Original Article

Effect of the body fat status of female students aged 17-19 years, engaged in aerobics, on the thermoregulation system during cooling

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Abstract.

The purpose of the article is to study the effect of moderate cooling at an ambient temperature of 20-21 °C on maintaining the homeostatic balance of the skin in aerobics students of the three comparison groups with different fat status. Materials and methods. After a standard 15-minute warm-up the signal was recorded in aerobics students aged 17-19 years with a BALTECH TR-01500 thermal imager (Germany). Recording was performed from the entire surface of the body in the infrared frequency range for 10 minutes. Depending on the percentage of adipose tissue in the body (AT), which was determined using the Tanita BC - 418 MA analyzer (Japan), the subjects were divided into three comparison groups with the following average AT values: 22.31 ± 0.23% (values between 20-25%; group 1, n1 = 21), 16.11 ± 0.46% (values between 15-20%; group 2, n2 = 16), 30.89 ± 0.78% (values more than 25 %; group 3, n3 = 14). Results: according to average values of the temperature of the skin located above the regions of the examined muscles, Microsoft Excel built graphs of the changes in the average skin temperature of the students of the three groups according to the data registered every 30 seconds. The dynamics of temperature curves of all studied muscle groups for the left and right part of the body (abdominal muscle, deltoid muscle, biceps, triceps, trapezius, latissimus dorsi, biceps femoris, quadriceps femoris, anterior tibia, gastrocnemius muscle) was almost identical for the three examination groups, except for trapezius. The slight differentiation of the manifestations of non-contractile thermogenesis among the students of group I throughout the entire exposure to cooling kept the temperature of the skin at almost the same level (the temperature range was 0.8 °C). Students of the second and third groups, starting from the first session of thermography, showed an abrupt change in average temperature, significantly different from the temperature curve of the first group. Discussion and conclusions: the strategy of maintaining thermal balance allowed the system of thermoregulation in the first group to effectively control the temperature homeostasis of the muscles actively involved in sports movements, indicating better adaptation to moderate cooling, which is one of the necessary conditions for the effectiveness of muscle activity. In students of the second and third groups, skin temperature fluctuations during exposure to cold reached 1.8 °C, which was explained by the functional insufficiency of the adaptive thermoregulatory systems due to excessive ergothermal load on the adaptive capabilities of the body.

Key words: skin temperature, thermoregulation, homeostasis, thermal adaptation, students.

Introduction.

The purpose of the article is to study the effect of moderate cooling on maintaining the temperature balance of the skin in aerobics students with different fat status.

The human body is able to maintain homeostasis when exposed to many environmental factors. When comparing different types of physiological homeostasis, the most important for the human body is maintaining optimal body temperature, regulated mainly by the hypothalamus, which receives sensory signals from central and peripheral nodes (Charkoudian, N., 2016). This is confirmed by the fact that the coefficient of performance (COP) of the thermoregulation system is 13.5 times higher than that of the baroreceptor system for regulating blood pressure (Guyton, A.C., Hall, J. E., 2008).

However, exercise and repetitive efforts can be a problem for thermal homeostasis (González-Alonso, J., 2012, Lim, C.L. Byrne, C., Lee, J.K., 2008, Nybo, L., 2010). During training, thermoregulatory control of skin blood flow plays a fundamental role in maintaining normal core temperature and leads to hemodynamic changes that affect thermal signals (Charkoudian, N., 2010).

The temperature of the skin is the result of heat transferred by the blood circulation of the skin and thermoregulatory heat transfer reactions, such as conductivity, convection, radiation, evaporation of sweat,

environmental conditions and various biophysical factors associated with body surface area or body composition (Fernández-Cuevas, I., Bouzas Marins, J.C., Arnáiz Lastras, J. et al, 2015, Kenney, W.L., Johnson, J.M., 1992). Therefore, measuring skin temperature, which is the result of a complex interaction between skin blood perfusion, ambient temperature, heat loss processes, and biophysical characteristics (Fernández-Cuevas, I., Bouzas Marins, J.C., Arnáiz Lastras, J. et al, 2015, Kenney, W.L., Johnson, J.M., 1992), provides useful information about complex thermal control systems, especially in sports practice.

