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Effects of the Liquid Circulation Cooling Vest on a Physiological Strain Level in Solders During Exertional Heat Stress

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The present study was conducted in order to evaluate the efficiency of a personal body cooling system based on a chilled water flow through a tube system and its effects on solders' psycho-physiological suitability during exertional heat stress in hot environment. The obtained results are based on the examinations conducted in the climatic chamber in the Military Medical Academy Institute of Hygiene in Belgrade. Ten male solders-volunteers were subjected to a exertional heat stress test (EHST) consisting of walking on a motorized treadmill at a speed of 5 km/h in hot environment (air temperature 40°C). The tests were performed with male solders (25.8 ± 2.4 years, 72 ± 10 kg, 182 ± 8 cm), in cases of wearing a field camouflage uniform without any cooling system (NoCOOL) and using the Waist Pack Style personal cooling system DP 103 (COOL). As physiological strain indicators, the following parameters have been determined: mean skin (Tsk) temperature, tympanic (Tty) temperature and heart rate (HR), while sweat rate (SwR) was calculated in order to determine the change in the water and electrolyte status. The exercises in hot conditions induced a physiological response to heat stress, manifested through increasing Tty, HR and SwR. The results confirmed that the cooling vest worn over the field uniform was able to attenuate the physiological strain levels during exercise, when compared to the identical exposure without the cooling system

Key words: **protective equipment, soldier equipment, cooling vest, temperature effects, high temperatures, heat stress, physiological strain.**

Introduction

THERMAL insulation of clothing systems mainly depends on the physical activity and the ambiental conditions (temperature and relative humidity). The amount of heat produced by humans depends on the physical activity and can differ from 100 W while resting to over 1.000 W during maximum physical performance. At extreme activity, which is often a case with winter sports, the body temperature rises with enhanced heat production. To maintain this increase within a certain limit, the body perspires in order to dissipate thermal energy from the body by evaporative cooling. If the thermal insulation of the clothing is decreased during physical activity, a part of the generated heat can be removed by convection, thus the body does not have to perspire so much.

The quality of insulation in a garment in terms of heat and cold will be widely managed by the thickness and density of its component fabrics. High thickness and low density make insulation better. It is observed in many cases that thermal insulation is offered by air gaps between the garment layers. However, the external temperature also influences the effectiveness of the insulation. The more extreme the temperature, be it very high or very low, the less effective the insulation becomes. Thus, a garment designed for its capability to protect against heat or cold is chosen by its wearer on the expectation of the climate in which the garment is to be worn.

The accumulation of heat, reflecting the peripheral and body core temperature, occurs during heavy physical exertion or exposure to warm and humid environment. Long-term accumulation of heat in a quantity of about 0.5 W/kg during 1 h to 2 h, leads to an increase in the body temperature that some people are unable to tolerate [1]. Heat stress can occur in a compensated and uncompensated form. Compensed heat stress (CHS) occurs when the heat loss is in balance with its production, so that it can reach the equilibrium (steady state) core temperature at a given physical activity. It is usually present in most of the activities related to the implementation of dedicated military tasks. Uncompensated heat stress occurs when demands for disclosure of heat (sweat evaporation) overcome the evaporative capacity of the environment. During uncompensed heat stress (UCHS), the body cannot achieve the steady state core temperature, so it rises until it reaches physiological limits. Heat exhaustion in terms of UCHS occurs at a relatively low internal temperature. Due to inadequate cooling (due to lack of evaporation of sweat), the skin temperature remains high. The bloodstream is relocated to expanded vascular circulation in order to remove the heat from inside the body, which reduces the

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minute volume and increases the frequency of heart. UCHS reduces a physical performance extremely, so that these conditions demand special regimes of work and rest cycles, with the use of active cooling during breaks [2].

An ability to compensate heat stress is primarily determined by biophysical factors (environmental conditions, clothing, the intensity of physical exertion), and moderately by the influence of biological condition (acclimatization to heat and hydration) [3]. The correlations between the main heat stress factors and the levels of risk are displayed in Fig.1.

