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ORIGINAL ARTICLE

THE INFLUENCE OF SELECTIVE COOLING OF THE BODY SURFACE ON THE IMPROVEMENT OF PHYSIOLOGICAL INDICATORS OF THE BODY AND THE SUBJECTIVE ASSESSMENT OF THERMAL COMFORT DURING ACTIVITIES CARRIED OUT IN THE HOT CLIMATIC ZONE

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Introduction: The aim of the study was to determine whether the applied type of selective cooling of limited neck area improves physiological parameters of the body and changes subjective sensations of thermal condition and fatigue level.

Methods: The experiment was attended by 12 healthy men who were not accustomed to high temperatures. Two experimental series were carried out throughout the study (the 1st series was a control group, without selective cooling, in the 2nd series a "cooling pad" was applied in the neck area). Each unit test was performed under simulated positive heat load conditions (Ta = 40 ± 1°C, RH = 30 ± 1%, t = 90 min) accumulated with moderate physical effort. The thermal exposure included three stages: 1) 10 min period of adaptation to environmental conditions, 2) 20 min period of effort on cycling ergometer performed in three repetitions (alternating with 5 min period of rest) and 3) 10 min period of rest. During the individual examination, changes in core body temperature (Tc), heart rate (HR) and body weight were recorded. At the beginning and in 90 minutes of the exposure in the thermal chamber the subjects made a subjective assessment of the state of thermal comfort felt in relation to the whole body and the degree of nuisance of the work performed.

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Results: As a result of exposure to simulated heat conditions (40°C) combined with moderate physical activity, the heart rate increased significantly ($p < 0.05$). In the first series of experiments, the mean value of heart rate (HRmean) achieved in the thermal chamber was HRmean = 93 ± 4 bpm, whereas in the II series HRmean = 86 ± 3 bpm (statistically significant difference, $p < 0.05$). Average core body temperature values in both experimental series were similar ($T_c = 37.0 \pm 0.2$°C). The dynamics of change of this parameter was almost the same in both series I and II. In control conditions, the total loss of water from the body along with sweat was on average $\Delta = 0.91 \pm 0.12$ kg and as a result of the action of the "cooling pad" $\Delta = 0.78 \pm 0.23$ kg (n.s.). The subjective evaluation of thermal comfort by the respondents at the end of the first series of experiments deteriorated and was assessed as "too warm" (6.1 ± 0.4). Respondents using selective cooling in the same test phase described the state of thermal comfort as "pleasantly warm" (5.2 ± 0.7). The subjective evaluation of the workload nuisance (fatigue) in the last minute of cycling ergometer operation was rated at the level of 6.1 ± 0.6 (series I) and 5.0 ± 0.4 (series II) ($p < 0.05$).

Conclusions: Under thermal stress conditions, the psychophysical state of the body determines, to a large extent, the feeling of thermal comfort and fatigue level. As a result of the use of "cooling pads", favourable changes in physiological parameters (heart rate, sweat loss) and improvement of subjective sensations were achieved, both in terms of thermal comfort and the degree of nuisance of the work performed.

Keywords: selective cooling, cooling pad, psychophysical condition, thermal comfort, fatigue, workload

INTRODUCTION

Flight personnel services, such as those related to pilotage activities in desert or tropical climates, are often in danger of weakening thermoregulatory mechanisms. The risk of disturbing thermal homeostasis is increased by the use of anti-gravity suits, which are conducive to the formation of an unfavourable under-clothing microclimate. The uncontrolled development of hyperthermia with all its negative effects is also supported by waiting for the take-off or performing manoeuvres at low altitudes in full sunlight, as well as by the occurrence of failures of air-conditioning systems while overcoming the thermal barrier (in supersonic aviation) [20,6].