Time delays before competitions arising due to reasons independent of the athlete can adversely affect the sports result. Thus, the rate of muscle contraction decreases by 4.7%, and the maximum strength by 4-6% with a decrease in muscle temperature of only 1 °C (Fernandes, A.D.A., Amorim, P.R.S., Brito, C.J., et al, 2018). Cooling has a greater effect on dynamic and fast contractions (16–17% per 1 °C of decrease in muscle temperature) than on isometric and slow (2–10% per 1 °C) (Fernandes, A.D.A., Amorim, P.R.S., Brito, C.J., et al, 2018). Fatigue during cooling can occur almost twice as early (Meigal, A.Yu., Oksa, J., Gerasimova, L.I., Rintamäki, H., 2000, Oksa, J., Ducharme, M.B., Rintamäki, H., 2002).

The authors of (Oksa, J., Rintamäki, H., Rissanen, S., 1997) showed that a decrease in the ambient temperature from 25 °C to the lower limit of thermal comfort (up to 20 °C) causes a decrease in intramuscular temperature by only 1 °C, however, a disproportionately large decrease (by 17%) occurs in relative muscle performance (Oksa, J., Rintamäki, H., Rissanen, S., 1997).

It is believed (Jansky L., Matoušková, E., Vavra, V. et al., 2006) that a healthy human body with moderate cooling can successfully maintain the temperature balance due to non-contractile thermogenesis for several tens of minutes, although this causes metabolic activation up to 15-25% of the level of basal metabolism (Blatteis, C.M., Lutherer, L.O., 1976, Jessen, K., Rabuľ, A., Winkler, K., 1980), and sometimes reaches up to 50% (Jansky L., Matoušková, E., Vavra, V. et al., 2006). In any case, the forecast of dynamic changes in the functional status of a person when cooling is justifiably important for competitive activity (González-Alonso, J., 2012) and relates to the urgent tasks of sports physiology.

Materials and methods

The study involved 51 female students aged 17-19 years. The first stage was aimed at determining the percentage of adipose tissue (AT) of the body of students using the Tanita BC - 418 MA analyzer. Three groups of students with different fat status were formed. The first group (n1 = 21) included students, whose personal percentage of adipose tissue was in the range of 20-25% with an average group AT of $22.31 \pm 0.23\%$. The second group (n2 = 16) included students with a personal AT below 20% (the average group AT - $16.11 \pm 0.46\%$).

The average value of AT in the third group (n3 = 14) was $30.89 \pm 0.78\%$. The second stage of the examination consisted of non-contact infrared thermal imaging with a BALTECH TR-01500 thermal camera. Skin thermography was performed before a 15-minute warm-up of medium intensity (one exposure), causing moderate sweating, and after a 10-minute rest (moderate cooling) (40 exposures with 30 s interval, front and back views). In our previous studies (Romanova, L.A., Romanov, Yu.N., Eganov, A.V., Komkova, I.A., 2018), results were obtained indicating the presence of an inverse dependence of skin temperature and AT, which was confirmed in this study. For statistical processing, the temperature data of ten muscle groups actively involved in sports and fitness were selected from the entire array of thermograms.

Results

A series of thermal expositions of girls dressed in two-piece swimsuits at a humidity of 40% and an air temperature of 20-21 °C, which is 10-13 °C lower than the temperatures of the thermoneutral zone, caused the activation of the sympathetic nervous system. This led to a decrease in sweating activity, vasoconstriction, and, as a consequence, a decrease in heat transfer (Charkoudian, N., 2010).

According to the average values of the temperature of the skin located above the regions of the examined muscles, the Microsoft Excel built graphs of the changes in the average skin temperature of the students of the three groups according to the data registered every 30 seconds.

The dynamics of temperature curves of all studied muscle groups for the left and right part of the body (abdominal muscle, deltoid muscle, biceps, triceps, trapezius, latissimus dorsi, biceps femoris, quadriceps femoris, anterior tibia, gastrocnemius muscle) was almost identical for the three examination groups, except for trapezius. Figure I shows the change in average temperatures of the skin of the anterior wall of the abdominal muscles.

Fig. I. Change in the average temperature of the skin located above the abdominal muscles after warm-up during a cold exposure at rest

A slight differentiation of the manifestations of non-contractile thermogenesis among the students of group I throughout the entire exposure to cooling kept the temperature of the skin of the region presented at almost the same level (the temperature range was 0.8°C). Students from the second and third groups, starting from the first sessions of thermography, showed an abrupt change in the average temperature, significantly different from the temperature curve of the first group, indicating the instability of the inclusion of thermogenesis that supports the heat balance, and, therefore, instability of temperature balance.

