วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 17 ฉบับที่ 2, ธันวาคม 2560

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EFFECTS OF A NEWLY DESIGNED MILITARY SHIRT ON PHYSIOLOGICAL RESPONSES UNDER HEAT STRESS

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ABSTRACT

The operations of military forces require wearing battle dress uniform and a protective ballistic vest which may increase physiological strain and impair physical performance in hot and humid environment. **Objective**: to investigate and compare the effects of two military shirts; a newly designed long-sleeved military shirt (NMS) and a traditional military shirt (CON) on physiological responses, time to exhaustion (TTE), and subjective perception during exercise in hot and humid condition (NMS; 35.3 ± 0.1°C, 50.6 ± 1.2% , CON; 35.1 ± 0.2°C, 50.7 ± 0.8%). **Method**: Twelve healthy and physically active males (Age: 20.8 ± 0.4 years; BW: 66.6 ± 1.7 kg; Height: 173.6 ± 1.6 cm) volunteered to participate in this study. Subjects completed two experimental trials wearing NMS or CON covered by the standard military protective vest in a randomized order. Subjects walked on a motorized treadmill (3.5 km/h, 0% grade), wear a combat helmet and carry mission load including rifle and back pack over 120 minutes or until exhaustion. Core temperatures (T_{GI}), Skin temperatures, stroke volume (SV), cardiac output (CO), oxygen consumption rate (VO_2), rating of perceived exertion (RPE), and thermal responses were measured at rest and every 5 minutes during exercise. Two-way repeated measurement ANOVA was used to test the main effects of shirts and times, and interaction effect. Paired t-test and Wilcoxon signed rank test were applied for sweat loss, time to exhaustion and thermal subjective responses, respectively. **Results**: no main effect of shirts and interaction effects of shirts and time on core temperature and skin temperature, HR, VO_2, SV, and RPE were observed. Moreover, TTE and thermal responses of NMS and CON trials were not significantly different. However, CO at the end of exercise of CON (18.0 ± 0.5 $L.min^{-1}$) and NMS (16.6 ± 0.45 $L.min^{-1}$) was significantly different. **Conclusion**: Wearing NMS beneath a protective vest during exercise in hot, humid environment did not exert any different effects on time to exhaustion, physiological responses, and subjective perception when compared to CON. It is possible that a protective vest that covered the military shirt may impede the effectiveness of NMS on heat transfer.

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Keywords: Battle dress uniform / heat exchange / thermoregulation / physiological strain

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ผลของเสื้อทหารชนิดใหม่ที่มีต่อการตอบสนองทางสรีรวิทยาภายใต้สภาวะเครียดจากความร้อน

