(REFEREED RESEARCH)

AN INVESTIGATION ON THE COMFORT PROPERTIES FOR DIFFERENT DISPOSABLE SURGICAL GOWNS BY USING THERMAL MANIKIN

FARKLI ÖZELLİKTEKİ TEK KULLANIMLIK CERRAHİ ÖNLÜKLERİN KONFOR ÖZELLİKLERİNİN ISIL MANKEN KULLANILARAK BELİRLENMESİ

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ABSTRACT

The thermal properties of clothing materials, which relate thermal comfort of the user, involve the heat transfer between a clothed body and the environment. The thermal resistance of a clothing system represents a quantitative evaluation of how good the clothing provides thermal barrier to the wearer.

In many years, thermal manikins have been used to measure clothing insulation and to evaluate the thermal environment. The clothing industry uses manikins for development of clothing systems with improved thermal properties. The aim of this paper is to research thermal comfort properties of different disposable surgical gowns (Spunlace-normal, Spunlace-reinforced, and SMS-normal) by using the thermal manikin.

Key Words: Thermal manikin, Comfort, Thermal insulation, Disposable surgical gown, Nonwoven fabric.

ÖZET

Kullanıcıların giyim konforu ile direkt olarak ilgili olan giyim materyallerinin ısıl özellikleri, üzerinde giysi bulunan vücut ile bulunduğu çevre arasındaki ısı transferini kapsamaktadır. Bir giysinin ısıl özellikleri, o giysinin kullanıcısına ne ölçüde iyi ısıl bariyer sağladığının nicel bir değerlendirmesini sunmaktadır.

Isıl mankenler, uzun yıllardan beri giysilerin ısıl izolasyon değerlerinin ölçülmesinde ve ısıl çevrenin değerlendirilmesinde kullanılmaktadırlar. Hazır giyim endüstrisi, ileri düzeydeki ısıl özelliklere sahip giyim sistemlerinin geliştirilmesinde ısıl mankenleri kullanmaktadır. Bu çalışmanın amacı, farklı özellikteki (Spunlace-Normal, Spunlace-Takviyeli, SMS-Normal) tek kullanımlık ameliyat önlüklerinin ısıl konfor özelliklerinin bir ısıl manken kullanılarak belirlenmesidir.

Anahtar Kelimeler: Isıl manken, Konfor, Isıl izolasyon, Tek kullanımlık cerrahi önlük, Dokusuz yüzey kumaş.

Received: 27.12.2007 Accepted: 31.03.2008

1. INTRODUCTION

The physiological wear comfort, in other words, the breathability and heat and moisture management of the textiles, plays a crucial role in optimally supporting the physical and mental performance of the wearer. Rapid evacuation of the liquid perspiration and the creation of a dry microclimate on the skin support the body's thermoregulation, preventing cooling and chilling after physical activity (post-exercise chill) which feels unpleasant and can pose a risk to health. Textiles which adhere to wet skin also produce negative sensory stimuli and skin which is moist with perspiration is unnecessarily irritated. Body heat which can be quickly evacuated via ventilation openings helps to prevent heat stress and thus improve the wearer's performance (1).

Although clothing comfort is an important factor for every kind of clothes, it has more importance in the area of surgical clothing. Especially, if a surgical operation takes a long period of time, these kinds of clothes also used for protecting of surgical team should have sufficient comfort properties for the comfort of the user. The thermal insulation properties of clothing systems can be defined through physical measurements using thermal manikins or through wear trials using human test subjects.

Thermal manikins have served research and development purposes for more than 60 years. They are widely used for analysing the thermal interface of the human body and its environment (2). Thermal manikins are a fairly standard tool in environmental ergonomics. As they can provide a rapid, accurate, and reproducible simulation of the physical processes of dry heat loss to the environment, their main application is in the study of neutral or cold conditions at relatively low activity levels. 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. In a standard environment, these measures can be used to describe the thermal characteristics of clothing (3). In many years, thermal manikins, made from metal or plastic, shall be constructed to simulate the body of an adult human, consist of an anatomically formed head, chest, abdomen, back, buttocks, arms, hands, legs and feet, have been used to measure clothing insulation and to evaluate the thermal environment. The first thermal manikins were developed for testing of the military clothing and space suits, but the increasing demand for a better thermal indoor environment during the 1960s, caused a need for information about the insulation values of common daily clothing. At the same time, it was found that the best instrument for measuring the human sensation of the thermal environment is a body-model of the same size and shape as the human body. The model is heated to body temperature and wears the actual clothing. It is important that the manikin is able to react on the thermal environment in the same way as a human being in the same situation and wearing the same clothing. To be able to do this, the manikin is divided in 16 or more thermally independent sections (4).

