IMPACT OF HYPERTHERMIA AND DEHYDRATION ON SKELETAL MUSCLE OF ADULT WOMEN PERFORMING ISOMETRIC EXERCISE OF MAXIMUM INTENSITY

Kazys Vadopalas[1], Albertas Skurvydas[1], Marius Brazaitis[1], Pavelas Zachovajevas[1], Dalia Mickevičienė[1], Laimutis Škikas[1], Mindaugas Dubosas[1, 2]
Lithuanian Academy of Physical Education[1], Kaunas University of Technology[2], Kaunas, Lithuania

Kazys Vadopalas. Doctoral student at the Lithuanian Academy of Physical Education. Research worker at the joint-stock company "Baltic CNC Technologies". Research interests — muscle physiology: impact of hyperthermia and dehydration on muscle fatigue.

ABSTRACT

The aim of the study was to establish the impact of hyperthermia and dehydration on maximum voluntary contraction (MVC) force and central fatigue, as well as to assess the impact of rehydration on the function of skeletal muscle in conditions of hyperthermia when performing isometric exercise of maximum intensity for 2 minutes. The subjects were adult females (n = 8) not actively engaged in sports, aged 21.2 ± 2.4 years, body mass — 64.84 ± 8.4 kg and height — 170.8 ± 2.5 cm respectively.

Three studies were carried out: one control study and two experimental ones. During the first experiment the bodies of the participants in the study were subjected to hyperthermia and dehydration (the subjects sat immersed up to the pelvis in hot water (44 ± 1°C) bath for 45 min). During another experiment, the same methods of increasing hyperthermia being used, the bodies of the subjects experienced oral rehydration with 1000 ml NaCl 0.9% solution of 37°C.

*The MVC load lasted for 120 s (MVC-2 min) and every 15 s the muscle was stimulated by electrical impulses: the duration of the stimulation was 250 ms, the frequency — 100 Hz and the voltage — 85—105 V accordingly. We registered the movement of MVC (N * m) and the degree of voluntary activation of muscles according to the formula VA% = (MVF + electrical impulse) / MVF * 100. When the load was applied the subjects were motivated verbally and they were provided with the visual feedback of changes in force signals. After hyperthermia and dehydration was applied, the rectal body temperature increased from 37.48 ± 0.25 to 39.5 ± 0.23°C (p < 0.001), and the inner temperature of the muscle (3 cm deep) — from 36.91 ± 0.29 to 39.83 ± 0.31°C (p < 0.001) on the average. During the hyperthermia experiment the subjects had lost 0.4 ± 0.07 kg in weight on the average, and that was 0.62 ± 0.13% of their body mass. After oral rehydration in conditions of hyperthermia body mass of the subjects had increased by 0.48 ± 0.01 kg on the average, i. e. by 0.74 ± 0.08% of their body mass. Having analyzed the physiological index of heat stress (in the 10-point system) we have found that during both experiments the subjects had experienced a physiological stress of an extremely high level, e. g. in the case of hyperthermia — 8.85 ± 1.13 points and in the case of rehydration — 8.38 ± 0.98 points respectively. There was a significant decrease (p < 0.001) in MVC at the 3rd second of the load during both experimental researches and control research — at the 15th second of the load. These changes in MVC remained until the end of the 2nd min, compared to the indices registered before the load. During recovery, 5 min (A 300) after the load applied, MVC during control and experimental (hyperthermia) research had regained the level registered before the load (p > 0.05). Two-factor dispersion analysis revealed that the changes in the force in this case depended on time (p < 0.001), as well as on the body state (p = 0.001), whereas interaction of time and body state had no significant effect on the result (p > 0.05).*

After the analysis of the indices of voluntary activation we noticed that hyperthermia (p < 0.05) and rehydration (p < 0.01) had significantly increased the degree of voluntary activation (VA%), compared to the one established before the load. During the recovery time, 15 s after the load had been undertaken, the force index of voluntary activation regained the level that had been registered before the load. Two-factor dispersion analysis allowed us to establish that the changes in the force indices of voluntary activation depended on time (p < 0.001), the body state (p = 0.047) and the interaction between them (p < 0.05).

