LITHUANIAN SPORTS UNIVERSITY

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THE RESIDUAL EFFECT OF ECCENTRIC CONCENTRIC PRIOR EXERCISE ON PULMONARY GAS EXCHANGE AND MUSCLE ELECTRICAL ACTIVITY DURING CYCLING OF DIFFERENT INTENSITY

Summary of Doctoral Dissertation

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EKSCENTRINIO KONCENTRINIO PRIEŠKRŪVIO POVEIKIS KVĖPAVIMO DUJŲ APYKAITOS IR RAUMENŲ ELEKTRINIO AKTYVUMO KAITAI ATLIEKANT SKIRTINGO INTENSYVUMO KRŪVĮ VELOERGOMETRU

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CONTENT

ABBREVIATIONS

[La]	– blood lactate concentration
A	– amplitude
ATP	– adenosine triphosphate
CK	– creatine kinase
DOMS	– delayed onset muscle soreness
EMG	– electromyography
HCL	– heavy intensity constant cycling load
HR	– heart rate
ICL	– increasing ramp cycling load
MCL	– moderate intensity constant cycling load
MnPF	– mean frequency of power spectrum
MVC	– maximal voluntary contraction
PDJ	– preceding drop jumps test
PE	– preceding eccentric exercise test
RMS	– root mean square
RPE	– ratings of perceived exertion
T	– time constant
Ve	– pulmonary ventilation
VO_2	– oxygen uptake
VO_{2max}	– maximal oxygen uptake
VT1	– first ventilatory threshold
VT2	– second ventilatory threshold

INTRODUCTION

It is well established that unaccustomed eccentric concentric exercise evokes delayed onset muscle soreness (DOMS) (MacIntyre et al., 2001; Dannecker et al., 2005, 2008; Fredsted et al., 2008; Lewis et al., 2012), muscle fibre disarrangement (Hortobagyi et., al., 1998; Stupka et al., 2001; Carlsson et al., 2007), inflammatory cell emission into blood (Stupka et al., 2001; Laaksonen et al., 2006), increase of the activity of blood plasma creatinkinasis (Stupka et al., 2000; Chen et al., 2010; Skurvydas et al., 2010), decrease of muscle force production (Chen et al., 2010; Semmler et al., 2007; Skurvydas et al., 2010) and decrease of aerobic work capacity (Black, Dobson, 2012). The aforementioned functional, sensory, biochemical and structural changes independently from each other are displayed immediately after eccentric exercise and stay for up to 7 days, dependence on the level of damage (Clarkson et al., 1992; Skurvydas et al., 2000; Stupka et al., 2000, 2001; MacIntyre, 2001; Totsuka et al., 2002; Nottle, Nosaka, 2007; Tofas et al., 2008; Lewis et al., 2012; Paulsen et al., 2012).

It is still not clear what acute and residual effect of eccentric exercise on the pulmonary gas exchange is had during different intensity work. It was determined that one hour after eccentric concentric exercise, there increases absolute VO_2 during moderate (Zaičenkovienė, Stasiulis, 2010) and heavy intensity loads (Ratkevičius et al., 2006). 48 hours after eccentric exercise, when the evaluation of subjective pain is the greatest (Lewis et al., 2012), there increases VO_2 (Burt, Twist, 2011) pulmonary ventilation (Ve) and ratings of perceived exertions (RPE). It should be noted that other researchers present contradictory evaluations – they did not determine VO_2 changes 48 hours after preceding eccentric exercise (Gleeson et al., 1995; Davies et al., 2009, 2011; Schneider et al., 2007; Twist, Eston, 2009), during heavy intensity load. On the other hand, it was determined that Ve does not change, although RPE during heavy intensity load increases (Black, Dobson, 2013). After eccentric exercise, there increases blood lactate concentration during heavy intensity load (Gleeson et al., 1995; Schneider et al., 2007).

Eccentric edetermine the changes of muscle electric activity during the contraction, but it is not clear how after such pre-load the indices of electromyogram (EMG) during the dynamic load change. It was determined immediately after eccentric exercise of m. Quadriceps femoris, the EMG amplitude decreases during the maximum isometric torque (Bieuzen et al., 2008; Behrens et al., 2012). Evaluating in regard to time, the decrease of EMG amplitude was determined while during the isometric load of 40 per cent of maximum voluntary contraction (MVC) (Hedayatpour et al., 2009). While comparing the effects of concentric and eccentric exercise, it was determined that the first one increases the EMG amplitude while accomplishing the load on cycle ergometer immediately after the pre-load (Bieuzen et al., 2008). It was determined that EMG frequency decreases and the amplitude does not change after eccentric exercise (Ahmadi et al., 2007).

The indices of EMG and pulmonary gas exchange changes subject to the load intensity, and there exists the relation among them. It was determined that during increasing load, the changes of EMG and pulmonary gas exchange coincide (Lucia et al., 1999; Hug et al., 2003). L. M. Chin with the co-authors (2011) determined that there exists linear dependence between electrical activity of m. Quadriceps femoris and their oxygen saturation. Besides, EMG changes reflect the changes of VO_2 (Green et al., 2010) and metabolic costs (Blake, Wakeling, 2013) during the constant load.

There is little of data about how the pre-load influences the indices of pulmonary gas exchange and EMG changes, besides, the data is comparatively controversial. M. Burnley with the co-authors (2002) determined that the increased amplitude of VO_2 kinetics is related to EMG changes. J. U. Gonzales and B. W. Scheuermann (2006) present an oppositional theory and do not show any relation between EMG changes and VO_2 kinetics during a long duration load, after preceding heavy intensity load. The analysis of electric activity of working muscles would allow better understanding the changes of metabolism and their mechanism, as muscle EMG changes while working reflect their fatigue, and the changes of muscle group and motor unit recruiting (Scheuerman et al., 2001; Green et al., 2010). Muscle damage can also start by the increase of metabolic costs during the aerobic work. There exists an assumption that affected muscle fibres affect working fibres as an additional mechanical load (Lieber et al., 1996, Sandercock, 2000). While analysing the literature, we did not find any data about what is acute and residual effect is of different eccentric pre-exercise on muscle electric activity and pulmonary gas exchange indices during different intensity loads on cycle ergometer.

The aim of the research was to determine the acute and residual effect of preceding eccentric concentric exercise on pulmonary gas exchange and muscle electrical activity during different intensity load on cycle ergometer.

Research objectives:

1. To study the effect of preceding eccentric concentric exercise on the indices of pulmonary gas exchange and electrical activity of leg muscles during moderate and heavy cycling load.
2. To study the effect of preceding eccentric concentric exercise on the indices of pulmonary gas exchange and electrical activity of leg muscles during increasing cycling load.
3. To study the effect of one leg preceding eccentric exercise on the indices of pulmonary gas exchange and electrical activity of legs muscles during heavy cycling load.

Research hypothesis

Preceding eccentric concentric leg muscle exercise evokes muscle damage and force reduction, therefore can affect the indices of pulmonary gas exchange and can reduce the efficiency of aerobic work. It is likely that preceding eccentric concentric exercise will affect muscle electric activity as well, the changes of which will be directly related to the changes of the indices of respiratory function. The effect of prior exercise effect on the kinetics of functional indices, evaluated while performing different intensity loads, will allow better understanding the reasons influencing the efficiency of aerobic work.

Research originality

Preceding drop jumps exercise and one leg preceding eccentric exercises acute and residual effect on the indices of pulmonary gas exchange and aerobic efficiency as well as muscle electric activity during the constant intensity and increasing ramp cycling load was investigated for the first time. The study determined that after preceding drop jumps and one leg eccentric exercises an acute effect on the indices of pulmonary gas exchange was observed without any effect on work efficiency. Preceding drop jumps increased the electric activity of damaged muscles. After one leg preceding eccentric exercises unexpected muscle response was observed: the EMG of the leg affected by preceding eccentric exercises did not change, and EMG amplitude of the unaffected leg was decreased.

Practical application of the research

The data obtained have enriched the knowledge about the acute and residual effect of eccentric concentric exercise on the pulmonary gas exchange and muscle electrical activity during physical load. These data deepen understanding of the efficiency of aerobic work and to plan physical exercise and sports training regimen.

1. RESEARCH METHODS AND ORGANIZATION

1.1. Subjects

Healthy females and males volunteered to participate in this study. All the subjects were informed about the experimental research in detail. Written informed consent was obtained from the volunteers prior to their participation in this study. The Ethics Committee of Kaunas University of Medicine approved this study. The subject's characteristics are given in Table 1.

Table 1. *Indices of the subjects' age, height, body mass and maximal oxygen uptake (VO_{2max})*

	Participants (n)	Age (years)	Height (cm)	Weight (kg)	VO_{2max} (ml/kg/min)
Research I	Females (n = 11)	21.5 (1.9)	60.8 (4.5)	1.71 (0.06)	34.6 (3.9)
Research II	Males (n = 11)	21.9 (2.2)	77.6 (8.2)	1.81 (0.07)	45.6 (6.5)
Research III	Male (n = 10)	21.5 (1.4)	77.3 (7.9)	1.85 (0.05)	43.7 (4.2)

Note. Descriptive data are presented as group means and (SD)

1.2. Methods

1.2.1. Body composition analysis

The body weight of each subject was measured using electronic scale body composition analyzer "Tanita TBF-300" (Japan). When the subjects stood on a special platform, the device recorded their body

1.2.2. Pulsometry

During the cycling exercise heart rate (HR) was constantly registered by pulse measuring instrument with memory „Polar Precision Performance" (Finland) that recorded HR values every five seconds.

1.2.3. Spirometry

Aiming at establishing pulmonary gas exchange indices, was applied the portable gas analyzer „Oxycon Mobile“ (Germany) to register respiration indices for each subject: VO_2, speed of carbon dioxide output, Ve, regularly exchange ratio and ventilatory equivalents of oxygen and carbon dioxide. The mean intervals of five seconds of all registered indices were analyzed using „LAB Manager“ and „Microsoft Excel“ programs. Prior to each testing the respiratory gas analyzer was calibrated according to the automatic calibration method proposed by Jaeger.

