SCRUB SUITS VS CLEAN AIR SUITS – A THERMAL PROPERTIES COMPARISON

Isabel ABREU; Patrícia RIBEIRO & Maria José ABREU

Abstract: *In operationg room (OR), the health professionals are exposed to stress situations that can influence their physical and psychological performance. The thermal properties are an important requirement for the best performance of OR medical clothing, that plays a crucial role in thermal comfort of the user, that involve the regulation of heat and mass transfer between a clothed body and the environment.*
In this way, the aim of this work was comparison of thermal properties between scrub and clean air suits. The test was performed on a thermal manikin and Alambeta to measure clothing insulation and to evaluate the thermal comfort. These tests provide a good estimate of the total dry heat loss from the body and the distribution of heat flow between body surface and textile materials.
Keywords: *Scrub suit, clean air suit, comfort, thermal properties, thermal manikin, Alambeta*

1. Introduction

Over the last years, surgical scrub suits (SS) have been worn by health care workers in the operation room (OR) and for many other applications in healthcare outside the OR. They are used by health professionals as uniform. However, scrub suits are not considered a medical device, so there is no defined regulation nether scientific studies support the practice of using scrub suits as a means for preventing transmission of infection [1]. On the other hand, clean air suits (CAS) are considered Class I medical devices according to the definition and classification rules of the Medical Devices Directive 93/42/EEC, amended by 2007/47/EC [2]. Clean air suit is defined as a "suit intended and shown to minimize contamination of the operating wound by the wearer's skin scales carrying infective agents via the operating room air thereby reducing the risk of wound infection" by EN 13795:2011+A1:2013 [3]. In Figure 1 can be seen the appearance of a scrub suit and a clean air suit. The standard EN 13795 presents general performance requirements concerning properties which require assessment in CAS like resistance to microbial penetration, microbial and particle matter cleanliness, linting, bursting strength and tensile strength [3]. As further characteristic of medical clothing, EN 13795 takes in consideration the comfort of the users.
Inside of OR, thermal comfort of medical clothing apparel is a very important parameter, since the lack of comfort can lead to thermal stress that influence the physic and psychological conditions of the surgeon, as the ability to maintain constant vigilance and concentration, which the correct surgical procedure is dependent. Thermal comfort of the user of medical apparel depends on thermal properties and its adjustment to the environmental conditions in the OR during the surgery, among many other factors like design, size and fabric characteristics [4]. Extremely insulating and low absorbent medical apparel will results in an increase of skin temperature, leading to a greater moisture accumulation between professional skin and clothing. To overcome this situation, surgical clothing needs to satisfy some requirements; they should be comfortable, breathable, loose fitting, keep the user in cool conditions and allow heat changes between the body and environment [5].
For health professional can achieve thermal comfort, the mean skin temperature should be between 33 °C and 34 °C and sweating or chills should not occur. Studies have determined that surgeons experience thermal comfort when OR temperature is between 20 °C and 24 °C and if their clothing ensemble were consisted by shoes, cotton socks, nonwoven surgical clothing with viscose fiber and good air and water vapour permeability [6].
In this way, the aim of the presented study was to compare thermal properties between scrub and clean air suits.

a b

Figure 1: Scrub suits (a) and clean air suits (b).

2. Materials and Methods

2.1 Clothing ensemble

Disposable and reusable scrub and clean air suits were used in this study, Table 1. The clothing was stabilized on adiabatic chamber before each test.

Table 1: Description of clothing ensemble tested.

Reference	Clothing ensemble	Composition
A	Single-use scrub suit	Non-woven SMS
B	Reusable scrub suit	67% PES/ 33% cotton
C	Single use clean air suit	Non-woven SMS
D	Reusable clean air suit	99% PES/ 1% carbon fibre

