Joana Cunha
Ana Cristina Broega
Helder Carvalho
Bernardo Providência *Editors*

Advances in Fashion and Design Research II

Proceedings of the 6th International Fashion and Design Congress, CIMODE 2023, October 4–6, 2023, Mexico City, Mexico

Springer

Advances in Fashion and Design Research II

The Importance of Comfort in Sport Caps Through Subjective Assessment in Real Weather Conditions

Rosimeiri Naomi Nagamatsu[1](✉), Maria José Abreu[2], Cosmo Damião Santiago[3], Debora Mizubuti Brito[1], and Marcio Roberto Ghizzo[4]

[1] Fashion Design Department, Federal University of Technology – Paraná, Campus Apucarana, Apucarana, Brazil
naomi@utfpr.edu.br
[2] 2C2T, Textile Engineering Department, Minho University, Braga, Portugal
[3] Mathematics Department, Federal University of Technology – Paraná, Campus Apucarana, Apucarana, Brazil
cosmo@utfpr.edu.br
[4] Humanities Department, Federal University of Technology – Paraná, Campus Apucarana, Apucarana, Brazil
marcioghizzo@utfpr.edu.br

Abstract. This article aims to present the results of the investigation of the perception of the comfort properties of sports caps through wear trial in real weather conditions in an uncontrolled environment. The sensations of general comfort, temperature, humidity and the pressure that ten samples of sports caps exert on the head of ten volunteers during subjective assessment were evaluated. The two-way ANOVA statistical tool was used for statistical data analysis. Volunteers assigned very low averages to the affective ratings of the sports cap samples. This may indicate the volunteers' difficulty in judging the attributes when the caps are worn on the head. In future research, it is intended to compare the data obtained in this study with the data obtained in tests of use carried out in an environment of controlled temperature and humidity.

Keywords: Textile Comfort · Wear Trial · Sports Caps · Textile Attribute · Subjective Evaluation

1 Introduction

The clothing microenvironment is the space between the clothing and the skin. If clothing is a dynamic microenvironment, then how do you make that microclimate pleasant?

In large urban centers in southern Brazil, the occurrence of thermal amplitudes is very common, which can vary between 10° and 20 °C. Brazilians usually call this phenomenon "the four seasons of the day" and, in order to regulate the temperature of their microenvironment, in the morning they are wrapped up and, as the temperature

J. Cunha et al. (Eds.): CIMODE 2023, *Advances in Fashion and Design Research II*, pp. 173–182, 2024.
https://doi.org/10.1007/978-3-031-43937-7_15

rises, they take off the layers of clothing in an attempt to provide comfort to the body. Controlling the thermo-physiological properties of clothing during changing weather conditions is one of the factors that can contribute to thermos-physiological balance.

When studying microclimate issues related to clothing comfort, [1, 2] and [3] cite that, for [4], it is necessary to meet four fundamental aspects to achieve the total clothing comfort: ergonomic comfort, psychological comfort, thermo-physiological comfort and sensory comfort. Each of these aspects is formed by a set of factors/attributes that influence the performance of the garment.

Given the above, this article is focused on investigating the perceptions of the comfort properties of sports caps through subjective evaluation of use in real weather conditions in an uncontrolled environment.

1.1 Thermos Physiological Comfort

One of the functions of clothing is to protect the user from cold and heat, thus, heat transfer is one of the factors that help maintain the thermos-physiological balance, or, in some cases, that make it difficult for sweat to evaporate from the skin [5, 6] confirmed in their studies that a large part of total comfort is related to thermos physiological comfort.

Thermo-physiological comfort is defined by the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 55–66 and ISO 7730:2005 as "the mental condition in which man expresses satisfaction with the thermal environment" [7]. It is also defined as a state of comfort in thermal and humidity terms, which involves the transport of heat and water vapor through clothing. People reach this comfort state when they don't need to put on or take off clothes to be satisfied with the temperature.

The microclimate created by clothing encompasses the temperature, humidity and air velocity between the body and clothing. For [8], the microclimate considered comfortable for the user is 32 ± 1ºC for skin surface temperature, $50 \pm 10\%$ for relative humidity and 0.25 ± 0.15 m/s for air velocity.