2. MATERIAL AND METHOD

2.1 Material

The well-known disposable surgical gown types (Spunlace-Normal, Spunlace-Reinforced and SMS-Normal) were researched in this study. The technical informations of each group of surgical gowns can be seen in Table 1.

Table 1. The properties of nonwoven disposable surgical gowns

Disposable Surgical Gown Types	Weight in grams (g/m^2)
Spunlace (Normal)	78
Spunlace (Reinforced)	78
SMS (Normal)	50

Figure 1. Maria in standing position with SMS disposable surgical gown

Figure 1 shows a picture of the thermal manikin, Maria, used for the investigation. Maria has a woman's body and Maria's size and configurations are similar to an adult woman. Maria achieves a body temperature distribution similar to a real person. The mean skin temperature of Maria can be adjusted. Maria's arms and legs can be motorized to simulate 'walking' motion. All tests were conducted in the climatic chamber where defined air temperature and air humidity controlled. There was a dry heat flow from the manikin's skin surface area through the clothing into the ambient air, which was measured after steady-state conditions have been reached. From this heat flow, related to the nude manikin's body surface area, the surgical gown's thermal insulation calculated, conside-ring the temperature difference bet-ween the manikin's skin surface and the ambient air. It took about 3 days to complete all measurements when the manikin was in standing position.

2.2 Method

All disposable surgical gowns were tested according to ISO 15831. 5 samples were tested for each type of surgical gowns and it means totally 15 disposable surgical gowns were tested by using thermal manikin. The surgical gowns were conditioned at (20 ± 5) °C and (50 ± 20) % RH in the climatic chamber for 24 h. The skin surface temperature, *Tsi*, at each of the manikin's body segments, was maintained at 33 °C during the test period. The mean air temperature in the climatic chamber was 22,5 °C. PI control mode was used on the manikin. The test time of each measurement was 60 minutes. At the end of each measurement, the heat loss (P), thermal resistance (R) and thermal insulation (Clo) values were obtained and saved by the computer.

The thermal insulation of the clothing ensemble tested can be calculated either by adding the area-weighted local thermal insulation at the manikin's different body segments (serial model) or by using the total heat flow from the manikin's body (parallel model) (4).

a. Serial model — Surface area weighted thermal insulation

The total thermal insulation, *It*, or the resultant total thermal insulation, *Itr*, is calculated on the test results gained with the manikin respectively either stationary or moving its legs and arms, using Equation (1).

$$I_t \text{ or } I_{tr} = \sum_i f_t \times \left[\frac{(T_{si} - T_a) \times a_i}{H_{ci}} \right]$$

in square metre kelvins per watt (1)

where $f_i = \frac{a_i}{A}$ (2)

b. Parallel model — Surface area averaged thermal insulation

The total thermal insulation, *It*, or the resultant total thermal insulation, *Itr*, is calculated on the test results gained with the manikin respectively either stationary or moving its legs and arms, using Equation (3).

$$I_t \textbf{ or } I_{tr} = \left[\frac{(T_{si} - T_a) \times A}{H_c}\right]$$

in square metre kelvins per watt (3)

where

$$T_s = \sum_i f_i \times T_{si}$$

in degrees centigrade

$$H_c = \sum_i H_{ci} \text{ in watts}$$

where

*I*t is the total thermal insulation of the clothing ensemble with the manikin stationary, in square metre kelvins per watt;

*I*tr is the resultant total thermal insulation of the clothing ensemble with the manikin moving, in square metre kelvins per watt;

*T*s*i* is the local surface temperature of section *i* of the manikin, in degrees centigrade;

*T*a is the air temperature within the testing chamber, in degrees centigrade;

ai is the surface area of section *i* of the manikin, in square metres;

*H*c*i* is the local heat loss from section *i* of the manikin, in watts;

A is the total body surface area of the nude manikin, in square metres;

fi is the area factor of section *i* of the nude manikin;

*f*cl is the clothing area factor (4).

