INFLUENCE OF 200 mm Hg OCCLUSION PRESSURE ON ARTERIAL BLOOD FLOW IN SKELETAL MUSCLES AND PHYSICAL WORKING CAPACITY

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ABSTRACT

Research background and hypothesis. Different weights, resistance, scope of work, rest periods, frequency, and performance velocity are used to increase strength in training sessions. The traditional training facility with high resistance can be replaced by low resistance while limiting muscle blood flow. Hypothesis: a single 15-minute 200 mm Hg occlusion pressure can affect physical working capacity and blood flow intensity.

Research aim. was to analyze changes in the intensity of the calf muscle arterial blood flow and physical working capacity with and without 200 mm Hg pressure occlusion.

Research methods. were dynamometry, ergometry, venous occlusive plethysmography. The control group included six and experimental group – 12 male athletes in endurance sports. In both groups we recorded arterial blood flow at rest and after 75% of maximum voluntary contraction force (MVC) physical work lifting a weight until complete fatigue. Between the first and second physical workloads in the experimental group we applied 15 min occlusion with 40 mm wide cuff in the groin area.

Research results. During the physical load in the control group, arterial blood flow significantly increased, and during recovery it did not reach to baseline. In the experimental group arterial blood flow significantly increased and during recovery it did not reach the baseline. Blood flow intensity both the first and the second physical loads altered analogically. Before the second physical load in the experimental group, 200 mm Hg occlusion had a negative effect on skeletal muscle working capacity compared with the passive rest in the control group.

Discussion and conclusions. Occlusion of 200 mm Hg in the groin area reduces arterial blood flow intensity in calf skeletal muscles. Immediately after the removal of 200 mm Hg occlusion, arterial blood flow intensity increases and then decreases to its original value. 200 mm Hg occlusion pressure reduces blood flow intensity in the skeletal muscles. Before the second physical load, 200 mm Hg occlusion decreases skeletal muscle working capacity compared with passive rest in the control group.

Keywords: occlusion, physical working capacity, arterial blood flow.

INTRODUCTION

Sports training sessions include various training techniques and programmes enhancing athlete's fitness. Training with varying resistance is used to increase force (Jackson et al., 2004). Athletes use different weights, resistance, scope of work, rest periods, frequency, and speed of performance. Traditional training facility with high resistance can be replaced by low resistance together limiting muscle blood flow (Sato, 2004).

While sports performance improves, training load and intensity inevitably increase. Recently there has been an intensive search for ways and means to increase the efficiency of training and to reduce the duration of training sessions. To remedy this problem, various measures are applied. The possible measures include over-threshold electrostimulation. Such method as over-threshold electrostimulation significantly increases knee extensor isokinetic muscle strength (Brocherie et al., 2005). Muscle heating, passive warming up (muscle heating) carried out before the eccentric exercise may be more useful than active or not completely performed warming up (Evans et al., 2002). Cooling and heating effects on the body have been studied for quite a long time. Body temperature is one of the most important factors that affect physiological processes within animals and humans. Cryotherapy has long been used to treat inflammation of the internal organs, spinal cord injuries and other ailments. Heating and cooling effect has been widely used in rehabilitation. It has been shown that treatment with heating means increases tissue strength, elasticity, reduces joint stiffness, pain, muscle spasms, and accelerates blood flow. The importance of changes in external and deep tissue hemodynamics has been distinguished affirming that cold therapy reduces pain and muscle spasms. This includes using a variety of refrigeration sources and a wide temperature range. Besides heating and cooling skeletal muscle functional state can be improved in other ways, such as doing low-intensity exercise with skeletal muscle blood flow restriction. Hand metacarpal four-week workout performed with circulatory disturbance (200 mm Hg) influences the strength in hand and shoulder artery dilation. The hand grip strength in the control group increased by 8.32%, in the experimental group it increased by 16.17%. Shoulder artery dilation in the hands of the control group increased by 24.19%, while in the experimental group it decreased by 30.36%. (Credeur et al., 2009).