Applying the methods of passive muscle heating the participants in the study were subjected to hyperthermia and 1° dehydration. Hypertension increased the central fatigue. During the experiments of hyperthermia and dehydration MVC force fatigue altered homogeneously. In conditions of hyperthermia, rehydration had a negative impact on the central fatigue and increased it even more when maximum isometric load for 2 min had been undertaken.

Keywords: *hyperthermia, isometric exercise, dehydration, rehydration, central fatigue.*

INTRODUCTION

The ability of humans to perform physical exercise is directly dependent on fluctuation of the inner temperature in the body. Hyperthermia is a symptomatic increase in body temperature t° up to 38.2°C due to heat emission. With an increase in the core body temperature up to critical level (in the case of persons of average physical activity — 38.7 ± 0.2°C and in high performance athletes — 39.2 ± 0.1°C) the human body becomes overheated and fatigue conditioned by voluntary efforts reveals itself; hydratation and adaptation to heat had no effect on this change though (Cheung, McLellan, 1998). Hyperthermia increases physiological body tension which can bring about considerable decrease in working capacity what leads to exhaustion, overheating, traumas and even death. Most animals cease physical activity until their core temperature reaches safety margin. A hypothesis has been constantly raised in special literature that dangerously high inner body temperature directly contributes to increasing fatigue and accelerating exhaustion. The latter problem has been given considerable attention lately though final solution, as to the essential mechanisms of the phenomenon has not been found yet (Morrison et al., 2004). It has been established that in conditions of hyperthermia physical working capacity decreases due to an increase in the core temperature up to a critical point (Cheung, McLellan, 1998), during which activation of thermoregulatory and cardiovascular systems takes place (Rowell, 1974). In conditions of hyperthermia there occur changes in periphery and there is an increase in muscle contraction and relaxation rate (De Ruiter, De Haan, 2000). Hyperthermia can directly affect voluntary activation of muscles, as temperature in the motor unit changes impulse frequency that is necessary to trigger tetanic contraction (Todd et al., 2004).

It had been considered for some time that the mechanism accounting for the neuromuscular fatigue during hyperthermia may have been due to both central and peripheral nervous systems (Kent-Braun, 1999). The research done by M. M. Thomas et al. (2006) has proved, however, that hyperthermia decreased the neuromuscular working capacity and this depended on the incapability of the central nervous system to fully activate the muscle, whereas periphery had no direct effect on the process.

Temperature homeostasis manifesting itself during hyperthermia increases perspiration and activated the work of the cardiovascular system (Armstrong, 2000). The reason due to which there may occur a decrease in the physical working capacity of the muscles is dehydration, i.e. loss of liquid from the body. It has been established that because of loss of 2% of body mass human endurance decreases by 22% and a loss of 4% in body mass calls forth a decrease in human endurance by as much as 48% (Armstrong et al., 1992). It has been found that working in hot climate conditions or performing long-term physical exercise of high intensity an individual loses 0.8—1.4 l of liquid in perspiration per hour on the average (Armstrong, 2000). The greatest volume of liquid lost in perspiration amounted to 3.7 l / h (Armstrong et al., 1986). It has been established that persons adapted to certain conditions alongside with liquid in the form of sweat lose about 0.8—2.0 g NaCl / l and not adapted ones — about 3.0—4.0 g NaCl / l respectively (Armstrong, 2000). The latter electrolytes are considered the main ones in the human organism that ensure the maintenance of water tonicity in intracellular and intercellular medium, nervous conductivity and cellular metabolism and due to which blood volume, i.e. osmotic pressure and regulation in the human body is maintained (Armstrong, 2000). It is known that the maximum volume of liquid that is possible to be assimilated by physically active individuals is about 0.8—1.2 l / h (Coyle, Hamilton, 1990).

We have not come across in special literature so far any data showing what thermal effect and degree of dehydration is experienced by women not actively engaged in sports applying the methods of passive muscle warming proposed by A. J. Sergeant (1987). We have not found any data either that would indicate in what way in the course of 45 min passively evoked hyperthermia and dehydration affects the functional capacity of human muscles. We have no clear picture as to the effect of hydration in conditions of hyperthermia when performing isometric physical exercise of maximum intensity either.

The aim of the study was to establish the impact of hyperthermia and dehydration on MVC force and central fatigue, as well as to assess the impact of rehydration on the function of skeletal muscle in conditions of hyperthermia when performing isometric exercise of maximum intensity for 2 min.