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บทคัดย่อ

การปฏิบัติหน้าที่ทางทหารมีความจำเป็นต้องสวมเครื่องแบบการต่อสู้ทางทหารพร้อมกับสวมชุดเกราะป้องกันกระสุนซึ่งอาจเพิ่มความเครียดของระบบต่างๆทางสรีรวิทยาและส่งผลให้สมรรถภาพทางกายลดลงเมื่ออยู่ในสภาพอากาศร้อน-ชื้น การศึกษานี้มีจุดมุ่งหมายที่จะทดสอบและเปรียบผลของเสื้อทหารสองแบบ ได้แก่ เสื้อทหารแขนยาวที่ได้รับการออกแบบใหม่ (NMS) และเสื้อทหารแขนยาวแบบดั้งเดิม (CON) ต่อการตอบสนองทางสรีรวิทยา ระยะเวลาการออกกำลังกายจนเหนื่อยหมดแรง และความรู้สึกระหว่างการออกกำลังกายในที่ร้อน ชื้น (สภาวะ NMS; 35.3 ± 0.1°C, 50.6 ± 1.2% สภาวะ CON; 35.1 ± 0.2°C, 50.7 ± 0.8%) ผู้เข้าร่วมการวิจัยเป็นอาสาสมัครชายสุขภาพดีที่ออกกำลังกายเป็นประจำ จำนวน 12 คน (อายุเฉลี่ย 20.8 ± 0.4 ปี; น้ำหนักตัว 66.6 ± 1.7 กิโลกรัม; ส่วนสูง 173.6 ± 1.6 เซนติเมตร) ได้รับการสุ่มลำดับเพื่อเข้าทดสอบในสองสภาวะ โดยการสวมเสื้อแบบใหม่หรือแบบดั้งเดิม แล้วใส่ชุดเกราะป้องกันสวมทับ เดินบนเครื่องออกกำลังกายแบบลู่วิ่ง (ความเร็ว 3.5 กิโลเมตรต่อชั่วโมง ความชัน 0 เปอร์เซ็นต์) สวมหมวกนิรภัยทางทหารและแบกอุปกรณ์ในการทำภารกิจ ประกอบด้วยปืนยาวและกระเป๋าสะพายหลังเป็นระยะเวลา 120 นาทีหรือเหนื่อยล้าจนกระทั่งไม่สามารถออกกำลังกายต่อได้ ทำการวัดอุณหภูมิแกนกลาง อุณหภูมิผิวหนัง ประเมินอัตราการเต้นของหัวใจ ปริมาตรเลือดที่ถูกสูบฉีดออกจากหัวใจใน 1 ครั้ง ปริมาณเลือดที่ถูกสูบฉีดออกจากหัวใจใน 1 นาที อัตราการใช้ออกซิเจนของร่างกาย ระดับความรู้สึกเหนื่อย และการตอบสนองเชิงอุณหภาพและความร้อนในขณะพักและระหว่างการออกกำลังกายทุกๆ 5 นาทีใช้สถิติ Two-way repeated measurement ANOVA วิเคราะห์ผลของรูปแบบเสื้อ เวลา และอิทธิพลร่วมของทั้งสองปัจจัย เปรียบเทียบความแตกต่างของการสูญเสียเหงื่อระหว่าง NMS และ CON ด้วยสถิติ Paired t-test เปรียบเทียบระยะเวลาการออกกำลังกายจนเหนื่อยหมดแรง และการตอบสนองเชิงอุณหภาพและความร้อนของระหว่างสภาวะดังกล่าวโดยใช้ Wilcoxon signed rank test ผลการศึกษาพบว่าชนิดของเสื้อที่แตกต่างกัน (NMS และ CON) ไม่มีผลต่ออุณหภูมิแกนกลาง อุณหภูมิผิวหนัง อัตราการเต้นของหัวใจ อัตราการใช้ออกซิเจน ปริมาตรเลือดที่ออกจากหัวใจใน 1 ครั้ง และความรู้สึกเหนื่อยจากการออกกำลังกาย นอกจากนี้ยังพบว่าระยะเวลาการออกกำลังกายจนเหนื่อยหมดแรง ความรู้สึกเชิงความร้อนและความรู้สึกเชิงอุณหภาพของ NMS และ CON ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ อย่างไรก็ดีพบว่าปริมาณเลือดที่ออกจากหัวใจใน 1 นาทีที่แตกต่างกันอย่างมีนัยสำคัญทางสถิติระหว่าง CON (18.0± 0.5 ลิตรต่อนาที และ NMS (16.6± 0.5 ลิตรต่อนาที) ที่จุดสิ้นสุดการออกกำลังกายสรุปผลได้ว่าการสวมเสื้อทหารแบบใหม่ภายใต้ชุดเกราะป้องกันระหว่างออกกำลังกายในที่ร้อน-ชื้นไม่มีผลต่อการตอบสนองทางสรีรวิทยา ระยะเวลาในการออกกำลังกายจนเหนื่อยหมดแรง ระดับความรู้สึกเหนื่อยการตอบสนองเชิงอุณหภาพและความร้อนที่แตกต่างจากการสวมเสื้อทหารแบบดั้งเดิม เป็นไปได้ว่าชุดเกราะป้องกันที่สวมทับบนเสื้อทหารอาจจะลดประสิทธิภาพของเสื้อทหารแบบใหม่ในการส่งผ่านความร้อนออกจากร่างกาย