Many tests are available to measure the thermo-physiological comfort of clothing and can be performed using instruments (objective evaluation) or through wear trials with volunteers (subjective evaluation). For [9] measuring thermal comfort is highly complex, as the perception of thermal comfort by the user is affected by several parameters such as temperature and air movement, humidity, types of clothing, activity levels, radiant temperature, among others.

Investigations on thermo-physiological comfort are focused on subjective assessments of clothing, in which researchers usually use data from wear trial carried out in climate-controlled indoor environments. In open spaces, however, the difficulties lie in the "low control of temperature and humidity variables due to the transport of mass and energy provided by the action of the winds" [10].

2 Materials and Methods

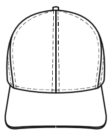
As a way of approaching the research question and the proposed objectives, the methodological procedures used are explanatory research, based on experimental procedures and applications of qualitative and quantitative analysis.

In this investigation, in evaluations of aspects of thermo-physiological comfort, the explanatory method experimentally collects data from subjective and instrumental evaluations of the relationship between the user and the clothing on the properties of thermo-physiological comfort during wear trial.

The application of surveys to obtain subjective and instrumental responses is carried out from a protocol, where the comfort of the cap is evaluated by the user through tests of use in real weather conditions. For this, a group of 10 evaluators were recruited in Brazil, who evaluated 10 different models of caps in 10 different tests in an external area of the University Campus of the Federal Technological University of Paraná, in real and uncontrolled climatic conditions, that is, in real conditions: temperature at 25.6 °C (±2 °C) and humidity at 74% (±5%) during the month of December.

The raw materials used to make the caps to be tested are five types of fabric used by the cap industries in Apucarana – Brazil, plus three in wool, in addition to the inclusion of a sample from Portugal (laminated cork), totaling nine samples. Of these nine samples, ten different caps were produced, five in the baseball model (Table 1), namely B1 (100% CO), B2 (100% CO), B4 (100% WO), B6 (65% PES/ 35% WO) and B8 (100% CORK and 100% PES), and five in the snapback model (Table 2), caps B3 (100% CO), B5 (65% PES and 35% WO), B7 (100% CORK), B9 (100% CORK and 100% PES) and B10 (100% PES).

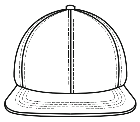
Table 1. Baseball caps samples

	Samples	B1	B2	B4	B6	B8
 Basebol Model	Composition	100% CO	100% CO	100% WO	65% PES 35% WO	Cork 100% PES
	Mass per unit area (g/m^2)	294	197	248	215	Cork 321 PES102
	Thickness (mm)	0,718	0,456	0,696	0,6	0,546
	Water vapour resistance (Pa/m^2/W^{-1})	4,2	2,88	4,48	3,22	Cork 36,5 PES -0,8
	Air Permeability (l/m^2/s)	72,4	81,8	215,6	0,6	-

It is not common to use 100% polyester warp knitting on the front of the caps, so in order to explore cork, a material rarely used in the development of caps in Apucarana/Brazil, two samples were made with two different raw materials - the front in cork and the sides and back in 100% polyester warp knitting, namely sample B8 in the baseball model and B9 in the snapback model.

The wear trial lasted 30 min and was divided into 3 phases, as shown in Table 3. In the first phase, the volunteers sat down for 5 min at rest to adapt to the weather conditions. Phase 2 was divided into two parts: first, the volunteer pedaled the ergometric bicycle at a moderate speed of 10 to 14 km/h for 15 min; and then at an intense speed of 15 to 30 km/h for 5 min, with the speed being monitored every minute. In the last phase, the volunteers

Table 2. Snapback caps samples

	Sample	B3	B5	B7	B9	B10
 Snapback Model	Composition	100% CO	65% PES 35% WO	100% Cork	100% Cork 100% PES	100% PES
	Mass per unit area (g/m2)	378	197	321	Cork 321 PES 102	430
	Thickness (mm)	0,756	0,448	0,748	Cork 0,748 PES 0,546	0,708
	Water vapour resistance (Pa/m2/W-1)	5,38	2,44	36,5	Cork 36,5 PES 0,8	5,6
	Air Permeability (l/m2/s)	45,67	178,6	-	45,67	138,2

remain seated at rest for another 5 min. At the end of each phase, the volunteers are photographed with an infrared camera and answer the questionnaire. Every 5 min, the heart rate and Peripheral Oxygen Saturation are recorded, with the aid of the oximeter, and the pressure that the cap exerts on the volunteer's head, with the pressure sensor.

