Scientific Research Journal,
Vol 18, No 1 (2021) 143 - 160
https://doi.org/10.24191/srj.v18i1.11304

Thermoregulatory Responses after Uphill Running while Wearing Enforcement Personnel Clothing

Norhayaty Zahari[1,2], Mohd Rozi Ahmad[1], Raja Mohammed Firhad Raja Azidin[3], Ridwan Yahaya[2], Ahmad Munir Che Muhamed[4], Mohamad Faizul Yahya[1]

[1]*Textile Research Group, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor Darul Ehsan*
[2]*Biophysical and Protection Technology Division, STRIDE, Taman Bukit Mewah, Fasa 9, 43000 Kajang, Selangor*
[3]*Faculty of Sport Science and Recreation, Universiti Teknologi MARA, 40450 Shah Alam, Selangor Darul Ehsan*
[4]*Advanced Medical and Dental Institute, Universiti Sains Malaysia, Bertam, 13200, Kepala Batas, Pulau Pinang*

Corresponding author's e-mail: rozitex@uitm.edu.my

Received: 27 November 2020
Accepted: 19 January 2021
Online First: 1 April 2021

ABSTRACT

The choice of clothing for enforcement personnel is vital to ensure minimum physical interference and optimum freedom of movement. The clothing type and fibre composition are important factors that have strong influence on the activities of enforcement personnel. This study presents an evaluation of the thermoregulatory responses for two type of enforcement personnel clothing after uphill running with different material composition. Eight recreational trained respondents (age, 24.4 ± 2.3; height, 166.9 ± 3.3; body weight,
64.0 ± 5.8; BMI 23.0 ± 1.8) completed an 8 km run on a treadmill with 6% elevation wearing enforcement personnel clothing. Both clothing used in the trials were made of polyester/cotton (P50C50) and nylon/cotton (N20C80) material composition. The findings revealed that compared to P50C50 clothing, the N20C80 clothing does not have a good thermal balance. The loss of body mass did not vary significantly but the sweating rate differed significantly between trials (P = 0.008). The rating of Perceived Exertion (RPE) of the participants was rated higher for N20C80 as compared to P50C50. The thermal sensation (P < 0.00l), sweating sensation (P = 0.05), skin wetness (P = 0.007), clothing comfort (P < 0.0l) and clothing humidity

(P = 0.00l) were significantly greater with N20C80 compared to P50C50 during exercise. The P50C50 clothing was more convenient to wear for the uphill running during the exercise. This study suggests that P50C50 would provide a better thermoregulatory response to regulate the thermal equilibrium between human skin and the environment.

Keywords:*thermoregulatory; RPE; heart rate; blood lactate; thermophysiological comfort*

INTRODUCTION

Enforcement personnel are usually equipped with different types of clothing such as parade suits, combat uniforms or operational uniforms, protective clothing for flying wear, high altitude dresses with extreme cold temperatures and security protection against nuclear, biological and chemical weapons [1]. The enforcement personnel safety and performance will depend heavily on the comfort of clothing that is worn [2]. Operational clothing, for example, should assist the personnel to act swiftly and efficiently while on duty without compromising comfort. The environment would be one of the main factors that influences the thermophysiological comfort of the personnel. This is due to increase in heat generation by the body resulting in inefficient heat loss that puts the body at risk for heat-related illnesses that may lead to death [3]. Many studies have been conducted focusing on thermal stress with regards to thermal comfort of clothing as it is the main factor for the deterioration of human performance [4]–[7]. During physical activities, heat will be generated by the body, leading to increase in the core temperature and the skin temperature [8]. Meanwhile, clothing creates microclimate environment between the skin surface and the environment which assist the body's thermoregulatory system to regulate the core temperature of the body in a safe range [9]. The human body can only stand the narrow range fluctuate of the core temperature which is 37^{o}C ± 2^{o}C [10]. The heat produced will be transferred to the environment through direct physical contact (conduction), emission of heat (thermal radiation) and heat transferred through air or water surrounding the body (convection) [11]. In order to cool the skin temperature and to regulate the core temperature, sweat will be produced. Anyhow, excessive sweat will lead to dehydration of the body [12]. Therefore, when physical activity is carried out in a warm environment, the clothing with good dissipation will be of great advantage. This is because water transfer property of the clothing material, instead of the water absorption property, assist to dissipate sweat faster and avoid the rise of humidity and temperature at the skin surface, thus regulating a comfort microclimate clothing [13].

Clothing demonstrates a crucial function in the thermoregulatory process as it modifies the loss of heat and changes the loss of moisture from the human skin through sweat evaporation and heat dissipation [14]. Thus, the heat dissipation qualities of clothing worn by enforcement personnel at moderate or high workloads is important. Body temperature increases during exercise because muscular work and the metabolic processes linked with the activity to produce the heat energy. Therefore, after any physical activity, the generated heat must move out from the body or hyperthermia can occur, which can hinder performance by affecting muscle function and metabolism, leading to premature fatigue [15]. Dissipation of heat could occur from convection or radiation of heat from the human skin to the environment, but heat is dissipated mainly by evaporation of perspiration from the skin. Gong *et al*. [16] studied the thermoregulatory reaction of physical activity in a controlled environment by studying the effect of the moisture transfer of clothing materials through the use of unskilled women. The designed physical activity is an activity that can cause distortion, where, water vapour and liquid water will be transferred simultaneously through the fabrics. It is inversely proportional to the rate of moisture transfer and the levels of relative humidity in the clothing microclimate. The higher humidity of the clothing microclimate will reduce the evaporation of sweat to the environment. The decreasing rate of the evaporation would cause the higher rectal temperature higher and as a consequence of this, the skin temperatures will also increase. Thus, this phenomenon has shows that the rate of moisture transfer plays a major role in the thermoregulation reaction during physical activity.