An increase in core body temperature induced by heat stress can lead to unpleasant physical symptoms such as nausea, stomach cramps or dehydration. Long-term exposure to the combined effects of specific high-temperature factors and exposure to strong overloads can increase the feeling of exhaustion. In addition, being in a hot environment combined with excessive workload significantly weakens psychomotor abilities, as well as the time of effective work. The cognitive and intellectual functions of concentration, divisibility and shifting of attention, decision making, vigilance and reflex, as well as visual and motor coordination, which determines the precision of pilot's movements during flight manoeuvres, deteriorate (increase in the number of errors). The analysis of air accidents shows a correlation between the weakening of cognitive and psychomotor functions and the decrease in staff safety in terms of the activities carried out [10,17,18].

Due to the hazards resulting from the unavoidable exposure of the flight personnel to positive thermal stress, the search for an effective way of counteracting the adverse effects of hyperthermia has been underway for a long time. The need to reduce excessive heat load is the basis for continuous improvement of the methods of selective cooling of the body. Thanks to such actions it is possible to modify subjective sensations of thermal comfort, and thus improve the state of human satisfaction with the surrounding thermal conditions. Depending on the subjective sensations the impact of local action of a given thermal stimulus causes more or less comfortable feelings. Therefore, all signals (thermal stimuli) reaching the central nervous system via sensory processes, depending on the current heat state of the body, are perceived as"comfortable" or "uncomfortable" and thus can modify the individual assessment of the human thermal state.

Previous studies suggest that cooling of the head area in warm conditions has a particular impact on subjectively assessed whole-body thermal comfort [14,15]. This is due to the fact that the head area is relatively heat sensitive, i.e. more sensitive to selective cooling than other parts of the body (e.g. limbs). In one of the experiments carried out, Nakamura et al. (2008) observed that in heat conditions, local cooling of the face surface has a positive effect on thermal comfort for the whole body. Therefore, selective cooling of the head area is an external interference in the mechanisms of thermoregulation, it positively affects not only the feeling of comfort for the whole body, but also it also contributes to the reduction of the degree of nuisance of the performed activities. An important factor here is the temperature of the skin, which very quickly changes as a result of the thermal conditions of the environment and improves the thermal sensations perceived by the body [10,17]. In conditions of positive thermal load, local cooling of the body surface may cause lowering of the average skin temperature (at the stimulus's location), thus delaying the increase of the body's internal temperature. Selective cooling also reduces sweat production and decreases heart rate increments during exercise in a hot environment. The studies confirmed that the improvement of thermal comfort (by lowering the temperature of the skin locally), affects the decrease in the level of fatigue felt, as a result of which the body's efficiency and the effectiveness of the tasks performed are increased [16].

Shaping the body's thermal state through selective cooling of the head and neck areas depends on stimulation of the skin nerves. This area, although representing only 10-12% of the total body surface, is of great importance for physiological reactions, as it is an area with a high concentration of nerve endings sensitive to temperature [15]. The influence of thermal stimulation (local cooling) on the state of thermal comfort explains the local feeling of low temperature stimulus in conditions of positive thermal load, which is correlated with the surface and uneven occurrence of cold and heat sensors in the skin [4,8]. The effect of the local feeling of cold is related to the specific, direct effect of the low temperature stimulus recorded by the cold sensation receptors (Krause's corpuscles) and transformed into a nervous impulse. These sensors activate thermosensitive neurons (i.e. thermodetectors) located in the thermoregulation centre in the hypothalamus [14] by passing the impulse through the skin nerves. This region of the brain is more sensitive to signals from cold receptors than to heat. The pulse is transmitted through specialized, thermosensitive TRP (Transient Receptor Potential) ion channels, which play a key role in sensing skin temperature differences. Some of them are characterised by significant sensitivity to cold temperatures or compounds that cause the feeling of cold (e.g. menthol) and have different thermosensitivity ranges. The TRPM8 channel plays an important role in the feeling of cold, thermoregulation and cold pain [4,14]. It is strongly expressed in sensory surface neurons and is involved in receiving stimuli at extremely low temperatures, but can also be activated at low cooling.