Three-week walking practice sessions with thigh muscle blood flow disturbance (160 mm Hg), influenced the functional state of muscles. After walking workouts with circulatory disturbance in the areas of the quadriceps muscle and the iliac, muscle bulk increased by 1.7 and 2.4%. Maximal voluntary contraction force (MVC) of legs increased by 7.3%, isometric knee extension force increased by 4.4%. Group without occlusion experienced no changes (Abe et al., 2009). However, there is little research how a single 200 mm Hg occlusion pressure affects muscle working capacity. Our hypothesis is that a single 15-minute 200 mm Hg occlusion pressure can affect physical working capacity and blood circulation intensity. Therefore, our aim was to analyze changes in the intensity of calf muscle arterial blood flow and physical working capacity under 200 mm Hg pressure occlusion.

RESEARCH METHODS

The study included 12 middle and long distance runners. Their training experience was four–six years: six men were in the control group, and 12 men – in the experimental group (Table 1). The age, height, weight, and body mass indices of the research participants were similar. Body mass index (BMI) is height to weight ratio, enabling the assessment of whether the person's weight is normal, too small, there is overweight or obesity. This index is calculated by the following formula: BMI = body weight (kg)/height (m^2). BMI within the normal range is 18.5–25 relative units.

Dynamometry. Feet flexor muscle strength was measured with a dynamometer. While determining foot flexor muscle strength, the subjects sat holding the dynamometry device with their hands. The subjects' knee of the working leg was fixed at the angle of 90^0, and the ankle – at the angle of 70^0. MVC size, measured in kilograms, was registered three times and charged at a higher value.

Ergometry. Feet flexor muscle working capacity was measured by ergometry methods using a dynamometry device. Dynamic work was done lifting weights (resistance – 75% of maximum voluntary contraction force determined before the workout) until the inability to continue this work. Amount of work expressed in kilogram/meters was considered as the indicator of muscle working capacity.

Venous occlusion plethysmography. Registration of arterial blood flow in the calf muscles was performed using venous occlusive plesthysmography method. The essence of the method of veno-occlusive plethysmography is that after pressing (occluding) the veins with a cuff, positioned more proximally from the segment tested, within the first few seconds the volume of the segment tested increases. This growth of the segment tested is directly proportional to arterial blood flow velocity. Therefore, the increase in the volume of the segment tested after venous occlusion indicates the amount of blood flowing that was before venous occlusion. The amount of arterial blood is one of the main factors in the evaluation of peripheral blood circulation. It characterizes what amount of blood was received per unit of time for the tested segment.

Research organization. The study was carried out in LAPE Laboratory of Kinesiology. Initially, foot flexor muscle MVC was measured three times in with three minutes of rest between the measurements. Thirty min after the MVC measurements arterial blood flow at rest was recorded. After recording arterial blood flow, the first physical load of 75% of MVC was done lifting a weight until complete fatigue. Arterial blood flow intensity was recorded immediately after physical load, after 21, 36, 53, 77, 107, 142, 168, 196, 231, 257, 284, 307 s. After that there was a 15 min passive rest. After passive recovery there was a second physical load of 75% of MVC lifting a weight until complete fatigue. Recording of arterial blood flow was done in the same way as after the first physical load (Table 2).

The study in the experimental group was performed similarly to that in the control group, but after 5 minutes after the first physical load, 15 min circulatory disturbance was performed with a 40 mm wide cuff on the groin with 200 mm Hg pressure (Table 2).

Statistical analysis. We calculated arithmetic means and standard deviations of indicators for all groups. The equity of sample means was estimated according to Student's t-test. The difference of $p < 0.05$ was considered to be significant. Before testing the equity of means, the equity of variances was verified. Calculations were performed using *Microsoft Excel* statistical package and a specialized statistical program *Statistica*.

RESEARCH RESULTS

The indicators of three measurements of maximal voluntary contraction force in the control and the experimental groups differed slightly ($p > 0.05$) (Figure 1).