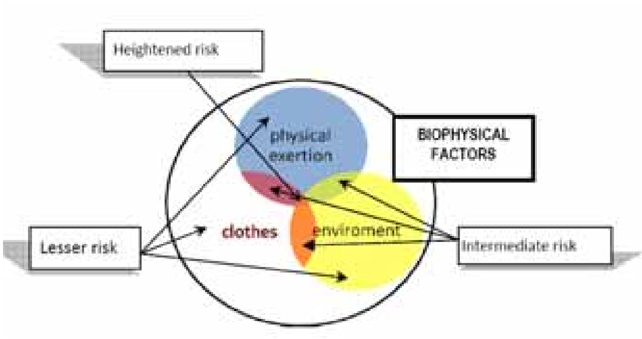

Figure 1. Biophysical factors and risk levels

Physiological thermoregulation involves the activation of the mechanism for the disclosure of excess heat and the increase of blood flow through the skin, which is achieved by enhancing the heart rate and by simultaneous increasing of sweating [4]. During physical activity in hot conditions, the sweat rate ranging from 1 l/h to 1.5 l/h is not unusual, and may even reach a value of 2 l/h under extreme efforts, providing a potential loss of excess heat by evaporation of 4500 kJ, or 1 kW (14 W/kg for a person whose body weight is 70 kg). In the absence of adequate rehydration, this process leads to the loss of body fluids from all body compartments, including the vascular component. Dehydration causes an increase of the body core temperature and cardiovascular strain. For each percent of weight lost, the core temperature additionally raises by 0.15°C to 0.2°C, while the heart rate increases by 5 bpm [5].

In long periods of exposure to a hot environment, the major mechanism for dissipating heat is sweat evaporation, which is proportional to the effective (exposed) skin area, the water vapor pressure gradient between the skin and the environment, and the water vapor permeability of the clothing. Hence, when protective military clothing is worn, sweat evaporation rates decrease and heat dissipation is reduced [6]. The efficiency of physiological adaptation depends on the heat amount generated in the active muscles, the intensity of the external work carried out as well as the level of biophysical heat exchange with the environment [7].

Contemporary needs of military forces request the best possible physiological suitability and comfort of solders during accomplishments of missions and tasks in different conditions. With this in mind, different systems for body cooling have been developed, with the main purpose to increase comfort as well to reduce thermal stress. The cooling system military application has many other significant valid benefits, such as increased mission duration, decrease in hydration needs, improved mental acuity and maintained physical performance. Although many systems exist today, they generally can by classified in five basic groups: evaporative cooling products, products based on PCM (Phase Change Materials), compressed air systems, liquid circulation systems and thermoelectric systems [8].

This focus of this study was is to investigate the efficiency of the cooling vest based on the liquid circulation tube system, combined with the field uniform, on soldiers' physiological suitability during physical efforts in hot environments. We hypothesized that vest wearing will alleviate soldiers' physiological strain and increase the ability of military personnel to complete any mission successfully in extremely hot conditions.

Experimental methods and procedures

Subjects

The participants in the examination were 10 male professional solders (25.8 ± 2.4 years), with similar anthropometric parameters (72 ± 10 kg, 182 ± 8 cm). Before exercises had started, the subjects were briefed on the nature of the experiment, its purpose, conditions, safety measures and potential medical risks. Each participant read and signed a specific form, in accordance with the standards of medical safety during examination in extreme hot or cold environments [9]. The protocol for the investigation was approved by a competent Ethical committee. The procedures performed in the present study corresponded to the standards of thermal strain evaluation by psychological measurements [10].

The obtained results are based on exertional heat stress tests (EHST) conducted in the climatic chamber in the Military Medical Academy, Institute of Hygiene, in Belgrade, in the period from May to September 2011.

Body Cooling System

The cooling system tested in this study was the Waist Pack Style Personal Cooling System DP103. The cooling effect is based on a chilled water flow through the tube system incorporated into the vest. The water flow process is provided by a micro-pump with a power source. The temperature is set up between 19-25°C. The system consists of a bottom connection channel (tube) vest, a waist pack (a smaller bag for a water pump and a battery and a bigger one for a bladder and an ice box storage), a water micro-pump (7.4 V/5 A, flow rate 7.5 l/min, duration 7000 hours), a lithium battery (Li, 7.4 V/2200 mAh, 12 hours), a battery charger (110-240V AC), a plastic ice bottle-cooling source of 0.5 l and a bladder.

The vest is made of J40^{S}C long-staple cotton and 210^{D}U fabric, while the tubes where produced from clear thermoplastic polyurethane (TPU). The shoulder pack consists of the "Oxford" fabric (100% polyamide fiber) outside layer and the inner layer made of silver waterproof material. The working time is 1.5 hours (intensive physical effort) to 4 hours (without much physical effort).