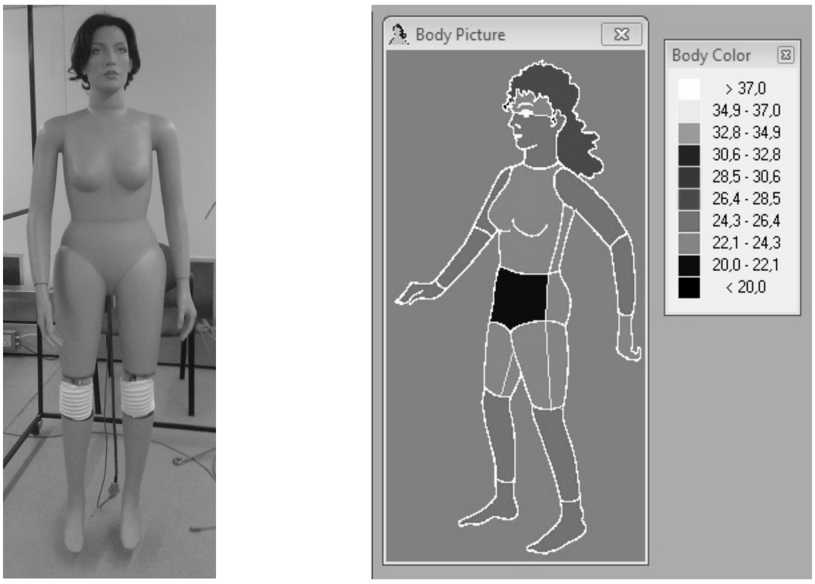
2.2 Alambeta

Alambeta measuring device (Figure 2) is the fast measuring of transient and steady state thermo-physical properties (thermal insulation and thermal contact properties) [7] , which simulates, during a very small initial contact, the heat flux between skin and fabrics. Alambeta measures thermal parameters like, thermal conductivity, resistance, diffusivity and absorbance.

Figure 2: Alambeta equipment for thermal properties measurement.

2.3 Thermal Manikin

The thermal insulation of clothing ensemble was measured using a thermal manikin (Figure 3) with controlled skin surface temperature. This thermal manikin called has a woman's body; its size and configurations are similar to an adult woman. It is divided in 20 thermally independent sections and only sense dry heat transfer. Thermal manikin, positioned 0.1 m from the floor, was kept standing with their legs and arms held in vertical position without any motion. The skin temperature was set, and during the test period maintained at 33 ± 0.1 °C. The tests were conducted in a climatic chamber where ambient conditions characteristic of an operating theatre were simulated, 20 °C ± 2 °C and 60% Rh. The climatic chamber can achieve temperatures around 15 °C to 35 °C and relative humidity around 35% to 85%.



a b

Figure 3: Thermal manikin: photo of nude thermal manikin used on tests(a) and software body picture of thermal manikin and color legend of body segments temperature (b).

Heat flux lost was recorded and thermal insulation calculated according to global method, Equation 1, where $\bar{T}_{sk}$ [°C] is the mean skin temperature, T_0 [°C] is the room temperature, $\dot{Q}_s$ [W/m^2] the sensible heat flux of the manikin and f_i the relationship between the surface area of segment i of the manikin [8]. This is the general formula for defining the whole body resistance and the one that best fits the definition of thermal insulation expressed [9]. Furthermore, global method is less susceptible to significant variations to calculate thermal insulation

$$I_T = \frac{\sum_i (f_i \times \bar{T}_{sk,i}) - T_0}{\sum_i (f_i \times \dot{Q}_{s,i})} \qquad (1)$$

The effective clothing insulation (I_{cle}), consisting of the difference between I_T and I_a are calculated by the Equation 2, considering I_a is measured by operating the manikin nude:

$$I_{cle} = I_T - I_a \qquad (2)$$

3. Results

3.1 Alambeta

Figure 4 shows thermal properties of tested clothing. Scrub suits have higher conductivity than CAS. SS B has cotton in its composition; which has higher conductivity than polyester, reason why it has higher conductivity than CAS D. Scrub suits have higher diffusivity than clean air suits. This property represents heat propagation velocity of material, so SS will diffuse the heat faster than CAS.
Thermal absorptivity is a warm-cool feeling parameter and represents instantaneous heat flow that appends when two bodies, with different temperatures, come into contact. The higher is the thermal absorptivity, the

higher is the thermal flow and the worse is the initial contact sensation, because it corresponds to a cooler surface. This property is also related with structure and fabric composition. Single-use scrub suit and clean air suit have the same absorptivity value and it is lower than for reusable SS and CAS. Each material that can absorbs and conducts heat well, will easily remove the heat from the skin and make the user feels fresher [10].