In this research, the total thermal insulation, Itr, including resistance was calculated by using the serial method. Because, the measurement of thermal changings in the each body segments was aimed. Because, the local thermal insulation values for some body segments like chest, sleeve etc. are more important for surgical gowns. The body segments of thermal manikin are divided in two different groups for easy measurement and determination of thermal changings in the body segments. The body segments of each group can be seen at Table 2.

Table 2. The body segments of the thermal manikin

No	Group A	Group B
1	L Foot	Face
2	R Foot	Scull
3	L. Low leg	L. Hand
4	R. Low leg	R. Hand
5	L. Front Thigh	L. Forearm
6	R. Front Thigh	R. Forearm
7	L. Back Thigh	L. Upper arm
8	R. Back Thigh	R. Upper arm
9	Pelvis	Chest
10	Back side	Back

3. RESULTS

Experimental results of the measurements are listed in the following tables:

4. STATISTICAL EVALUATION

In this section, the aim is to test several hypotheses using the data given in Table 3 to determine if there is any difference among the surgical gown types according to thermal insulation values using one-way analysis of variance procedure (5). Analysis of variance result is given in the following section for each surgical gown type. Selected value of significance level (α) for all statistical tests in the study is 0.05. We have 3 different values (treatments) of a single factor (surgical gown) that we wish to compare. The thermal insulation values, given in Table 3, 4 and 5, say y_{ij}, represents the *j*th observation taken under treatment *i*. *i* = 1,2,3 represents gowns type namely spunlace-normal,

Table 3. Heat loss (P), thermal resistance (R) and thermal insulation (Clo) values of Spunlace-Normal disposable surgical gowns

Surgical Gown Type	P (W/m^2)		R (m^{2}K/W)		Clo (Total)	
	Group A	Group B	Parallel	Serial	Parallel	Serial
Spunlace 1	69,10	44,00	0,168	0,292	1,081	1,883
Spunlace 2	61,40	41,10	0,162	0,32	1,048	2,067
Spunlace 3	65,20	38,80	0,166	0,85	1,073	5,483
Spunlace 4	61,10	39,50	0,162	0,357	1,044	2,306
Spunlace 5	81,70	51,00	0,159	0,227	1,025	1,463
Mean	67,70	42,88	0,163	0,409	1,054	**2,64**

Table 4. Heat loss (P), thermal resistance (R) and thermal insulation (Clo) values of Spunlace-Reinforced disposable surgical gowns

Surgical Gown Type	P (W/m^2)		R (m^{2}K/W)		Clo (Total)	
	Group A	Group B	Parallel	Serial	Parallel	Serial
SMS 1	58,20	38,10	0,172	0,678	1,109	4,374
SMS 2	76,20	50,00	0,160	0,236	1,029	1,520
SMS 3	66,80	41,90	0,167	0,328	1,080	2,116
SMS 4	64,70	39,60	0,170	1,035	1,099	6,679
SMS 5	57,50	39,50	0,177	0,518	1,144	3,339
Mean	64,68	41,82	0,169	0,559	1,092	**3,606**

Table 5. Heat loss (P), thermal resistance (R) and thermal insulation (Clo) values of SMS-Normal disposable surgical gowns

Surgical Gown Type	P (W/m^2)		R (m^{2}K/W)		Clo (Total)	
	Group A	Group B	Parallel	Serial	Parallel	Serial
Spunlace Reinforced 1	64,10	45,10	0,176	0,289	1,135	1,861
Spunlace Reinforced 2	67,50	41,40	0,175	0,440	1,130	2,841
Spunlace Reinforced 3	61,70	39,30	0,175	0,354	1,126	2,285
Spunlace Reinforced 4	60,20	38,30	0,178	0,370	1,146	2,384
Spunlace Reinforced 5	56,20	37,70	0,183	0,653	1,179	4,211
Mean	61,94	40,36	0,177	0,421	1,143	**2,716**

Table 6. ANOVA table for the values of thermal insulation (serial model)

Source	DF	SS	MS	F	P
Fabric Type	2	2,88	1,44	0,57	0,581
Error	12	30,43	2,54		
Total	14	33,31			