Clothing

During exercises, the participants are dressed in the standard battle dress uniform model M10 (boots, trousers and shirt). The trousers are made of 50% cotton and 50% polyester fabric, a surface mass of 260 g/m^2 (± 5%), water vapor permeability at least 3500 g/m^2/24 h, with a hydrophobic and oleophobic treatment. The shirts were produced of 67% cotton and 33% polyester fabric of 150 g/m^2 surface mass (± 5%). They were made of combed cotton yarn the fineness of which is 20 tex in the "right-left" interlacement. The surface mass of the knits with 8.5%

humidity was 140 g/m^2 (± 5%). During the EHST, the participants wore the same type of underwear made of 100% cotton.

All uniform parts have a waterproof protection. The components of the uniform are made to protect the user from high temperatures up to +50°C.

Experimental protocol

Each subject performed two tests, both times wearing the uniform, with and without the cooling vest over. In both cases, the exercises were performed under the same climatic conditions (40°C). Before each test was conducted, it was necessary to prepare the climatic chamber, the treadmill, the measurement devices and other equipment. The climatic chamber was turned on minimum one hour before the tests, in order to achieve the projected temperature. Each subject was weighed without any equipment, before and after every experiment.

Taking into consideration the environmental conditions, each test was initially limited to 45 minutes maximum. The criteria for a termination before the maximum time were: achieving critical value of the tympanic temperature (39°C), or heart rate (190 beats per minute), or participant’s subjective feeling of unbearable effort.

All temperature measurements from the subjects during every exposure were automatically monitored and recorded in real-time using a physiological data monitoring system (Biopac Systems, Inc. USA) [11,12]. The system consists of the MP150 acquisition unit, the universal interface module (UIM100C) and five skin temperature amplifier modules (SKT 100C), single channel, with a differential amplifier specially designed for skin and core temperature monitoring.

The UIM100C Universal Interface Module (2) is the interface between the MP150/100 and external devices. Typically, the UIM100C is used to input pre-amplified signals (usually greater than ± 0.1 volt peak-peak) and/or digital signals to the MP150/100 acquisition unit. Other signals (e.g., those from electrodes or transducers) are connected to various signal-conditioning modules.

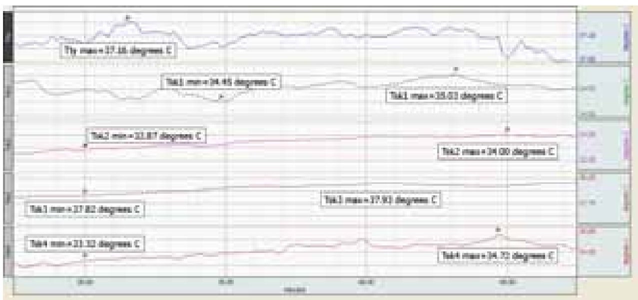

Figure 2. Continuous monitoring review of the tympanic and skin temperature values simultaneously in five channels using Biopac AcqKnowledge Software

The Universal Interface Module (UIM100C) is designed to serve as a general-purpose interface to most types of laboratory equipment. The UIM100C consists of sixteen 3.5mm mini-phone jack connectors for analog inputs, two 3.5mm mini-phone jack connectors for analog outputs, and screw terminals for 16 digital lines, an external trigger, and supply voltages [11].

The SKT100C skin temperature amplifier module (3-7) is a single channel, differential amplifier specially designed for skin and core temperature and respiration flow (rate) monitoring. The SKT100C is designed for general temperature measurement, respiration rate determination, psycho-physiological investigations and sleep studies [11].

Figure 3. BIOPAC TSD202 series transducers

The SKT100C employs any of the BIOPAC TSD202 series thermistor transducers (Fig.3) to measure temperature. The SKT100C includes a lower frequency response selection switch that permits either absolute (DC) or relative (via a 0.05 high-pass filter) temperature measurements [11].

Heart Rate was measured and recorded automatically using a Quinton® Q4500 Exercise Test Monitor (Quinton Instruments Company, USA). Continual monitoring was done using monitors that received readings from the heart rate straps fastened to each subject (on the chest and the bottom of the spine). The same device was used for controlling and handling the treadmill (speed and grade).

The data is presented as mean values and standard deviations (±SD). The normal distribution was tested by Shapiro-Vilk’s test. The differences between the NoCOOL and the COOL groups performing the EHST where tested by Student’s test. The SPSS 17.0 was used to process statistical material and the 0.05 level of significance was used.