Literature and personal experience have shown that under conditions of positive thermal stress, local cooling of the head area has a beneficial effect on subjective thermal sensations. Such an effect is related to the local activity of the stimulus of low temperature on the skin surface, which can change the thermal sensations perceived from the cold sensation receptors and thus improve the subjective state of thermal comfort and the subjective degree of nuisance of the work performed. The aim of the research carried out in the Military Institute of Aviation Medicine was to determine whether the use of a "cooling pad" on a limited neck area (180 cm^2) in combined positive heat (40°C) and physical load conditions improves the physiological parameters of the body and modifies subjective feelings of thermal condition and fatigue.

MATERIAL AND METHODS

Selection of the method of selective cooling

The selection of material and methods of selective cooling was based on the analysis of literature data and the results of own experiments (data not published). As a selective cooling method, "cooling pads" (cooling surface - 180 cm^2) were used, which were filled with non-toxic propylene glycol with gel consistency and temperature of 16-17°C. The refrigerant was sealed in a welded plastic bag, which was a durable and tear-resistant bag. This type of compress did not cause a feeling of humidity (as in the case of melting ice).

The "cooling pads" used in the tests have many beneficial properties: 1) the elasticity of the material ensures that, even after freezing, the "pads" adhere well to the body surface without sticking to the skin; 2) a non-toxic coolant (propylene glycol) with a very high specific heat of 3.38 KJ/kg deg. Favorable heat transfer coefficient makes the compress well receive heat from the surface of the body; 3) do not constitute an additional load; 4) do not limit the comfort of movement; 5) are economical due to the possibility of repeated use (during operation there are no irreversible chemical changes in the gel, the cooling effect is always the same). However, this type of cooling requires external cooling in the refrigerator prior to use. In addition, they do not ensure a long-term return of the cold accumulated in them, they have a limited time of operation.

Participants in experimental research

All candidates (12 healthy men, n = 12) who are not acclimated to high temperatures have undergone qualification tests to determine their general health status. The scope of these studies included anthropometric measurements (age: 23 ± 2 years; body weight: 66.8 ± 1.4 kg, height: 171 ± 2 cm; BMI: 25 ± 1.5), measurements of blood pressure, body temperature and level of physical fitness determined using the indirect method (VO_{2max}). Based on the medical officer, the participants were admitted to experimental tests, which were carried out in identical and reproducible environmental conditions. During the experiment they were dressed in a summer field uniform.

The participants undertook the experiment after having a standard breakfast and were obligated to maintain a hygienic lifestyle during the day before the experiment (no alcohol, no drugs, use of dietary recommendations).

In order to reduce the level of situational stress, all participants were acquainted with the course of the individual study. Before the experiment, each of them agreed in writing to participate in the experiment. The research received a positive opinion from the Ethics Committee of the Military Institute of Aviation Medicine, in accordance with the requirements for conducting research on humans.

Organization of research

The whole experiment was divided into two series: the 1st series - experiment in controlled conditions (without selective cooling), the 2nd series - with selective cooling in the form of a “cooling pad” (applied in the neck area). The experiments were conducted according to a strict schedule. Each of the subjects participated in the experiment twice, with a 24-hour break between successive exposures.

Each time, before application, the “pad” was cooled to 16-17°C and then, after drying with a cotton towel, it was fixed in a specific place using flexible tapes.

Physical characteristics of the environment

Both series I and II of the experiment were conducted in simulated conditions of a hot climate chamber of the Military Institute of Aviation Medicine. In both series constant and repeatable conditions of the chamber interior were maintained: air temperature Ta = 40 ± °C, relative humidity RH = 30 ± 1%, air flow velocity V = 1 m/s.