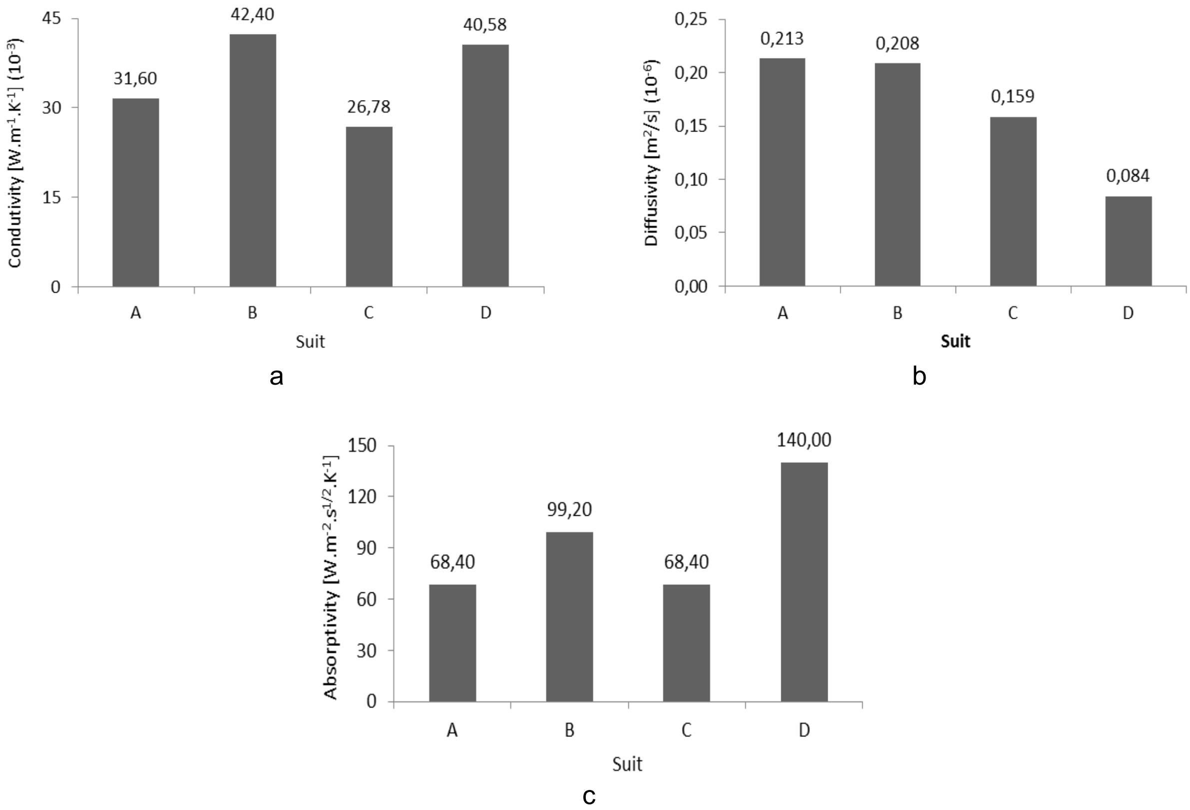


Figure 4: Thermal properties of clothing measured on Alambeta: condutivity (a), diffusitivity (b) and absoptivity (c).

3.2 Thermal Manikin

Figure 5 shows the heat loss from manikin body segments. According to Hensel citated in [10], the higher is the heat loss from the skin to the environment, the faster the temperature will drops and more intense is the freshness feeling. So, as said earlier, the material that could absorb and conduct heat well, will remove heat from the skin and give the sensation of being a "coolest" garment. Hence, heat loss is closely related to thermal insulation, they are inversely proportional parameters. In this particular case, as expected, unclothed parts like feet, hands, forearms and face have higher heat loss. The differences of heat loss between SS and CAS are not significant.

