasing the sense of responsibility and making it as an employees' habit and organizational culture.

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References

1. Becker, J.E.: Implementing 5S to promote safety and housekeeping. Prof. Saf. **46**, 29–31 (2001)
2. Ho, S.K.: 5s practice: the first step toward total quality management. Total Qual. Manag. Bus. Excell. **10**(3), 345–356 (1999)
3. Ho, S.K.: Workplace learning: the 5S way. J. Workplace Learn. **9**(6), 185–191 (1997)
4. Hirano, H.: 5 pillars of the visual workplace: the sourcebook for 5S implementation (Talbot, B., Trans.). Productivity Press, New York (1995)
5. Michalska, J., Szewieczek, D.: The 5S methodology as a tool for improving the organization. J. Achiev. Mater. Manuf. Eng. **2**(24), 211–214 (2007)
6. Marria, P., Williams, S.J., Naim, M.: Six S: creating an efficient and safer work environment. Total Qual. Manag. **25**(12), 1410–1428 (2014)
7. Singh, A., Ahuja, I.S.: Review of 5S methodology and its contributions towards manufacturing performance. Int. J. Process Manag. Benchmarking **5**(4), 408–424 (2015)
8. Osada, T.: The 5S's: five keys to a total quality environment. Quality Resources (1991)
9. Asia Commercial Bank: WI-01/5S instruction for implementing the 5S program (2017)