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คำสำคัญ:เครื่องแบบการต่อสู้ทางทหาร / การแลกเปลี่ยนความร้อน / การควบคุมอุณหภูมิ / ความเครียดทางสรีรวิทยา

INTRODUCTION

Exercise in hot environment can alter physiological and subjective perceptual responses. Especially wearing clothing which has high insulation and low vapor permeability can impede heat transfer and impair wearer's performance.[1] There are many risks occupations including military, policeman, firefighters, and emergency workers that require wearing highly insulated clothing for each safety during operation. Additionally, military often operate under extreme environment while wearing clothing with protective vest and this may increase physiological strain and risk of heat illness. Wearing ballistic protective vest in hot environment has been shown to increase physiological stain (higher core temperature, skin temperature, heart rate, and sweat rate).[10, 15] Generally, human body can dissipate heat through four ways, conduction, convection, radiation, and evaporation.[2]However, when exercise in hot environment, sweat evaporation becomes only effective way to cope with accumulated heat in the body.[3] Clothing with cotton fabric has property of high water absorption which may reduce skin temperature during exercise.[4] In contrast, clothing with polyester fabric has more effectiveness of high moisture transfer through clothing compared to cotton fabric.[5]However,previous studies revealed no different changes in physiological responses compared between cotton and polyester shirts in warm to hot conditions.[6 – 8] Numerous studies of cooling techniques including convection (air-cooled garment), conduction (liquid cooled garment) ,and evaporation have been developed to decrease physiological strain when wearing combat clothes.[9-11] A blowing device presenting as "active strategy" beneath a protective vest has been investigated. The result showed that rectal temperature (T_{re}) was lower during exercise in both hot-dry (40°C, 40% RH) and hot-humid (35°C, 60% RH) conditions.[12] However, the recent study investigating perforated clothing combined with a spacer device has revealed no effect of shirts on physiological responses during exercise in hot environment.[13]The effectiveness of previous cooling techniques remains unclear. In addition to, these techniques may be not suitable for practical application.

Therefore, a new clothing design suitable for using on field is needed, i.e., a long-sleeved shirt of battle dress uniform(BDU) with increasing porosity at chest, back, and trunk sides, and change types of clothes to improve the effectiveness of heat transfer.The present study aimed to study and compare between effects of a newly designed military shirt (NMS) and a traditional military shirt (CON) on physiological responses, time to exhaustion (TTE), and subjective perception during exercise under heat stress. The hypothesis was NMS may exert different effects on physiological responses, time to exhaustion (TTE), and subjective perception compared to CON during exercise under heat stress.

METHODS

Subjects

Twelve physically active males with age between18 - 25 years, regularly exercise (60 min/d, ≥ 3 d/wk) for at least 3 months, and peak oxygen capacity (VO_2peak) ranged between 40 – 45 ml.kg^{-1}.min^{-1}, volunteered to participate in this study. Participants who has joint and muscle injuries, cardiorespiratory diseases, obstructive disease of gastrointestinal tract, swallowing problem, and body mass index (BMI) (< 19 or > 25 Kg/m^2) were excluded. Termination criteria were reach when subjects' core temperature were more than ≥ 39 °C, HR >190 b/min and voluntary to stop. All participants were explained about the nature of the investigation, purposes, benefits, experimental procedures, and possible risks associated with study before the informed consent was signed. The study protocol and procedure were approved by Mahidol University Central Institutional Review Board (MU-CIRB; 2016/042.2103).

Experimental protocol

Two experimental trials were conducted in a hot, humid environment (NMS; 35.3 ± 0.1°C, 50.6 ± 1.2%, CON; 35.1 ± 0.2°C, 50.7 ± 0.8%), separated each by 7 days. This environment was selected to mimic a warm summer day within most of Thailand. The battle dress uniform (BDU) is the standard uniform worn by military forces. The BDU was worn in 2 trials in randomized order, either wearing a traditional long-sleeved military shirt (CON), or wearing a newly designed long-sleeved military shirt (NMS) covered by a ballistic protective vest.In each trial, subjects were asked to carry combat loads including backpack and rifle (~13 kg) and put on their individual's sport shoes.