1.2.4. Determination of maximal oxygen uptake

Maximal oxygen uptake (VO_2max) was determined according to increasing ramp cycling load (ICL) data according the dependence of average VO_2 during 15 s on the work intensity (Fig. 1). The highest value of VO_2 during 15 s of ICL was considered as VO_{2max}. Relative VO_{2max} is usually calculated dividing absolute index l/min by the body mass of the subject.

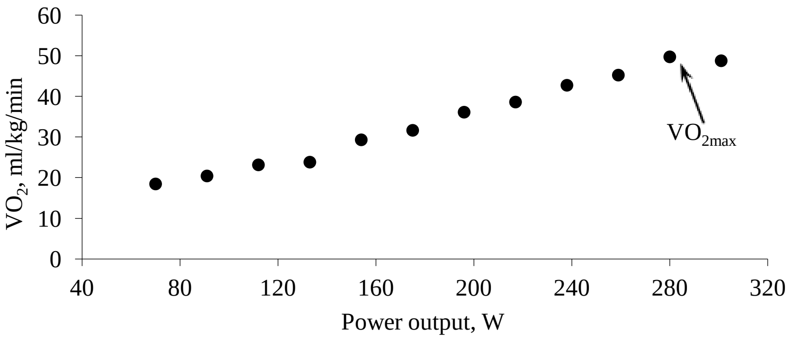


Fig 1. *Determination of maximal oxygen uptake (VO_{2max})*

Note. VO_{2max} was the highest VO_2 achieved in 15 s during the test of ramp increasing load

1.2.5. Determination of ventilatory thresholds

The first (VT1) and the second (VT2) ventilation thresholds were established according to the dependence of pulmonary ventilation as well as ventilation equivalents of oxygen (Ve/VO_2) and carbon dioxide

(Ve/VCO_2) at the end of expiration on the work intensity performing ICL test. VT1 was considered to be the intensity of the work load when the Ve increase accelerated for the first time, and the Ve/VO_2 started increasing without any changes in the Ve/VCO_2. VT2 was the intensity of the work load when the Ve increase accelerated for the second time, and the Ve/VO_2 started increasing even faster with the increase in the Ve/VCO_2 (Beaver et al., 1986; Whipp, Ward, 1991) (Figure 2).

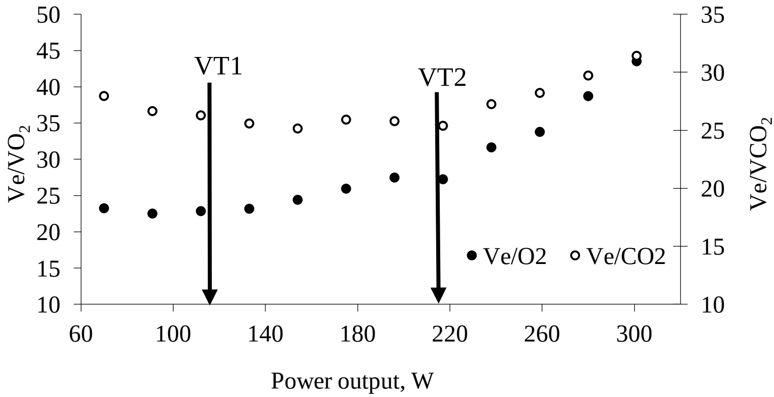


Fig. 2. *Determination of ventilation thresholds (VT1 and VT2) according to the dependence of ventilation oxygen and carbon dioxide equivalents (Ve/O_2 and Ve/CO_2) on the power*

1.2.6. Analysis of oxygen uptake kinetics

The VO_2 kinetics during moderate constant cycling load (MCL) was analyzed applying "Microcal Origin" program and mono-exponential equation:

$$VO_2\,(t) = VO_2\,(b) + A1\,(1 – e – t/T1),$$

where y (b) – VO_2 is the average initial value during the last 30 s of the work; A – the amplitude reflecting the size of change in y value; T1 – the time constant (s), reflecting the speed of change in y value; t – duration (s) from the beginning of the interval of work.

The VO_2 kinetics during heavy constant cycling load (HCL) was analyzed applying "Microcal Origin" program and bi – exponential equation:

$$VO_2\,(t) = VO_2\,(b) \pm A1\,(1 – e – t/T1) + A2\,(1 – e – t/T2),$$

where VO_2 is the average initial value during the last 30 s of the work; A1 and A2 – amplitudes, showing the changes in VO_2 fast and slow components; t – duration (s) from the beginning of work. Due to the so-called "cardiodynamics" component (Whipp et al., 1982) before the analysis of VO_2 adopting exponential equations, 20 s after the beginning of each work load all the data were rejected. The slow phase component was calculated between the indices of the registered data during the load of high intensity: the difference between the indices of the 6^{th} and 3^{rd} minute of work.

1.2.7. Ergometry

Increasing ramp cycling load.

ICL was performed on an electronically braked cycle ergometer "Ergometrics–800S" (Ergo Line, Medical Measurement Systems; Binz, Germany) at a pedal cadence of 70 rpm. The test was started by 3 min of baseline pedalling at 20 W and was increasing two Watts every five seconds until the intensity of cycling could not be maintained at the required level for longer than 10 s. The seat and handlebar positions on the cycle ergometer were adjusted for each subject prior to initial exercise test and maintained in that position for the subsequent tests.

Moderate intensity constant cycling load

MCL was performed on cycle ergometer. During the test of MCL the intensity was 80% of individual VT1. The MCL was preceded by 3 min of baseline pedalling at 20 W when 6 min moderate intensity cycling and 3 min baseline pedalling at a pedal cadence of 70 r.p.m. were performed.

Heavy intensity constant cycling load

HCL was performed on cycle ergometer. During the test of HCL the intensity was individualized for each subject according to ventilator thresholds (VT1 + (VT2 – VT1)/2). The HCL was preceded by 3 min of baseline pedalling at 20 W when 6 min or 9 min of heavy intensity and 3 min baseline pedalling at a pedal cadence of 70 r.p.m. were performed.

1.2.8. Electromyography

Bipolar Ag-AgCl surface electrodes were used for EMG recordings (silver bar electrodes, diameter 10 mm, centre-to-centre distance 20 mm) of the of right or both legs m. Vastus lateralis and m. Vastus medialis during ICL, MCL and HCL (DataLog type no. P3X8 USB, Biometrics Ltd, Gwent, UK). The skin at the electrode site was shaved and cleaned with alcohol wipes. The ground electrode was positioned on the wrist. Electromyography files were stored on the memory card and copied to PC biometrics Datalog (version 5.03; Biometrics Ltd, Gwent, UK) for data processing and analysis.

Measures of the recruited muscles activity were analyzed using available software (Biometrics Data Log) and minute average values of the amplitude of EMG as the root mean square (RMS) and the mean frequency of EMG power spectrum (MnPF) were calculated.

1.2.9. Maximal voluntary contraction

The isometric torque of knee extensor muscles of the right leg was measured by using an isokinetic dynamometer (System 3; Biodex Medical Systems, Shiley, New York). The subjects sat upright in the dynamometer chair with the knee joint positioned at an angle of 130° (full knee extension – 180°). Maximal voluntary contraction (MVC) was measured twice. The subjects were asked to perform MVC as hard as possible.

1.2.10. Preceding eccentric concentric exercise test

As an eccentric concentric exercise subject performed 100 prior drop jumps (PDJ). Before the jumps the subjects had a warm-up where they did leg muscle stretching exercises. PDJ were performed every 20 s (during which they prepared for the following jump without rush, i.e. they stepped on the platform), hands on hips, dropping from 0.5 or 0.7m height.

1.2.11. Preceding eccentric exercise test

The subjects performed preceding eccentric exercise test (PE) in 10 series of 12 knee eccentric extension repetitions (the right leg) with the maximal intensity at angle velocity 160°/s (the range of knee angle was from 150° to 70°; full knee extension is equalled to 180°) using an isokinetic dynamometer. The time period between series was one minute.

1.2.12. Ratings of perceived exertion

The subjects were asked to rate their perceived exertion at the end of each minute of ICL and at end of the minute 3, minute 6, minute 9 during MCL and HCL) applying the Borg RPE scale with values from 6 to 20 (7 - very, very light and 19 - very, very hard).

1.2.13. Delayed onset muscle soreness evaluation

After 24 h after PDJ and PE the subjects evaluated delayed onset muscle soreness (DOMS) of thigh muscle using the Borg's CR-10 scale (0 – No muscle soreness and 10 - Acute muscle soreness interfering with walking).

1.2.14. Mathematical statistics

Descriptive data is presented as group means and standard deviation (SD). The effect of experiment and time of measurements (VO_2, Ve, HR, RPE, [La] and EMG) were assessed using two-way repeated-measures ANOVA. The values for CK and DOMS pre/post PE or PDJ were assessed using a dependent measure one way ANOVA. Significant results were further analyzed using Turkey HDS post hoc test. Statistical significance was accepted when $p<0.05$.

The data were processed using computer programs: "LAB Manager", "Microcal Origin", "Polar Precision Performance", "Microsoft Excel", "Statistica for Windows".

1.3. Organization of the studies

The subjects were familiarized with the research and they signed informed consent to participate in it. The studies were conducted at the Laboratory of Sports Physiology the Department of Applied Physiology and Physiotherapy. The subjects were tested under the same conditions. A warm-up preceded all test sessions. It comprised of 8 min cycling with the power set 50 – 70 W, the cadence was70 r.p.m. The subjects were not allowed to perform any kind of physical exercise throughout the experimental period.

1.3.1. Design of the first study

During the first session participants performed ICL. Right after cycling they lied down for 5 min. On the 5^{th} min after ICL capillary blood samples were taken from their fingers to estimate the blood [La]. At least after 3 days subjects performed control MCL and after 5 min rest HCL. At least 3 later days' subjects performed 100 PDJ from 0.5 m height platform and after 45 min (45 min after PDJ) they performed MCL and HCL. During the fourth testing day of this study, 24 h after PDJ participants reported their muscle pain; the capillary blood samples were taken to estimate the plasma CK activity and subjects performed MCL and HCL. Before and immediately after MCL and HCL capillary blood samples were taken to estimate the blood [La] (Figure 3).