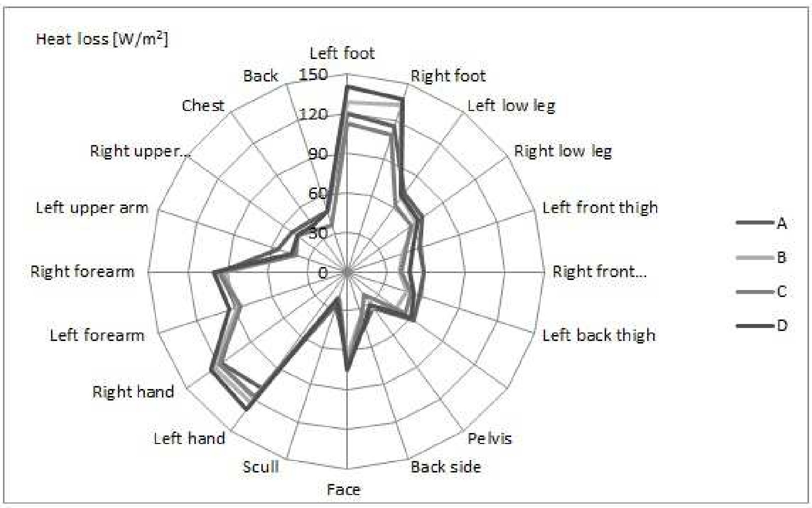


Figure 5: Heat loss from body section of manikin dressed with CAS (a) and SS (b).

Through heat loss values, total (I_T) and effective clothing thermal insulation (I_{cle}) can be calculated. In Figure 6 can be seen that SS A have the lower thermal insulation, the difference between single use scrub and clean air suits (A and C) is around 15% and for disposable ones (B and D) it is around 6%. However, the difference between SS and CAS is significant when we compare SS A with CAS C, and there is also a significant difference between scrub suits A and B. Despite of being made of same fabric, disposable SS and CAS (A and C) have different insulation behaviour. This can be possibly due to the design and lining of CAS. CAS openings for head, arms, waist and feet are closed by tightly fitting cuffs and the heat loss through these openings is lower and the thermal insulation increases. Moreover, this CAS has lining in upper part of shirt and trousers, which can also result in increased insulation.
When the effect of air layer thermal insulation is removed (I_{cle}), clothing thermal insulation decreases but show the same behaviour. For A suit, can be observed a decrease around 73%, about 58% and 57% for B and C, respectively, and 61% for D.

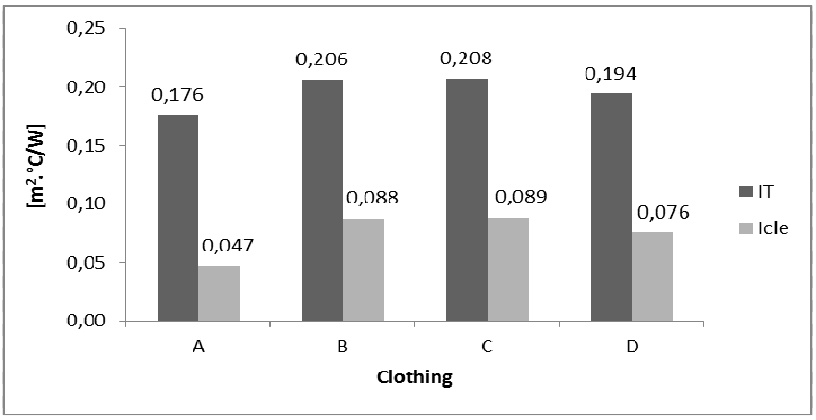


Figure 6: Total thermal insulation and effective clothing insulation of scrub and clean air suits.

Thermal insulation of clothing can also be expressed in Clo. The higher the value of Clo, the greater is thermal insulation. Clo value of 1 is defined as the amount of clothing required to a human being at rest to be comfortable at room temperature of 21 °C [10]. In this way, A suits has the closer Clo value from being thermal comfortable.

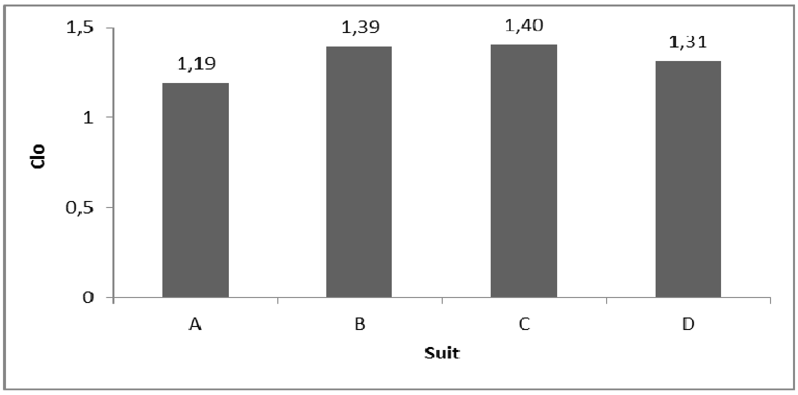


Figure 7: Total thermal insulation of scrub and clean air suits.