Subjects were asked to perform two hours of continuous treadmill walking was performed (3.5 km/h, 0% inclination) or until exhaustion. This duration of exercise and walking speed were selected to simulate the duration of march training in real situation of military forces. All experimental testing was conducted at the same time of day to control for circadian fluctuation in body temperature.

Clothing ensemble

All participants were asked to wear battle dress uniform (BDU); either long-sleeved shirt or trousers (blended cotton and polyester fabrics) in CON, or long-sleeved shirt (modified type of cloths) in NMS. The long-sleeved military shirt of the BDU was worn over a 100% cotton T-shirt in both experimental trials to simulate the actual layers. Participants wore a ballistic protective vest with the plates of ceramic at front and back of the outer vest (~7.5 kg weights) covered on the BDU, and wore ballistic helmet. Additionally, all participants carried combat loads (backpack and rifle; ~13 kg). They wore their individual athletic shoes in order to reduce blister formation from the combat shoes. A newly designed long-sleeved military shirt was manufactured by increased porosities at front, back, and sides of torso and modified type of cloths aiming to enhance evaporative cooling effects.

Procedures

Subjects were asked to refrain from alcohols, caffeine, and intense exercise 24 hours before the experimental trials. They were instructed to sleep for at least 6-8 hours and ingest core temperature pill for 4-6 hours before the investigation started. Meals and water were provided by the researcher before 2-3 hours of each test including 300 mL of water 30 minutes before exercise. Urine specific gravity (USG) was determined in order to determine euhydration state (USG $\leq$0.020) by a refractometer (Atago Inc, Japan). Before and after installing clothing ensembles and measurement devices on subject's body, nude and fully dressed body weights were measured on an electronic weighing apparatus, respectively. Subjects were asked to rest quietly in the control room for 5 minutes before exercise. During rest and every 5 minutes of continuous exercise until the subject's cessation, their core temperature were recorded using a core temperature pill (Palmetto, FL 34221-4802, USA), which transmits the temperature of the GI environment wirelessly to an external logger[14]. Skin temperatures (T_{sk}) were measured using thermistors (New YSI 400 series, Japan) located on 5 sites(chest, back, arm, thigh and calf) and mean skin ($\overline{T}_{sk}$) and torso temperatures (T_{torso})[10] were calculated using the following equations (A and B, respectively).

$$\textbf{(A)} \quad T_{Msk} = 0.15\,(T_{chest}) + 0.15\,(T_{back}) + 0.3\,(T_{forearm}) + 0.2\,(T_{thigh} + T_{calf})$$

$$\textbf{(B)} \quad T_{torso} = 0.5\,(T_{chest}) + 0.5\,(T_{back})$$

Heart rate (HR), stroke volume (SV), and cardiac output (CO) were measured usingSignal Morphology-based Impedance Cardiography (Physioflow, France) recordedin real-time.

Physiological strain index (PSI)was computed from the changes of cardiovascular (HR) and thermal loads (T_{GI}) (Moran et al., 1998).A universal scale of 0-10 units was used:

$$\textbf{PSI} = [5(HR - HR_0) \times (180 - HR_0)^{-1}] + [5(T_{GI} - TGI_0) \times (39.5 - T_{GI0})^{-1}]$$

Where HR and T_{GI} are measured at the end of exercise and HR_0 or T_{GI0} value measured at the starting of exercise or during rest.

Oxygen consumption (O_2) was measured by gas analyzer (Oxycon mobile, Germany) which volume, flow, and gases were calibrated.

Subjective perceptions consisted of rating of perceived exertion (RPE) using 6-20 scales[23]; where 6 determines no effort and 20 determines extremely hard effort (Brog, 1962), thermal sensation (TSS) (0-4) scales; where 0 is a normal and 4 is very hot, and thermal discomfort (TDS) (0 to -4) scales; where 0 is a normal and -4 is very uncomfortable.[24]

Sweat loss (SL) was calculated as the different between pre-test and post-test nude body weights plus the amount of total water intakes during exercise.Time to exhaustion (min) was recorded as the duration from the onset of exercise till the end of exercise. During exercise, 150 mL of water was provided to subject every 15 minutes until the cessation of exercise.