1.3.2. Design of the second study

The second study consists of three sessions. During the first session subjects performed ICL as control test. At least after 3 days the plasma CK activity and the MVC of knee extensor muscles of the right leg were measured. Then subjects performed PDJ from 0.7 m height platform. During the third session participants reported their muscle pain, the plasma CK activity and MVC were measured and subjects performed ICL 24 hours after PDJ. Right after all ICL participants lied down for 5 min. The capillary blood samples were taken at minute 5 after ICL to measure [La]. Subjects rated their perceived exertion every minute during control ICL and 24 after PDJ (Figure 4).

1.3.3. Design of the third study

Figure 5 shows third study protocol which consists of four sessions. During the first testing day subjects performed ICL. At least 3 days later on the second session of this study subjects performed control HCL. During the third session (not less than 3 days after control HCL) plasma CK activity and MVC were measured and then subjects performed one leg PE and after one hour (1 h after PE) the MVC was measured and then subjects performed HCL. Upon arrival at the laboratory on the forth testing day 24 hours after PE, participants reported their muscle pain, capillary blood samples were collected to measure CK activity and MVC was measured. Then the subjects performed HCL. Before and immediately after all HCL capillary blood samples were taken to estimate the [La]. During minute 3, minute 6 and minute 9 of HCL participants rated their perceived exertions.

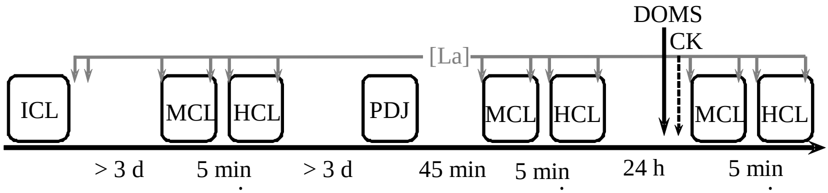


Fig. 3.*The first study protocol*

Note. ICL – increasing ramp cycling load; MCL – moderate intensity constant cycling load; HCL – heavy intensity cycling load; PDJ – prior drop jumps test; [La] – blood lactate concentration; CK – plasma creatine kinase activity; DOMS – delayed onset muscle soreness.

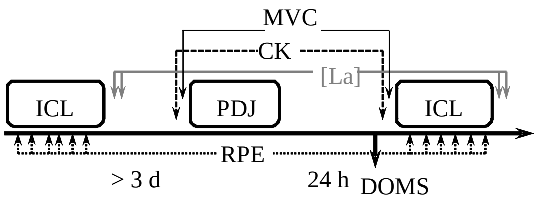


Fig. 4. *The second study protocol*

Note. ICL – increasing ramp cycling load; PDJ – prior drop jumps test; [La] – blood lactate concentration; CK – plasma creatine kinase activity; RPE – ratings of perceived exertions; MVC – maximal voluntary contraction; DOMS – delayed onset muscle soreness.

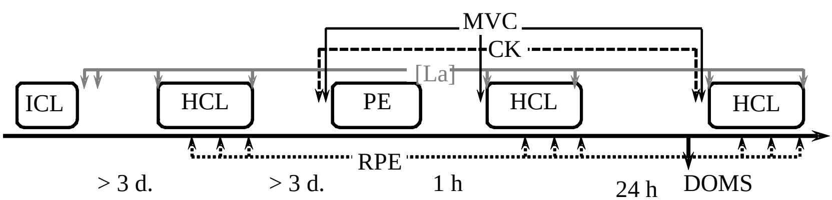


Fig. 5. *The third study protocol*

Note. ICL – increasing ramp cycling load; HCL – heavy intensity cycling load; PE – preceding eccentric exercise test; [La] – blood lactate concentration; CK – plasma creatine kinase activity; RPE – ratings of perceived exertions; MVC – maximal voluntary contraction; DOMS – delayed onset muscle soreness.

2. RESEARCH RESULTS AND DISCUSSION

2.1. The influence of preceding drop jumps on pulmonary gas exchange kinetics and electrical activity of leg muscles during moderate and heavy intensity constant cycling

Muscle soreness and CK activity

The participants felt moderate (5.1 (2.1) points) pain in thighs muscles and the plasma CK activity was 308.3 (283.1) IU/l 24 h after PDJ.

Pulmonary gas exchange kinetics

The [La] in blood after control 45 min and 24 h after PDJ cycling of moderate intensity was respectively 3.3 (1.0), 3.6 (0.9) and 3.5 (0.6) mmol/l ($p>0.05$). RPE at the 6^{th} min of MCL did not change significantly ($p>0.05$) during control, 45 min and 24 h after PDJ (11.6 (1.4) points, 11.9 (1.5) points and 11.6 (1.5) points, respectively).

There was no significant difference ($p>0.05$) in VO_2 during MCL under different testing conditions (Control; 45 min after PDJ; 24 h after PDJ; Figure 6).

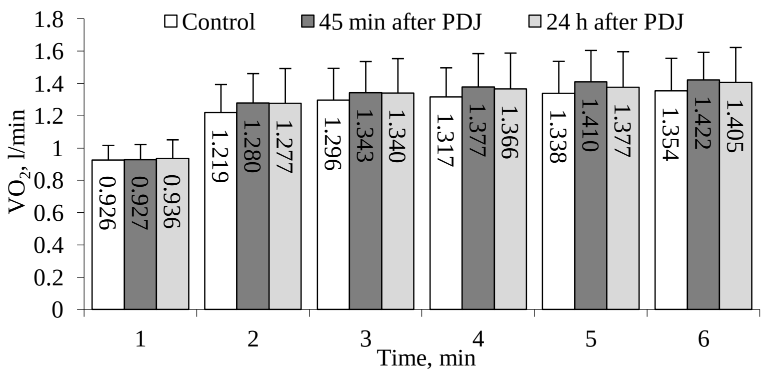


Fig. 6. *Oxygen uptake (VO_2) during moderate intensity constant cycling*

Note. PDJ – preceding drop jumps test.

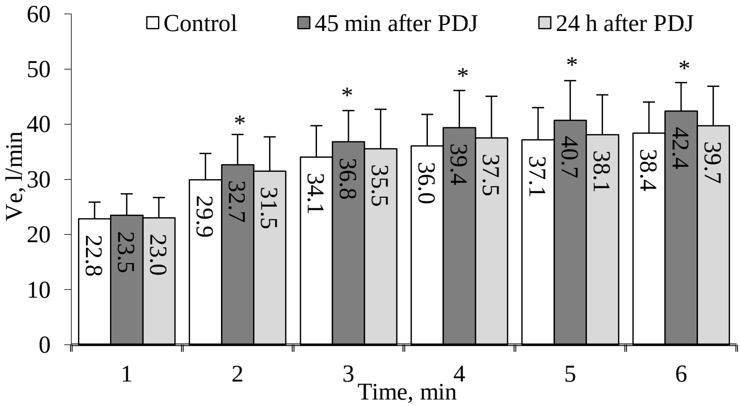


Fig. 7. *Pulmonary ventilation (Ve) during moderate intensity constant cycling*

Note. PDJ – preceding drop jumps test.* – the difference is statistically significant compared to the control value, $p<0.05$.

The Ve increased significantly ($p<0.05$) 45 min after PDJ compared to control during MCL, but not 24 h after PDJ (Figure 7).

Table 2 presents mean values of baseline, fast component's amplitude and time constant of the VO_2 kinetics calculated applying the mono-exponential equation during MCL, but there were no significant differences ($p>0.05$) of these indices under different testing conditions (Control; 45 min after PDJ; 24 h after PDJ). The difference between 6th and 3rd minutes of VO_2 kinetics was similar ($p>0.05$) 45 min after PDJ and 24 h after PDJ compared to control.

Table 2. *Oxygen uptake kinetics values during moderate intensity constant cycling, calculated applying mono-exponential equation*

Indices	Control	45 min after PDJ	24 h after PDJ
Baseline, l/min	0.700 (0.071)	0.692 (0.041)	0.714 (0.061)
A1, l/min	0.648 (0.160)	0.700 (0.170)	0.640 (0.184)
T1, s	32.65 (8.33)	32.85 (9.73)	29.22 (8.75)
6 min – 3 min, l/min	0.065 (0.057)	0.055 (0.085)	0.062 (0.053)

Note. Descriptive data are presented as group means and (SD). PDJ – preceding drop jumps test. A1 – amplitude of fast phase. T1 – time constant of fast phase.

The [La] in blood was similar ($p>0.05$) between control (6.7 (2.0) mmol/l), 45 min after PDJ (6.7 (2.2) mmol/l) and 24 h after PDJ (7.1 (2.3) mmol/l) at the end of HCL. RPE at the 6th min of HCL did not change significantly ($p>0.05$) between different testing conditions (control 14.8 (1.4) points, 45 min after PDJ 15.7 (1.8) points and 24 h after PDJ 15.7 (2.2) points)

The absolute VO_2 (Figure 8) and the Ve (Figure 9) during HCL did not change significantly ($p>0.05$) between testing conditions (Control; 45 min after PDJ; 24 h after PDJ).

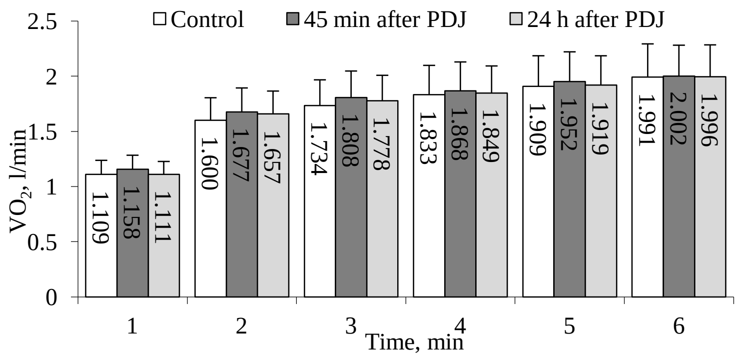


Fig. 8. *Oxygen uptake (VO_2) during heavy intensity constant cycling*

Note. PDJ – preceding drop jumps test.