In another study, Brazaitis *et al*. [17] examined the physiological and psychological reactions of several human subjects through intensive physical activity in a warm and humid environment. The eight selected subjects wore different type of fabric shirts made of polyester and cotton. It was found that doing exercise while wearing polyester fabric gave lower clothing regain but greater sweating efficiency compared to cotton fabric. Nevertheless, both fabrics gave identical thermophysiological comfort and subjective sensations. However, after the physical activity, subjects wearing the t-shirt made from polyester material felt faster skin temperature going back to the initial level but at slower thermal and rate of sweating sensation.

The fact that body temperature is the most significant factor contributing to comfort means that the mechanisms in which textile fabrics help or impede the maintenance of clothing temperature in the body should be examined closely. Therefore, optimum clothing selection for any given environmental conditions is important for unobstructed performance. In other words, it is necessary to assess the thermophysiological comfort of fabrics commonly used in operational clothing that applies to its use. Apart from that, the personnel responses on human performance under the controlled environment and the designed activity are important to evaluate the thermal stress or thermal regulatory next to the skin.

MATERIALS AND METHODS

Materials

The chosen materials are fabrics that are currently used for enforcement personnel clothing which were obtained from the Science and Technology Research Institute for Defense (STRIDE). Two materials were chosen as a follow-up from a previous study on the study of thermophysiological properties [18]. A code was given to each fabric; the first and second letters are abbreviations of the first and second fibres, and the number represents the percentage of fiber content, as indicated in Table 1.

Table 1: Fabric Parameters

No.	Material composition	Code
1.	50% Polyester / 50% Cotton	P50C50
2.	20% Nylon / 80% Cotton	N20C80

Participants

The research was conducted at the Faculty of Sports Science and Recreation, Universiti Teknologi MARA in the Exercise Physiology Laboratory. Eight (*n*=8) healthy, recreationally trained male participants were involved in this study. Prior to enrollment, information and risks relevant to experimental protocols were clarified and written informed consent forms were received from each participant. The participants were measured with a calibrated scale in the height (cm) and body mass (kg). Body fat percentage was measured using Bioelectrical impedance analysis (BIA, InBody 720, Korea) as shown in Table 2.

Table 2: Participants Descriptive Data (*n*=8)

Variables	Male (*n*=8)
Age (Years)	24.4 ± 2.3
Body height (cm)	166.9 ± 3.3
Body mass (kg)	64.0 ± 5.8
Body fat (%)	18.3 ± 5.1
BMI (kg/m2)	23.0 ± 1.8

This study was performed using a motor-driven treadmill (HP Cosmos, Quasar, Germany) and participants ran for 8 km with a 6% elevation rate by referring to the study conducted by Struhar *et al*. [19]. Before commencing with the trials, a survey form was distributed to each participant. Prior to the trial, participants were weighed before and after each trial, wearing only shorts and a t-shirt as well as the tested clothing. During the test, each participant was asked to wear a heart rate monitor chest strap, and the reading was monitored by a sensor worn at the wrist. Test sessions were terminated when participants feel unable to continue. The whole test procedure took approximately 70 to 80 mins per participant. The temperature of the skin at the chest and thigh area and also the Rating of Perceived Exertion (RPE) were recorded every ten mins during exercise and the recovery period was set at 15 mins. Participants were asked to ascertain their perceptual of thermal sensation, sweating sensation, skin wetness, clothing comfort, and clothing humidity according to the scale given as shown in Table 3.

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to compare the clothing performance for P50C50 and N20C80 for the body mass loss, sweating rate, micro-environment and blood lactate analysis. A paired sample t test was applied to determine perceive exertion, thermal sensation and comfort. All analyses were conducted using Statistical Package for Social Sciences (SPSS Inc. 16^{th} edition, Chicago, IL). All data are as mean ± standard deviation (SD). An Alpha level of $P \leq 0.05$ was considered significant.

Table 3: Scale of Respondent's Perception [5]

Sensation	Scale					
Thermal Sensation	1	2	4	5	6	7
	Very Cold	Cold	Comfortable	Warm	Hot	Very Hot
Sweating Sensation	0	3	6	10	-	-
	Not at all	Slightly Sweating	Moderately Sweating	Heavily Sweating	-	-
Skin Wetness	1	2	5	7	-	-
	Dry	Clammy	Moist	Wet	-	-
Clothing Comfort	0	3	5	7	10	-
	Very Comfortable	Slightly Comfortable	Neutral	Slightly Uncomfortable	Very Uncomfortable	-
Clothing Humidity	0	4	5	7	10	-
	No Sensation	Slightly Damp	Neutral	Moderately Damp	Correspond to Wet	-

RESULTS AND DISCUSSION

In a warm to a hot environment, evaporation is the most critical mechanism for heat dissipation during exercise. Therefore, clothing with less resistance to evaporation will be advantageous. Thus, the study on the thermoregulatory responses is designed to understand the effects of the fabric materials in the form of clothing on the performance of the enforcement personnel. As mentioned earlier, for this study, the P50C50 and N20C80 clothing were used for comparisons. The average temperature in the physiological laboratory was set at 25 ± 2°C with relative humidity of around 55 ± 5 %RH, with 2 m/s air velocity.