Statistical analyses

Statistical analysis was performed using SPSS v.20 for Windows (IBM SPSS Software, Armonk, NY, USA). The participant's characteristics were presented (in Table 1) as Mean ± SD. The variables including T_{GI}, $\overline{T}_{sk}$, T_{torso}, HR, CO, SV, PSI, VO_2, RPE, TDS, TSS, sweat loss, and TTE were presented as Means ± SEM. The normal distribution of the data was tested using Shapiro-Wilk W test. Two-way repeated measurement ANOVA was used to test the main effects of shirts and times, and interaction effect of parameters (T_{GI}, $\overline{T}_{sk}$, T_{torso}, HR, PSI, VO_2, and RPE) during 45 minutes of exercise. Pairwise T-test was used to compare time points at rest or end point of exercise between trials and test sweat loss. Wilcoxon signed rank was used to test time to exhaustion and thermal responses. Statistical significance was set at $p < 0.05$.

RESULTS

The subject's general characteristics and physiological responses

The general characteristics of the participants showed in Table 1. There were no significant differences of T_{GI}, $\overline{T}_{sk}$, T_{torso}, HR, SV, CO, VO_2 at rest between CON and NMS trials (T_{GI}; 37.39 ± 0.08°C vs. 37.36 ± 0.09°C (Figure 1), $\overline{T}_{sk}$; 35.80 ± 0.19 °C and 35.82 ± 0.30 °C, and T_{torso}; 35.80 ± 0.19 °C and 35.82 ± 0.30 °C (Figure 2), HR; 80.27 ± 2.68 $b.min^{-1}$ and 84.33 ± 3.21 $b.min^{-1}$, SV; 80.05 ± 3.88 ml and 80.17 ± 2.89 ml; CO; 6.23 ± 0.25 $L.min^{-1}$ and 6.46 ± 0.22 $L.min^{-1}$ (Figure 1), and VO_2; 5.54 ± 0.39 $ml.kg^{-1}.min^{-1}$ and 5.34 ± 0.21 $ml.kg^{-1}.min^{-1}$, respectively). During 45 minutes of exercise, rise of T_{GI}, $\overline{T}_{sk}$, and T_{torso}, HR, SV, CO, and VO_2 were not different between CON and NMS. No main effect of shirts and interaction effects of shirts and time on T_{GI}, $\overline{T}_{sk}$, and T_{torso}, HR, SV, CO and VO_2. At immediately after exercise, T_{torso} (CON; 38.12 ± 0.63 °C vs. NMS; 38.16 ± 0.43°C) was near to T_{GI} (CON; 38.52 ± 0.12 °C vs. NMS; 38.44 ± 0.14 °C). However, there were no significant differences of measured variables between CON and NMS except CO (CON; 17.97 ± 0.48 $L.min^{-1}$ vs. NMS; 16.55 ± 0.48 $L.min^{-1}$) ($p < 0.05$) immediately after exercise (Figure 2). The highest point of PSI observed was 6.48 ± 0.33 and 6.67 ± 0.41 in CON and NMS, respectively; however, there was no significant difference between trials.In addition to, sweat loss between CON (1.41 ± 0.12 L) and NMS (1.52 ± 0.11 L) showed no significant difference.

Table 1 The general characteristics of the participants (n = 12). Values are expressed as mean ± SD.

Variables	Mean ± SD
Age (y)	20.75 ± 0.42
Body weight (kg)	66.58 ± 1.70
Height (cm)	173.58 ± 1.60
%Body fat	13.12 ± 1.0
BMI (kg/m^2)	22.15 ± 0.42
RHR (b.min^{-1})	71.0 ± 2.0
Blood pressure (mmHg)	
Systolic BP	124.41 ± 3.15
Diastolic BP	69.91 ± 1.75
$\dot{V}O_2$peak (ml/kg/min)	44.47 ± 1.29