Running of the specific test procedure

The studies were conducted in the morning, in standardized and comparable environmental conditions. During the experiment the participants did not consume any liquids. The experiment was started with a 20-minute period of adaptation to thermoneutral conditions (Ta = 21 ± 1°C, RH = 30 ± 1%), during which initial measurements of physiological indicators were performed and then a “cooling pad” was applied in the neck area. Then, for 90 minutes they were tested in the chamber and exposed to the combined effects of high temperature (Ta = 40 ± 1°C, RH = 30 ± 1%) and moderate physical activity. Exposure in the chamber started with a 10-minute period of adaptation to the hot conditions in the sitting position. Physical effort on the cycloergometer (with the load not exceeding 30% VO_{2max}, the amount of effort was determined by the load W/kg) was carried out in three 20-minute repetitions alternately with a 5 min rest. The test in the thermal chamber ended with a 10-minute resting period in the sitting position. During this time the subjects expressed their subjective opinions within the scope of: 1) whole-body thermal comfort level - based on the 7-point Bedford scale, assuming 1 means “very cold”, 7 means “very warm”, where the rating in the range of 3-5 determines the state of thermal comfort and 2) the degree of nuisance of the physical work performed - based on the 12-point Borg scale, assuming that 1 means “very light work”, 12 means “very heavy work”.

During exposure to simulated heat conditions, the following physiological parameters were recorded: core body temperature (Tc) in the external ear canal using an electronic infrared thermometer and heart rate (HR) using an electronic shoulder pressure monitor. Tc and HR were measured

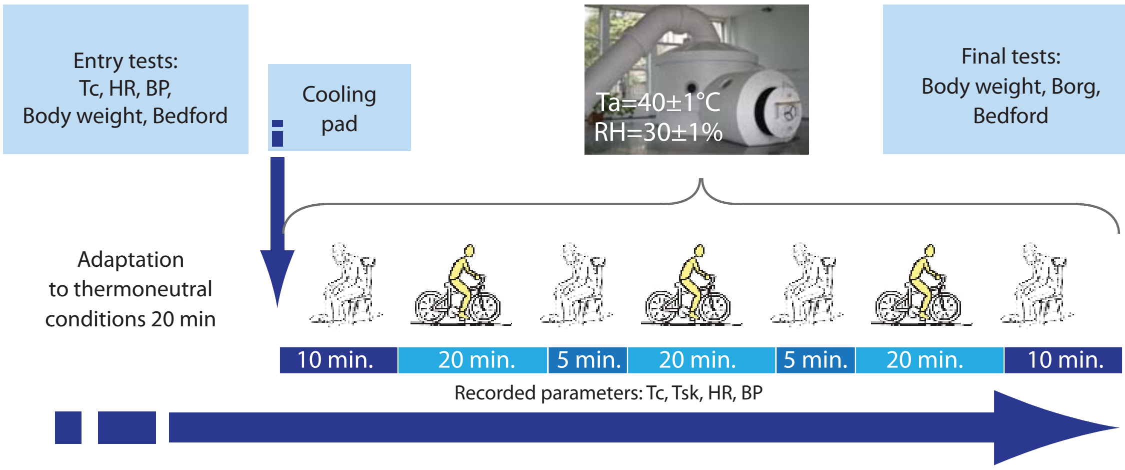

Fig. 1. Progress of unit study under simulated hot conditions in a WIML climate chamber.

before and after each exercise, six times in total in 90 minutes. The total loss of water excreted from sweat was determined on the basis of weight measurements before and after exposure. During the exposure, the skin temperature (Tsk) was also controlled by Ellab thermocouples, a device equipped with humidity and temperature sensors, and the measurement of systolic and diastolic pressure (BP) was controlled by means of an electronic shoulder pressure monitor.

The course of the individual study under control conditions was identical, the only difference being the lack of the use of a “cooling pad” (Fig. 1).

Statistical analysis of results

The values of parameters obtained in series II (with selective cooling) were related to control tests of series I. Changes in the analyzed psychophysical indicators were evaluated using the t-Student parametric test for dependent trials (assuming normality of distribution). The obtained data is presented as mean values ± SD. The significance of the differences was assumed at the level of $p<0.05$. StatSoft Polska Statistica 6.0 statistical package was used to analyze the results.