Heart Rate

The average resting heart rate of the participants was around 68 ± 6 beats per min (bpm). The average heart rate until the end of the trial exercise was monitored as shown in Figure 1. The average heart rate reading was 172 ± 2 bpm throughout the trials. The heart rate during the 15 min recovery time was seen to reduce by almost 60% from the post-exercise heart rate, reaching around 110 bpm. The 75% to 85% heart rate was achieved after 10 minutes running and the rates were maintained throughout the test for 8 km distance.

Body Mass and Sweating Loss

The body mass loss of the participants for both the clothing was not significantly different from each other for the entire period of trial (P = 0.23). The range of body mass loss for P50C50 is 0.95 ± 0.05 kg whereas for N20C80 is 0.90 ± 0.11 kg. The body mass loss of the participants fluctuated, with no significant trend observed for these two samples.

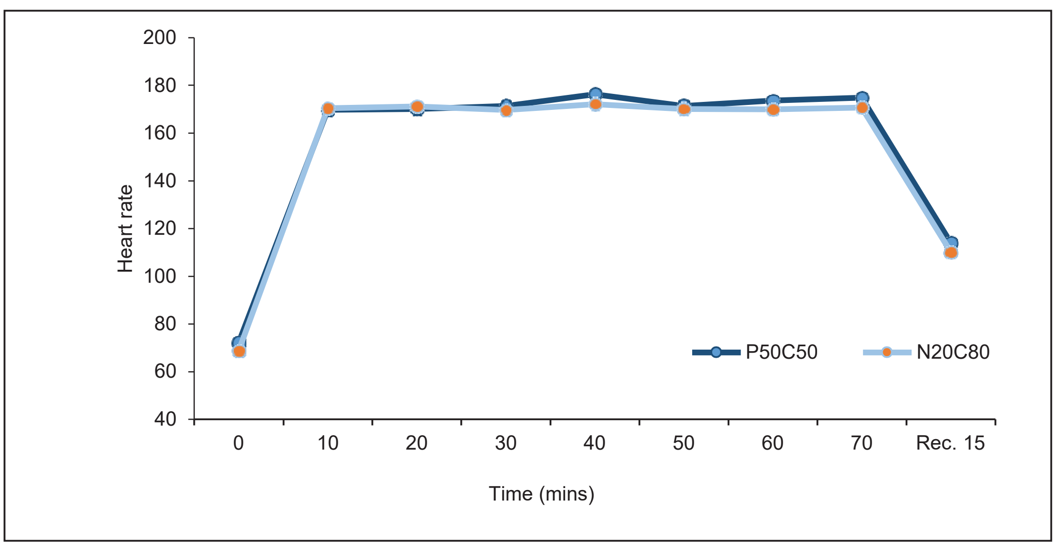

Figure 1: Mean Value Across Time for 75 % to 85% Heart Rate Monitoring

The sweating rate seems to be significantly different between these two types of clothing materials (P = 0.008). The average sweat loss for clothing P50C50 was 0.83 ± 0.04 L h-1, while the sweat loss for clothing N20C80 was 0.74 ± 0.09 L hr-1. In general, all the participants produced less sweat when wearing N20C80 clothing as shown in Figure 2. This was attributed to the significantly higher content of cotton in the N20C80 in contrast with the P50C50. As mentioned by Ha *et al.* (1995), the amount of sweat was significantly higher in the clothing conditions of hydrophobic (polyester) fabrics than those of hydrophilic (cotton) fabrics in a warm environment. In addition, the amount of sweat loss was also affected by the surface area coverage by clothing, physical activities, micro-environment temperature and fitness status [5]. Furthermore, participants with P50C50, 7.1 ± 0.5 km/hr were observed using 8.8% higher speed compared to the participant that wore N20C80, 6.5 ± 0.7 km/hr. Thus, it resulted in a shorter time to complete the 8 km run. The higher speed used would encourage the body to produce more amount of sweat. Higher perspiration rates will also be generated when more energy is spent on muscle contraction during a training exercise. Sweat will be produced by the body to create a cooling effect to maintain the thermoregulatory system of the body [21].

