

INFLUENCE OF PASSIVE FOOT FLECTION MOVEMENTS APPLIED AFTER EXERTION ISOMETRIC WORKOUTS ON MUSCULAR BLOOD FLOW

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ABSTRACT

Research background and hypothesis. Blood flow intensity plays an important role in the recovery after exercising.

Research aim was to compare the effect of passive rest and passive foot movement on calf muscle blood flow applying dosed static physical loads.

Research methods. Eighteen adult males were divided into two sub-groups. Participants of the study performed two isometric 30-s workouts at 75% of MVC with 20 minutes interval for the recovery between the workouts. During the first stage one sub-group performed workout and a passive recovery was applied while the subjects of the second sub-group performed passive foot flexion movements. During the second stage the form of recovery was changed. Arterial blood flow intensity was registered during venous occlusion plethysmography and passive foot flexion movements were performed by special mechanical equipment.

Research results. The results obtained during the study showed that maximal increase of blood flow registered at 21 second after the workout was (52.0 ± 2.9 ml/min/100 ml), while the application of passive movements before the workout decreased the blood flow intensity (45.0 ± 2.6 ml/min/100 ml). It was significantly ($p < 0.05$) lower compared to passive rest.

Discussion and conclusions. These effects can be explained by reduced venous filling and increased venous vascular reserve capacity in the calves. The results obtained during this research allow concluding that passive foot flexion manoeuvre applied before the isometric workload faster decreases the blood flow intensity during the recovery.

Keywords: arterial blood flow recovery, isometric physical workout, passive foot movement, passive rest.

INTRODUCTION

Working capacity and recovery of athlete's body after exhausting physical loads are affected by many factors, such as systemic and muscular blood flow characteristics. Various regulatory mechanisms and their interaction lead to the final result – the intensity of blood flow. With increased training workloads and contest activities, athlete recovery has probably become the main object of investigation. Fatigue levels in the process of sports training are one of the factors that determine the performance of exercise and the body adaptation to physical load. It is the recovery

period, when the most significant adaptive changes occur, which are the basis for long-term adaptation.

Muscle blood flow changes directly affect the intensity of oxidative metabolic processes (Friedmann et al., 2007) suggesting that the intensification of muscle blood flow can increase the rate of tissue respiration, reduce fatigability and improve muscle working capacity. When looking for an advanced solution to this problem, researchers propose a variety of blood flow activation effects applying additional recovery measures. Extra mechanical impact on blood vessels is one of the

self-regulatory phenomena causing vasodilator response (Boutcher, Y. N., Boutcher, S. H., 2005). The problem of the relationship between muscle blood flow and working capacity is still relevant and not fully understood (Hughson et al., 1996).

Local work carried out to failure lasts longer at a good functional state. Applying recovery exercises after the physical load, physical working capacity significantly improves for non-activated muscles during exercise compared to passive rest (Fujita et al., 2009). After physical work there are great changes in muscle blood flow. To assess the recovery measures (effect of passive rest and passive foot movement on calf muscle blood flow) we applied a functional test – static physical load of dosed duration.

Research aim was to compare the effect of passive rest and passive foot movement on calf muscle blood flow applying dosed static physical loads.

