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Comparison of different medical clothing used in Operating Rooms (OR's)—the importance of thermal comfort at work

I.M. Abreu, P. Ribeiro & M.J. Abreu
2C2T—Centre of Textile Science and Technology, Department of Textile Engineering, University of Minho, Guimarães, Portugal

ABSTRACT: In operating room, 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, tri-dimensional test that simulates the use of clothing measuring clothing insulation and to evaluate the thermal comfort. The test provides a good estimate of total dry heat loss from the body, between body surface and textile materials, and esteem the comfort level of this work wear.

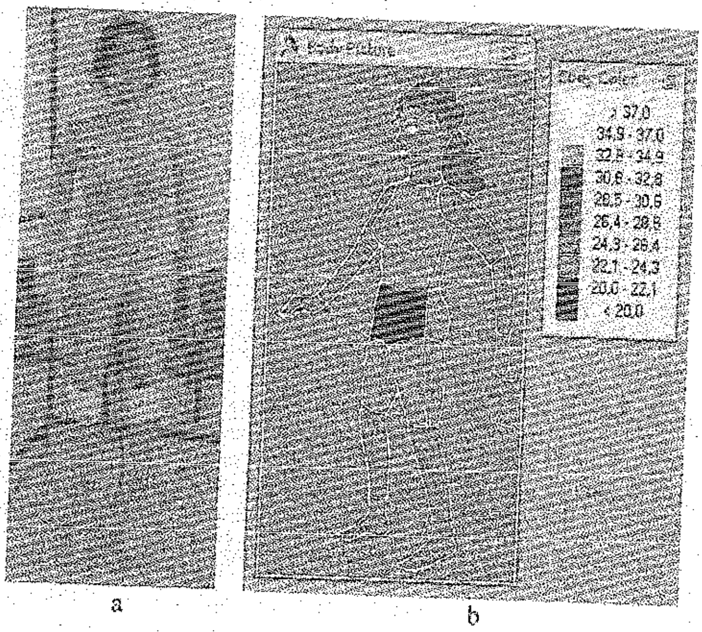
1 INTRODUCTION

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 neither scientific studies support the practice of using scrub suits as a means for preventing transmission of infection (Abreu, 2012, Abreu, 2014). 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 (Council Directive 93/42/EEC) [3] [3]. 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 (CEN, 2011). 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 (CEN, 2011). 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 (Cho et al., 1997). 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 exchange changes between the body and environment (Fanger, 1973).

The mean skin temperature of, approximately, 33 °C and non-occurrence of sweating or chills are the general condition for a health professional experience thermal comfort. Studies have determined that surgeons experience thermal comfort when OR temperature is between 20 °C and 24 °C and if their clothing system were consisted by shoes, cotton socks, nonwoven surgical clothing with viscose fiber and good air and water vapor permeability (Bogdan et al., 2011).

In this way, the aim of the presented study was to compare thermal properties between scrub and clean air suits.



a b

Figure 1. 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).

2 MATERIAL AND METHODS

2.1 *Clothing system*

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

2.2 *Thermal manikin*

The thermal insulation of clothing ensemble was measured using a thermal manikin, Figure 1, with controlled skin surface temperature that simulates the wear. This thermal manikin, called "Maria", 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 of all body 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%.

Data acquisition started after achieving stationary conditions and did not take more than 60 min. During the acquisition period, the heat flux and the skin temperature of each body part record every minute. Thermal insulation (I_T) was calculated according to global method, Equation 1, where T_{sk} [°C] is the mean skin temperature, T_0 [°C] is the room temperature, $\dot{Q}_s$ [W/m²] the sensible heat flux of the manikin and fi the relationship between the surface area of segment i of the manikin (ISO 9920:2007) [8] [8]. This is the general formula for defining the whole body resistance and the one that best fits the definition of thermal insulation expressed (Oliveira et al., 2008). Furthermore, global method is less susceptible to significant variations to calculate thermal insulation.