Discussion

During the warm-up, the preoptic region of the anterior hypothalamus was heated, which contributed to the release of sweat with simultaneous dilatation of the skin vessels. This reaction ensured heat transfer and the return of body temperature to normal values. In addition, there was a blockage of excess heat production associated with increased metabolism. At the end of the warm-up, thermoregulation consisted of heat removal in the form of radiation, sweat evaporation, convection and skin vasodilation, which led to an increase in skin blood flow with the transfer of excess heat from the core to the upper layers of the body (Priego Quesada, J.I., Martínez Guillamón, N., Ortiz Cibrián R.M et. al., 2015).

When students took t-shirts and leggings off immediately after warming up, the skin on the entire surface of the body began to cool moderately. Since the students underwent moderate cooling, the phenomenon of muscle tremors did not occur. This involved reflex mechanisms aimed at warming and stabilizing the skin temperature. First, there was inhibition of sweating and vasoconstriction due to stimulation of the sympathetic centers of the posterior hypothalamus. Secondly, there was an increase in heat production due to chemical thermogenesis: sympathetic stimulation and circulation of adrenaline and norepinephrine in the blood caused an immediate increase in the metabolic rate in the cells of the body due to the separation of oxidative phosphorylation reactions, when during the oxidation of a large amount of nutrients, the energy was released in the form of heat but not stored in the form of adenosine triphosphoric acid (Guyton, A.C., Hall, J. E., 2008). Strategies for maintaining the body's heat balance after warming up in a rest pause as a result of moderate air

cooling made it possible to maintain temperature homeostasis quite effectively, but when analyzing the results obtained, it was found that the physiological mechanisms in the students of the three groups were significantly different. It is obvious that the students differed in the nature of the urgent adaptation of muscle activity in terms of the interaction of the mechanisms of heat production and heat transfer. When performing physical exercises that are structurally included in the warm-up, clothes influenced heat transfer, increasing insulation and reducing heat loss of convection, radiation, and evaporation. We did not consider the thermoregulatory aspects associated with sportswear in connection with a wide range of t-shirts and leggings used by students in our studies.

Thermogenesis as the generation of heat to maintain the temperature homeostasis of the homeothermic organism occurs almost constantly, differing in its intensity depending on the ambient temperature and the metabolic status of the organism itself. When evaluating the graph of skin temperature above the abdominal muscles, its periodic decrease, increase and, in some parts of the graph, temperature “plateaus” occurring due to the equality of the “arrival” of heat and its radiation from the body surface are observed. In other words, the temperature homeostasis of the student body is a kind of oscillatory rhythmic system. It can be hypothetically assumed that the energy pulsation presented in the graph is the basis of human biorhythms, since biological processes cannot occur without the expenditure of energy resources, and they occur rhythmically.

Conclusion

The strategy of maintaining the body's heat balance after warming up at rest allowed the system of thermoregulation of students from the first group, which included girls with an average group percentage of adipose tissue content of $22.31 \pm 0.23\%$, to effectively control the temperature homeostasis of the skin (range of $0.8\text{ }^{\circ}\text{C}$) located above the muscles actively involved in sports movements. The temperature balance control system in group 1 is better adapted to moderate cooling, which is one of the necessary conditions for the effectiveness of muscle activity. In students of the second ($16.11 \pm 0.46\%$) and third ($30.89 \pm 0.78\%$) groups, skin temperature fluctuations during exposure to cold reached $1.8\text{ }^{\circ}\text{C}$, which was explained by the functional insufficiency of adaptive thermoregulatory systems. This indicated a decrease in the efficiency of thermoregulatory processes in preserving simultaneously coexisting functional systems and the entire set of morphofunctional parameters at certain levels that support normal metabolism.

Any violation of homeostatic dynamic balance in the body causes a chain of central peripheral processes aimed at restoring this constancy, which is associated with additional energy costs. However, the higher skin temperature of students of the second group, whose AT was $16.11 \pm 0.46\%$, despite the additional energy costs while maintaining temperature homeostasis, showed the higher potential of the muscular system in demonstrating sports achievements.

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