METHODS AND ORGANIZATION OF THE STUDY

The subjects were adult females (n = 8) not actively engaged in sports, aged 21.2 ± 2.4 years, body mass — 64.84 ± 8.4 kg and height — 170.8 ± 2.5 cm respectively. The subjects were acquainted with the aims of the study, its procedure and the possible discomfort. They confirmed in writing their consent to participate in the study.

The research has been done in accordance with the principles laid down in the Helsinki declaration of 1975 regarding the ethics of experiments with humans. The protocol of the research has been discussed and approved by the Kaunas Regional Ethics Committee of Biomedical Research (Protocol No 130/2005; Authorisation No BE–2–54).

Adjustment of dynamometer and posture. The isometric force of calf stretching muscles was assessed using the isokinetic dynamometer (Biodex Medical System 3. New York). The subjects were seated in the chair with dynamometer equipment and the right leg was tested. An extra calf-fixing device was attached to the dynamometer. The anatomic axis of the knee joint was established and equalized with the axis of the dynamometer. The whole amplitude of the knee joint (from 0º with the leg extended to the calf of the leg flexed at 115º angle) was established. To diminish the movements of the whole body caused by inertia the subjects were fixed with belts through shoulders, trunk and hips. The calf of the leg was fixed with a belt above the heel-bone knot at the lower third of the leg. The leg was fixed through the knee joint at the angle of 90º and 60º and it was weighted when it was fixed at the angle of 72º ± 5º (with gravity force in operation). On the control panel isometric regime was chosen. Registration of MVC force was done.

Logic of the experiment. Prior to the experiment a pilot study was undertaken during which the subjects were expected to get used to the laboratory environmental conditions and to learn how to undertake the load of voluntary isometric contraction of the highest intensity. No earlier than a week later the girls participated in either control or one of experimental tests chosen at random.

Three tests — one control and two experimental ones were performed. During control test the subjects after a non-intensive warming-up 10 min of running (pulse frequency — 110—130 beats / min) were seated in a special isokinetic dynamometer chair and were subjected to testing according to the same protocol, except for passive body warming.

Experimental test 1 differed from the control one in the sense that during it instead of warming-up hyperthermia was evoked passively. In experimental test 2 conducted using the same methods hyperthermia was evoked applying oral rehydration of the body having used 1 000 ml 37ºC (body temperature) of physiological NaCl 0.9% solution.

Applying the methods of passive warming the subjects having come to the laboratory used to sit still for 30 min in the room of usual temperature (20—22ºC). Then their rectal temperature was measured. Subsequently control MVC measuring was performed, i.e. three maximum voluntary muscle contractions extending the calf of the leg through the knee joint at the fixed 120º angle (muscle contraction duration — 5 s) with 2 min intervals between the contractions. Approximately at the 2nd—3rd second of these contractions *m. quadriceps femoris* was stimulated at 100 Hz frequency by a series of electrical impulses with the duration of 250 ms. Then passive leg warming was applied and immediately after warming rectal temperature was measured again. No later than 5 min after leaving the bath the subjects were seated in a special dynamometer chair where they performed (MVC-2 min). Control testing was applied 15 s and 300 s after the load undertaken. During the load the subjects wore warm long sports clothing, as well as a bath-room cap, to preserve hyperthermia during experimental test. To ensure hypothermia control, at the end of both experiments rectal temperature was measured.

MVC-2 min. Maximum voluntary isometric load was undertaken for 120 s. Percutaneous electrical stimulation of the femoral nerve using high voltage stimulator (*model MG 440, Medicor*, *Budapest, Hungary*) was performed every 15 s. The duration of stimulation was 250 ms, frequency — 100 Hz and voltage volume — 85—105 V respectively. Voltage volume was selected for each subject individually. Voltage of the electrical impulse was continuously increased until the involuntary muscle contraction force reached 70—75% of maximum force (duration of stimulation — 1 s, frequency — 100 Hz) (Nybo, Nielsen, 2001). Maximum voluntary force moment (N · m) and the degree level of muscle voluntary activation VA% = MVC + electrical impulse / MVC * 100 was registered. The smaller VA%, the greater central fatigue (100% shows full muscle activation). The subjects were motivated verbally during the load by providing them with visual feedback of changes in force signal.