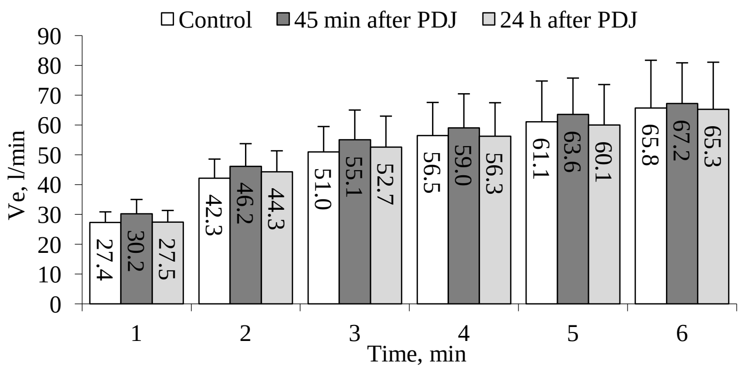


Fig. 9. *Pulmonary ventilation (Ve) during heavy intensity constant cycling*

Note. PDJ – preceding drop jumps test.

The time constant and amplitude of the fast and the slow phases' of VO_2 kinetics did not differ ($p>0.05$) during HCL between different testing conditions (Control; 45 min after PDJ; 24 h after PDJ). The differences between 6th and 3rd minutes of VO_2 slow component kinetics was lower ($p<0.05$) 24 h after PDJ compared to control (Table 3).

Table 3. *Oxygen uptake kinetics values during heavy intensity constant cycling. calculated bi-exponential equation*

Indices	Control	45 min after PDJ	24 h after PDJ
Baseline, l/min	0.722 (0.106)	0.695 (0.061)	0.697 (0.052)
A1, l/min	0.783 (0.216)	0.853 (0.207)	0.926 (0.176)
T1, s	12.9 (5.7)	12.9 (5.7)	15.6 (5.0)
A2, l/min	0.682 (0.150)	0.551 (0.186)	0.487 (0.170)$^{\#}$
T2, s	228.8 (91.5)	218.6 (124.1)	245.6 (117.6)
6 min – 3min, l/min	0.206 (0.107)	0.173 (0.089)	0.197 (0.117)

Note. Descriptive data are presented as group means and (SD). PDJ – preceding drop jumps test. A1 – amplitude of fast component. A2 – amplitude of slow phase. T1 – time constant of fast phase. T2 – time constant of slow phase.# – the difference is statistically significant compared to the control value, $p<0.05$.

EMG of thigh muscles

The RMS of EMG of m. Vastus lateralis significantly ($p<0.05$) increased 24 h after PDJ compared to control with no changes of m. Vastus medialis (Figure 10) during MCL.

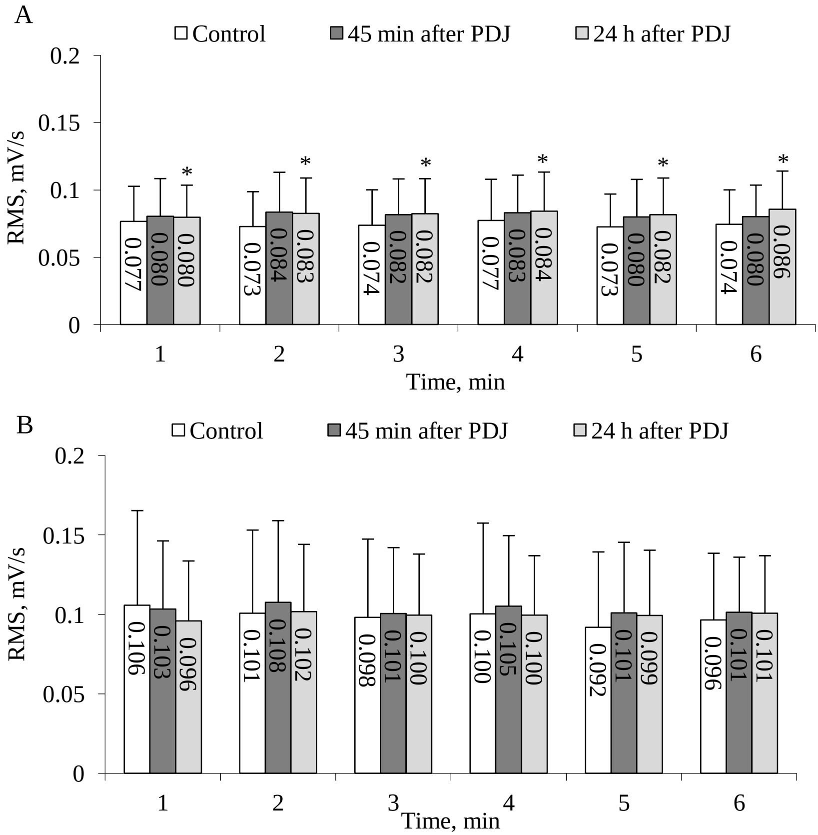
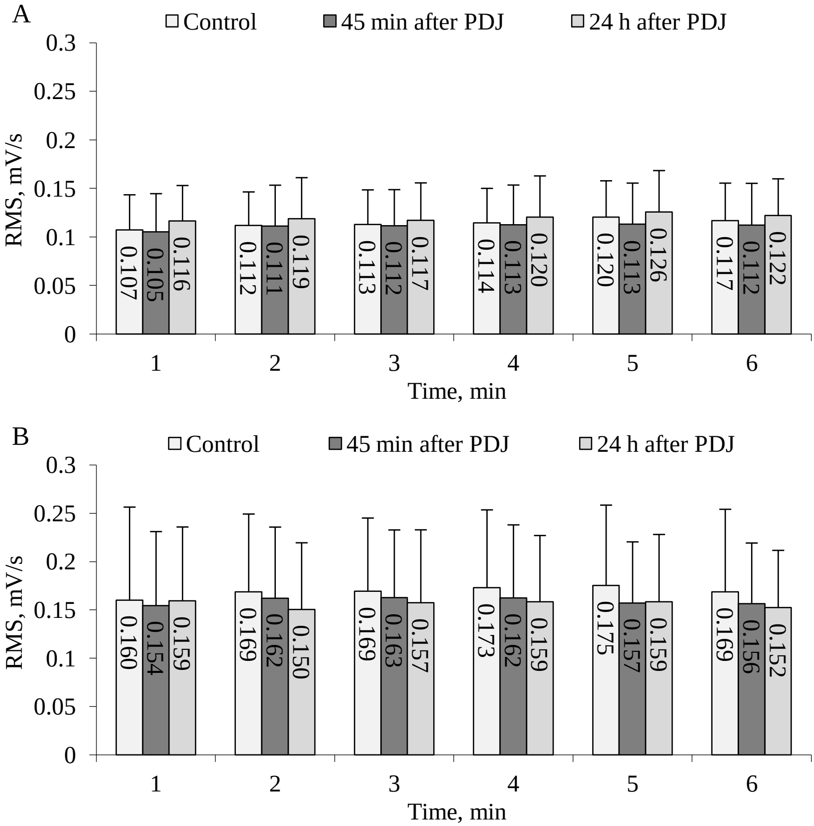


Fig. 10. *Root mean square (RMS) of EMG of m. Vastus lateralis (A) and m. Vastus medialis (B) values during moderate intensity constant cycling*

Note. PDJ – preceding drop jumps test. * – the difference is statistically significant compared to the control value, $p<0.05$.

There was no significance difference ($p>0.05$) observed in RMS of EMG of m. Vastus lateralis and m. Vastus medialis during HCL comparing control, 45 min and 24 h after PDJ (Figure 11).



11 Fig. *Root mean square (RMS) of EMG of m. Vastus lateralis (A) and m. Vastus medialis (B) values during heavy intensity constant cycling*

Note. PDJ – preceding drop jumps test.

Table 4 presents the MnPF of m. Vastus lateralis and m. Vastus medialis at minute 3 and minute 6 of MCL and HCL. There was no change ($p>0.05$) both during control MCL and control HCL compared to 45 min PDJ and 24 h after PDJ.

Table 4. *Mean frequency of EMG power spectrum of thigh muscle during moderate and heavy intensity constant cycling under different testing condition*

	Control	45 min after PDJ	24 h after PDJ	Control	45 min after PDJ	24 h after PDJ
	3 min of cycling			6 min of cycling		
Moderate intensity constant cycling						
m. Vastus lateralis	71.2 (7.2)	71.9 (6.3)	71.5 (6.2)	71.8 (8.0)	73.1 (7.0)	72.2 (5.9)
m. Vastus medialis	73.3 (9.2)	73.0 (10.5)	73.1 (10.6)	74.0 (10.1)	73.3 (10.1)	73.5 (9.3)
Heavy intensity constant cycling						
m. Vastus lateralis	70.1 (6.3)	73.2 (5.2)	70.9 (4.0)	69.8 (5.3)	73.2 (5.5)	72.3 (4.1)
m. Vastus medialis	71.2 (9.5)	70.8 (8.7)	72.4 (8.1)	70.6 (8.9)	71.6 (6.2)	73.1 (8.0)

Note. Descriptive data are presented as group means and (SD). PDJ – preceding drop jumps test.

The positive statistically significant relationship ($p<0.05$) between changes from control testing in VO_2 and RMS of EMG of m. Vastus medialis was observed during last 3 minutes of HCL 45 min and 24 h after PDJ (Figure 12)

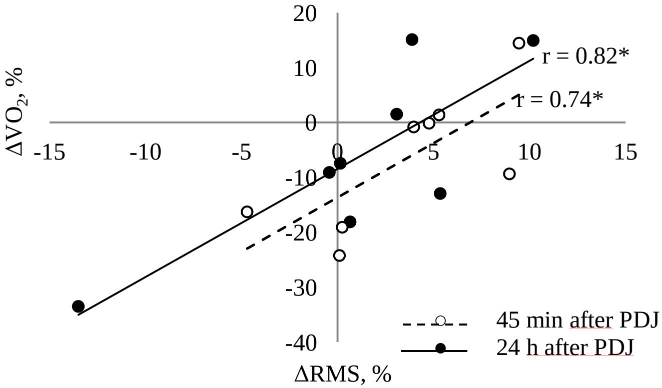


Fig. 12. *The correlation between changes (from control condition) on oxygen uptake (ΔVO_2) and EMG root mean square (ΔRMS) of m. Vastus medialis during heavy intensity constant cycling load*

Note. PDJ – preceding drop jumps test. * – the difference is statistically significant compared to the control value, $p<0.05$.