Measurement of the tympanic temperature (Tty)

The method used in this study aims at mesuring the tempeature of the tympanic membrane whose vascularisation is provided in part by the internal carotid artery, which also supplies the hypothalamus. As the thermal inertia of the eardrum is very low, due to its low mass and high vascularity, its temperature reflects the variations in the arterial blood temperature, which influence the centers of thermoregulations [10].

The tympanic temperature was measured by inserting the thermo-element TSD202A into the aural channel and placing it as close as possible to the eardrum. This measurement was continual, with data recorded every 10 seconds.

Measurement of the skin temperature (Tsk)

The skin temperature varies widely over the surface of the body, especially during extreme ambiental conditions.

The skin temperature is influenced by:
- the thermal exchanges by conduction, convection, radiation and evaporation at the surface of the skin, and
- the variations of the skin blood flow and of the temperature of the arterial blood reaching the particular part of the body [10].

In warm and hot enviroments, except in the precence of high asymmetrical radiation, local skin temperatures tend to be homogeneous, so a few measuring points can be used with accuracy [10]. In this study case, the mean body skin temperature (Tsk) was determined continually, mesuring local body temperatures at four points, using the TSD202E and TS202F transdusers types.

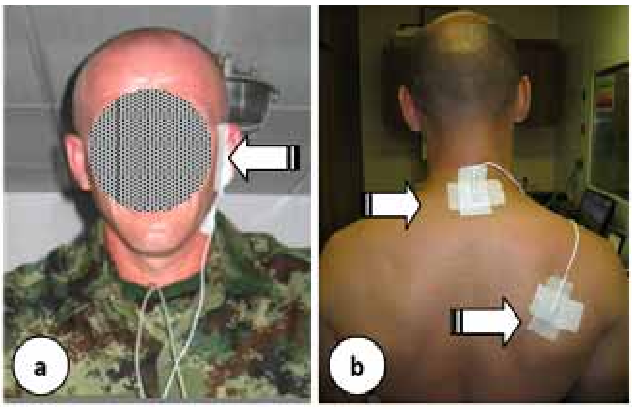

Figure 4. Location of the thermo-elements on the body: TSD202A position inside the aural channel (a), TSD202E replacement on two local points (b)

Assessment of thermal strain on the basis of heart rate (HR)

The heart rate (*HR*) over a time interval t (in min) is defined as $HR = n/t$, where *n* is the number of heartbeats observed during this time interval. It is expressed in beats per minute (bpm) [10].

At any given time, the heart rate *HR* can be considered as the sum of several components not independent of each other:

$$HR = HR_0 + \Delta HR_M + \Delta HR_S + \Delta HR_T + \Delta HR_N + \Delta HR_\varepsilon \quad (1)$$

In the context of this study, only the increase in the heart rate connected with the thermal strain experienced by the subject (ΔHR_T), was examined. The other components represent:
- limit of the heart rate (HR_0),
- increase in the heart rate linked with work metabolism (ΔHR_M),
- increase in the heart rate linked with static exertion (ΔHR_S),
- increase in the heart rate due to psychological factors (ΔHR_N), and
- residual component in the heart rate (ΔHR_ε).

Assessment of physiological strain on the basis of the body-mass loss (Δm_{sw}) due to sweating

The gross body-mass loss (Δm_g) of a person during a given time interval is the sum of several components:

$$\Delta m_g = \Delta m_{sw} + \Delta m_{res} + \Delta m_0 + \Delta m_{wat} + \Delta m_{sol} + \Delta m_{clo} \quad (2)$$

Hence, the total mass loss depends on the sweat loss (Δm_{sw}), the diference between carbon dioxide and oxigen (Δm_0), the evaporation of the respiratory tract (Δm_{res}), the intake (food) and excretions (stools) of solids (Δm_{sol}), the intake and excretions (urine) of water (Δm_{wat}), and the sweat accumulation in the chlothing (Δm_{clo}). In the context of this study, only the sweat loss component (Δm_{SW}) is considered and calculated as the rate of sweating (SwR), from the difference between the pre-test and the post-test nude body weights (digital scale Chyo MW-100K) [10].

Subjective assessment of the level of comfort

A subjective assessment of the level of comfort was rated by each subject using the scale of perceived exertion (RPE). This scale values range from 1 to 7, where 1 denotes "comfortable" and 7 denotes "extremely intolerable hot". The subjects were asked to point on the scale their subjective assessment every 5 minutes during the exposure.