Subjective perceptual responses

RPE at the beginning was determined as 7.00 ± 0.39 in CON and 7.00 ± 0.27 in NMS which indicated that subjects felt comfortable. When exercise up to at the cessation, RPE increased up to with showed hard feeling (CON; 19.33 ± 0.28 and NMS; 19.33 ± 0.33). No effect of shirts and interaction effects of shirts and time were found. At start and immediately after exercise, TSS and TDS were not significantly different between CON (TSS; 0.83 ± 0.17 and 3.83 ± 0.11, TDS; 0.08 ± 0.26 and -3.75 ± 0.13, respectively) and NMS (TSS; 0.83 ± 0.21 and 3.92 ± 0.08, TDS; 0.08 ± 0.36 and -3.83 ± 0.11, respectively). A Wilcoxon Signed-Ranks test indicated that the mean NMS ranks of TSS and TDS were not significantly different when compared with the mean CON ranks.

Time to exhaustion (TTE)

The median (range) of TTE was 58.57 (47.23 – 91.43 minutes) in CON trial and 62.50 (45.00 – 93.45 minutes) in NMS trial. A Wilcoxon Signed-Ranks test indicated that the mean NMS rank was not significantly different when compared to the mean CON rank.

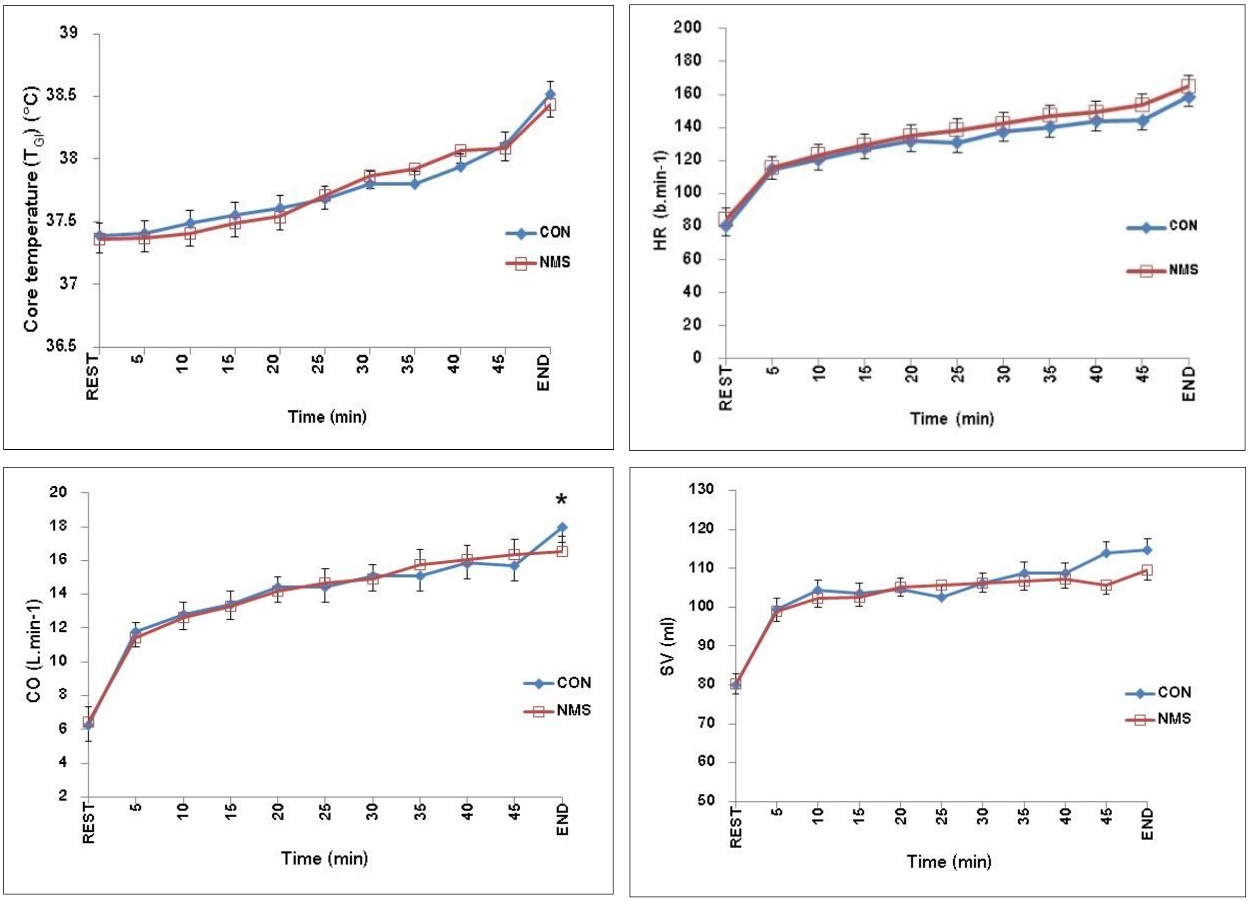

Fig 1 Thermo-cardiovascular responses (T_{GI}, HR, SV, and CO) at rest (before exercise), during 45 minutes, and at the end of exercise for CON and NMS trials. No significant main effect of shirts (n = 12) *Significant difference at the end of exercise compared between trials (p < 0.05). Data are means ± SEM.

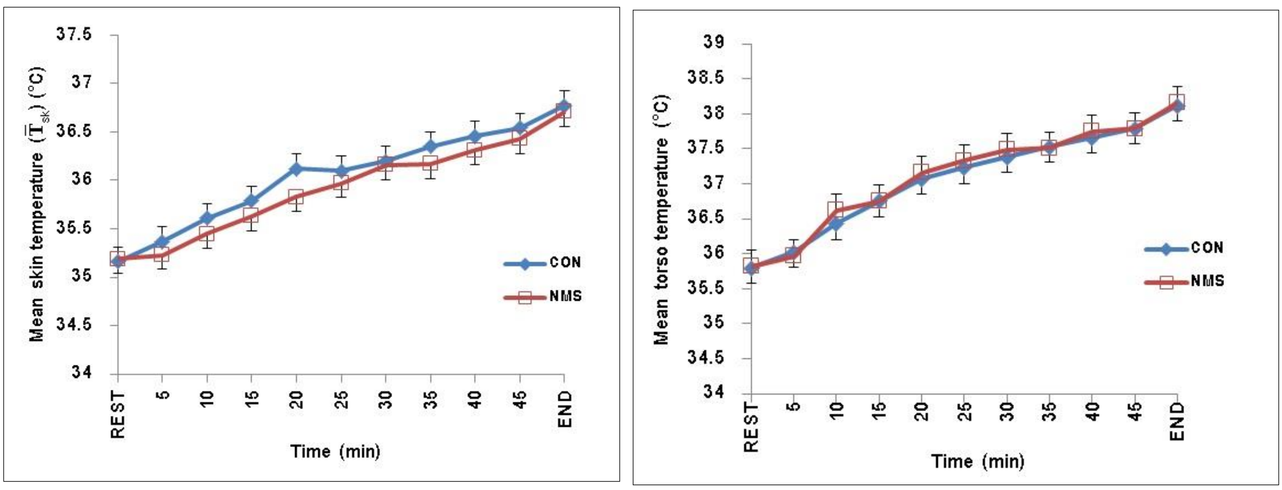

Fig 2 Skin temperatures ($\bar{T}_{sk}$ and T_{torso}) (°C) at rest (before exercise), during 45 minutes, and at the end of exercise for CON and NMS trials. No significant main effect of shirts (n = 12; p > 0.05). Data are means ± SEM.