Methods of passive warming. The subjects sat immersed up to the pelvis in hot water (44 ± 1ºC) bath for 45 min in room temperature of 20—22ºC. During warming the subjects could not make use of artificial cooling equipment. At the end of warming the temperature in the muscle 3 cm deep of the subject rises by ≈ 2.7ºC (Sargeant, 1987). Water temperature was measured by a hydrothermometer and room temperature — by a standard thermometer.

Methods of measuring inner muscle temperature. Inner muscle temperature was measured with the help of a needle thermometer (Ellab A / S, type DM 852, Denmark) before and after passive warming. After desinfesting the site of prick with 5% spirit-iodine solution the needle thermometer was inserted into the median third (3 cm deep) of the *m. vastus latarelis femoris* to the side of the femoral bone. Temperature registered in such muscle depth is considered mean temperature of the exercised muscle (Bloomstrand et al., 1984). After using the needle thermometer was sterilized in the autoclave (*M. O. COM Via delle Azlle 1, 20090 Buccinaso, Italy*). The duration of the process of sterilization — 30 min at temperature 121ºC.

Methods of measuring rectal temperature. Rectal temperature was measured with the help of a probe covered with silicone resin with a built-in thermosensing element (Ellab, type Rectal probe, Denmark). Before and after passive warming the subjects placed the probe with a thermosensing element into the rectum (time — 10 s, depth — 12 cm) (Proulx et al., 2003). After using the probe with a thermosensing element was sterilized in the autoclave.

Assessment of the cardiac and cardiovascular system. During passive warming heart rate (HR) was registered with the pulse measuring device "Polar 625x" (Finland) every 5 s.

Methods of measuring physiological stress index (FSI) of the heat. FSI was calculated according to the formula (Moran et al., 1998):

$$FSI = 5\,(T_{rectal\,t} - T_{rectal\,0}) \times (39.5 - T_{rectal\,0})^{-1} + (HR_t - HR_0) \times (180 - HR_0),$$

where $T_{rectal\,0}$ and HR_0 — basic measurings; $T_{rectal\,t}$ and HR_t — measurings repeated with time intervals.

Assessment of FSI — no stress or extremely low stress (0—2 points); low stress (3—4 points); medium stress (5—6 points); high stress (7—8 points) and extremely high stress (9—10 points).

Rehydration. It has been established that during hyperthermia the human body loses 0.8—1.4 l of sweat on the average, and 1 l of sweat contains from 0.8 to 4.0 g NaCl. The human body can assimilate about 0.8—1.2 l of liquid per hour (Armstrong et al., 1986; Armstrong, 2000). To restore the liquid lost 15 min before passive warming the subjects were given to drink physiological solution (0.9% NaCl) of 37ºC (body temperature). In the course of 60 min the subjects slowly drank up 1000 ml of liquid (100 ml every 6 min). Before and after passive warming the women the women were weighted on the electronic scales "Tanita TBF 300" (The USA). The difference in weight found showed the volume of liquid lost by the subjects.

Mathematical statistics. Arithmetical means and standard deviations of indices were calculated. Changes in neuromuscular indices depending on muscle temperature and alterations in time were analyzed applying two-factor dispersive analysis. The significance of difference between arithmetic means was established according to the bilateral Student's *t* criterion of independent samples. The difference was considered statistically significant when $p < 0.05$.

RESULTS

After evoking hyperthermia and dehydration the rectal body temperature of the subjects increased from 37.54 ± 0.24 to 39.62 ± 0.25ºC ($p < 0.001$), and after performing rehydration in conditions of hyperthermia the temperature rose