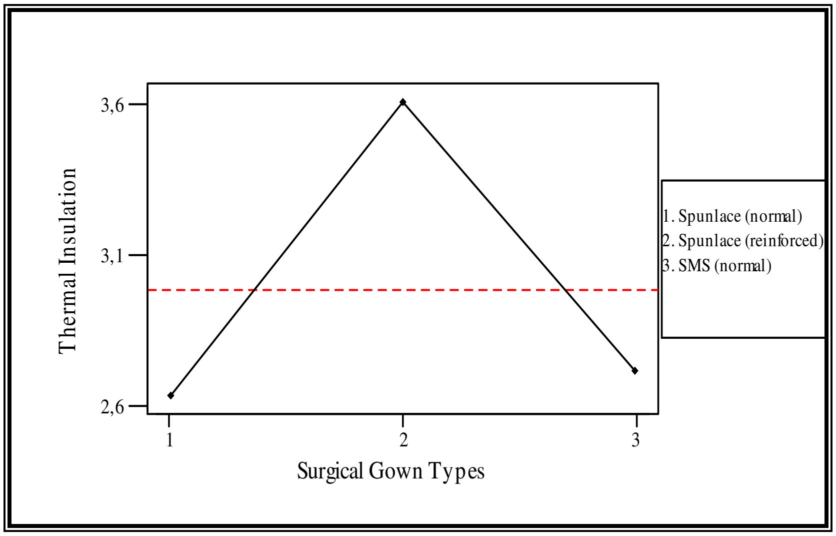

Figure 2. Main effects diagram for thermal insulation values of disposable surgical gowns

spunlace-reinforced, and SMS-normal respectively. We may describe the observations by the one-way analysis of variance model,

$$y_{ij} = \mu + \tau_i + e_{ij} \qquad (4)$$

where μ is overall mean thermal insulation , τ_i is the effect of *i*th surgical gown type, ε_{ij} is a random error component. In this one-way analysis of variance model, r_i denotes the number of observations at *i*th level of the factor. That is $r_1 = 5$, $r_2 = 5$ and $r_3 = 5$. The appropriate hypotheses are

$H_0 : \tau_1 = \tau_2 = \tau_3 = 0$; $H_1 : \tau_i \neq 0$ for at least one *i*.

If the null hypothesis is true, then we conclude that surgical gown types do not significantly affect the mean thermal insulation.

Minitab Release 13.20 statistical software package was used for conducting these tests.

5. DISCUSSION

The analysis of variance for testing the hypotheses above is summarized in Table 6. Since *P* value (> α), we can not reject H_0 and conclude that surgical gown types don't significantly affect the thermal insulation. In Figure 2, mean effects of treatments can be also seen clearly.

As can be seen in this figure, Spunlace – Normal type surgical gown has the lowest value of thermal insulation while Spunlace - Reinforced has the highest value.

Regarding all of the outcomes that obtained from this study, it is possible conclude below mentioned discussions:

* Thermal manikins are necessary instruments for measuring the thermal insulation, thermal resistance and heat loss of clothing systems, which are important parameters relevant to clothing thermal comfort.
* The reinforced materials are reduced the thermal conductivity of disposable surgical gowns. For this reason, it is more comfortable to choice these types of gowns for the surgical operations that have more liquid-blood in the surgical theatre.
* SMS materials are cheaper than Spunlace. In this research, it is possible to say that Spunlace-Normal and SMS-Normal surgical gowns have the proximity values. According to these datas, SMS-Normal surgical gowns should be preferred especially for the short-time surgical operations for increasing the production costs.
* The types of surgical gowns, of course, affect the thermal insulation. But, according to the statistical evaluation, there is no significant difference between surgical gowns types used in this research.

ACKNOWLEDGEMENTS

The test applications were done at Minho University Textile Engineering Laboratories, in Portugal. The authors are grateful to this organization and also the technical team for their valuable assistances.

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*Bu araştırma, Bilim Kurulumuz tarafından incelendikten sonra, oylama ile saptanan iki hakemin görüşüne sunulmuştur. Her iki hakem yaptıkları incelemeler sonucunda araştırmanın bilimselliği ve sunumu olarak **"Hakem Onaylı Araştırma"** vasfıyla yayımlanabileceğine karar vermişlerdir.*