Results and discussion

During the EHST, not one soldier showed any symptoms of the heat stroke, or any disturbances related to serious types of heat illness. The tests lasted the maximum of 45 minutes, with the only 2 recorded cases of early completion, due to a subjective report of intolerable effort (RPE level 7). There were no cases of cancellation owing to achieving the limitary values of the tympanic temperature (39°C) or the heart rate (190 bpm). The values of the main thermal strain indicators, measured in the last minute of the exercises, are shown in Table 1.

Table 1. Comparison of the mean values (±SD) for the temperature and the heart rate during tests

Parameters	Without cooling system, 45th min, 40°C	With DP 103 cool vest, 45th min, 40°C
Tty (°C)	37,73±0,18	37,1±0,24
Tsk (°C)	36,05±0,22	35,6±0,16
HR (bpm)	142±14	130±12

In parallel with measuring of the thermal strain parameters, the exercises on the treadmill were discontinuously recorded by a standard camera and a thermal imaging camera (FLIR SC600 640 × 480 LWIR Resolution & 0.03°C Sensitivity), every 5 minutes. The footage analysis shows the efficiency of the vest cooling features, from the start to the end of the exercise, based on the thermal imaging display of the hot and cold zones on the vest and the torso area (Fig.5).

Figure 5. Vest snapshot recorded with a standard (a) and a thermal imaging camera (b), in 30th minute of exercise

Tympanic temperature

The comparable reviews of the tympanic temperature values with the cooling system and without it are displayed in Fig.6.

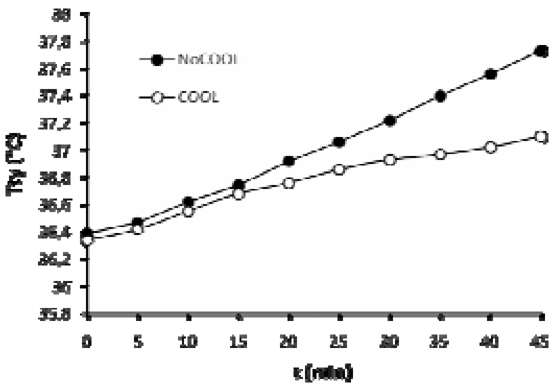

Figure 6. The mean tympanic temperature of all 10 subjects during 45 min without cooling (NoCOOL) and with the DP-103 cooling vest (COOL)

The mean tympanic temperatures for the whole group without cooling varied from 36.39°C to 37.73°C for the maximum exercise time of 45 minutes. In the case with cooling, around the 15th minute the temperature began to grow noticeably slower, so in 35th minute it was lower by 0.43 ± 0.04°C. The maximum difference of 0.63 ± 0.05°C was recorded at the end of the EHST ($p < 0.05$).

Body skin temperature

Fig.7 presents the changes in Tsk through the 45 minute-long heat-stress exposures, with the cooling system and without it.

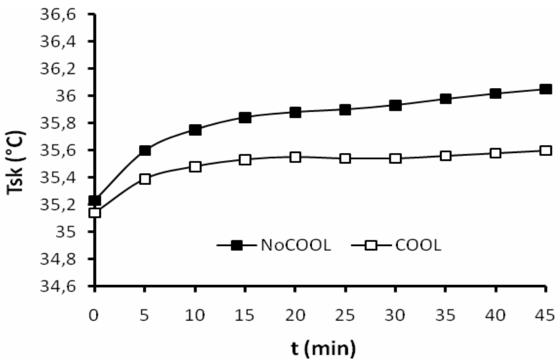

Figure 7. The mean body skin temperature of all 10 subjects during 45min without cooling (NoCOOL) and with the DP-103 cooling vest (COOL)

The body skin temperature was increased in a similar way in all cases, much faster in the first 15 minutes, then more slowly. The maximum value of Tsk was achieved in the case NoCOOL in 45th minute (36.05±0.22°C), while with the cooling vest the temperature was at the same time 35.6 ± 0.16°C.

At two measuring points in the torso area (neck and scapula), significantly lower values of the skin temperature were observed in relation to the option COOL (an average of 0.9 ± 0.03°C), as a direct consequence of the cooling vests effects. The measured values of Tsk at the other two points (a leg and an arm) did not differ significantly, as expected ($p > 0.05$).

Heart rate

The dynamics of the average heart rates in both cases is displayed in Fig.3. No significant differences were observed in the values of the heart rate during tests. The heart rate in both cases increased in a similar manner, but a limit of 190 bpm was not reached during any single exercise.

The maximum recorded heart rate was 142 bpm, without the vest, in 45th minute. During the EHST, in the COOL case, the heart rate was lower on average for 6 bpm (the maximum difference of 12 bpm was noted at the end of the EHST).