RESULTS

Physiological indicators

As a result of exposure to simulated heat conditions (40°C) combined with moderate physical activity, the heart rate changed significantly ($p < 0.05$). In the first series of experiments, being a control group, different peak values of the heart rate (HRpeak) were observed in each exercise cycle. In the first exercise cycle (30 min experiment) HRpeak = 106 ± 2.5 bpm was observed, in the second exercise cycle (55 min experiment) HRpeak = 109 ± 4.0 bpm and in the third exercise (80 min experiment) HRpeak = 111 ± 3.5 bpm was observed (Fig. 2). In the second series of the study, in which selective cooling was used, the heart rate peaks after each exercise cycle were HRpeak = 101 ± 2 bpm, HRpeak = 107 ± 3 bpm and HRpeak = 107 ± 2 bpm, respectively. In the first series of experiments, the mean heart rate (HRmean) obtained during 90 minutes of exposure to high temperature (40°C) was HRmean = 93 ± 4 bpm, and in the second series HRmean = 86 ± 3 bpm.

In the experiment, the core body temperature (Tc) was determined on the basis of measurements in the external ear canal. The maximum average core body temperature during the entire unit study did not exceed 37.3 °C (Fig. 3). The obtained mean values of this parameter in both experimental series (I and II) were similar and amounted to 37.0 ± 0.2°C. The increase was almost identical and reached the value of $\Delta Tc = 0.41 \pm 0.01$°C in the control group (I series) and $\Delta Tc = 0.40 \pm 0.01$°C after the application of selective cooling (II series) (no statistically significant differences).

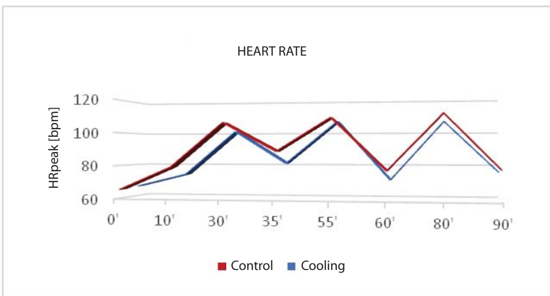

Fig. 2. The progress of changes of the heart rate peak values of HRpeak [bpm] obtained during exposure to the thermal chamber, both in series I (control) and series II (after application of “cooling pad”) (n=12).

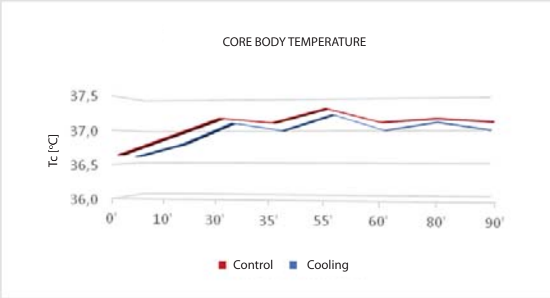

Fig. 3. Dynamics of changes of core body temperature Tc [°C] obtained during exposure in thermal chamber, I series (control) and II series (after application of "cooling pad") (n=12).

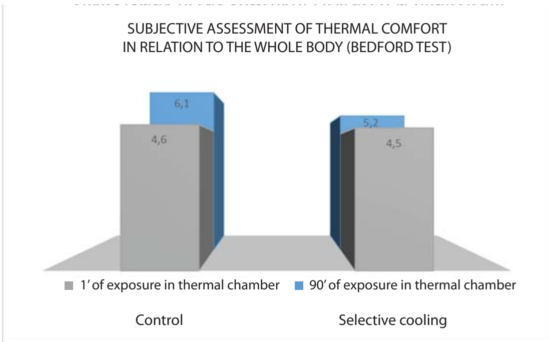

Fig. 4. Average values of subjective assessment of body thermal state (Bedford test) obtained in the group of subjects using selective cooling (II series) and in the control group (I series) (n=12).