In the control group, during the second physical load, physical work less than by 3.8% was carried out compared to the first physical load. In the experimental group, during the second physical load, physical work less by 13.2% was carried out compared to the first physical load ($p < 0.05$). In the experimental group, 15 min 200 mm Hg occlusion pressure applied before the second physical load had a negative effect on skeletal muscle working capacity compared with passive rest in the control group (Figure 2).

In the control group, blood flow intensity before the first dynamic work was 2.4 ± 0.3 ml/100 ml/min. After the first dynamic work until complete fatigue the intensity of blood flow increased to

Subjects	n	Age, years	Height, cm	Weight, kg	BMI
Control goup	6	22.8 ± 0.8	181.2 ± 2.5	74.0 ± 3.4	22.5 ± 0.8
Experimental group	12	22.4 ± 0.7	180.1 ± 1.5	71.4 ± 2.1	22.0 ± 0.5

Table 1. **Antrapometric data of subjects in control and experimental groups**

Note. (mean ± SE).

Determination of MVC force	30 min rest	Recording the initial value of arterial blood flow	First physical load of 75% MVC	Recording arterial blood flow for 305 s	1) 15 min rest 2) 15 min 200 mm Hg occlusion	Second physical load of 75% MVC	Recording arterial blood flow for 305 s

Table 2. **The organization of research on calf muscle arterial blood flow intensity and working capacity in control and experimental groups**