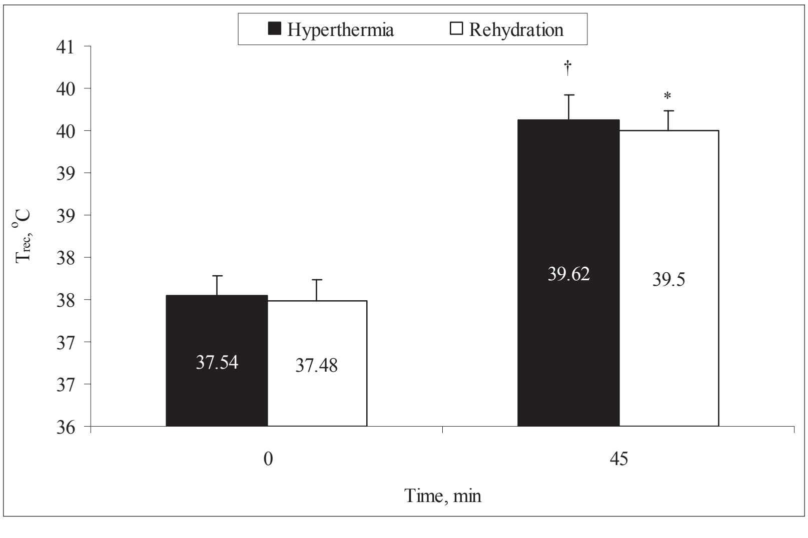

Fig. 1. **Indices of rectal temperature before and after passive warming**

Note. †, * — change, compared to the basic value ($p < 0.05$).

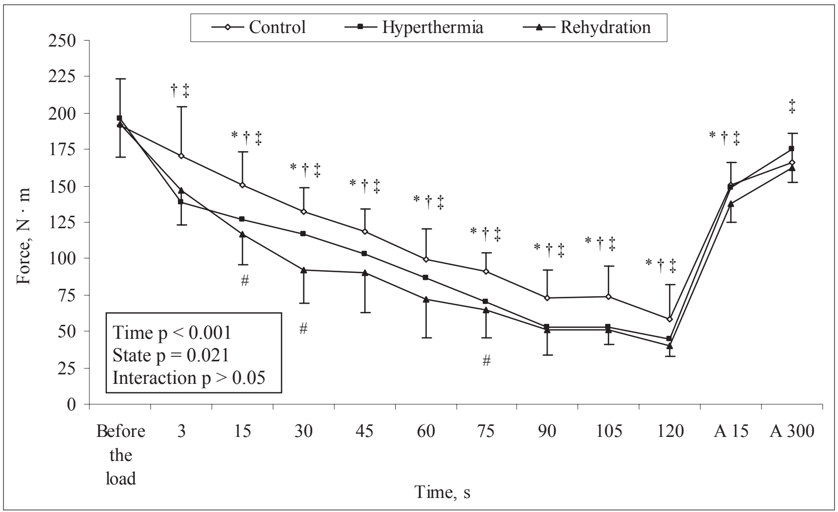

Fig. 2. **Indices of maximum voluntary force performing (MVC) for 2 min extending the calf of the leg through the knee joint at the fixed 120º angle**

Note. # — difference between control and rehydration ($p < 0.05$); † — changes in hyperthermia indices, compared to basic ones / basic values ($p < 0.05$); ‡ — changes in rehydration indices, compared to basic ($p < 0.05$); * — changes in control values, compared to basic ($p < 0.05$).

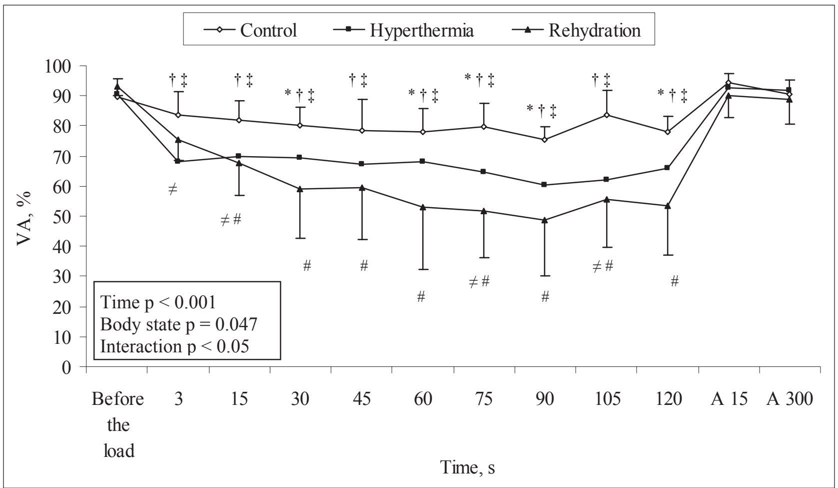

Fig. 3. **Indices of voluntary activation performing (MVC) for 2 min extending the calf of the leg through the knee joint at the fixed 120º angle**

Note. # — difference between control and rehydration ($p < 0.05$); ≠ — difference between control and hyperthermia ($p < 0.05$); † — changes in hyperthermia indices, compared to basic ones / basic values ($p < 0 05$); ‡ — changes in rehydration indices, compared to basic ($p < 0.05$); * — changes in control values, compared to basic ($p < 0.05$).

from 37.48 ± 0.25 to 39.5 ± 0.23ºC ($p < 0.001$) on the average (Fig. 1).