4. Conclusion

This study was performed to compare thermal properties between scrub suits and clean air suits made of woven and nonwoven fabric. Thermal properties of fabric were measured on Alambeta and thermal insulation of clothing was carried on a thermal manikin.
Regarding to fabric thermal properties there is no suit with all ideal properties. Reusable SS and CAS have similar conductivity, but in terms of diffusivity they are almost the opposites.
Concerning to the thermal insulation of clothing, it is dependent upon their specific design, size and fabric characteristics, particularly air space between skin and clothing that represents the main percentage of thermal insulation, always above 55%.

Acknowledgments

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References

[1] Abreu, M. J.: Prevention of airbone disposal from staff in the O.R. reducing the risk of infection: What are the benefits of using clean air suits or scrub suits? *Proceeding book of International Symposium on Occupational Safety and Hygiene*. ISBN: 978-972-99504-9-0, Guimarães, February 2012, Portuguese Society of Occupational Safety and Hygiene (SPOSHO), Guimarães, (2012).
[2] Council Directive 93/42/EEC of the European Parliament and of the Council of 14 June 1993 concerning medical devices. *Official Journal L* 169, 12.7.1993, pp. 1.
[3] EN 13795:2011+A1:2013, Surgical drapes, gowns and clean air suits, used as medical devices for patients, clinical staff and equipment – General requirements for manufacturers, processors and products, test methods, performance requirements and performance levels.
[4] Cho, J. S.; Tanabe, S. I.; Cho, G.: Thermal Comfort Properties of Cotton and Nonwoven Surgical Gowns with Dual Function Finish. *Applied Human Science*, Vol. 16 (1997), No. 3, pp. 87-95.
[5] Fanger P.O.: Assessment of man's thermal comfort in practice. *British Journal of Industrial Medicine* Vol. 30 (1973), pp. 313-24.
[6] ISO 9920:2007, Ergonomics of the thermal environment -- Estimation of thermal insulation and water vapour resistance of a clothing ensemble.
[7] Bogdan A., Sudol-Szopinska I., Szopinski T.: Assessment of Textiles for Use in Operating Theatres with respect to the Thermal Comfort of Surgeons. *Fibres & Textiles in Eastern Europe*, Vol. 19 (2011), pp. 65-69.
[8] Devanand U.: Objective Measurement of Heat Transport through Clothing, *International Journal of Engineering Research and Development*, Vol. 2 (2012), Issue 12, pp. 43-47, e-ISSN: 2278-067X.
[9] Oliveira AV, et al.: Measuring thermal insulation of clothing with different manikin control methods. Comparative analysis of the calculation method., *Proceedings Book of 7th International Thermal Manikin and Modelling Meeting*, Coimbra, Portugal, September 2008.
[10] Song, G.: *Improving Comfort in Clothing*. Woodhead Publishing. ISBN: 978-1-84569-539-2. (2011).

Author(s):

Isabel ABREU, MSc
2C2T - Centre of Textile Science and Technology; Department of Textile Engineering;
University of Minho; Campus de Azurém
Alameda da Universidade; 4800 - 058 Guimarães; Portugal
E-mail: isabelabreu15@hotmail.com

Patrícia RIBEIRO, B
2C2T - Centre of Textile Science and Technology; Department of Textile Engineering;
University of Minho; Campus de Azurém
Alameda da Universidade; 4800 - 058 Guimarães; Portugal
E-mail: patricia.ri1990@gmail.com

Prof. Maria José ABREU, Ph.D.
2C2T - Centre of Textile Science and Technology; Department of Textile Engineering;
University of Minho; Campus de Azurém
Alameda da Universidade; 4800 - 058 Guimarães; Portugal
Tel. +351-253510274 E-mail: josi@det.uminho.pt