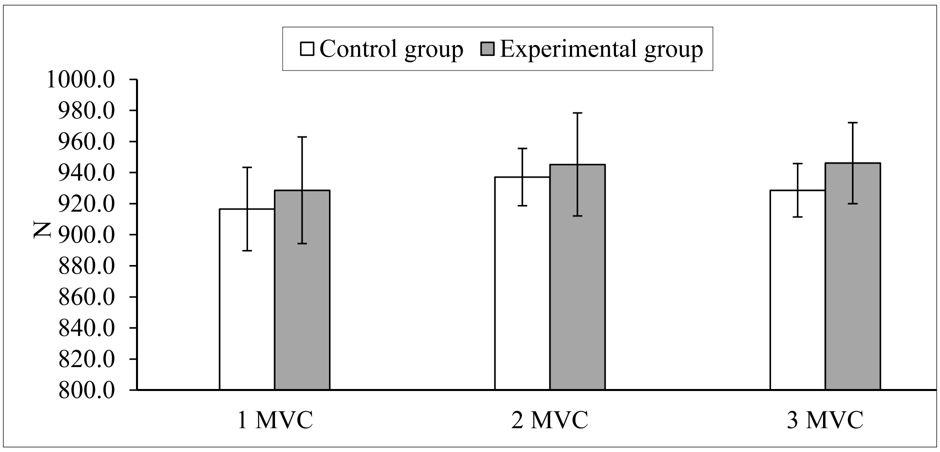
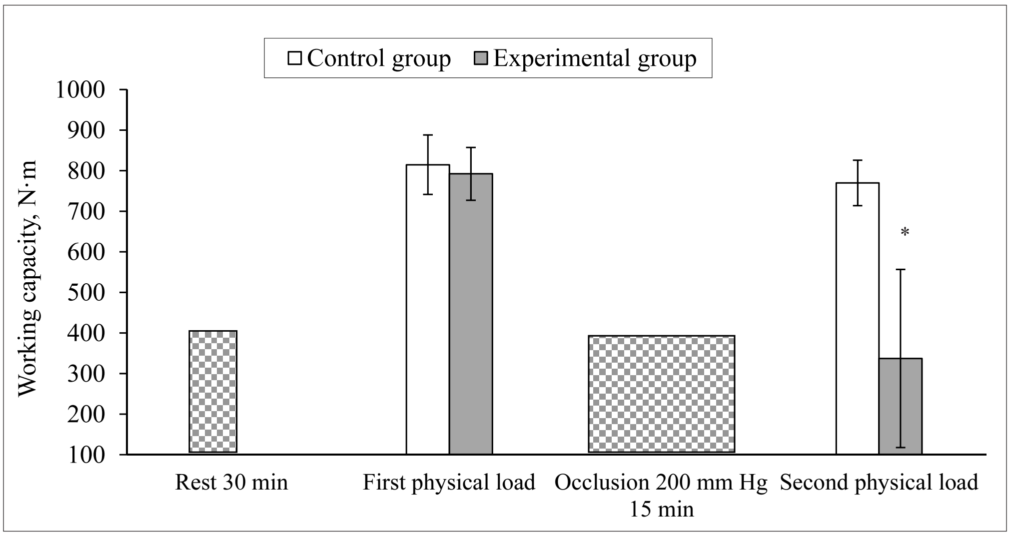
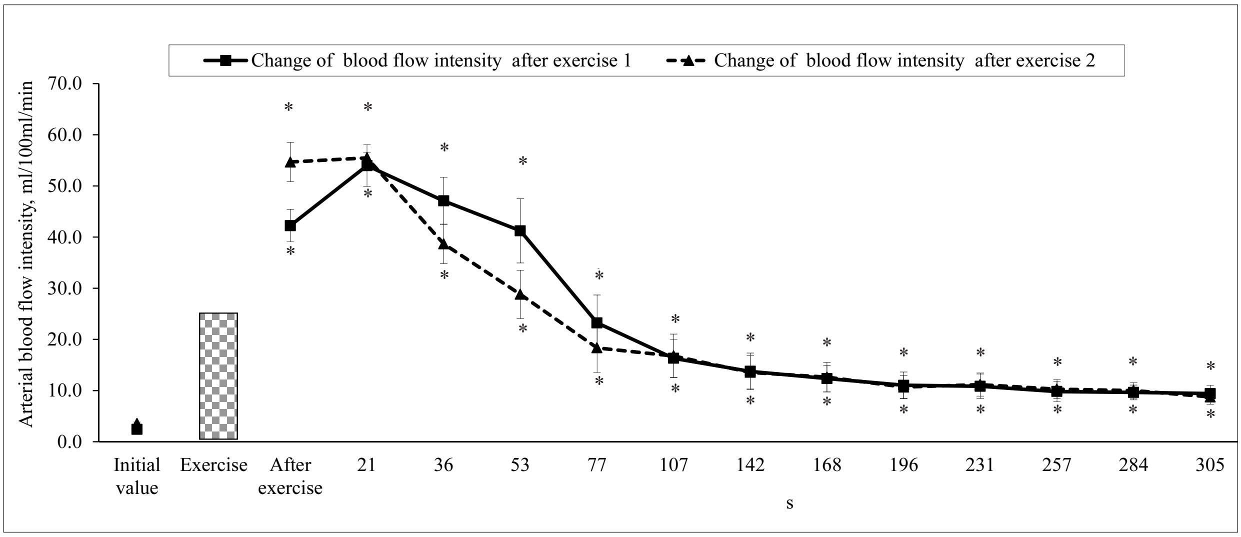


Figure 1. **Changes of maximal voluntary contraction in control and experimental groups**