The purpose of the present study was to investigate effects of a newly designed military shirt (NMS) on physiological responses and exercise performance compared to a traditional military shirt (CON). In this study, hydration status and circadian patterns were controlled to reduce physiological variability. The main finding of the present study is that wearing NMS beneath a protective vest has no any significant effects on physiological responses and time to exhaustion during exercise in hot-humid condition. The results were consistent with previous studies that investigated the effects of cooling and ventilating clothing under a protective vest during exercise in hot conditions.[10, 13, 15] Subjectterminated on set criteria was not found in the present study; T_{GI} and HR did not reach the limitation. Rise in T_{GI} and HR was similar between CON and NMS, and had no significant differences. T_{GI} rise is evidently associated with a rise in HR during the cardiovascular drift at submaximal exercise.[22] Factors of uncompensated-heat stress which can induce the increase of physiological strain consisted of the exercise intensity, the stressful environments, and the clothing which impede the effectiveness of heat loss. The present study controlled constant load of exercise and ambient environment to find out the different effects of two shirts, but found that NMS did not exert the increase of the effective heat loss through clothing. Therefore, T_{GI}, $\overline{T}_{sk}$, HR, and subjective perception were not shown significant differences between NSM and CON. Gravin et al.,[6] studied effects of polyester and cotton materials on physical performance during exercise at 70% $\dot{V}O_2$max in condition (30 °C, 35% RH) and Braziltis et al.,[7] performed more 70% $\dot{V}O_2$max in the similar condition; however, they found no significant difference in rectal temperature (T_{re}) between trials. The present study revealed that rise in T_{torso} at the end of exercise was near to T_{GI} in either CON or NMS. The possibility that internal heat of the body could not dissipate through a ballistic vest as sweat excreted from skin at that time effectively. The result confirmed that a ballistic vest is the factor that impedes sweat evaporation in corresponding to previous studies.[15, 16] At the end of constant exercise under the ambient temperature (35° C, 50% RH) induced exercise intensity at 48.23 ± 2.78 % VO_2peak in CON and 46.25 ± 1.77% VO_2peak in NMS. The intensities were lower than Braziltis et al.'s study.[7] Increased clothing permeability and ventilation lead to an increase of heat dissipation from the body to the environment[17] resulted to lower skin temperature. The present study, although NMS has higher permeability and ventilation in shirt than CON, it was covered by a ballistic vest like CON. Due to subject's fluid loss between trials in the present study had the equivalent amounts, a result in a uniform cardiovascular stress. Therefore, no significant differences of HR, SV, and CO at rest and during 45 minutes of exercise between trials were found. Previous studies revealed that exercise wearing the military battle dress uniform (BDU) with air-filled vest or a spacer garment device had no HR improvement compared to wearing without it.[13, 15] At the end of exercise, CO of NMS was lower than that of CON. The possibility that amounts of sweat loss in NMS was higher than that in CON lead to drop in SV resulted to decreased CO at the same time. However, the present study had found no significant difference of sweat loss between trials after exercise. PSI at immediately after exercise was 6.48 ± 0.33 and 6.67 ± 0.41 in CON and NMS, respectively, which it was categorized in a hard level. The PSI calculated from a relation between T_{GI} and HR[18] which showed no significant differences between trials. Therefore, the PSI had no change.Adverse effects of thermoregulatory and cardiovascular strains leading impair subject's performance.[19, 20]Subjects stopped exercise at intensity of 45.83 % VO_2peak in CON and 46.07% VO_2peak in NMS. The intensity was categorized in light to moderate submaximal exercise. At this intensity, the active muscles can receive blood from cardiovascular center enough to generate energy, not need to complete thermoregulation system which transfers blood to skin to dissipate heat through sweating. Therefore, using VO_2 for food oxidation was similar between trials. A study showed that there was no significant difference in VO_2 during exercise at the intensity of 70% VO_2max compared among three shirts wearing in hot condition.[6]RPE can decrease during exercise in the heat by applying a cool stimulus to the skin despite elevated core temperature.[21]However, NMS did not increase a cooling effect at skin; therefore, the RPE showed no significant difference compared to CON. Yet there are previous studies found the significantly different effects between using ventilated clothing and traditional clothing on TSS and TDC under heat conditions. From all results of this study, there were thermoregulatory and cardiovascular strains similarly in both trials. Therefore, no significant difference in time to exhaustion was observed.

CONCLUSION

Wearing NMS beneath a protective vest during exercise in hot and humid environment did not exert any different effects on time to exhaustion, physiological responses, and subjective perception when compared to CON. It is possible that a protective vest that covered the military shirt may impede the effectiveness of NMS on heat transfer. In further study, a ballistic protective vest would be newly designed with more light weight and less tight cloths to enhance moisture transfer to environment.

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