During the hyperthermia experiment the subjects lost 0.4 ± 0.07 kg in weight on the average, and that was 0.62 ± 0.13% of their body mass. After oral rehydration in conditions of hyperthermia body mass of the subjects increased by 0.48 ± 0.01 kg on the average, i.e. by 0.74 ± 0.08% of their body mass. During the hyperthermia experiment the inner temperature of the muscle (3 cm deep) risen from 36.97 ± 0.28 to 39.96 ± 0.31ºC ($p < 0.001$) and after rehydration was applied — from 36.91 ± 0.29 to 39.83 ± 0.31ºC ($p < 0.001$) accordingly. Having analyzed the physiological index of heat stress (in the 10-point system) we found that during both experiments the subjects experienced a physiological stress of an extremely high level, e.g. in the case of hyperthermia — 8.85 ± 1.13 points and in the case of rehydration — 8.38 ± 0.98 points respectively.

There was a significant decrease ($p < 0.001$) in MVC at the 3rd s of the load during both experimental tests, and during control test — at the 15th second of the load. These changes in MVC remained until the end of the 2 nd min, compared to the indices registered before the load (Fig. 2).

During recovery, 5 min (A 300) after the load, MVC during control and experimental (hypothermia) tests had recovered to the index value registered before the load ($p > 0.05$). Two-factor dispersion analysis revealed that the changes in the force indices analyzed depended on time ($p < 0.001$) and on body state ($p = 0.021$), whereas interaction of time and body state had no significant effect on the result ($p > 0.05$).

After the analysis of the indices of voluntary activation we noticed that hyperthermia ($p < 0.05$) and rehydration ($p < 0.01$) had significantly increased the degree of voluntary activation (VA%), compared to the one established before the load (Fig. 3). It is of importance to note that during the rehydration experiment central fatigue had increased to a greater extent, compared with the hyperthermia experiment. This insignificant difference was established within the range of 30—120 s of MVC — 2 min ($p > 0.05$).

During recovery, 15 s (A 15) after the load, the degree of VA had recovered to the value registered before the load. Two-factor dispersion analysis revealed that the changes in the VA indices analyzed depended on time ($p < 0.001$), the body state ($p = 0.047$) and the interaction between them ($p < 0.05$).

DISCUSSION OF RESULTS

So far we have not come across any data in other research showing what thermal effect and degree of dehydration is experienced by women not actively engaged in sports applying the methods of passive muscle warming proposed by A. J. Sergeant (1987). Using similar methods we evoked hyperthermia and dehydration of the body during the hyperthermia experiment. The subjects lost 0.4 ± 0.07 kg in weight (0.62 ± 0.13% of their body mass), experienced a physiological stress of an extremely high level, the rectal body temperature rose from 37.54 ± 0.24 to 39.62 ± 0.25ºC ($p < 0.001$) on the average and the inner muscle temperature — from 36.97 ± 0.28 to 39.96 ± 0.31ºC ($p < 0.001$) respectively.

We have not found in special literature any data either that would indicate in what way in the course of 45 min passively evoked hyperthermia and dehydration affects the functional capacity of human muscles. It has been established that with an increase in the core body temperature up to 38.7ºC (in the case of persons of average physical activity) or to 39.2ºC (in the case of high performance athletes) the human body becomes overheated and fatigue conditioned by voluntary efforts reveals itself (Cheung, McLellan, 1998). We have found during the hyperthermia experiment that hyperthermia and dehydration had increased MVC fatigue performing MVC-2 min and evoked a higher degree of voluntary activation, i. e. central fatigue, compared to the data of the control test. We believe the extremely sudden rise in the core body temperature and dehydration of the body to have a significant effect on the final results of the research.

The scientists have been using different methods of passive warming and rehydration — the rectal temperature up to 39.5ºC was reached in 110 min and the subjects consumed some 1.4 l of liquid (Thomas et al., 2006). The effect of preliminary hydration in conditions of hyperthermia on MVC and central fatigue that is observed frequently performing isometric exercise of maximum intensity has not been clarified yet.