2.2. The influence of preceding drop jumps on respiratory system parameter kinetics and electrical activity of leg muscles during increasing ramp cycling

Muscle soreness, MVC and CK activity

The subjects felt moderate (5.0 (1.5) points) pain in thigh muscle and the blood plasma CK activity was statistically significantly ($p<0.05$) higher 24 h after PDJ. (503.4 (208.9) IU/L) compared to control (105.6 (2.7) IU/L). MVC significantly ($p<0.05$) decreased 21 (5) % 24 h after PDJ (219.7 (33.3) N·m) compared to control measurement (279.4 (45.5) N·m).

Pulmonary gas exchange kinetics

There was no significant difference ($p>0.05$) observed in absolute VO_2 during ICL comparing control and 24 h after PDJ (Figure 13).

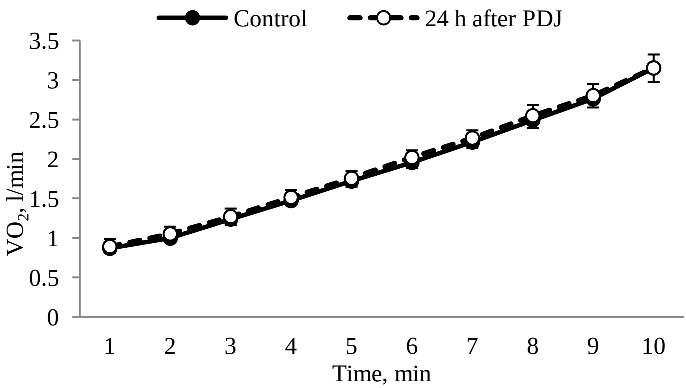


Fig. 13. *Oxygen uptake (VO_2) during increasing ramp cycling*

Note. PDJ – preceding drop jumps test.

Figure 14 shows Ve during ICL between different testing conditions (Control and 24 h after PDJ). The Ve increased significantly ($p<0.05$) 24 h after PDJ compared to control ICL.

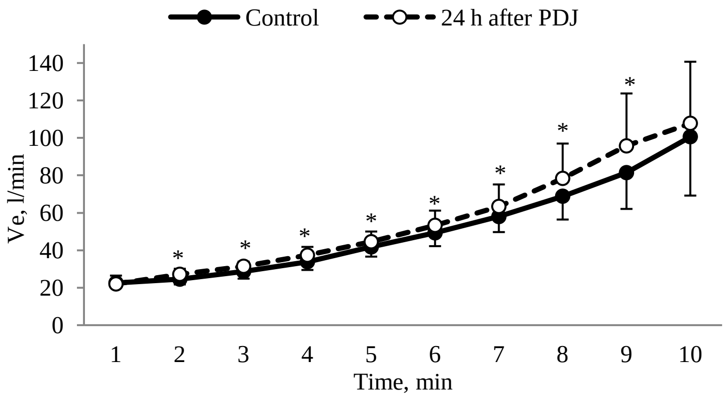


Fig. 14. *Pulmonary ventilation (Ve) kinetics during increasing ramp cycling*

Note. PDJ – preceding drop jumps test. * – the difference is statistically significant compared to the control value, $p<0.05$.

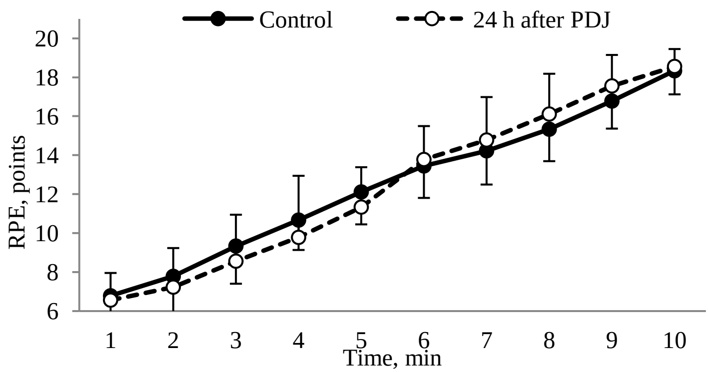


Fig. 15. *Ratings of perceived exertion (RPE) during increasing ramp cycling*

Note. PDJ – preceding drop jumps test.

The RPE did not changed significantly ($p>0.05$) between different testing condition (Control and 24 h after PDJ) during ICL (Figure 15)

Table 5 presents peak values of VO_2, Ve, HR, power output and RPE at the end of control ICL and 24 h after PDJ. The peak value of Ve and power output significantly ($p<0.05$) increased 24 h after PDJ compared to control ICL. The [La] minute 5 after ICL did not differ 24 h after PDJ compared to control measurement. The peak values of VO_2, HR and RPE at the end of ICL were similar ($p>0.05$) under different testing conditions (Control and 24 h after PDJ).

Table 5. *The peak values during increasing ramp cycling test*

Indices	Control	24 h after PDJ
Oxygen uptake, l/min	3.328 (0.230)	3.204 (0.211)
Pulmonary ventilation, l/min	118.3 (29.9)	130.6 (33.3)*
Heart rate, bt./min	185.6 (8.7)	185.7 (11.4)
Power output, W	255.8 (21.7)	247.3 (24.7)*
Ratings of perceived exertion, point	19.6 (0.5)	19.7 (0.5)
[La] 5 min after ICL, mmol/l	11.2 (2.0)	10.6 (1.7)

Note. Descriptive data are presented as group means and (SD). PDJ – preceding drop jumps test. ICL – increasing ramp cycling load * – the difference is statistically significant compared to the control value, $p<0.05$.

EMG of thigh muscles

The RMS of EMG of m. Vastus lateralis significantly ($p<0.05$) increased 24 h after PDJ compared to control but there was no significance difference ($p>0.05$) observed in this index of m. Vastus medialis comparing control and 24 h after PDJ during ICL (Figure 16).

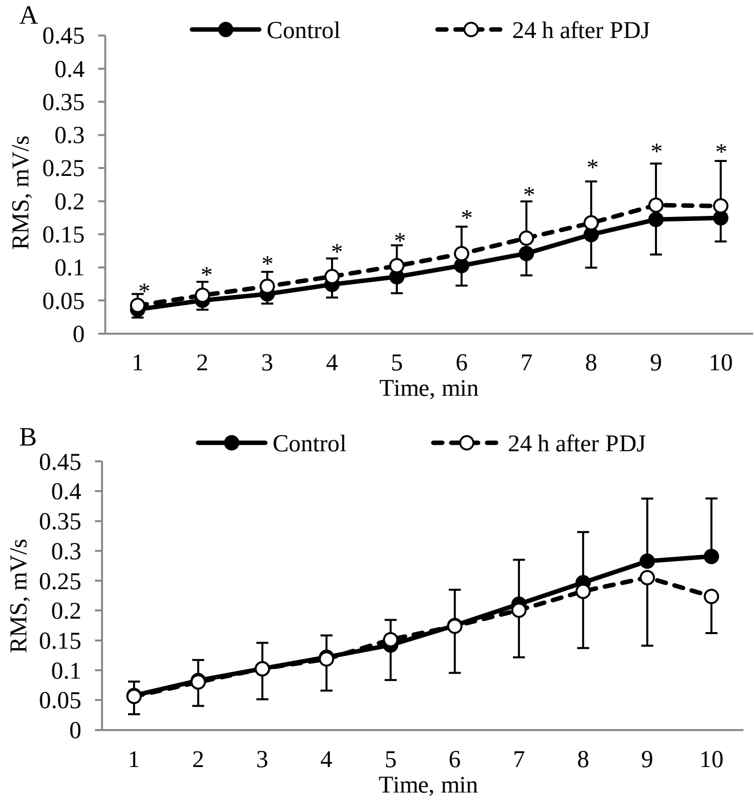


Fig. 16. *Root mean square (RMS) of EMG of m. Vastus lateralis (A) and m. Vastus medialis (B) values during moderate intensity constant cycling*

Note. PDJ – preceding drop jumps test. * – the difference is statistically significant compared to the control value, $p<0.05$.

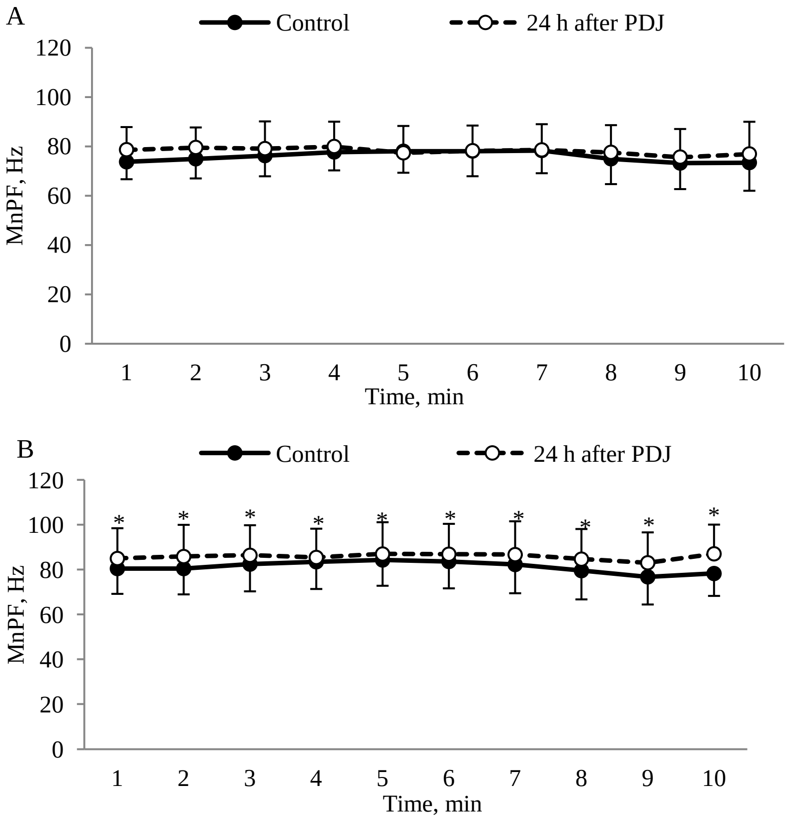


Fig. 17. *Mean frequency of EMG power spectrum (MnPF) of m. Vastus lateralis (A) and m. Vastus medialis (B) values during increasing ramp cycling*

Note. PDJ – preceding drop jumps test. * – the difference is statistically significant compared to the control value, $p<0.05$.