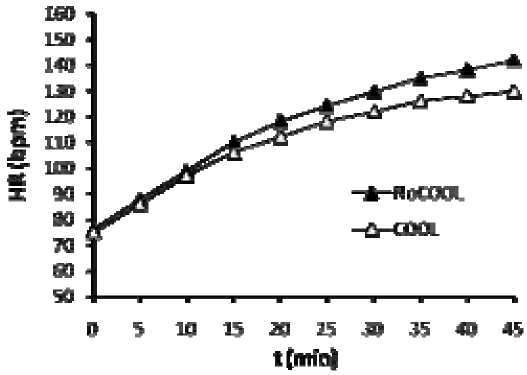

Figure 8. The mean heart rate (HR) of all 10 subjects during 45 min without cooling (NoCOOL) and with the DP-103 cooling vest (COOL)

Sweat rate

The average rate of sweating, as expected, achieved a higher value in the NoCOOL case (0.48 ± 0.08 $l/m^2/h$), while the value was significantly lower (0.34 ± 0.06 $l/m^2/h$; $p < 0.05$) when using the cooling system.

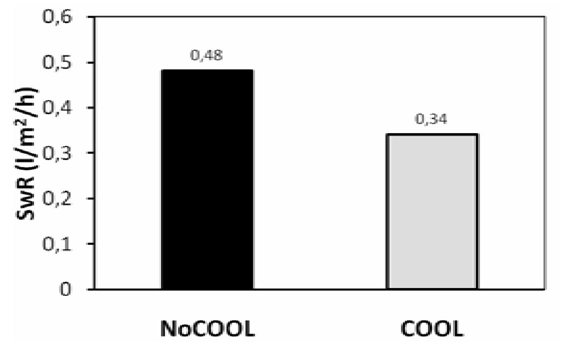

Figure 9. Comparison of the mean (±SD) sweat rates of all 10 subjects with the cooling system DP-103 (COOL) and without it (NoCOOL)

Subjective assessment of comfort

From 5th to 45th minute, the participants expressed 1-2 levels better feeling of comfort while wearing the cooling vest than in the cases without it. The subjective assessments of the level of comfort during the exercises, with the cooling vest and without it, are showed in Fig. 5.

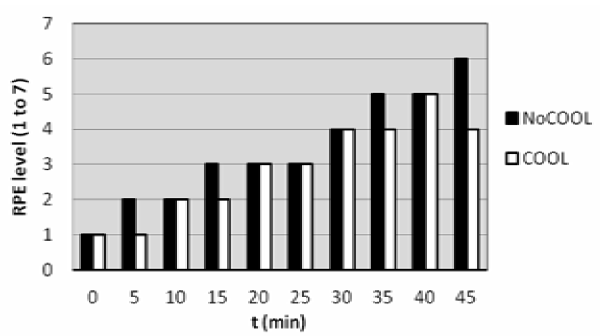

Figure 10. Comparison of the subjective assessment of the level of comfort of all 10 subjects with the cooling system DP-103 (COOL) and without it (NoCOOL)

Impaired physical, cognitive and working ability is a well-known consequence of heat strain. This is particularly important for military services [13]. Core temperature is considered as a relevant indicator of thermal strain [4], [13].

While carrying out specific military tasks and missions, military training guidelines tolerate high levels of body core temperature, even up to 40°C [14]. Given that such high internal body temperatures are possible and very common during military missions, they deserve to be investigated.

As the greatest benefit of all cooling systems, the subjects cited easier breathing and less strain compared to the tests without cooling, which is confirmed by the measured lower values of the heart rate.

Sweating as a mechanism for disclosure of excess heat has a special importance in the thermal stress caused by physical activity, when it occurs not only as a consequence of thermal factors (increasing of body core and skin temperature), but also due to non-thermal factors such as central activation, activation of muscle-mechano receptors metabolism and activation of baroreflex due to physical activity. According to the test results, the rate of sweating is lower when using the body cooling systems average by 0.14 $l/m^2/h$ (29%, $p < 0.001$). Because the exercises did not last equaly long for all the subjects, the rate of sweating was expressed per hour.