RESEARCH METHODS

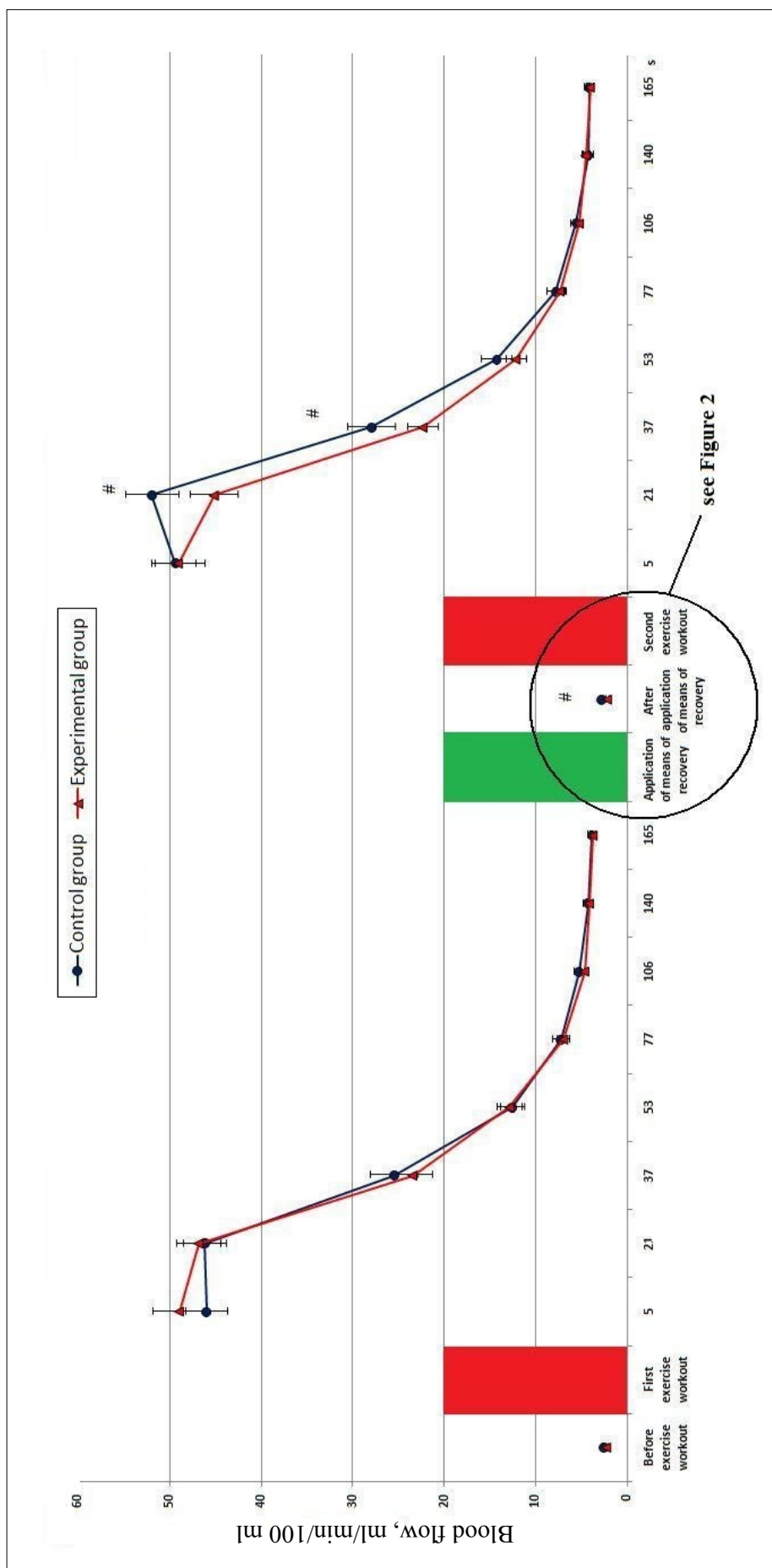
Research participants were 18 persons adapted to endurance physical loads. Their age was 20.3 ± 2.1 years, height 178 ± 4.2 cm, body mass 71.2 ± 3.5 kg. Two studies were carried out using different recovery means (passive rest, passive foot movement). All subjects were assigned to two groups, 9 persons in each group: control and experimental, where recovery measures were administered in a certain order in each group. The control group had passive rest for 20 min between the two physical loads, and the experimental group – passive rest for 5 min and passive foot movements for 15 min. Physical working capacity is the greatest when the passive foot movements last for 15 min. After three days the recovery measures applied to groups were interchanged – the control group received 5 min passive rest and 15 min passive foot movements, while the experimental group – 20 min passive rest. Such interchanging is necessary in order to avoid training and adaptation effect for subjects under the experimental conditions. In each study, after 20 min of adaptation, the calf muscle blood flow was recorded using venous occlusion plethysmograph while the subject was in a sitting position. We determined maximal voluntary contraction force of foot flexors, and two 30 s static physical workloads of 75% of the maximum voluntary contraction force were performed. The maximal voluntary contraction force (MVC) was determined using the dynamometric device. The

maximal voluntary contraction force value was recorded three times and the highest value was taken for analysis. We captured the subjects' joints of the working knee at the 90° angle and the ankle – at the 70° angle. Maximal muscle endurance (MME) was determined by pressing the foot on the operating plate with 75% of the maximal voluntary contraction force. The subjects had to perform a 30 s static physical load by pressing the plate and maintaining the same amount of force. Passive foot flexion was performed using a mechanical device. The feet were attached to the pedals which were moved by the electric motor. The angle of pedal movement and the range of motion of flexion and extension were 35° , and the frequency was 30 movements per minute.