Figure 17 presents the MnPF of m. Vastus lateralis and m. Vastus medialis during control ICL and 24 h after PDJ. There was no change ($p>0.05$) in MnPF of m. Vastus lateralis, but this index of m. Vastus medialis significantly ($p<0.05$) increased 24 h after PDJ compared to control ICL.

2.3 The influence of preceding one leg eccentric exercise on the pulmonary gas exchange kinetics and electrical activity of legs muscles during heavy constant intensity cycling

Muscle soreness, MVC and CK activity

The MVC of right thigh muscles significantly decreased ($p<0.05$) one hour after PE (178 (33) N·m) and remained decreased 24 h after PE (170 (41) N·m) compared to control measurement (278 (42) N·m). The subject felt moderate (5.4 (1.4) points) right thigh muscle soreness and the plasma CK activity was significantly higher 24 after PDJ (715.3 (504.9) IU/l) compared to control (118.6 (45.1) IU/) measurement.

Pulmonary gas exchange kinetics

The [La] in blood did not differ ($p>0.05$) at the end of HCL 1 h after PE (6.4 (2.8) mmol/l) and 24 h after PE(6.4 (28) mmol/l) compared to control (6.5 (2.6)).

No differences ($p>0.05$) in VO_2 were observed during HCL between different testing conditions (Control, 1 h after PE and 24 h after PE; Figure 18).

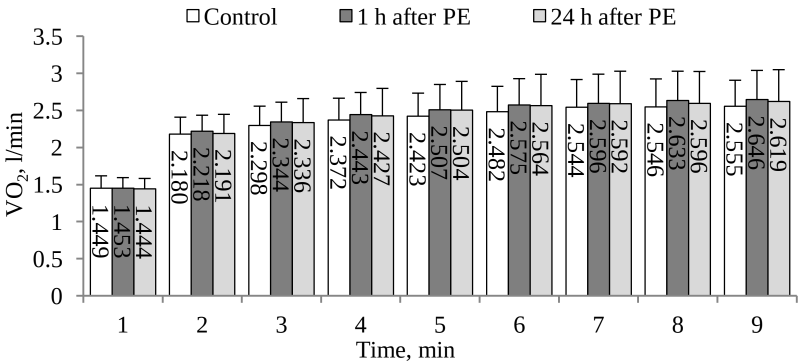


Fig. 18. *Oxygen uptake (VO_2) during heavy intensity constant cycling*

Note. PDJ – preceding drop jumps test.

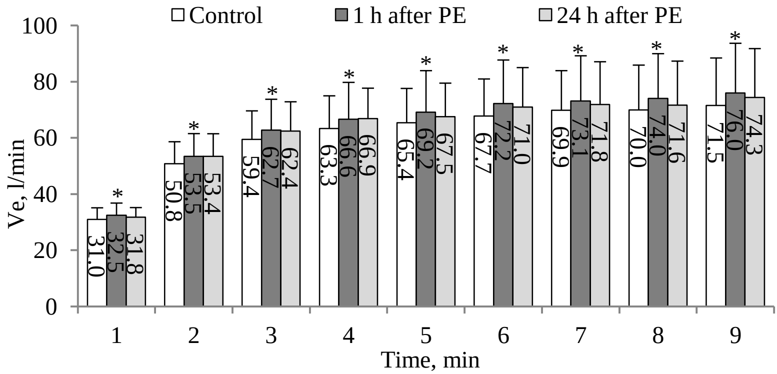


Fig. 19. *Pulmonary ventilation (Ve) during heavy intensity constant cycling*

Note. PE – preceding eccentric exercise test. * – the difference is statistically significant compared to the control value, $p<0.05$.

The Ve increased significantly ($p<0.05$) 1h after PE compared to control during HCL. There was no significant difference ($p>0.05$) between Ve 24 h after PE and control during HCL (Figure 19).

The time constant and the amplitude of the fast and the slow phases' of the VO_2 kinetics calculated applying the bi-exponential equation did not differ ($p>0.05$) between different testing conditions (Control, 1 h after PE and 24 h after PE) during HCL (Table 6).

Table 6. *Oxygen uptake kinetics values during heavy intensity constant cycling. calculated bi-exponential equation*

Indices	Control	45 min after PE	24 h after PE
Baseline, l/min	0.909 (0.101)	0.873 (0.101)	0.853 (0.110)
A1, l/min	1.161 (0.280)	1.188 (0.179)	1.166 (0.208)
T1, s	21.4 (7.7)	19.0 (4.5)	18.6 (5.8)
A2, l/min	0.603 (0.299)	0.675 (0.255)	0.827 (0.259)
T2, s	293.8 (185.2)	263.7 (127.7)	253.8 (138.3)

Note. Descriptive data are presented as group means and (SD). PE – preceding eccentric exercise test. A1 – amplitude of fast phase. A2 – amplitude of slow phase. T1 – time constant of fast phase. T2 – time constant of slow phase.

EMG of thighs muscles

No differences (p>0.05) in RMS of EMG of the right leg's m. Vastus lateralis and m. Vastus medialis, which were affected by PE (preceding exercise), were observed between different testing conditions (Control, 1 h after PE and 24 h after PE) during HCL (Figure 20).

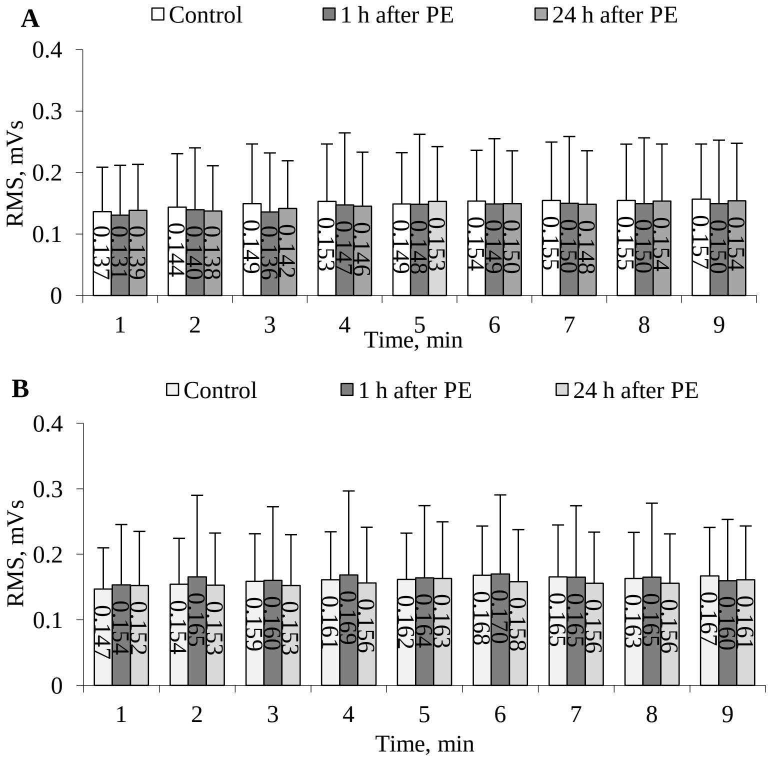


Fig. 20. *Root mean square (RMS) of EMG of right leg m. Vastus lateralis (A) and m. Vastus medialis (B) values during moderate intensity constant cycling*

Note. PDJ – preceding drop jumps test.

The RMS of EMG of the left leg's m. Vastus lateralis, which was unaffected by PE, significantly decreased ($p<0.05$) 1 h after PE compared to control and 24 h after PE during HCL. There was no difference ($p>0.05$) observed in RMS of EMG of m. Vastus medialis comparing control, 1 h after PE and 24 h after PDJ during HCL (Figure 21).

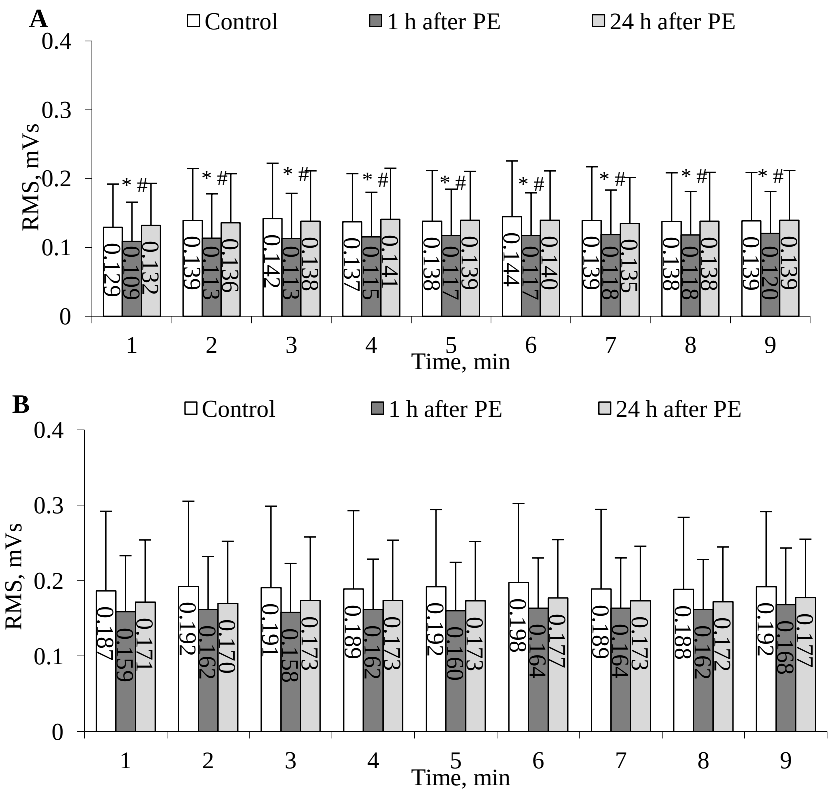


Fig. 21. *Root mean square (RMS) of EMG of left leg m. Vastus lateralis (A) and m. Vastus medialis (B) values during moderate intensity constant cycling*

Note. PDJ – preceding drop jumps test. * – the difference is statistically significant compared to the control value, $p<0.05$. # – the difference is statistically significant compared to the 24 h after PDJ value, $p<0.05$.