Table 3. Phases of wear trial test.

Phases	Position	Activity	Time	Descriptions
Pre-test		Resting	5 minutes	At this stage you will be seated resting
Exercise		Low velocity	15 minutes 10 a 14 km/h	At this stage you will exercise on the bike.
		High velocity	5 minutes 15 a 20 km/h	
After-Exercise		Resting	5 minutes	At this stage you will be seated resting

The ISO 10551 standard – Ergonomics of the thermal environment–Evaluation of the influence of the thermal environment using subjective judgment scales [11] presents 3 types of scales for subjective judgment: perception scale, affective evaluation scale and preference scale. These scales were adapted for data collection.

The perception scale was used in this work to assess thermal comfort, as shown in Table 4.

Affective rating scales were used to rate sensations of humidity, general comfort, the pressure that the cap exerts on the head and the attributes: weight, thickness, roughness,

Table 4. Perception scale to assess thermal comfort

Attribute	Scale						
Thermal Sensation	–3 Very cold	–2 Cold	–1 Cool	0 Natural	1 Warm	2 Hot	3 Very Hot

stiffness and itching, as presented in Table 5. The attributes were extracted from the list of attributes developed by [12] and [13].

Table 5. Attribute affective assessment scale

Attribute	Scale				
Humid sensation	0 Dry	1 Less dry	2 Slightly wet	3 wet	4 Very wet
Comfort sensation	0 Comfortable	1 Slightly comfortable	2 uncomfortable	3 Very uncomfortable	4 Extremely uncomfortable
Pressure sensation	0 No	1 Slightly	2 Neutral	3 Very	4 Extremely
Weight sensation	0 No	1 Slightly	2 Neutral	3 Very	4 Extremely
Thickness sensation	0 No	1 Slightly	2 Neutral	3 Very	4 Extremely
Rough sensation	0 No	1 Slightly	2 Neutral	3 Very	4 Extremely
Stiffness sensation	0 No	1 Slightly	2 Neutral	3 Very	4 Extremely
Itches Sensation	0 No	1 Slightly	2 Neutral	3 Very	4 Extremely

Two-way ANOVA with repetitions was conducted for statistical analysis of the data, with the aim of identifying differences between the samples, and using the Pairwise Comparison Method, the sample averages were compared pairwise in relation to each attribute.

The SIDAK correction was used as a complement to the analysis of variance, as it performs each test within a limited significance level to ensure that the false-positive rate applied to the test set does not exceed the specified value [14, 15 and 16]. The mean difference is significant at the 0.05 level, that is, if $p < 0.05$ there are differences between samples and if $p > 0.05$ there are no differences between samples. For the treatment of the data collected, the SPSS software was used.

Because it is a research involving human beings, the experimental protocols of this project were submitted to the Ethics Committee in Research involving Human Beings of UTFPR - Federal University of Technology of Paraná, with registration CAAE 45651115.5.0000.5547.