Statistical analysis. The difference between the groups was considered to be reliable with Student's *t* test statistical significance set at $p < 0.05$. Before the test of means, equality of dispersion was checked up. The data are expressed as means \pm standard error. These calculations were performed using statistical functions of the *SPSS Statistics 17.0*.

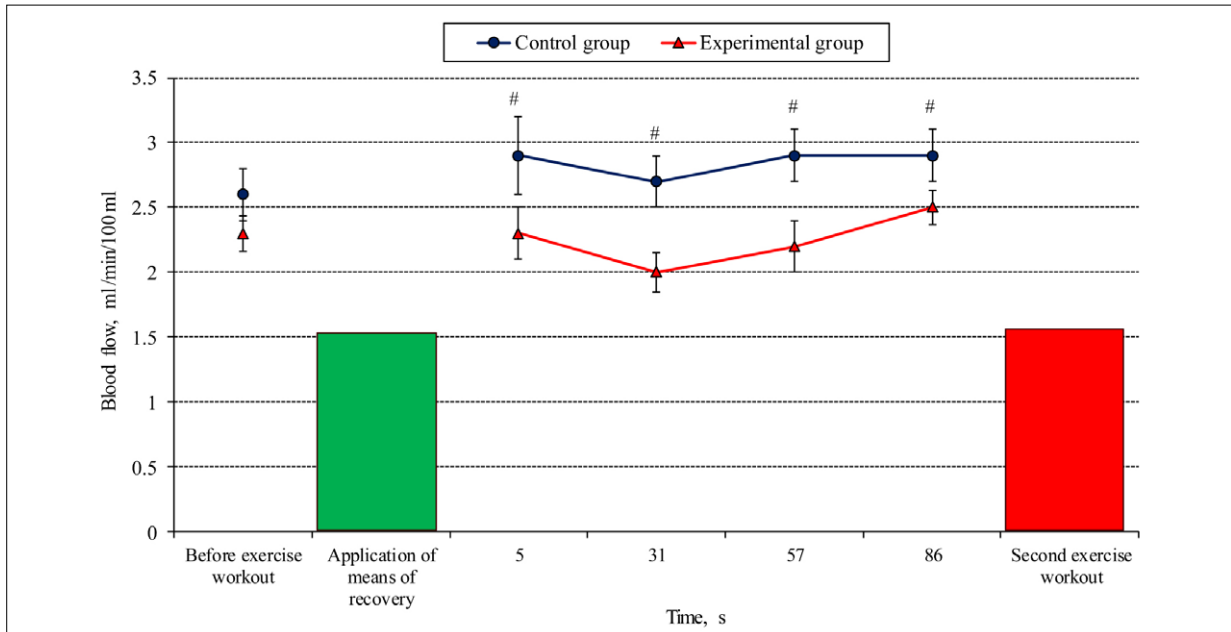
RESEARCH RESULTS

In the control group, the arterial blood volume before the first dosed static physical load was 2.6 ± 0.2 ml/min/100 ml, and immediately after the load it increased to 46.0 ± 2.3 ml/min/100 ml, at the 21st s it was 46.2 ± 2.3 ml/min/100 ml. At the thirty-seventh and fifty-third second we observed a significant decrease in the blood flow, respectively to 25.5 ± 2.6 ml/min/100 ml, 12.6 ± 1.3 ml/min/100 ml. Arterial blood flow at the one hundred sixty-ninth second was still significantly greater than the initial value (Figure 1). In the experimental group, the arterial blood volume before the first dosed static load was 2.3 ± 0.14 ml/min/100 ml, and immediately after the exercise it increased to 49.0 ± 2.9 ml/min/100 ml, at the 21st second – to 46.9 ± 2.4 ml/min/100 ml (Figure 1). At the thirty-seventh and fifty-third second a considerable blood loss was observed, respectively to 23.5 ± 2.2 ml/min/100 ml, 12.9 ± 1.3 ml/min/100 ml. Arterial blood flow at the one hundred sixty-ninth second was still significantly higher than the initial value. After passive rest, the intensity of calf muscle arterial blood flow in the control group before the second physical load was significantly higher than that in the group with passive foot movements (Figure 2).