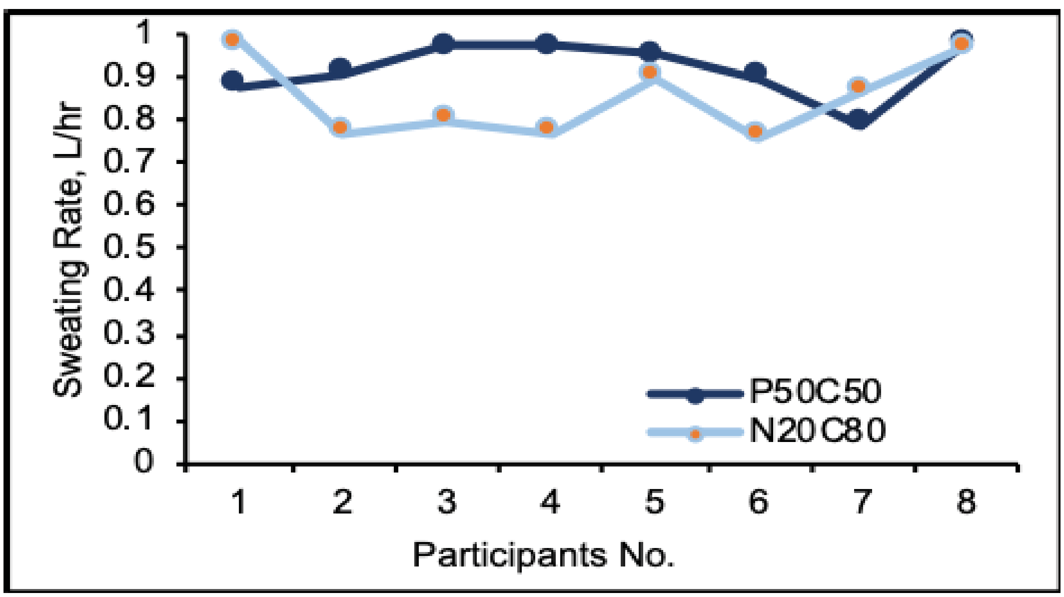

Figure 2: Sweating Rate Loss for Each Respondent

The average exercise time for the participants when wearing the P50C50 clothing was 6.6% faster (68.9 ± 2.4 min) compared to the participants that wore the N20C80 clothing (73.6 ± 5.0 min). The exercise time was influenced by the speed used while the heart rate was maintained at 75% to 85% of resting heart rate. The participant would increase the speed and attempted to get run faster when they did not feel too hot. Therefore, they would reduce the pace, but the heart rate was still maintained between 75% to 85% of their resting heart rate. The participant's thermal perception can be seen from their perceived thermal sensation assessment. There was a significant difference in the thermal sensation between P50C50 and N20C80 clothing ($p < 0.001$).

Micro-Environment

Figure 3 and 4 shows the mean value for the micro-environment temperature throughout the test and between the tested clothing at the chest and thigh area, respectively. As can be seen from Figure 3, there was no significant difference shown during the exercise trials for the micro-environment temperature at the chest area ($P = 0.55$; P50C50 28.5 ± 0.3°C, N20C80 28.5 ± 0.4°C), between both samples. During the recovery period, which was 15 min, it was also found there was no significant difference between the two tested clothing ($P = 0.07$; P50C50 29.1 ± 2.3, N20C80 27.3 ± 3.3). However, significant differences were shown for micro-environment temperature at the thigh area ($P < 0.001$) for P50C50 30.6 ± 0.2°C and 30.9 ± 0.2°C for N20C80 clothing during the trial, as shown in Figure 4. No significant differences were shown during the recovery period for the micro-environment temperature at the thigh area between the tested clothing ($P = 0.73$; P50C50 33.3 ± 1.6°C and N20C80 33.5 ± 1.4°C). During the recovery period, the temperature recorded in both areas appears to increase, and this is related to the heat trapped due to the inactivity of the respondent.