3 Results

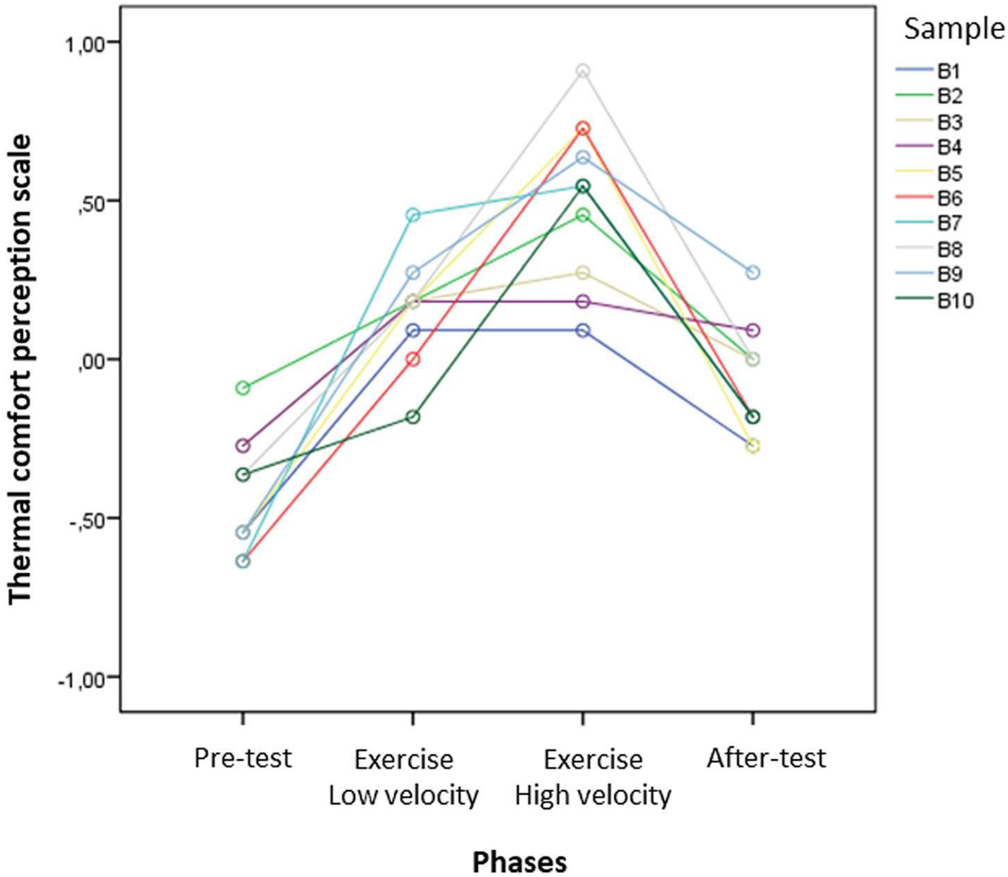
Tests for use in real weather conditions were conducted in the external areas of the Federal University of Technology of Paraná Campus Apucarana during the month of December. The temperatures recorded during the tests were 21 °C minimum and maximum 29 °C, relative air humidity between 72% and 95% and air speed from 0 to 4 m/s.

Volunteers were recruited on UTFPR premises and are students and people from the local community. The tests were scheduled according to the volunteers' availability, so that the tests would not compromise the volunteer's routine.

In tests in external environments under real weather conditions, oxygen levels among volunteers did not differ significantly, and heart rate, thermal sensation and humidity sensation accompanied the rhythm of physical activities from wear trial.

Regarding the thermal sensation, the samples did not show significant differences in their averages, but some showed differences between the phases of the wear trial. It was possible to verify that some samples presented the same behavior, having been, in this way, grouped. Samples B1 (100% CO), B2 (100% CO), B3 (100% CO), B4 (100% WO) and B10 (100% PES) did not show significant differences between phases. The means of samples B5 (65% PES/ 35% WO) and B8 (100% CORK and 100% PES) show that the thermal sensations suffered a gradual increase until the phase of intense activity and, in the last phase, a rapid cooling, not differing from the means of the pre-test. In samples B6 (65% PES/ 35% WO) and B9 (100% CORK and 100% PES), the thermal sensation had a gradual increase until the phase of intense activity and, in the last phase, the volunteers judged that the thermal sensations were similar to those of the moderate activity phase. With regard to sample B7 (100% CORK), the volunteers felt that the head temperature rose more quickly during moderate physical activity, which remained stable at the end of intense physical activity, and felt a slight cooling in the post-test.