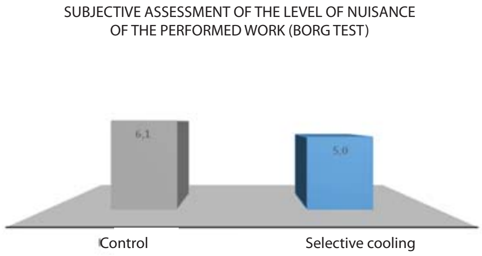

Fig. 5. Average values of subjective evaluation of the degree of nuisance of physical work (Borg test) obtained in the group of respondents using selective cooling (II series) and in the control group (I series) (n=12).

The total loss of water with sweat was determined on the basis of weight measurements taken before and after the exposure in the climatic chamber (the subjects did not absorb any liquids during the experiment, therefore it was not necessary to take this aspect into account in the calculations). In control conditions (I series) the total loss of body weight was on average $\Delta = 0.91 \pm 0.12$ kg and after selective cooling $\Delta = 0.78 \pm 0.23$ kg (statistically insignificant difference).

SUBJECTIVE INDICATORS OF THERMAL COMFORT AND WORKLOAD

In this experiment, the subjects twice made a subjective assessment of whole-body thermal comfort (i.e. before and after simulated heat exposure) based on a 7-point Bedford scale. In the first series of studies (control group) the subjective evaluation of comfort in the first minute of exposure was 4.6 ± 0.3 (which corresponded to the "pleasant" evaluation) and after 90 minutes it was 6.1 ± 0.4 (which corresponded to the "warm" evaluation) (Fig. 4). In the second series of experiments (selective cooling effect), the mean initial and final values were 4.5 ± 0.5 ("pleasant") and 5.2 ± 0.7 ("pleasantly warm"), respectively. In the control group the increase in the analysed value (related to the deterioration of perceived comfort) was $\Delta = 1.5$, whereas in the persons using selective cooling the assessment of comfort was increased by $\Delta = 1.1$ (differences at the level of statistical significance, $p < 0.01$).

Both in the first and the second series of experiments, participants only once (in the last 90 minutes of exposure to combined heat and physical effort) made a subjective assessment of the degree of nuisance of the work they were doing (Fig. 5). Based on a 12-point Borg scale, the subjects assessed fatigue in series I and II at an average of 6.1 ± 0.6 ("very heavy") and 5.0 ± 0.4 ("heavy"), respectively. The difference in the assessment of the feeling of burden of physical effort between I and II series of experiments was $\Delta = 0.9$ and was statistically significant ($p < 0.05$).

DISCUSSION

In the field of aviation medicine, actions are continuously being taken on the impact and feasibility of real application of selective body cooling. This emerges from the need to indicate an effective and efficient method of preventing hyperthermia, and thus the possibility of extending the limits of human tolerance to high temperatures of the working environment. In this article, through the use of a "cooling pad" (a small cooling area of 180 cm^2 at the neck) filled with gel at a temperature of 16-17°C, an attempt was undertaken to improve the physiological parameters of the body and modify the subjective sensations of heat state and fatigue.

The selective cooling method used in the study has many beneficial properties, such as thanks to being a plastic material, the "pads" adhere precisely even to areas of the body that are difficult to reach, do not constitute an additional load and do not limit the comfort of movement (due to their small size and weight). They are easy to transport and do not require a power supply. In addition, they are economical due to their reusability, as no irreversible chemical changes occur during gel operation (the cooling effect is the same both at the beginning and after repeated use). In addition, the refrigerant is non-toxic and harmless to human health and the environment. The choice of the product used was made on the basis of our own experiments (data not published) and a detailed analysis of the literature. The data gathered shows that this type of selective cooling can limit the increase in core body temperature and skin temperature, as well as the heart rate when performing tasks in hot conditions. Modification of body temperature by local and short-term application of a low-temperature stimulus is of great importance for the state of human satisfaction with the surrounding thermal conditions. This can have a positive effect on the subjective assessment of thermal comfort while improving the psychomotor capabilities of personnel during flight operations.