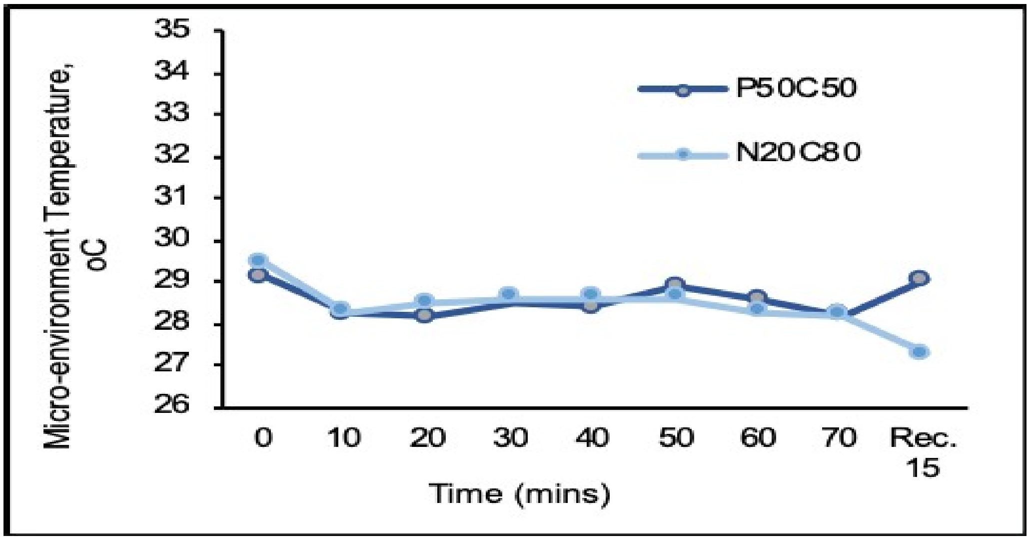

Figure 3: Micro-Environment Temperature at Chest Area

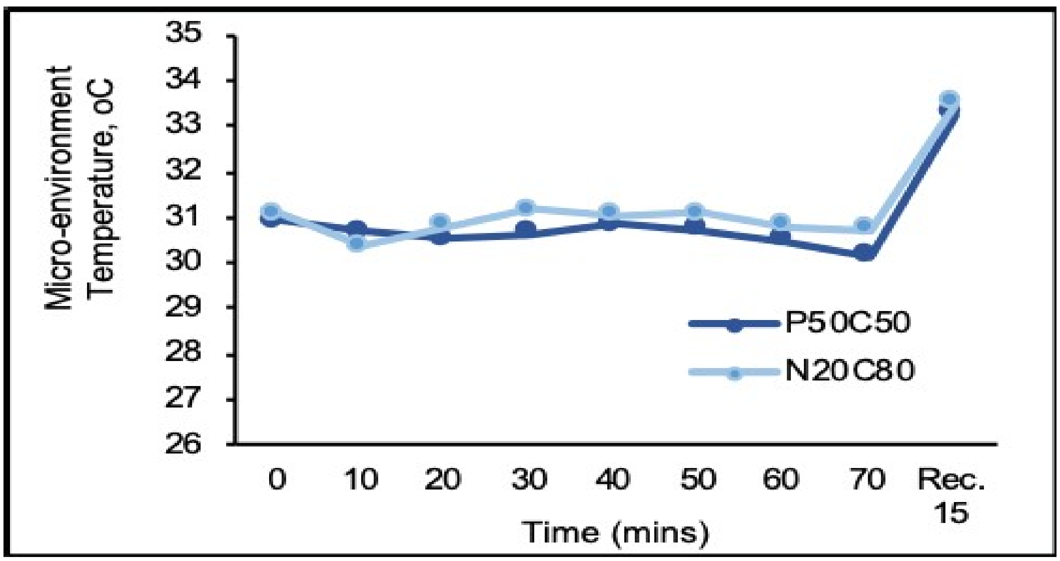

Figure 4: Micro-Environment Temperature at Thigh Area

Comparisons between the temperature at the chest and thigh area indicated that the key factor that affected both clothing samples were air gap thickness. The chest area had thicker air gap thickness as compared to the thigh area; thus, this condition may cause the heat to be quickly dispersed or distributed and lowered the micro-environment temperature. It was a thinner air gap observed at the thigh area due to tight trouser. Thus, the heat was trapped in the micro-environment, which is between the human and inner surface of the clothing and the temperature is naturally higher compared to the chest area that had a looser micro-environment. This finding was supported by Mert *et al.* (2016) stating that the size of the air gap thickness could be one of the major factors that influence the heat and moisture transfer between the human body and the environment [22]. As seen in Figure 4, the micro-environment temperature at the thigh area for N20C80 is slightly higher compared to the P50C50 clothing. The N20C80 has higher cotton fibre content, thus this cotton retained more moisture (sweat) and then emitted a certain amount of heat into the near-air region of the skin. This would increase the temperature of the micro-environment at the thigh area [20].

RPE and S-RPE

Participants were asked to rate the RPE on how physically demanding the exercise trial was, in accordance to the Borg scale 6-20 given in Table 4. As can be seen in Figure 5, a significant difference between P50C50 and N20C80 ($P < 0.001$) was observed. The participants tend to rate higher RPE while wearing the N20C80 as compared to P50C50. The results are consistent throughout the test for all participants. These responses correspond to the comfort properties of the N20C80 fabric, which had lower water vapour permeability, lower air permeability and poor one-way transport index (AOTI) properties compared to the P50C50 fabric [18]. Thus, the heat is not being transferred to the outer environment, and this trapped heat affects the participant's RPE. The participants felt more heat and damp during the exercise trials compared to the P50C50 clothing. The P50C50 fabric had higher air permeability and higher water vapour permeability; thus, a part of heat was permeated to the outer environment, and the wearer felt more comfortable and less heat.

Table 4: Borg Scale 6-20

6	NOT EXERTION AT ALL Just above sleeping
7	
8	EXTREMELY LIGHT You could maintain this pace four hour and carry on conversation
9	
10	
11	LIGHT Comfortable pace, breathing little bit heavier
12	
13	MODERATE Sweating a bit and breathing heavier
14	
15	HARD (HEAVY) Dificult to maintain intensity
16	
17	VERY HARD Barely breath
18	
19	EXTREMELY BARE MAXIMAL EXERTION
20	