Table 4 presents the MnPF of right (affected by PE) and left (unaffected by PE) legs m. Vastus lateralis and m. Vastus medialis at minute 3, minute 6 and minute 9 during HCL. There was no change ($p>0.05$) in this index both right and left thigh muscles control HCL compared to 1 h PE and 24 h after PE.

Table 7. *Mean frequency of EMG power spectrum of thigh muscle during moderate and heavy intensity constant cycling under different testing condition*

	Control	1 h after PDJ	24 h after PDJ	Control	1 h after PDJ	24 h after PDJ
Time of cycling	Right m. Vastus lateralis			Right m. Vastus medialis		
3 min	71.0 (13.8)	69.6 (8.1)	71.8 (10.2)	80.8 (9.4)	79.3 (10.3)	82.7 (13.4)
6 min	70.9 (13.7)	69.9 (7.4)	72.1 (8.9)	82.2 (11.4)	80.4 (10.5)	82.6 (12.6)
9 min	71.4 (11.2)	71.2 (8.1)	73.6 (7.2)	83.0 (11.0)	82.2 (10.4)	84.4 (10.4)
	Left m. Vastus lateralis			Left m. Vastus medialis		
3 min	72.7 (7.7)	73.6 (5.3)	73.2 (11.1)	77.5 (13.8)	75.2 (1.4)	77.4 (15.4)
6 min	74.5 (9.5)	74.0 (5.5)	74.3 (10.3)	77.1 (14.8)	75.9 (12.0)	78.3 (15.8)
9 min	75.0 (8.0)	74.8 (5.9)	76.1 (10.7)	78.8 (14.7)	77.6 (12.3)	79.7 (14.9)

Note. Descriptive data are presented as group means and (SD). PE – preceding eccentric exercise test.

The positive statistically significant relationship ($p<0.05$) between changes in VO_2 and RMS of EMG of left leg's m. Vastus medialis which was unaffected by PE was observed during last 3 minutes of HCL 24 h after PE (Figure 22).The correlation between these indices the of right leg was insignificant ($p>0.05$) between different testing conditions (1 h after PE – $r=0.2$ and 24 h after PE – $r=0.05$).

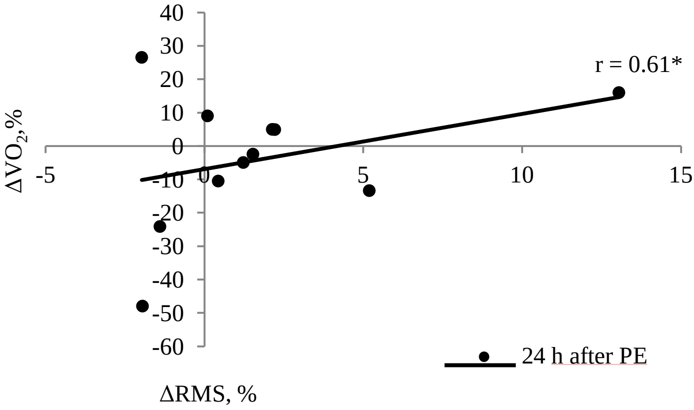


Fig. 22. *The correlation between changes (from control condition) in oxygen uptake (ΔVO_2) and EMG root mean square (ΔRMS) of left leg's m. Vastus medialis during heavy intensity constant cycling load*

Note. PE – preceding drop jumps test. * – the difference is statistically significant compared to the control value, $p < 0.05$.

GENERALISATION OF THE RESULTS

It was hypothesized that preceding eccentric concentric and eccentric exercise will affect pulmonary gas exchange and will increase electrical activity of the muscles affected by the pre-exercise, and the aforementioned changes will be inter-related. This hypothesis was partially proved. During the study, subjects performed PDJ as an eccentric concentric exercise or one leg eccentric exercises on purpose of evoking muscle damage, which displayed itself in indirect changes of muscle damage indices. Subjects of all groups felt moderate muscle pain, also, the increase of CK activity of blood plasma was determined as well as the reduction of power of m. Quadriceps femoris measured in two groups 24 hours after preceding exercises. The received results coincide with the studies of other researchers who determined that eccentric concentric exercises evoke muscle pain (MacIntyre et al., 2000; Stupka et al., 2000, 2001; Dannecker et al., 2005, 2008; Fredsted et al., 2008), increase of CK activity (Stupka et al., 2000; Chen et al., 2010; Skurvydas et al., 2010) and reduction of MVC (Chen et al., 2010; Semmler et al., 2007; Skurvydas et al., 2010).

Most attention during these studies was given to the changes of pulmonary gas exchange indices and muscle electric activity during different-intensity loads, after one and 24 hours, although during one study, the aforementioned indices were evaluated 24 hours after PDJ. During the first study it was determined that Ve significantly increased during MCL, 45 min after PDJ, during HCL 45 min after PDJ and during MCL and HCL 24 hours after the mentioned preceding load Ve was not changed. When residual (after 24 hours) effect of PDJ was evaluated on the changes of pulmonary gas exchange indices, Ve was also determined, and at the same time the increase of HR during the ICL. One leg PE also had influence on the Ve after 1 hour, but not 24 hours during HCL. Although during this study the mass of the muscle affected by the damage was lower, as PE was performed with one leg and 90 per cent from MVC, unlike after PDJ, when jumps from the platform were performed with both legs with maximum effort. After PDJ, Ve can be influenced by group III and IV afferents, reacting to the internal muscle deformation, blood-vessel strain and increased in-cell pressure, also to in-cell chemical changes (Ward, 2000; Haozi, Chenuel, 2005; Hotta et al., 2009).

After the accomplishment of the study, the tendency was noticed that Ve increases when aerobic load, independent of intensity and duration, is performed the first one after the pre-load which evoked damage. Considering that Ve increases 45 min after PDJ or 1 hour after one leg EP, muscle pain, emerging after several hours (Dannecker et al., 2005; Lewis et al., 2012), is not related to Ve. Previously studies data shows that 48 hours after eccentric pre-loads there increases a RPE during the different intensity loads (Gleeson et al., 1995; Schneider et al., 2007; Davies et al., 2009; Twist, Eston, 2009) which can be related to the increased Ve, but this does not coincide with the data of this study, as in all cases, the increased Ve was not accompanied by RPE increase. Thus, it is likely that Ve, which increased after PDJ or one leg PE, is not related to the increased RPE while performing different-intensity loads on cycle ergometer.

It was determined that HR changed in two cases after PDJ, i.e. during the first study, while performing the MCL after 45 minutes and during ICL 24 hours after the PDJ. After one leg PE HR was not changed neither after 1 hour nor 24 hours during HCL. These results can be related to the fact that damage was evoked on m. Quadriceps femoris of one leg, and the size of damage was not sufficient for changing the reactions of cardiovascular system functions during the HCL. In all study cases, neither after PDJ nor after eccentric one leg PE no increase of blood [La] was determined, VO_2 did not change either. Therefore, after the pre-load which evoked damage, independent of affected muscle mass and the size of damage (jumps from 0.5 or 0.7 m performed with maximum effort or one leg submaximal eccentric exercise), the amount of metabolic costs was not changed and the aerobic works efficiency was unaffected.

Although the data of the present study are in contrast with the data of A. Ratkevičius (2006) and his co-authors, when it was determined that after that when 1 hour after PDJ VO_2 increased while performing HCL. The experiment of single fibres and the whole muscle data shows that for reaching the same power of isometric contraction type II muscle fibres consume more ATP than type I fibres (Horrowitz et al., 1994, Nakagawa et al., 2005). The participation of type II fibres, which increased in such a way, can increase metabolic costs of the work and increase VO_2. Supposedly, the damaged muscle fibres affect the working fibres as additional mechanic load (Lieber et al. 1996, Sandercock, 2000). It is little likely that one or 24 hours after PDJ or PE which evoked muscle damage additionally recruiting type II muscle fibres, thus increasing metabolic costs during different intensity cycling load.

It is the first study during which the influence of prior eccentric concentric as well as one leg eccentric exercise was evaluated on the changes of electrical activity of m. Vastus lateralis and m. Vastus medialis 1 and 24 hours after the prior exercises. It was determined that after preceding eccentric exercise EMG amplitude can increase the changes of which are related to recruiting of additional motor units, when it is necessary to maintain constant power compensating the reduction of power because of affected motor units or because of the increase of already recruited motor unit frequency, also because of coactive increase of muscle antagonists or motor unit synchronisation (Semmler et al., 2007). Because of the varied motor unit impulse frequency, MnPF of EMG can also change after eccentric exercise (Ahmadi et al., 2007). The increase of MnPF of EMG is observed in case of additional type II muscle fibre during the work (Gerdle et al., 1991; Scheuermann et al., 2001). Sarcomeres are mechanically affected after eccentric exercises, therefore an uncontrolled Ca^{2+} emission into sarcoplasm begins (Proske, Morgan, 2001) and electromechanical relation is disrupted (Warren et al., 2001). Because of these processes there changes the most proper muscle length which is necessary for power generation, there increases the intensity of passive muscle and there asserts the reduction of the greatest muscle power (Proske, Allen, 2005; Skurvydas et al., 2010). EMG of m. Vastus lateralis and m. Vastus medialis are distinguished with small variability during the dynamic load (Hug, Dorel, 2009), the damage was evoked precisely for these muscles, therefore during the tests electrical activity of these muscles was registered.