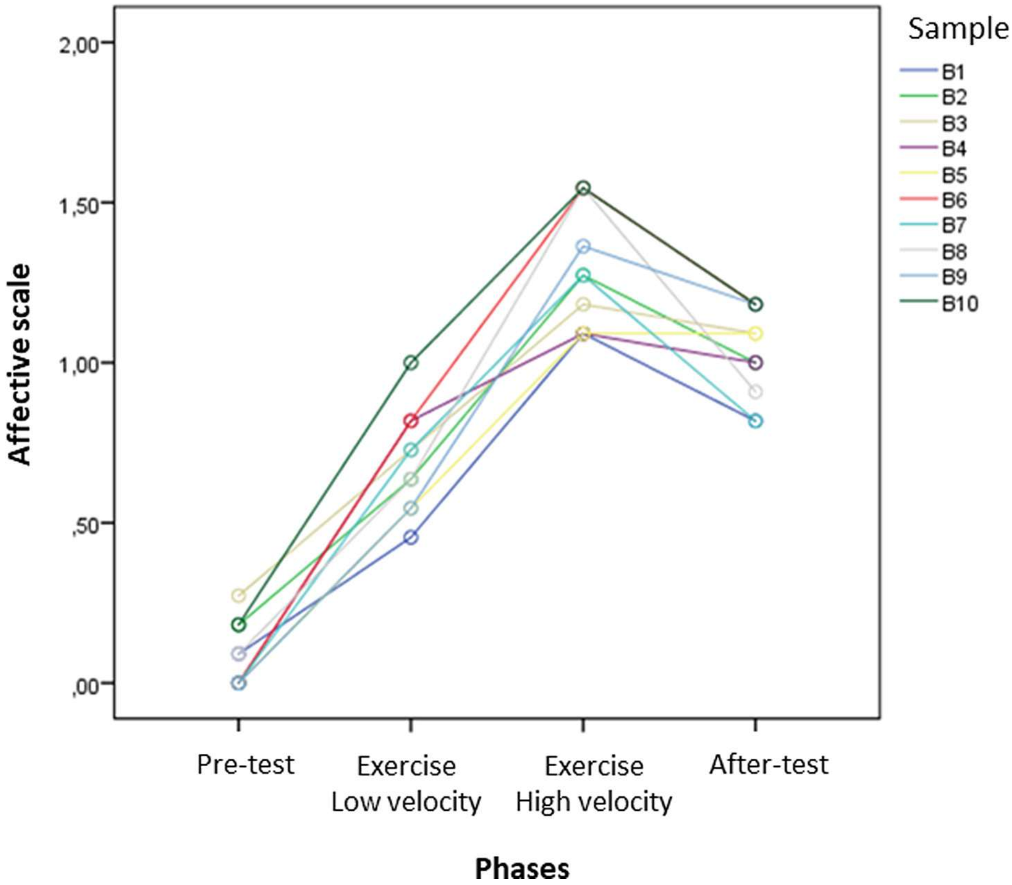
For the purposes of a better understanding of the data, it was verified that the equality between the variances of the samples demonstrates that there is no sudden change in the thermal sensation. Considering that the averages closest to the zero axis are ideal for the sensation of thermal comfort, it is assumed that samples B3 (100% CO) and B4 (100% WO) are the ones with the best thermal performance, suffering an increase in the sensation of heat at the beginning of the physical activities and remaining homogeneous until the end of the test, while the worst are samples B5 (65% PES / 35% WO), B6 (65% PES / 35% WO) and B8 (100% CORK and 100% PES), as shown in Graph 1.



Graph 1. Averages of thermal sensations in real weather conditions.

Graph 2 illustrates the averages of the sensations of humidity perceived by the volunteers. In the pre-test, samples B4 (100% WO), B5 (65% PES/ 35% WO), B6 (65% PES/ 35% WO), B7 (100% CORK) and B9 (100% CORK/100% PES) were judged by the volunteers as dry and sample B3 (100% CO) as the least dry. In the moderate physical activity phase, sample B1 (100% CO) was the driest and B10 (100% PES) the least dry. In the phase of intense physical activity, samples B1 (100% CO), B4 (100% WO) and B5 were considered by the volunteers as the least humid and samples B6 (65% PES and 35% WO) and B10 (100% PES) as the most humid.