Our results are consistent with the study of A. Hadid & R. Yanovich [6], who carried out the investigation related to the effects of the cooling system based on air circulation to the thermal stress caused by physical effort in soldiers. In this study, done by the same methodology, cooling was providing by using a personal ambient ventilation system under the ballistic vest. Twelve male volunteers were exposed to the climatic conditions of 40°C and 35°C during a 115 min exercise routine, followed by 70 min resting recovery while wearing a battle dress uniform and a ballistic vest, with a cooling system and without it. Generally, in both climates, the use of the cooling system reduced the physiological strain caused by physical exertion, with significant benefits in nearly all of the physiological parameters tested. In contrast, during resting recovery at the same climate conditions, no differences were obtained between the exposure with the cooling and without it. In the 40°C climate conditions, the average rate was 21% lower for the exposure when the cooling vest was worn ($p < 0.005$). In the 35/60 climate conditions, it was 25% lower ($p < 0.001$).

Tom M. McLellan [15] obtained similar results exploring the efficacy of an air-cooling vest to reduce thermal strain for Light Armour Vehicle (LAV) personnel. In this study, seven males were exposed to either hot, dry (HD, 49ºC, 10% relative humidity) or warm, humid (WH, 35ºC, 70% relative humidity) conditions while either receiving (C) or not receiving (NC) cooling through an air-vest. All subjects completed the 3 hours of heat-stress exposure during all conditions but the rise in rectal temperature approached 2ºC during HD with NC. When cooling was provided, the rise in the rectal temperature was minimal throughout the heat stress. It was concluded that micro-climate conditioning was an effective way to reduce the thermal strain of LAV crew.

Conclusion

The methodology used in this study and the experimental protocols were carried out in accordance with contemporary standards in the area of thermal strain evaluation by physiological measurements (ISO 9886), with respect to the prescribed measures of medical supervision of subjects exposed to extreme hot environment (ISO 12894). All laboratory tests were conducted using high performance equipment (Biopac, Quinton®), with technical features that enable measuring, monitoring and recording necessary physiological parameters in real time. Among other things, the validity of the results confirms the engagement of a sufficient number of test subjects (volunteers) with similar anthropometric parameters, selected according to the strict criteria from a larger number of potential participants.

The cooling system evaluation in this study resulted in two important conclusions: in the case of wearing the cooling vest covering the torso area, the body core temperature (measured through the tympanic temperature) grows more slowly, and the mean body skin temperature is significantly lower. Moreover, the heart rate values and the subjective assessment of comfort levels point to the much expressed solders physiological stability, which is a very important result from the aspect of confidence and efficiency in fulfilling military missions.

The results of this study have clearly identified the benefits of a liquid circulation cooling vest in lowering the thermal strain for soldiers. The tympanic temperature, as an index of thermal strain, and the heart rate, as an index of cardiovascular strain, were significantly reduced when cooling was provided during exposure to hot conditions.

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Uticaj prsluka za hlađenje tela, na bazi tečne cirkulacije, na nivo fiziološkog opterećenja vojnika izloženog fizičkom naporu u uslovima ekstremno visokih temperatura

Rad predstavlja rezultate istraživanja na polju efikasnosti sistema za hlađenje tela na bazi cirkulacije rashladne tečnosti i njegov uticaj na psiho-fiziološko opterećenje vojnika u uslovima izloženosti fizičkom naporu i ekstremno visokim temperaturama. Podaci i dobijeni rezultati zasnovani su na sprovedenim ispitivanjima u klimatskoj komori Instituta za higijenu VMA u Beogradu. Deset vojnika muškog pola dobrovoljno je podvrgnuto testovima toplotnog opterećenja usled fizičkog napora, izazvanog hodanjem na pokretnoj traci sa brzinom hoda od 5 km/h, u toploj sredini (temperatura vazduha 40°C). Testovi su realizovani sa ispitanicima srednjih godina (25.8 ± 2.4) i sličnih antropometrijskih parametara (72 ± 10 kg, 182 ± 8 cm), u varijanti nošenja terenske maskirne uniforme bez ikakvog rashladnog sistema (opcija NoCOOL) i uz upotrebu rashladnih prsluka za hlađenje tela, model DP 103 (opcija COOL). Kao pokazatelji fiziološkog opterećenja određivane su: srednja kožna (Tsk) temperatura, timpanična (Tty) temperatura i frekvencija srčanog rada (HR), dok je intenzitet znojenja (SwR) računat kao pokazatelj vodeno-elektrolitskog statusa. U svim slučajevima izlaganje fizičkom naporu u toploj sredini indukovalo je fiziološki odgovor manifestovan kroz povećanje Tty, frekvencije srčanog rada i intenziteta znojenja. Ekspreimentalni rezultati dokazali su uticaj rashladnog prsluka, korišćenog preko letnje vojničke uniforme, na snižavanje nivoa fiziološkog opterećenja tokom izlaganja vojnika ekstremnim uslovima, u poređenju sa identičnim testovima u varijanti bez hlađenja tela.