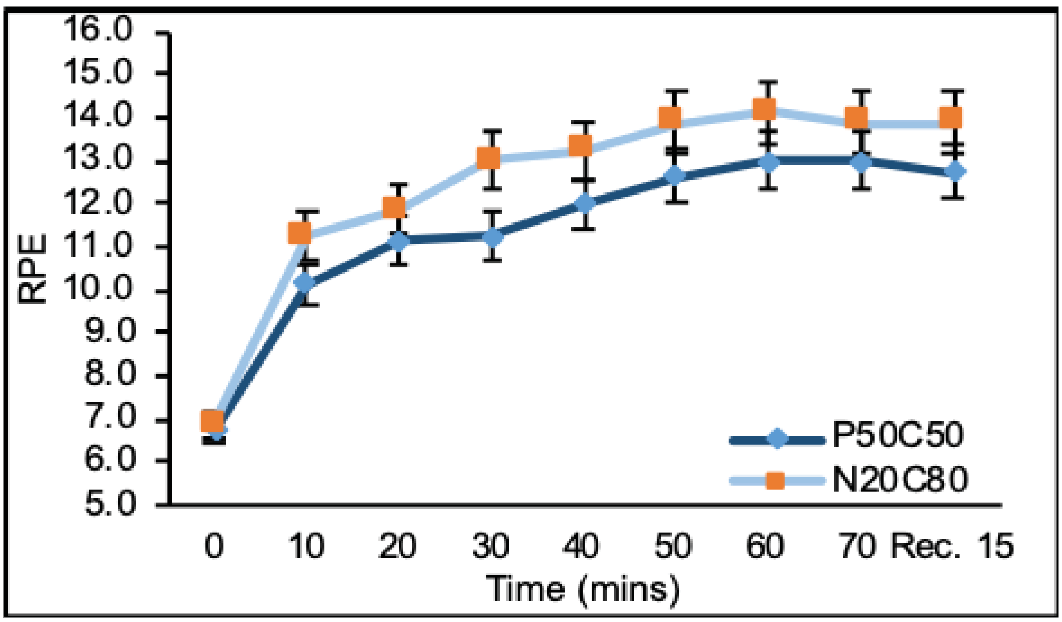

Figure 5: RPE Mean Value for P50C50 and N20C80 (*n* = 8)

Thermal Sensation

Figure 6 presents the participant's perceptions of; thermal sensation, sweating sensation, skin wetness, clothing comfort, and clothing humidity. The thermal sensation ($P < 0.001$), sweating sensation ($P = 0.05$), skin wetness ($P = 0.007$), clothing comfort ($P < 0.01$) and clothing humidity ($P = 0.001$) were significantly greater with N20C80 compared to P50C50 during exercise. The results of thermal sensation showed that the respondent rate the N20C80 as hot and P50C50 as warm. It showed that the heat was entrapped in the micro-environment of the N20C80 clothing. These results are interrelated to the thermophysiological findings which suggested that the N20C80 had lower water vapour permeability, lower air permeability and poor AOTI properties [18]. Respondents rate the sweating sensation for N20C80 as moderate sweating but heavy sweating for P50C50. This response referred to the results of the sweat loss, in which the clothing made of hydrophobic material (polyester), would cause the body to create a quantity of heat rather than the clothing made of hydrophilic materials [20]. This sweating sensation results correspond to the skin wetness and clothing humidity results, which rated as moist, damp for P50C50 and wet, for N20C80. The respondent's rated clothing comfort for N20C80 to be uncomfortable whereas neutral for P50C50. During the 15 min recovery period, only clothing comfort shows a significant difference ($P = 0.02$; P50C50 4.8 ± 1.3, N20C80 6.9 ± 1.6). No significance difference was shown for thermal sensation ($P = 0.17$; P50C50 1.5 ± 0.8, N20C80 2.0 ± 1.1), sweating sensation ($P = 0.51$; P50C50 3.8 ± 2.7, N20C80 4.6 ± 2.6), skin wet-ness ($P = 0.23$; P50C50 3.1 ± 1.6, N20C80 4.1 ± 1.9) and clothing humidity ($P = 0.11$; P50C50 5.8 ± 1.4, N20C80 7.0 ± 1.6) during the recovery period.

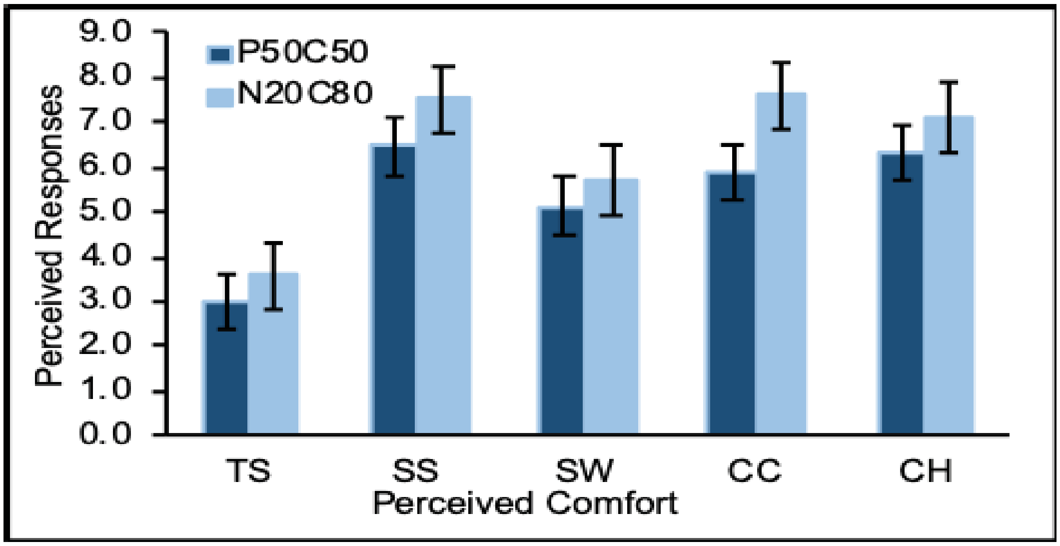

Figure 6: Mean Value in Thermal Sensation (TS), Sweating Sensation (SS), Skin Wetness (SW), Clothing Comfort (CC), and Clothing Humidity (CH) During Exercise Bout (*n*=8)