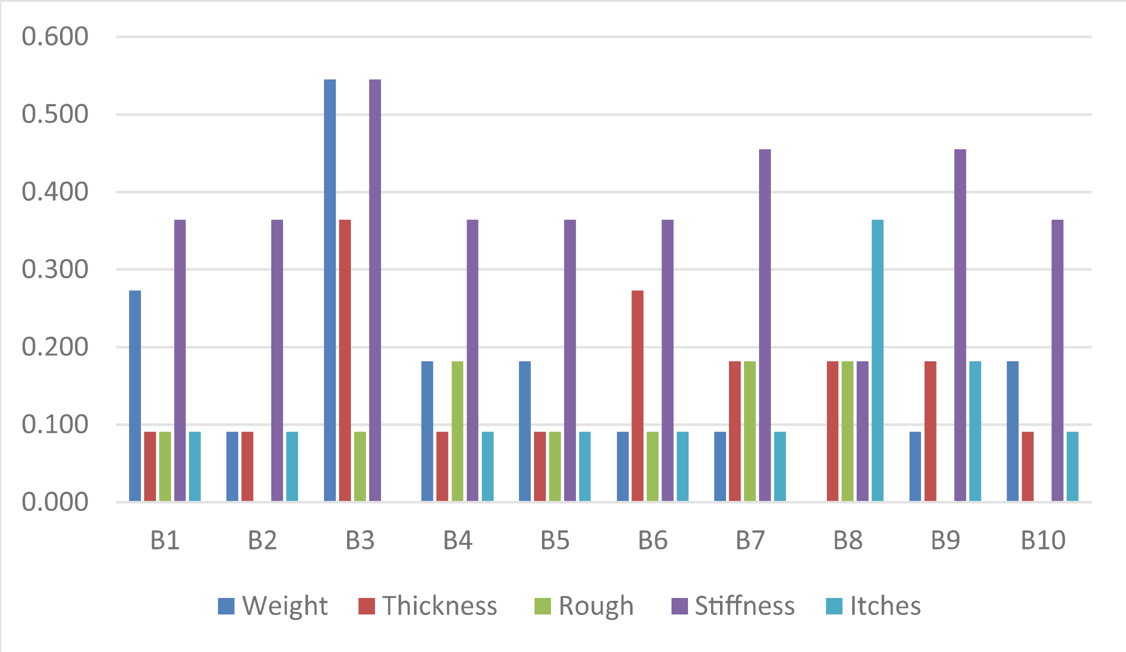
In the post-test, samples B1 (100% CO) and B7 (100% CORK) were the least humid and samples B6 (65% PES and 35% WO), B9 (100% CORK and 100% PES) and B10 (100% PES) were the wettest. In general, sample B1 (100% CO) was judged by the volunteers as the driest and sample B10 (100% PES) as slightly wet, according to the affective scale.



Graph 2. Average humidity sensations in real weather conditions.

In Graph 3, the means of the affective evaluation of the attributes did not show significant differences. In the weight attribute, the volunteers did not feel the weight of sample B8 (100% CORK and 100% PES), in turn, sample B3 (100% CO) was judged as the heaviest. In the thickness attribute, samples B1 (100% CO), B2 (100% CO), B4 (100% WO), B5 (65% PES/ 35% WO) and B10 (100% PES) were considered the thinnest and B3 (100%CO) is the thickest. The volunteers did not feel rough samples B2 (100% CO), B9 (100% CORK and 100% PES) and B10 (100% PES), samples B4 (100% WO), B7 (100% CORK) and B8 were considered the roughest and B2 (100% CO), B9 (100% CORK and 100% PES) and B10 (100% PES) the least rough. Regarding the stiffness attribute, sample B8 was considered by the volunteers to be the least stiff and B3 (100% CO) to be the stiffest. The volunteers felt no itching in sample B3 (100% CO) and sample B8 (100% CORK and 100% PES) felt itchier.

Sample B1 (100% CO) performed better in thermal sensation and humidity, sample B3 (100% CO) in general comfort and sample B6 (65% PES/ 35% WO) in pressure sensation. The evaluators pointed to sample B8 (100% CORK and 100% PES) as the warmest, B10 (100% PES) as the most humid and B7 (100% CORK) with the worst performance in the feeling of general comfort and pressure.



Graph 3. Sensory profile of cap samples in real weather conditions.

4 Final Considerations

The main objective of this article was to present the results of the investigation on the perceptions of the comfort properties of sports caps through a test of their use in real climatic conditions in an uncontrolled environment.

It was observed that the volunteers assigned very low averages to the cap samples (0 to 0.6). This may indicate difficulty in judging these attributes when worn.