Ključne reči: **zaštitna oprema, oprema vojnika, rashladni prsluk, uticaj temperature, visoke temperature, toplotni stres, fiziološki zamor.**

Влияние жилетки для охлаждения тела на основе циркуляции жидкости на уровне физиологической нагрузки солдат в военных операциях в экстремально жарких условиях

В статье представлены результаты исследования в области эффективности системы для охлаждения тела на основе циркуляции жидкости в охладителе и его влияние на физиологические пригодности солдат в условиях воздействия физических нагрузок и экстремально высоких температур. Данные и полученные результаты основаны на испытаниях, проведённых в климатической камере Института гигиены в Белграде в Военно-медицинской академии.

Десять мужчин солдат добровольно прошли испытания тёпловой нагрузки и стресса в связи с физической нагрузкой, вызванной ходьбой на беговой дорожке ходьбы со скоростью 5 км/ч, в тёплом помещении (температура воздуха 40°C). Испытания проводились с мужчинами среднего возраста (25,8 ± 2,4) и с аналогичными антропометрическими параметрами (72 ± 10 кг, 182 ± 8 цм), в варианте в камуфляжной форме без системы для охлаждения (опция NoCOOL) и с помощью охлаждения жилет для охлаждения тела, модель DP 103 (опция COOL).В качестве индикаторов физиологического стресса и нагрузки измеряли: среднюю температуру кожи (Tsk), барабанную температуру (Tty) и частоту сердечных сокращений (Чсс), а интенсивность потоотделения (КСВ) рассчитываемую как индикатор водно-электролитного статуса. Во всех случаях воздействие физических нагрузок в жарких условиях индуцировало физиологическую реакцию, которая проявляется через увеличение Tty, частоту сердечных сокращений и интенсивность потоотделения. Результаты экспериментов подтвердили влияние охлаждения жилетки, используемой в единой военной летней форме, на снижение уровеня физиологического стресса и нагрузки при воздействии экстремальных условий на солдат, по сравнению с идентичными испытаниями в вариянте отсутствия охлаждения тела.

Ключевые слова: **защитное оборудование, оборудование солдат, жилетка для охлаждения, влияние температуры, высокые температуры, тепловой стресс, физиологическая усталость.**

L'influence du gilet de refroidissement basé sur la circulation liquide au niveau de la charge physiologique des soldats pendant les opérations militaires dans l' ambiances extrêmement chaude

Ce travail présente les résultats des recherches sur l'efficacité du système de refroidissement du corps basé sur la circulation de liquide refroidie et son influence sur les capacités physiologiques des soldats exposés aux efforts physiques et aux températures extrêmement hautes. Les données et les résultats obtenus sont basés sur les essais réalisés dans la chambre climatique de l'Institut pour l'hygiène au sein de l'Académie militaire médicale à Belgrade. Deux soldats mâles volontaires ont subi les tests de la charge thermique causée par l'effort physique par la marche sur le tapis roulant à la vitesse de 5km/h dans l'ambiance chaude (température de l'air 40°C). Les tests ont été réalisés avec les participants âgés de 25.8 ± 2.4 ans et leurs paramètres anthropométriques étaient similaires (72 ± 10kg, 182 ± 8cm). Ils portaient les uniformes de camouflage sans système de refroidissement (option NoCOOL) et avec l'emploi des gilets pour le refroidissement du corps, modèle DP 103 (option COOL). Les indicateurs de la charge thermique étaient : la température moyenne de peau (Tsk) , la température tympanique (Tty) et la fréquence de cœur (HR) alors que l'intensité de sueur (SwR) indiquait l'état de l'eau et d'électrolytes. Dans chaque cas l'exposition à l'effort physique dans cette ambiance a provoqué la réponse physique manifestée par l'augmentation de Tty, de la fréquence cardiaque et de l'intensité de sueur. Les résultats expérimentaux ont confirmé que le gilet de refroidissement porté sur l'uniforme d'été peut diminuer le niveau de la charge physiologique pendant les exercices dans les conditions extrêmes en comparaison avec les tests identiques d'exposition sans le système de refroidissement.

Mots clés: **équipement de protection, équipement de soldat, gilet de refroidissement, influence de température, hautes températures, charge thermique, fatigue physiologique.**