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

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

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

3 RESULTS

3.1 *Thermal manikin*

Figure 2 shows the heat loss from manikin body segments. According to Hensel cited in (Song,

Table 1. Description of clothing system tested.

Reference	Clothing system	Composition	Thickness (mm)	Air permeability (l/m²/s)
A	Single-use scrub suit	Non-woven SMS	0.52	1824
B	Reusable scrub suit	67% PES/33% cotton	0.43	411.2
C	Single use clean air suit	Non-woven SMS	0.35	464.8
D	Reusable clean air suit	99% PES/1% carbon fiber	0.30	291.8

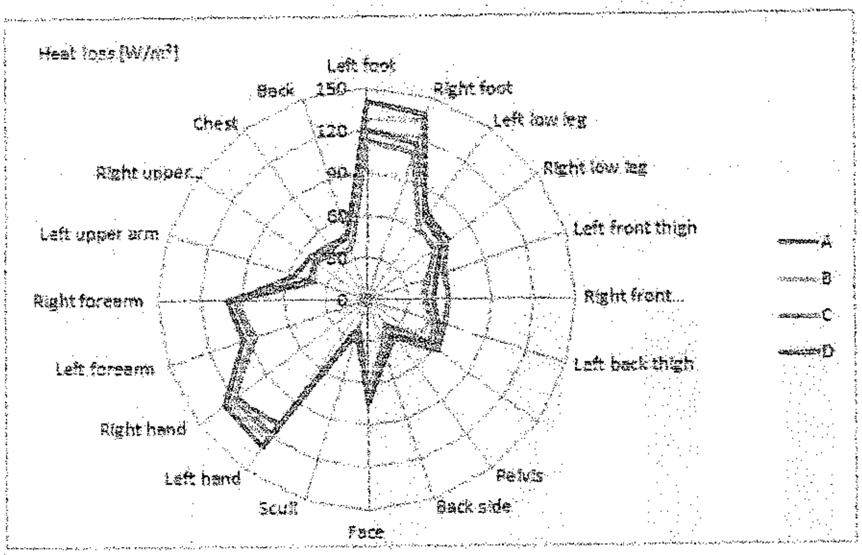


Figure 2. Heat loss from body section of manikin dressed with CAS (a) and SS (b).

2011), 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.

Through heat loss values, total (I_T) and effective clothing thermal insulation (I_{cle}) can be calculated. In Figure 3 can be seen that SS A have the lower thermal insulation, the difference between single use SS and CAS (A and C) is around 0,032 m².°C/W and for disposable ones (B and D) it is around 0,012 m².°C/W. 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 SS A being the scrub suit with higher thickness value, 0.33 mm (Table 1), its lower thermal insulations can be explained by higher value of air permeability, 1824 l/m²/s (Table 1) that allow a better heat exchanges between body surface and environment.

In spite of being made of same fabric, disposable SS and CAS (A and C), its different insulation behaviour can be also possible 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.

Thermal insulation of clothing can also be expressed in clo, Figure 4a. 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]. The differences between clothing clo values are statistically significant (p-value < 0,05), except between scrubs B and C (p-value > 0,05), Figure 4b. So, the differences of