In simulated hot conditions with moderate intensity of work, both control group (I series) and selective cooling group (II series) observed systematic increases in peak heart rate values (HRpeak) (Fig. 2). Recorded changes indicate a gradual and moderate response of the circulatory system to high-temperature exertion. In the second series of studies, peak rises in heart rate values (HRpeak) in all three exercise cycles were significantly lower with respect to control conditions ($p < 0.05$). In addition, taking into account the lower mean heart rate values (HRmean) observed in the second series, it can be concluded that the partial thermo-regulatory effect of neck cooling has been achieved. Moreover, the values obtained confirm that the selective cooling applied resulted in a slower rate of circulatory system load accumulation, which reduces the risk of cardiac disturbances.

In the experiment, the core body temperature was determined on the basis of temperature measurements in the external ear canal. In conditions of positive thermal stress, the dynamics of change in this parameter was modified very little, regardless of the local action of the low temperature stimulus. As a result of local cooling of a limited body area (II series), the values of the tested parameter remained slightly lower during the whole test than under control conditions (I series). In patients who did not use a "cooling pad", slightly higher increases were observed ($Tc = 0.41 \pm 0.01$°C) than in those who were exposed to a low-temperature stimulus ($Tc = 0.40 \pm 0.01$°C). However, during exposure to the influence of exogenous heat load combined with physical load being a source of endogenous heat, no significant differences in dynamics of this parameter were found (Fig. 3). Therefore, selective cooling of a small area (180 cm^2) and the size of the thermal stimulus in the range of 16-17°C in hot conditions (40°C) combined with moderate effort did not have a significant influence on the change in the temperature of the interior of the body. No significant changes in this physiological indicator are consistent with the observations of other authors [7,14,15].

The total sweat loss based on body weight measurements (without the necessity to take into account the amount of fluid absorbed) showed a tendency to lower water loss after cooling. In the second series of the study, after selective cooling at the neck surface was applied, the mean loss in body weight ($\Delta = 0.78 \pm 0.23$ kg) was equivalent to 1.1% body weight dehydration. In the first series (control group) the dehydration of the system reached 1.4% of body weight (statistically significant difference). The obtained results show that the applied selective cooling of a limited body area safely lowered the activity of sweat glands and thus the amount of sweat emitted (lower loss of water and electrolytes from the body). Therefore, the use of a "cooling pad" has had a positive effect on the limitation of the risk of water balance disturbance and the development of excessive system dehydration. Control of body hydration during exercise in a hot environment is particularly important, because the elimination of accumulated body heat occurs mainly through evaporation of sweat. As a result of the persistently high perspiration rate, combined with the rapid depletion of glycogen resources (e.g. anti-gravity manoeuvres among pilots of fighter planes), an increasing deficit of body fluids is observed. According to Balldin (2002), the loss of body water in the range of 3% (approx. 2 liters of water per 75 kg of body weight) may significantly reduce exercise capacity (by as much as 20%), reduce acceleration tolerance, psychomotor efficiency and aircraft handling capability [11,22]. With higher dehydration (over 4%), oral fluid replenishment is ineffective due to poor blood flow through the internal organs and deteriorated gastric emptying and intestinal absorption.