Note. Values are means ± SE. # – Significantly different from the value between groups ($p \leq 0.05$).

Figure 1. Arterial blood flow in the calf muscle after exercise workouts and after applying means of recovery (the passive rest and passive foot movement)



Note. Values are means \pm SE. # – Significantly different from the value between groups ($p \leq 0.05$).

Figure 2. Arterial blood flow in the calf muscle after applying means of recovery (the passive rest and passive foot movement)

The results obtained during the study showed that maximal increase of blood flow at 21 second after the workout was registered (52.0 ± 2.9 ml/min/100 ml), while the application of passive movement before the workout decreased the blood flow intensity (45.0 ± 2.6 ml/min/100 ml). This was significantly ($p < 0.05$) lower compared to passive rest. The same tendency of lower blood flow intensity was observed in the measurements up to 40 seconds after workouts.

After the second working hyperaemia (the twenty-first second), the largest difference in blood flow intensity was observed applying the passive rest – 5.8 ± 1.7 ml/min/100 ml, and the application of the passive foot movements resulted in 0.9 ± 2.4 ml/min/100 ml ($p < 0.05$). Passive foot flexion before the second static load reduces the maximum intensity of blood flow. The lower values of the highest blood flow can be explained by the fact that passive foot flexion decreased blood filling in venous vessels and increased calf venous vascular reserve volume. After the increase in venous reserve volume, peak blood flow after working hyperaemia decreased because the increase in maximal blood flow was limited by the increased rate of venous emptying.

DISCUSSION

R. M. Enoca and D. G. Stuart (1992) showed that the results are limited to the fatigue task performed because the relative contribution of

the different mechanisms to fatigue is highly task dependent. The fatigue task (to sustain 75% of MVC for 30 s) combined characteristics (high force level, relatively short duration) allowing a rapid muscle recovery (Petrofsky, 1981; Petrofsky, Philips 1981). During a high force level contraction, the consumption of short-term energy supplies in anaerobic muscle fiber (type II) and the hypoxia (blood flow occlusion) of aerobic muscle fibres (type I) led to a rapid decline of muscle force (fatigue) (Lariviere et al., 2003). However, this occurs without significantly increasing the negative effects of some hypothesis concerning muscular fatigue factors associated with a low force-level contraction to fatigue that take longer to restore (Fitts, Balog, 1996).

Static physical workloads of different intensity are applied in sports practice. Static endurance is an indicator of working capacity which depends on the person's maximal effort. When the subjects perform each physical load as a percentage of MVC, the experimenter ensures equal conditions for all subjects taking into account individual differences (Роженблат, 1975). V. V. Rozenblat (Роженблат, 1975) argues that static muscle endurance in physical loads at 50 or 75% of MVC is independent physiological functional test showing the functionality of the movement mechanism. In determining the static endurance, it is necessary to use static physical load of increased intensity. V. V. Rozenblat (Роженблат, 1975) recommends that it is appropriate to use physical workloads of

75% MVC until complete fatigue. Static endurance of 75% MVC as a test determining fatigue has several advantages: 1) fatigue occurs very quickly, 2) significant changes in the intensity of blood flow occur in the working muscles. Our previous study results showed that maximal muscle endurance (MME) of right foot flexors of athletes adapted to speed-strength physical loads was 58.9 s, and that of athletes adapted to endurance physical loads – 70.6 s. Other researchers' findings showed that maximal muscle endurance (MME) of persons not engaged in sports was 54.0 s. The chosen duration of dosed physical load was 30 seconds because it was about a half of the maximum endurance time (van Dieen et al., 1998). The intensity of the blood flow in the working muscle after static physical workloads depends on the intensity of the load performed.

After the working hyperaemia, the maximum values of arterial blood were not immediately after the physical load, but at the twenty-first second and later. The forces compressing blood vessels disappear immediately after exercise when the muscles are relaxed. It would seem that at this time the blood pressure should fully stretch the blood vessels. Why is the blood flow the largest not immediately after physical load, but after some time? What keeps fast stretching of blood vessels, if not of all of them, but at least some of them? The data of H. V. Sparks (1964) and R. T. Grant (1930) suggest what hinders this contraction of the blood vessels which are exposed to high compression during muscle contraction. H. V. Sparks showed that the part of the artery which is exposed to a fast stretch shrinks. Even more interesting and very important is the research by R. T. Grant. He observed that chronically denervated arterioles of a rabbit responded to a slight touch by localized dilatation, but their response to a strong compression resulted in a localized shrinkage. Later, intense slowly developing dilatation

occurred. Why the blood flow is the largest not immediately after the physical load, but after some time, can be explained on the basis of H. V. Sparks (1964) and R. T. Grant's work which suggests that during the load arterial blood vessels are strongly compressed, so it takes time for half-empty arterial blood vessels to fill up with blood. When they fill up with blood, the maximum values of arterial blood flow are reached.