The application of the evaluation of the comfort of sports caps was carried out with volunteers. In this way, other investigations can be carried out with users of caps, as well as with athletes who wear caps during competitions, such as: skateboarders and baseball players during sports and during long periods of time.

Acknowledgments. To the Araucária Foundation (Support for Scientific and Technological Development of Paraná) through CP20/2013, Doctoral Program in Textile Engineering in Partnership with a Foreign Institution (UMINHO/UEM/UTFPR).

To the Federal Technological University of Paraná (UTFPR), and Directorate of Research and Graduate Studies (DIRPPG).

This work was funded by FEDER through - COMPETE and by national funds through FCT - Foundation for Science and Technology under the project UID/CTM/00264/2021.

References

1. Abreu, M.J.A.M.:. Contribuição para o estudo da parametrização de têxteis hospitalares. Universidade do Minho (2004)
2. Broega, A.C. da L.: Contribuição para a Definição de Padrões de Conforto de Tecidos Finos de Lã. Universidade do Minho (2007)

3. Broega, A., Silva, M., Silva, R.: A neural network approach in the sensorial comfort of wool light fabrics by subjective and objective evaluation (2010). http://repositorium.sdum.uminho.pt/handle/1822/19255
4. Slater, K.: Subjective textile testing. J. Text. Inst. **88**(2), 79–91 (1997). https://doi.org/10.1080/004050009708658532
5. Das, A., Alagirusamy, R.: Science in Clothing Comfort. New Delhi: Wooldhead Plubishing India Pvt. Ltd. (2010b)
6. Stanković, S.B., Popović, D., Poparić, G.B.: Thermal properties of textile fabrics made of natural and regenerated cellulose fibers. Polym. Testing **27**(1), 41–48 (2008). https://doi.org/10.1016/j.polymertesting.2007.08.003
7. ISO, (2005). ISO 7730 - Ergonomics of the thermal environmet - Analytical deermination an interpretation of thermal comfort using calculation of the PMV an PPD indices and local thermal comfort criteria
8. Das, A., Alagirusamy, R.: Introduction of clothing comfort. In: A. Das and R. Alagirusamy, eds. science in clothing comfort. [online] New Delhi: Wooldhead Plubishing India Pvt. Ltd, pp.1–12 (2010a). https://doi.org/10.1533/9780857092830.1
9. Abreu, M.J., Catarino, A.P., Cardoso, C., Martin, E.: Effects of sportswear design on thermal comfort. AUTEX 2011 World Textile Conference, [online] (June), pp.50–55 (2011). http://repositorium.sdum.uminho.pt/handle/1822/15155
10. Monteiro, L.M.: Modelos preditivos de conforto térmico: quantificação de relações entre variáveis microclimáticas e de sensação térmica para avaliação e projeto de espaços abertos. Universidade de São Paulo (2008)
11. ISO, (1995). ISO 10551- Egonomic of thermal evironment - Assessment of the influence of the thermal evironment using subjective judgement scales
12. Nagamatsu, R.N., Abreu, M.J., Santiago, C.D.: Tactile feeling of textile: a comparative study between textiles comfortable attributes of France, Portugal and Brazil. In: FIBER SOCIETY, ed. FIBER SOCIETY (2017)
13. Nagamatsu, R.N., Abreu, M.J., Santiago, C.D., Braga, I.: Selection and training of a panel of evaluators for sensory analysis of tactile comfort in Brazil. Textiles, Identity and Innovation: Design the Future, pp.9–14 (2018). https://doi.org/10.1201/9781315100210-4
14. Conagin, A., Barbin, D.: Bonferroni's and Sidak's modified tests. Scientia Agricola, **63**(1), 70–76 (2006). https://doi.org/10.1590/S0103-90162006000100011
15. Abdi, H.: The Bonferonni and Šidák Corrections for Multiple Comparisons. Encyclopedia of Measurement and Statistics, pp.103–107 (2007). https://doi.org/10.4135/9781412952644
16. Filingeri, D., Redortier, B., Hodder, S., Havenith, G.: Thermal and tactile interactions in the perception of local skin wetness at rest and during exercise in thermo-neutral and warm environments. Neuroscience, **258**,121–30 (2014). https://doi.org/10.1016/j.neuroscience.2013.11.019