Subjective assessment of the body thermal state in relation to the whole body is a simple and fast, and most importantly, reliable method for determining the direct impact of thermal environment conditions on work comfort and human productivity [1,17]. It can be used in conditions of passive exposure to high temperature as well as cumulative action of exo- and endogenous heat, both in real and simulated hot conditions. In the course of the experiment, the participants made two subjective assessments of the heat condition (based on the 7-point Bedford test, grades 1-"very cold" to 7- "very warm"). The initial values of the thermal comfort index, which were determined before the start of exposure in the climatic chamber, both in the first and second series of the study, remained almost at the same level felt as "pleasant" (Fig. 4). In the second series (selective cooling) at the end of exposure to accumulated heat (exogenous and endogenous), the respondents described the state of thermal comfort as "pleasantly warm". However, after the end of exposure to high temperature in series I, the subjective evaluation of this parameter deteriorated. The respondents evaluated the heat condition as "too warm" (which translated into higher numerical values on the 7-point Bedford scale). Therefore, by applying a thermal stimulus on a limited area of the body in conditions of positive heat load, it resulted in a significant improvement in the state of thermal comfort of the tested, compared to the control conditions. Therefore, it may be suggested that the improvement of thermal comfort is a consequence of local feeling of thermal sensations (from the neck area), which at the same time shows that the head area is very sensitive to cooling. The above observations are confirmed by the results of the research conducted by Mundel et al. (2006) and Arens et al. (2006). The authors observed that cooling relatively small body areas, e.g.: the face area may eliminate the feeling of warmth and have a positive influence on the assessment of thermal discomfort in hot conditions.

The level of fatigue (the nuisance of physical activity) was determined based on a subjective indicator for assessing the level of workload (12-point Borg test, grades 1 -"very light work" to 12 - "very hard work") (Fig. 5). As a result of 90 minutes of positive thermal load exposure (40°C) in the second series of experiments (using a "cooling pad"), the average workload assessment was significantly lower with respect to the I series (statistically significant difference $p < 0.05$). In the light of the results obtained, selective cooling of the neck surface in simulated hot conditions decreased the feeling of fatigue, which indicates an improvement in the tolerance of moderate intensity of physical activity. By using a "cooling pad" on a small area of the body, a positive effect has been achieved by reducing the build-up of fatigue under the applied thermal stress conditions. The results obtained with respect to the evaluation of the workload confirm the observations of other authors [3].

CONCLUSION

Based on the analysis of the values of physiological parameters obtained after the application of the "cooling pad", significantly lower average increases in heart rate and lower amounts of perspiration were found (in relation to these indices without the use of selective cooling). The observed changes in core body temperature did not show statistically significant differences between individual unit tests (I and II series). Perhaps the magnitude of the low temperature stimulus used was too small to have a significant impact on this physiological indicator. However, in the light of the results with the thermal and physical load applied, it may be suggested that "cooling pads" can reduce the risk of thermal imbalance and hyperthermia development in hot conditions associated with physical exercise, although there is no visible reduction in the core body temperature. Selective neck cooling helps maintain body temperature in its physiological range, improves body thermal comfort and exercise capacity, and alleviates the undesirable effects of physiological stress, while minimizing the risk of heat trauma. The changes analysed in the presented paper, related to subjective psychophysiological indicators, unequivocally confirm that "cooling pads" through local and short-term action of low-temperature stimulus improve subjective evaluation of the state of thermal comfort (in relation to the whole body) and the degree of nuisance of the performed work. Therefore, under these conditions of temperature and workload, they provide sufficient protection against sensations of thermal discomfort, the effects of which limit the possibilities of effective and safe performance of activities.

The use of selective cooling in the form of a "cooling pad" can bring measurable benefits, which are important in view of the growing number of peace and stability missions in the hot climate zone. Selective cooling by improving subjective sensations of thermal comfort and workload may reduce the risk of failure of the performed tasks (increasing the level of safety of crews in situations where being in a hot environment during operations is unavoidable).

AUTHORS' DECLARATION:

Study Design: Anna Przewodzka, Anna Czerwińska; **Data Collection:** Anna Przewodzka, Anna Czerwińska; **Manuscript Preparation:** Anna Przewodzka, Anna Czerwińska; **Funds Collection:** Anna Przewodzka, Anna Czerwińska. The Authors declare that there is no conflict of interest.

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