To restore the liquid lost during the rehydration experiment the subjects were given to drink physiological solution (0.9% NaCl) of 37ºC (body temperature). After performing oral rehydration in conditions of hyperthermia body mass of the subjects increased by 0.48 = 0.01 kg on the average and that made up 0.74 ± 0.08% of their body mass. This indicates that the subjects before MVC-2 min had fully rehydrated.

We have found during this experiment that preliminary hydration in conditions of hyperthermia had no effect on MVC fatigue and recovery, compared to the hyperthermia experiment. Still it had caused a higher degree of voluntary activation, i. e. central fatigue performing MVC-2 min. We believe that this may be partly dependent on the temperature (37ºC) of the physiological NaCl 0.9% solution, on the changes in biochemical mechanisms due to penetration of this solution into the system of blood circulation, as well as on the energy consumption for resorbtion of liquids. Due to oral rehydration the balance of natrium and potassium in intracellular and intercellular medium may have been subjected to changes. The latter electrolytes are considered the main ones in the human organism that ensure the maintenance of water tonicity in intracellular and intercellular medium, nervous conductivity and cellular metabolism and due to which blood volume, i.e. osmotic pressure and regulation in the human body is maintained (Armstrong, 2000). Owing to this physiological-thermal stress and central fatigue had increased even more.

The results obtained are in accord with those obtained by other researchers and they prove the fact that hyperthermia diminishes voluntary force and increases the degree of voluntary activation performing physical exercises that require endurance. The research done by L. Nybo and B. Nielsen (2001) has proved that during hyperthermia (rectal temperature ≈ 39.7ºC) MVC muscle force after 2 min of continuous load had decreased by 58% and the degree of voluntary activation — by 54%, compared to the control value. In the course of this study at the end of the load MVC muscle force had decreased by 60% and the degree of voluntary activation — by 86%, compared to the control value.

It may be supposed that the response of a physiological-thermic stress is conditioned by a number of factors with physiological mechanisms of liquid assimilation and the selection of methods of passive warming among them.

CONCLUSIONS

1. Applying the methods of passive muscle warming evoked hyperthermia and dehydration in the subjects, participants in the experiment.
2. During the experiments of hyperthermia and dehydration there occurred homogeneous changes in MVC fatigue.
3. Hyperthermia caused an increase in central fatigue.
4. Rehydration in conditions of hyperthermia increased central fatigue even more markedly.

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HIPERTERMIJOS IR DEHIDRATACIJOS POVEIKIS SUAUGUSIŲ MOTERŲ GRIAUČIŲ RAUMENŲ NUOVARGIUI ATLIEKANT MAKSIMALAUS INTENSYVUMO IZOMETRINIUS PRATIMUS

Kazys Vadopalas[1], Albertas Skurvydas[1], Marius Brazaitis[1], Pavelas Zachovajevas[1], Dalia Mickevičienė[1], Laimutis Škikas[1], Mindaugas Dubosas[1, 2]
Lietuvos kūno kultūros akademija[1], Kaunas, Lietuva

SANTRAUKA

Tyrimo tikslas — nustatyti hipertermijos ir dehidratacijos poveikį maksimaliai valingajai jėgai (MVJ), centriniam nuovargiui ir įvertinti, kaip hipertermijos sąlygomis (atliekant 2 min maksimalų izometrinį krūvį) rehidratacija veikia griaučių raumenų funkcijas.

Tiriamosios — suaugusios aktyviai nesportuojančios moterys (n = 8). Jų amžius — 21,2 ± 2,4 metų, kūno svoris — 64,84 ± 8,4 kg, ūgis —170,8 ± 2,5 cm. Atlikti trys tyrimai — vienas kontrolinis, du eksperimentiniai. Vieno eksperimento metu buvo sukeliama organizmo hipertermija ir dehidratacija (tiriamosios 45 min sėdėjo iki dubens panirusios šiltoje vonioje, kurios vandens temperatūra 44 ± 1ºC), kito — ta pačia metodika sukeliant hipertermiją buvo atliekama peroralinė organizmo rehidratacija 1000 ml 37ºC NaCl 0,9% tirpalu. Maksimalus valingosios jėgos (MVJ) krūvis tęsėsi 120 s (kas 15 s raumuo buvo stimuliuojamas elektros impulsais — stimuliacijos trukmė 250 ms, dažnis 100 Hz, įtampos dydis 85—105 V). Registruotas raumenų MVJ momentas (N x m) ir raumenų valingojo aktyvavimo laipsnis: VA% = (MVJ + elektrinis impulsas) / MVJ × 100. Tiriamosios krūvio metu buvo žodžiu informuojamos, kaip kinta jėga.