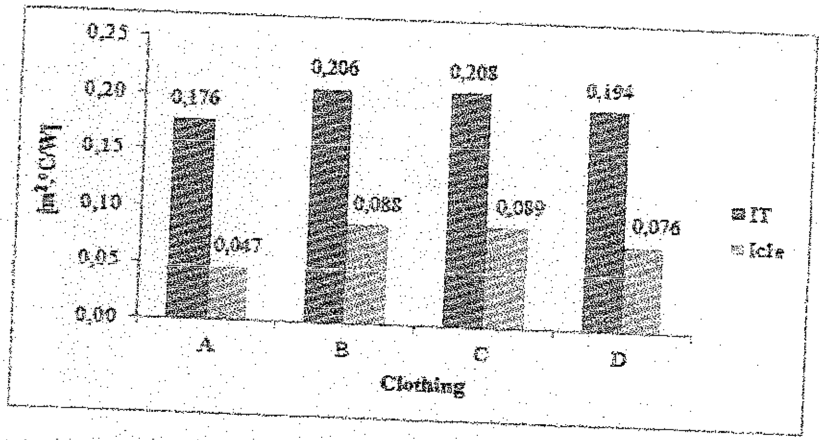
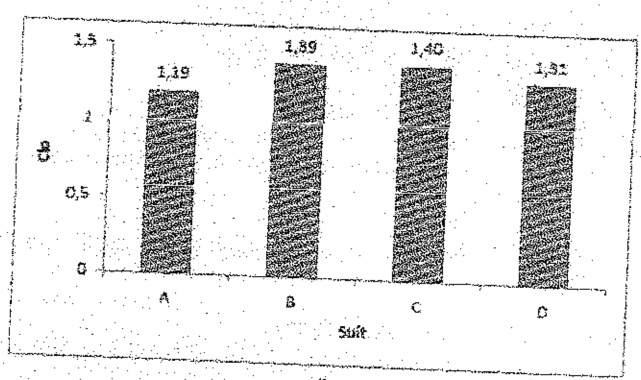


Figure 3. Total thermal insulation and effective clothing insulation of scrub and clean air suits.



a

Clothing systems	p-value
A-B	0.073
A-C	0.044
A-D	0.006
B-C	0.816
B-D	0.318
C-D	0.443

Figure 4. Clo value of total thermal insulation of scrub and clean air suits (a) and statistically differences between clothing systems (b).

wear scrub suit B or wear clean air suit C can't be perceived and A suit has the closer clo value from being thermal comfortable.

4 CONCLUSION

This study was performed to compare thermal properties between scrub suits and clean air suits made of woven and nonwoven fabric. Thermal manikins provide a good estimate of the total dry heat loss from the body and the distribution of heat flow over the body surface; these measures were used to describe the thermal characteristics of clothing. Clothing thermal insulation differences are statistically significant ($p < 0.5$) which means the user will perceive thermal differences between scrub suits. Regarding to fabric thermal properties there is no suit with all ideal properties.

Thermal insulation of clothing, it is dependent upon their specific design, size and fabric characteristics, particularly air permeability that allows heat exchage between skin surface and environment.

REFERENCES

Abreu, M.J. 2012. 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? *In:* HYGIENE, I.S.O.O.S.A. (ed.) *International Symposium on Occupational Safety and Hygiene.* Guimarães.

Abreu, M.J. 2014. Suitable Control Choices. Exploring the roles of clean air suits and scrub suits in infection control. *European Medical Hygiene Magazine,* 21–27.

Bogdan, A., Sudol-Szopinska, I. & Szopinski, T. 2011. Assessment of Textiles for Use in Operating Theatres with respect to the Thermal Comfort of Surgeons. *Fibres & Textiles in Eastern Europe,* 19, 65–69.

[illegible] 2011. 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.

[illegible] J.-S., Tanabe, S.-I. & Cho, G. 1997. Thermal Comfort Properties of Cotton and Nonwovens Surgical Gowns with Dual Functional Finish. *Applied Human Science*, 16, 87–95.

Council Directive 93/42/EEC of the European Parliament Council of 14 June 1993 concerning medical devices. Official Journal L 169, 12.7.1993, pp. 1.

[illegible], P.O. 1973. Assessment of man's thermal comfort in practice. *British Journal of Industrial Medicine*, 30, [illegible]3–324.

ISO 9920:2007, Ergonomics of the thermal environment—Estimation of thermal insulation and water vapour resistance of a clothing ensemble.

Oliveira, A.V.M., Branco, V.J., Gaspar, A.R. & Quintela, D.A. 2008. Measuring Thermal Insulation of Clothing with Different Manikin Control Methods Comparative Analysis of the Calculation Methods. *7th International Thermal Manikin and Modelling Meeting*. University of Coimbra.

Song, G. 2011. *Improving Comfort in Clothing*, Woodhead Publishing.