Figure 2. **Changes of working capacity in control and experimental groups**

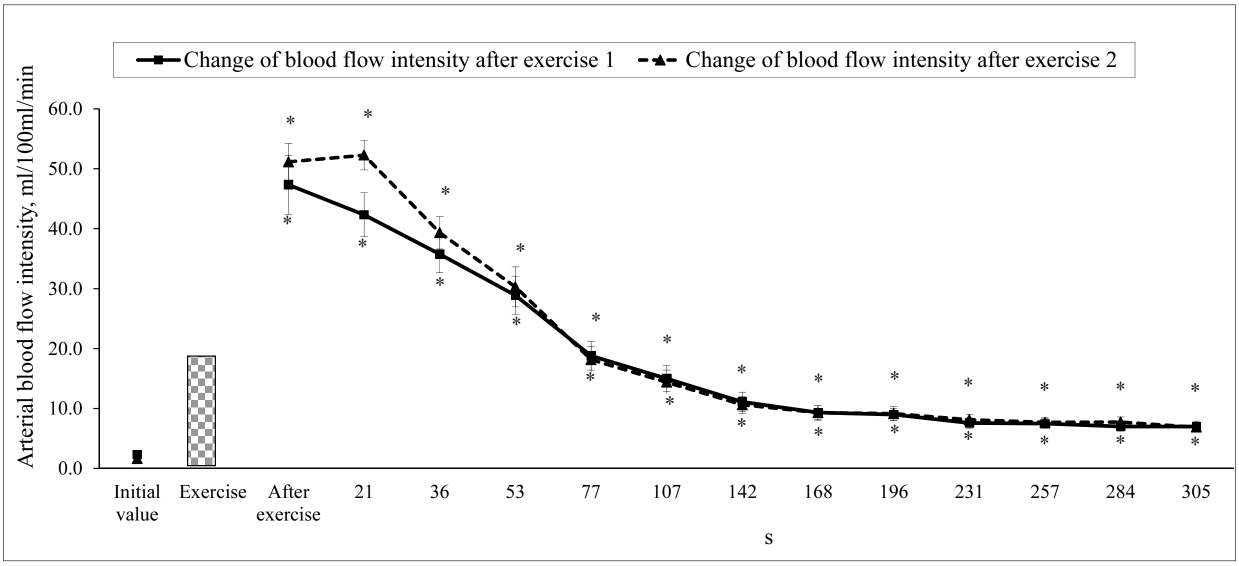


Note. * – $p < 0.05$, compared with the first physical load.



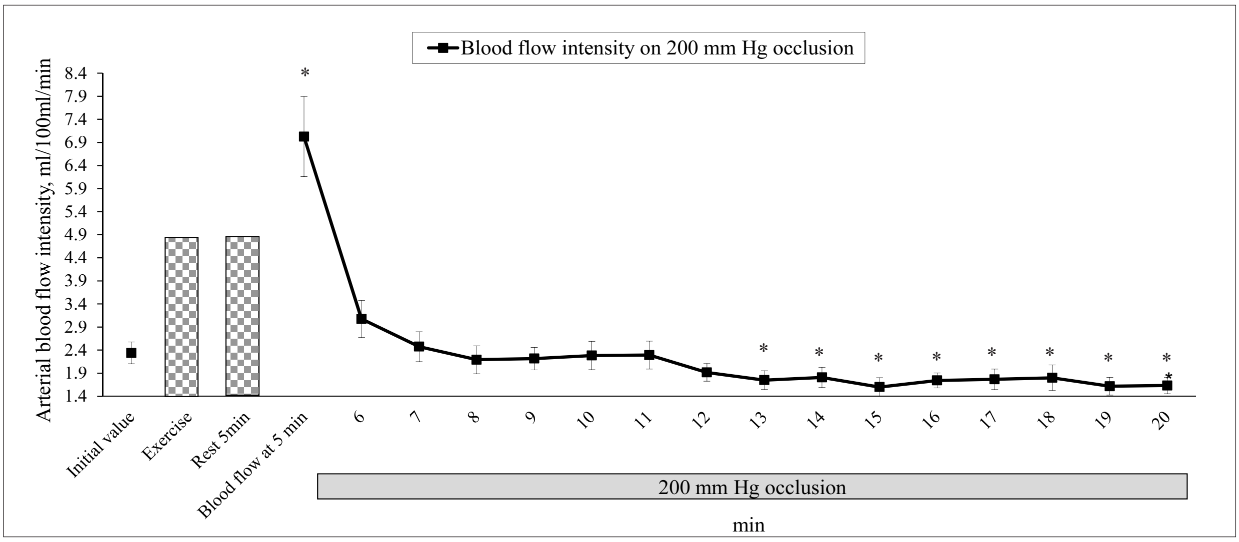
Note.* – $p < 0.05$, compared with the initial value.

Figure 3. **Changes of arterial blood flow intensity after the first and the second exercises in the control group**



Note.* – $p < 0.05$, compared with the initial value.