Sukėlus hipertermiją ir dehidrataciją, rektalinė kūno temperatūra vidutiniškai padidėjo nuo 37,54 ± 0,24 iki 39,62 ± 0,25ºC ($p < 0,001$), raumenų vidinė temperatūra (3 cm gylyje) — nuo 36,97 ± 0,28 iki 39,96 ± 0,31ºC ($p < 0,001$). Atlikus rehidrataciją hipertermijos sąlygomis, rektalinė kūno temperatūra vidutiniškai padidėjo nuo 37,48 ± 0,25 iki 39,5 ± 0,23ºC ($p < 0,001$), raumenų — nuo 36,91 ± 0,29 iki 39,83 ± 0,31ºC ($p < 0,001$). Hipertermijos eksperimento metu tiriamosios vidutiniškai neteko 0,4 ± 0,07 kg, ir tai sudarė 0,62 ± 0,13% kūno svorio. Atlikus peroralinę rehidrataciją hipertermijos sąlygomis, tiriamųjų kūno svoris vidutiniškai padidėjo 0,48 ± 0,01 kg, ir tai sudarė 0,74 ± 0,08% bendrosios kūno masės. Išanalizavus fiziologinį šilumos streso indeksą (10 balų sistema) nustatyta, kad tiriamosios per abu eksperimentinius tyrimus patyrė labai didelį fiziologinį stresą: hipertermijos atveju — 8,85 ±1,13, rehidratacijos — 8,38 ± 0,98. Abiejų eksperimentinių tyrimų metu MVJ reikšmingai sumažėjo 3 krūvio sekundę, o per kontrolinį — 15 krūvio sekundę ($p < 0,001$), ir šis pokytis išliko iki MVJ-2 min pabaigos, lyginant su prieš krūvį nustatytais rodikliais. Atsigavimo metu, praėjus 5 min (A 300) po krūvio, MVJ rodikliai kontrolinio ir eksperimentinio hipertermijos tyrimo metu grįžo iki prieš krūvį nustatyto dydžio ($p > 0,05$). Dviejų veiksnių dispersinė analizė atskleidė, kad jėgos rodiklių pokytis priklausė nuo laiko ($p < 0,001$), būsenos ($p = 0,021$), o sąveikos tarp jų rezultato skirtumo reikšmingai nepaveikė ($p > 0,05$). Išanalizavus valingojo aktyvavimo rodiklius pastebėta, kad hipertermija ($p < 0,05$) ir rehidratacija ($p < 0,01$) reikšmingai padidino raumenų valingojo aktyvavimo laipsnį VA%, lyginant su prieš krūvį nustatytu. Atsigavimo metu, praėjus 15 s (A 15) po krūvio, valingojo aktyvavimo jėgos rodikliai grįžo iki prieš krūvį nustatyto dydžio. Atlikus dviejų veiksnių dispersinę analizę nustatyta, kad analizuojamų valingojo aktyvavimo jėgos rodiklių pokytis priklausė nuo laiko ($p < 0,001$), būsenos ($p = 0,047$) ir sąveikos tarp jų ($p < 0,05$).

Taikydami pasyvaus raumenų šildymo metodiką, tiriamųjų organizme sukėlėme hipertermiją ir dehidrataciją. Hipertermija padidino centrinį nuovargį. Hipertermijos ir rehidratacijos eksperimentų metu MVJ nuovargis kito vienodai. Rehidratacija hipertermijos sąlygomis turėjo neigiamos įtakos ir dar labiau padidino centrinį nuovargį atliekant 2 min maksimalų izometrinį krūvį.

Raktažodžiai: hipertermija, izometriniai pratimai, dehidratacija, rehidratacija, centrinis nuovargis.

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Kazys Vadopalas
Lithuanian Academy of Physical Education
(Lietuvos kūno kultūros akademija)
Sporto str. 6, LT-44221 Kaunas
Lithuania (Lietuva)
Tel +370 37 302671