Blood Lactate

Figure 7 presents the level of blood lactate at pre-test (0 min), 20 min trial, post-trial and after 15 min recovery time for each sample. There were no significant differences in the blood lactate level between P50C50 and N20C80 (pre-test (0 min) $P = 0.05$, after 20 min trial $P = 0.11$, post-trial $P = 0.09$, recovery 15 min $P = 0.60$). The highest blood lactate level observed after 20 mins exercise. It was due to the highest energy used by the participants. It is because the higher energy used, the higher blood lactate will be produced by the body [23]. It was gradually reduced towards the end of the exercise and continued to reduce during the recovery period. The reduction of the blood lactate level was 79.3% and 62.5% compared to the post-trial stage for P50C50 and N20C80, respectively.

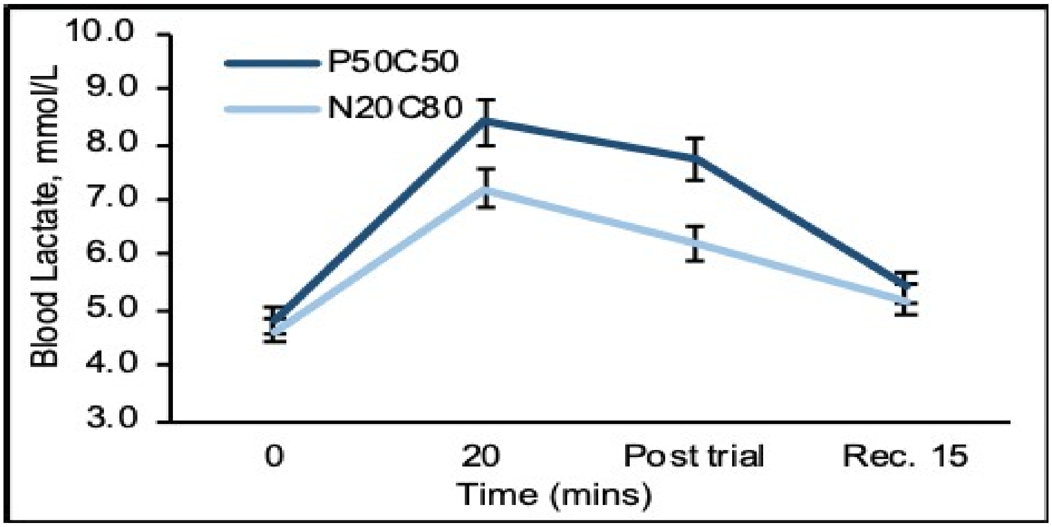

Figure 7: Average Blood Lactate Pre-Trial, After 20 min, Post-Trial and During the Recovery Period

CONCLUSIONS

The results of the thermoregulation study show that the N20C80 clothing has poor thermal balance characteristics compared to the P50C50 clothing. The P50C50 clothing produced a higher work rate and more sweat compared to the N20C80 clothing. The hydrophobic materials would affect the amount sweat produced more than the hydrophilic fabrics in a warm environment. The air gap thickness would be one of the main factors to the micro-environment temperature. The thinner air gap thickness the more heat trapped in the micro-environment rather than dissipate out to the environment. According to the Borg scale rated by participants, there was a higher rating for N20C80 compared P50C50. This demonstrates that participants wearing N20C80 clothing felt warmer than P50C50 clothing. This result is consistent with the thermophysiological findings suggesting that N20C80 had lower water vapour permeability, lower air permeability and poor AOTI properties. According to the Perceptual Response Survey of the respondents, the P50C50 was more convenient to wear during the 8 km uphill running on a treadmill. This indicated that P50C50 would have a better thermoregulatory response to regulate the thermal equilibrium between human skin and the environment.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Higher Education for the funding under the Fundamental Research Grant Scheme (FRGS/1/2018/STG07/UITM/02/1). The authors would also like to acknowledge the assistance given by the Science and Technology Research Institute for Defense (STRIDE), Ministry of Defence, Malaysia and the Research Management Center (RMC), Universiti Teknologi MARA.

REFERENCES

[1] A. V Cardello, C. Winterhalter, and H. G. Schutz, 2003. Predicting military sensory development application psychophysical. *Text. Res. J., 73*(3), pp. 221–237.

[2] S. Duncan, T. Mclellan, and E. G. Dickson, 2011. Improving comfort in military protective clothing. In G. Song (eds), *Improving Comfort in Clothing*. United Kingdom: Woodhead Publishing. https://doi.org/10.1533/9780857090645.3.320

[3] E. G. Hanna and P. W. Tait, 2015. Limitations to thermoregulation and acclimatization challenge human adaptation to global warming. *Int. J. Environ. Res. Public Health, 12*(7), pp. 8034–8074. DOI: 10.3390/ijerph120708034.

[4] Armand V. Cardello, H. G. Schutz, and C. Winterhalter, 2002. Development and application of new psychophysical methods for the characterization of the handfeel and comfort properties of military clothing fabrics. Defense Technical Information Centre, Massachusetts.