Figure 4. **Changes of arterial blood flow intensity after the first and the second exercises in the experimental group**



Note.* – p < 0.05, compared with the initial value.

Figure 5. **Blood flow intensity during 15-minute occlusion in the experimental group**

42.2 ± 3.2 ml/100 ml/min, and on the 21st second – up to 54.0 ± 4.1 ml/100 ml/min. During other measurements at 36, 53, 77, 107s, arterial blood flow declined substantially. Later (142 s), the intensity of blood flow decreased from 13.8 ± 3.6 ml/100 ml/min to 9.4 ± 1.6 ml/100 ml/min (305 s). Blood flow intensity before the second dynamic work was 3.5 ± 0.3 ml/100 ml/min. After the second dynamic work, blood flow intensity increased to 54.7 ± 3.8 ml/100 ml/min, and at 21 s – up to 55.5 ± 1.1 ml/100 ml/min. During other measurements at 36 s, 53 s, 77 s, arterial blood flow declined substantially. Later, at 107 s, blood flow intensity decreased from 16.8 ± 4.3 ml/100 ml/min to 8.8 ± 1.4 ml/100 ml/min (305 s) (Figure 3).

In the experimental group, the intensity of blood flow before the first dynamic work was 2.3 ± 0.2 ml/100 ml/min. Immediately after the first dynamic work, blood flow intensity increased to 47.4 ± 4.9 ml/100 ml/min. In other measurements at 21, 36, 53, 77, 107 s, arterial blood flow declined substantially. Later (142 s), the intensity of blood flow decreased from 11.1 ± 1.6 ml/100 ml/min to 7.0 ± 0.9 ml/100 ml/min (305 s) and did not reach the baseline ($p < 0.05$). Blood flow intensity before the second dynamic work was 1.6 ± 0.2 ml/100 ml/min. Immediately after the second dynamic work to complete fatigue, the intensity of blood flow increased to 51.1 ± 3.1 ml/100 ml/min and at 21 s – up to 52.3 ± 2.5 ml/100 ml/min. In other measurements at 36 s, 53 s, 77 s, 107 s, arterial blood flow declined substantially. Subsequently, the intensity of blood flow (142 s) decreased from 10.6 ± 1.4 ml/100 ml/min to 6.9 ± 0.7 ml/100 ml/min (305 s) (Figure 4).

Blood flow before the first exercise was 2.3 ± 0.2 ml/100 ml/min. After physical load, during recovery, on the fifth minute, the blood flow was 7.0 ± 0.9 ml/100 ml/min ($p < 0.05$), while on the sixth minute, after blood flow disturbances with the cuff on the thigh in the groin area, blood flow intensity decreased to 3 1 ± 0.4 ml/100 ml/ min. During subsequent measurements from 7 min (2.5 ± 0.3 ml/100 ml/min) to 12 min (1.9 ± 0.2 ml/100 ml/min), blood flow intensity slightly decreased. From 13 min (1.8 ± 0.2 ml/100 ml/min) to 20 min (1.6 ± 0.2 ml/100 ml/min) blood flow intensity was lower ($p < 0.05$) than the initial value (2.3 ± 0.2 ml/100 ml/min) (Figure 5).

DISCUSSION

Exercise intensity and exercise volume in training sessions are alternated. Recently, non-traditional training methods have been used, such as the skeletal muscle blood flow disturbances known as KAATSU methodology. KAATSU-walking workout can be a potentially useful method to improve muscle function (muscle hypertrophy, strength, and endurance) for a wide range of people. It is applied for the rehabilitation of people of all ages with health problems and after injuries.

The intensity of human muscle blood flow under the conditions of rest varies, depending on their functional state, and quite a lot of differences can be found in the data of various authors. M. Raitakari et al. (1996), using the tomography methodology of labeled positron emission, conducted research and revised the indices of muscle blood flow intensity under the conditions of rest. According to the data of those authors, human muscles blood flow is 1.1 to 7.5 ml/100 ml/min under the conditions of rest. It is believed that such large individual differences in resting muscle blood flow can be the residual effect of the work performed before. In our study, blood flow at rest ranged from 1.5 to 6.3 ml/100 ml/min, and the dissemination of results was analogous to M. Raitakari submitted data.