The last question for discussion is about the duration or rest intervals between testing procedures. According to the measurements theory (Crocker, Algina, 1986), the reliability of the measurement can be increased by taking the average of multiple tests. However, in the specific case of fatigue tests, the reliability is affected not only by the random error across tests but also by the systematic error associated with the lack of recovery from the preceding fatigue tests. One way to attenuate the effect of this systematic error is to increase the rest period between tests. Studies in which repeated back muscle fatiguing contractions were performed and where a complete recovery between the tests was assumed used varying rest interval ranging between 10 and 15 min (Kondraske et al., 1987; Roy et al., 1989) and 20 min (Macarez, 1976). The rest intervals appear to be in agreement obtained with handgrip fatiguing contractions (Petrofsky, 1981). Consequently the purpose of the present study was the evaluated rest interval 20 min after performing a short fatiguing contraction.

CONCLUSIONS AND PERSPECTIVES

The results obtained during this research allow concluding that passive foot flexion manoeuvre applied before the isometric workload decreases the blood flow intensity during the recovery.

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PASYVAUS PĖDŲ LANKSTYMO POVEIKIS BLAUZDOS RAUMENŲ KRAUJOTAKAI PO IZOMETRINIŲ FIZINIŲ KRŪVIŲ

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Kraujotakos intensyvumas po fizinių krūvių yra svarbus veiksnys atsigavimo metu. Šio tyrimo uždavinys išsiaiškinti, kaip pasyvus pėdų lankstymas po izometrinių fizinių krūvių veikia raumenų kraujotaką.

Tikslas – nustatyti pasyvaus poilsio ir pasyvaus pėdų lankstymo poveikį blauzdos raumenų kraujotakai taikant dozuotus statinius krūvius.

Metodai. Buvo tiriama 18 asmenų, adaptuotų ištvėmės fiziniams krūviams. Atlikti du tyrimai taikant skirtingas atsigavimo priemones (pasyvų poilsį, pasyvų pėdų lankstymą). Visi tiriamieji suskirstyti po devynis į dvi grupes (kontrolinę ir eksperimentinę), kurioms atsigavimo priemonės buvo skiriamos tam tikra tvarka. Kiekvieno tyrimo metu po 20 minučių adaptacijos blauzdos raumenų kraujotaka buvo registruojama veniniu okliuziniu pletizmografu tiriamajam sėdint. Buvo nustatoma pėdos lenkiamųjų raumenų maksimalioji valinga jėga ir atliekami du 75% maksimaliosios valingos jėgos 30 s trukmės statiniai fiziniai krūviai.

Rezultatai. Kraujotaka labiausiai padidėjo po krūvio dvidešimt pirmą sekundę ir siekė $52,0 \pm 2,9$ ml/min/100 ml taikant pasyvų poilsį, o pasyviai lankstant pėdas – $45,0 \pm 2,6$ ml/min/100 ml ($p < 0,05$). Trisdešimt septintą ir penkiasdešimt trečią sekundę pastebėtas didelis kraujotakos sumažėjimas – atitinkamai $25,5 \pm 2,6$ ml/min/100 ml ir $12,6 \pm 1,3$ ml/min/100 ml.

Aptarimas ir išvados. Darbo metu tiriamųjų arterinės kraujagyslės buvo stipriai suspaustos, todėl reikėjo laiko joms užsipildyti krauju. Kai jos prisipildo, pasiekiamos didžiausios arterinės kraujotakos reikšmės. Rezultatai parodė, kad pasyvus pėdų lankstymas, taikytas prieš izometrinių fizinių krūvių, sumažina kraujotakos intensyvumą atsigavimo metu.

Raktažodžiai: arterinės kraujotakos atsigavimas, izometrinis fizinis krūvis, pasyvus pėdų lankstymas, pasyvus poilsis.

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