[5] J. K. Davis *et al*., 2012. Fluid balance, thermal stress, and post exercise response in women's Islamic athletic clothing. *Eur. J. Appl. Physiol., 112*(2), pp. 725–734. DOI: 10.1007/s00421-011-2026-9.

[6] J. H. Guy, G. B. Deakin, A. M. Edwards, C. M. Miller, and D. B. Pyne, 2015. Adaptation to hot environmental conditions: An exploration of

the performance basis, procedures and future directions to optimise opportunities for elite athletes. *Sport. Med., 45*(3), pp. 303–311. DOI: 10.1007/s40279-014-0277-4.

[7] F. Sun, Z. Du, W. Yu, and N. Chen, 2016. In-situ characterization of fabric thickness under tension based on CHES-FY system. *J. Eng. Fiber. Fabr., 11*(2), pp. 40-50. DOI: 10.1177/155892501601100206.

[8] A. K. Roy Choudhury, P. K. Majumdar, and C. Datta, 2011. Factors affecting comfort: Human physiology and the role of clothing. In G. Song (eds), *Improving Comfort in Clothing*. United Kingdom: Woodhead Publishing. https://doi.org/10.1533/9780857090645.1.3

[9] D. Grujic and J. Geršak, 2017. Examination of the relationships between subjective clothing comfort assessment and physiological parameters with wear trials. *Text. Res. J., 87*(12), pp. 1522–1537. DOI: 10.1177/0040517516657054.

[10] A. Schmidt, R. Paul, E. Classen, S. Morlock, and J. Beringer, 2016. Comfort testing and fit analysis of military textiles. In L. Wang (eds), *Performance Testing of Textiles*. United Kingdom: Woodhead Publishing. https://doi.org/10.1016/B978-0-08-100570-5.00003-7

[11] F. SteRens, S. E. Gralha, I. L. S. Ferreira, and F. R. Oliveira, 2019. Military textiles - An overview of new developments. *Key Eng. Mater.*, *812*, pp. 120–126. DOI: 10.4028/www.scientific.net/KEM.812.120.

[12] S. Racinais *et al*., 2015. Consensus recommendations on training and competing in the heat. *Scand. J. Med. Sci. Sport.*, *25*(S1), pp. 6–19. DOI: 10.1111/sms.12467.

[13] D. Gupta, V. K. Kothari, and Y. Jhanji, 2014. Heat and moisture transport in single jersey plated fabrics. *Indian J. Fibre Text. Res., 39*(June), pp. 115–121, 2014.

[14] A. Afzal *et al*., 2017. Influence of fabric parameters on thermal comfort performance of double layer knitted interlock fabrics. *AUTEX Res. J., 17*(1), pp. 20–26. DOI: 10.1515/aut-2015-0037.

[15] J.E.Wingo and R. G. McMurray, 2007. Cardiovascular and thermoregulatory responses to treadmill running while wearing shirts with different fabric composition. *Biol. Sport, 24*(2), pp. 177–187,

[16] R. H. G. P. Zhang, 2002. Effects of clothing material on thermoregulatory responses. *Text. Res. J.,72*(1), pp. 83–89.

[17] M. Brazaitis, S. Kamandulis, A. Skurvydas, and L. Daniusevičiute, 2010. The effect of two kinds of T-shirts on physiological and psychological thermal responses during exercise and recovery. *Appl. Ergon 42* (1), pp. 46–51. DOI: 10.1016/j.apergo.2010.04.001.

[18] N. Zahari, M. R. Ahmad, M. F. Yahya, A. M. C. Muhamed, and R. Yahaya, 2018. Thermophysiological comfort properties of ripstop fabrics for enforcement personnel clothing. *Int. J. Eng. Technol., 7*(4.18), pp. 196–199. DOI: 10.14419/ijet.v7i4.18.21908.

[19] I. Struhar, M. Kumstat, and D. M. Kr, 2018. Effect of compression garments on physiological responses after uphill running. *J. Hum. Kinet., 61*(March), pp. 119–129. DOI: 10.1515/hukin-2017-0136.

[20] M. Ha, H. Tokura, and Y. Yamashita, 1995. Effects of two kinds of clothing made from hydrophobic and hydrophilic fabrics on local sweating rates at an ambient temperature of 37°C. *Ergonomics, 38*(7), pp. 1445–1455. DOI: 10.1080/00140139508925201.

[21] S. Kanjana, A. Babu, and G. Nalankilli, 2018. Fashion technology & textile engineering breathable garments with thermo - physiological wear comfort - A review. *Fash. Technol. Text. Eng., 3*(1), pp. 22–27. DOI: 10.19080/CTFTTE.2018.03.555605.

[22] E. Mert, S. Böhnisch, A. Psikuta, M. A. Bueno, and R. M. Rossi, 2016. Contribution of garment fit and style to thermal comfort at the lower body. *Int. J. Biometeorol., 60*(12), pp. 1995–2004. DOI: 10.1007/s00484-016-1258-0.

[23] M. Price and P. Moss, 2007. The effects of work:rest duration on physiological and perceptual responses during intermittent exercise and performance. *J. Sports Sci., 25*(14), pp. 1613–1621. DOI: 10.1080/02640410701287248.