H. Iida et al. (2005) found that disruption of blood flow in both legs with occlusive cuffs increased the accumulation of venous blood in the legs, and then venous return to the heart decreased. After the removal of blood flow disturbances, the return of venous blood to the heart increases. Performing physical loads of 75% of maximum voluntary contraction force until complete fatigue, arterial blood flow in the control group significantly increased, and during recovery it did not reach the baseline. Blood flow intensity both after the first and the second the physical loads altered analogically. The greatest work of 814.62 ± 73.2 N•m was first performed during the first physical load, and the second work of 769.92 ± 56 N•m was lower than the first one ($p > 0.05$). In the experimental group arterial blood flow significantly increased and during recovery it did not reach the baseline. Blood flow intensity both after the first and the second the physical loads altered analogically. The greatest work of 792.4 ± 65.2 N•m was first performed during the first physical load, and the second work of 687.1 ± 62.7 N•m was lower than the first one ($p > 0.05$). After the first physical load until complete fatigue, after 5 min, 200 mm Hg occlusion on the thigh significantly reduces blood flow intensity in the calf muscles. In the experimental group, before the second physical load, 200 mm Hg occlusion had a negative effect on skeletal muscle working capacity compared with passive rest in the control group. Muscle activity increase depends on the amount of occlusion. High or moderate occlusion more increases muscle activity than in the group without occlusion. Strength increases under the conditions of moderate pressure occlusion compared with the group without occlusion, but in comparison with the high-pressure occlusion group, less work was carried out (Yasuda et al., 2009). At the start of the workload, the use of energy increases instantaneously, but the blood flow adaptation and aerobic metabolism takes time resulting in arterial blood and oxygen debt. Their size depends on the intensity of physical activity (Schmidt, Thews, 1996). During occlusion the blood flow intensity decreases as arterial blood vessels are mechanically pressed. After the removal of the occlusion arterial blood flow in the calf muscles increases three times. Blood flow increase after the removal of occlusion can affect the supply of blood to working muscles. In the control group without occlusion, working capacity during the performance of the second physical load slightly decreased compared with the first physical load. In the experimental group, working capacity during the performance of the second physical significantly declined compared with the first physical load. The results show that 200 mm Hg occlusion, significantly exceeding arterial blood pressure, reduces muscle working capacity.

CONCLUSIONS AND PERSPECTIVES

1. Arterial blood flow intensity after physical loads significantly increases. During the recovery time after the first physical load, 200 mm Hg occlusion pressure reduced blood flow intensity in the skeletal muscles in the experimental group.
2. The indices of maximum voluntary contraction force in the control and the experimental groups of differed insignificantly ($p > 0.05$). Before the second physical load, 200 mm Hg occlusion decreased skeletal muscle working capacity compared with passive rest in the control group.

REFERENCES

Abe, T., Kearns, C. F., Fujita, S. et al. (2009). Skeletal muscle size and strength are increased following walk training with restricted leg muscle blood flow: Effect of training frequency. *Medicine & Science in Sports & Exercise*, 5, 474–483.

Brocherie, F., Babault, N., Cometti, G., Maffiuletti, N., Chatard, J. C. (2005). *Electrostimulation Training Effects on the Physical Performance of Ice Hockey Players. Medicine Exercise,* 3, 455–460.

Credeur, D, P., Hollis, B. C., Welsch, M. A. (2009). Effects of handgrip training with venous restriction on brachial artery vasodilatation. *Medicine & Science in Sports & Exercise*, 4, 67–75.

Evans, R., Knight, K., Kenneth, L. et al. (2002). Effects of warm-up before eccentric exercise on indirect markers of muscle damage. *Medicine & Science in Sports & Exercise,* 12, 1892–1899.

Iida, H., Takano, H., Meguro, K. et al. (2005). Hemodynamic and autonomic nervous responses to the restriction of femoral blood flow by KAATSU. *International Journal of KAATSU Training Research*, 1, 57–64.

Jackson, N., Hickey, M., Reiser F. et al. (2004). Maximum strength versus strength endurance resistance training: Effects on the performance of cyclists. *Medicine & Science in Sports & Exercise,* 5, 118–123.

Raitakari, M., Nuutila, P., Ruotsalainen, U. et al. (1996). Relationship between limb and muscle blood flow in man. *Journal of Physiology (London),* 496, 543–552

Sato, Y. (2004). History and recent progress of KAATSU resistance training (in Japanese). *Clinical Journal of Sport Medicine,* 21, 209–213.

Schmidt, R. F., Thews, G. (1996). *Human Physiology*. London.

Yasuda, T., Brechue, W. F., Fujita, T. et al. (2009). Muscle activation during low-intensity muscle contractions with restricted blood flow. *Journal of Sports Sciences,* 5, 479–489.

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200 mm Hg SLĖGIO OKLIUZIJOS POVEIKIS GRIAUČIŲ RAUMENŲ KRAUJOTAKAI IR DARBINGUMUI

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Jėgai didinti pratybose naudojami įvairūs svarmenys, pasipriešinimas, skirtinga darbo apimtis, nevienodi poilsio periodai, dažnis ir atlikimo greitis. Tradicinę pratybų priemonę – didelį pasipriešinimą – galima pakeisti mažu pasipriešinimu kartu apribojant raumenų kraujotaką. Hipotezė: vienkartinė 15 minučių trukmės 200 mm Hg slėgio okliuzija gali paveikti fizinį darbingumą ir kraujotakos intensyvumą.

Tikslas – išanalizuoti blauzdos raumenų arterinės kraujotakos intensyvumo kaitą ir fizinį darbingumą taikant 200 mm Hg slėgio okliuziją ir be jos.

Metodai. Dinamometrija, ergometrija, veninė okliuzinė pletizmografija. Tirtos dvi grupės. Kontrolinėje grupėje bubo 6, eksperimentinėje – 12 ištvermės sporto šakų vyrų. Abiejose grupėse registruojama arterinė kraujotaka ramybėje ir po 75% maksimaliosos valingos jėgos (MVJ) fizinio darbo kilnojant svarmenį iki visiško nuovargio. Eksperimentinėje grupėje tarp pirmo ir antro fizinių krūvių atliekama 15 minučių okliuzija uždėjus 40 mm pločio varžtį kirkšnies srityje.

Rezultatai. Kontrolinėje ir eksperimentinėje grupėse atliekant fizinį krūvį arterinė kraujotaka smarkiai didėjo, o atsigavimo metu nepasiekė pradinių dydžių. Kraujotakos intensyvumas tiek po pirmo, tiek po antro fizinio krūvio kito analogiškai. Eksperimentinėje grupėje prieš antrą fizinį krūvį atlikta 200 mm Hg okliuzija neigiamai paveikė griaučių raumenų darbingumą, palyginti su pasyvaus poilsio rodikliais kontrolinėje grupėje.

Aptarimas ir išvados. 200 mm Hg dydžio okliuzija kirkšnies srityje mažina arterinės kraujotakos intensyvumą blauzdos griaučių raumenyse. Tuoj po 200 mm Hg slėgio okliuzijos pašalinimo arterinės kraujotakos intensyvumas padidėja, vėliau sumažėja iki pradinio dydžio. 200 mm Hg slėgio okliuzija smarkiai mažina kraujotakos intensyvumą griaučių raumenyse. Prieš fizinį krūvį atlikta 200 mm Hg slėgio okliuzija mažina griaučių raumenų darbingumą, palyginti su pasyvaus poilsio rodikliais kontrolinėje grupėje.

Raktažodžiai: okliuzija, fizinis darbingumas, arterinė kraujotaka.

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