During the first study, 24 hours after PDJ, the increase of RMS of EMG of m. Vastus lateralis was determined during MCL, but MnPF of EMG did not change. While performing HCL 5 minutes after MCL, no changes of muscle EMG were determined after PDJ after 1 and 24 hours. RMS of EMG which increased after PDJ during MCL can be related to the increase of additionally recruited type I motor units, as no changes of MnPF of EMG were determined (Scheuermann et al., 2001).

The increase of RMS of EMG of m. Vastus lateralis determined during the ICL is related to the fact that motor units were additionally recruited, as MnPF of EMG did not change. RMS of EMG of m. Vastus medialis did not change, and MnPF of EMG increased. Therefore II muscle fibres were recruited additionally which work with greater consumptions and can decrease work intensity and possibly increase the frequency of motor unit impulse (Ahmadi et al., 2007). While evaluating the changes of EMG of both studies, it is important to notice that EMG changes of m. Vastus lateralis and m. Vastus medialis are different. Also, EMG changes during cycling after PDJ occur 24 hours after the prior exercise.

During the third study, when PE was performed with right leg and the RMS of EMG of right m. Vastus lateralis and m. Vastus medialis did not increase during HCL, as it was anticipated 1 or 24 hours after the prior exercise. Considering that eccentric exercise evokes structural fatigue the RMS of right leg m. Vastus lateralis and/or m. Vastus medialis should increase, but in case of our study, it did not differ 1 and 24 hours after the prior eccentric exercise. It was also determined that 1 hour after PE right leg RMS of EMG of left leg m. Vastus lateralis decreased, and after 24 hours it was similar to control testing. PE was not performed with left leg and therefore on purpose of maintain the constant pedal cadence of cycling the additional motor units were not recruited, but one can envisage left leg adaptation to the load, therefore there reduces the recruiting of motor units to maintain the constant pedal cadence. Nevertheless, one can believe that, while performing the load on cycle ergometer, compensating mechanisms function not only on the level of muscle fibres, and tired muscles can be compensated by nearby muscles or m. Quadriceps femoris antagonists muscle can assert. After the reduction of the activity of m. Quadriceps femoris antagonists, the muscles affected by structural fatigue work more economically and there reduces the amount of RMS of EMG of these muscles, although this is related to the changes of central nerve system, but the reasons and mechanisms are purely understood (Hautier et al., 2000; Sarre, Lepers, 2005; Hug, Dorel, 2009). Summarizing the data of the present study, it can be stated that EMG changes during the cycle performed after one leg PE is intricately interpreted and possibly additional studies are necessary for the evaluation of electric activity of other muscles.

During all these studies, the changes of VO_2 and EMG were assessed after PDJ and one PE during different intensity cycling. It was determined that while performing different intensity cycling, the amplitude of EMG directly correlates with the indices of pulmonary gas exchange (Lucia et al., 1999; Hug et al., 2004; Chin et al., 2011; Blake, Wakeling, 2013). The data about prior exercise effect onVO_2 and EMG correlation during the heavy intensity load are controversy. It has been previously demonstrated that the relationship between VO_2 and EMG exists (Burnley et al., 2002). Contrary, there was no correlation of VO_2 and EMG during constant cycling after prior exercise (Gonzales, Scheuermann, 2006). Statistically significant correlation was determined during the first present study between VO_2 and the changes of RMS of EMG of m. Vastus medialis, but not of m. Vastus lateralis during HCL 45 minutes and 24 hours after PDJ. There was no correlation between the changes of VO_2 and RMS of EMG of m. Vastus lateralis and m. Vastus medialis during MCL. The changes of VO_2 and RMS of EMG of m. Quadriceps femoris did not correlate 24 hours after PDJ during ICL in different intensity zones (VT1; VT2 and the peak power output). After one leg PE, statistically significant positive correlation was determined between VO_2 and RMS of m. Vastus medialis. In summary, there exist the correlations between changes in VO_2 and vastus medialis EMG after prior eccentric concentric exercise during HCL.

CONCLUSIONS

1. The prior eccentric concentric exercise has significant effect on pulmonary ventilation and heart rate during moderate but not heavy constant cycling load 45 minutes after preceding eccentric concentric exercise. There was no effect on theses indices 24 hours after eccentric concentric exercise during moderate and heavy constant cycling load. The EMG amplitude only of m. Vastus lateralis increased 24 hours after eccentric concentric exercise during moderate intensity constant cycling. The prior eccentric concentric exercise has neither acute nor residual effects on aerobic work efficiency during different intensity constant cycling.

2. During increasing ramp cycling load aerobic work efficiency was unaffected by eccentric concentric exercise but it increased pulmonary ventilation, heart rate and EMG amplitude of m. Vastus lateralis, the mean frequency of EMG power spectrum of m. Vastus medialis decreased 24 hour after eccentric concentric exercise.

3. The pulmonary ventilation increased and the EMG of the right leg's m. Vastus medialis, which was affected by preceding eccentric exercise, did not change, but EMG amplitude of unaffected leg's m. Vastus lateralis decreased during constant cycling load one hour after preceding eccentric exercise. There was no effect on these indices 24 hours after preceding eccentric exercise during heavy constant cycling load.

SANTRAUKA

Atlikta daug tyrimų, kuriais nustatyta, kad neįprasti ekscentriniai koncentriniai fiziniai pratimai sukelia vėluojantį raumenų skausmą (MacIntyre et al., 2001; Dannecker et al., 2005, 2008; Fredsted et al., 2008; Lewis et al., 2012), raumeninių skaidulų pažaidą (Hortobagyi et al., 1998; Stupka et al., 2001; Carlsson et al., 2007), uždegiminių ląstelių išskyrimą į kraują (Stupka et al., 2001; Laaksonen et al., 2006), kraujo plazmos kreatinkinazės aktyvumo padidėjimą (Stupka et al., 2000; Chen et al., 2010; Skurvydas et al., 2010), raumenų jėgos sumažėjimą (Chen et al., 2010; Semmler et al., 2007; Skurvydas et al., 2010) bei aerobinio darbo galingumo sumažėjimą (Black, Dobson, 2012). Minėti funkciniai, sensoriniai, biocheminiai ir struktūriniai pakitimai nepriklausomai vienas nuo kito pasireiškia iš karto po ekscentrinių krūvių ir išlieka iki 7 parų, priklausomai nuo pažaidos dydžio (Clarkson et al., 1992; Skurvydas et al., 2000; Stupka et al., 2000, 2001; MacIntyre, 2001; Totsuka et al., 2002; Nottle, Nosaka, 2007; Tofas et al., 2008; Lewis et al., 2012; Paulsen et al., 2012).

Vis dar nėra aišku, koks yra ūminis ir liekamasis ekscentrinio krūvio poveikis kvėpavimo dujų apykaitos rodiklių kaitai įvairaus intensyvumo darbo metu. Nustatyta, kad, praėjus vienai valandai po ekscentrinio koncentrinio krūvio, padidėjo absoliučios VO2 reikšmės vidutinio (Zaičenkovienė, Stasiulis, 2010) ir didelio intensyvumo krūvių metu (Ratkevičius et al., 2006). Praėjus 48 val. po ekscentrinio krūvio, kai subjektyvus skausmo vertinimas yra didžiausias (Lewis et al., 2012), padidėja VO2 (Burt, Twist, 2011), plaučių ventiliacija (Ve) ir subjektyvus pastangų vertinimas (SPV). Pažymėtina, kad kiti tyrėjai pateikia prieštaringus vertinimus – jie nenustatė VO2 pokyčių, praėjus 48 valandoms po ekscentrinio prieškrūvio (Gleeson et al., 1995; Davies et al., 2009, 2011; Schneider et al., 2007; Twist, Eston, 2009), didelio intensyvumo krūvio metu. Kita vertus, nustatyta, kad Ve nepakinta, nors SPV didelio intensyvumo krūvio metu padidėja (Black, Dobson, 2013). Po ekscentrinių krūvių padidėja kraujo laktato koncentracija didelio intensyvumo krūvio metu (Gleeson et al., 1995; Schneider et al., 2007).

Ekscentriniai fiziniai krūviai lemia raumenų elektrinio aktyvumo pokyčius izometrinio susitraukimo metu, tačiau nėra aišku, kaip po tokio prieškrūvio pakinta elektromiogramos (EMG) rodikliai dinaminio krūvio metu. Nustatyta, kad iš karto po keturgalvio šlaunies raumens ekscentrinio krūvio sumažėja EMG amplitudės dydis maksimalaus

izometrinio krūvio metu (Bieuzen et al., 2008; Behrens et al., 2012). Vertinant laiko atžvilgiu, nustatytas EMG amplitudės sumažėjimas atliekant 40 proc. maksimalios valingos jėgos (MVJ) izometrinį krūvį (Hedayatpour et al., 2009). Lyginant koncentrinio ir ekscentrinio krūvių poveikius, buvo nustatyta, kad pirmasis lemia didesnį EMG amplidutės padidėjimą atliekant krūvį veloergometru iš karto po prieškrūvio (Bieuzen et al., 2008). Nustatyta, kad EMG dažnumas sumažėja, o amplitudė nepakinta (Ahmadi et al., 2007).

EMG ir kvėpavimo dujų apykaitos rodikliai kinta priklausomai nuo krūvio intensyvumo, o tarp jų egzistuoja ryšys. Nustatyta, kad sunkėjančio krūvio metu EMG ir dujų apykaitos pokyčiai sutampa (Lucia et al., 1999; Hug et al., 2003). L. M. Chin su bendraautoriais (2011) nustatė, kad tarp keturgalvio šlaunies raumens elektrinio aktyvumo bei jų prisotinimo deguonimi egzistuoja tiesinė priklausomybė. Be to, EMG pokyčiai atspindi VO2 (Green et al., 2010) ir metabolinių sąnaudų (Blake, Wakeling, 2013) pokyčius pastovaus krūvio metu.

Duomenų apie tai, kaip prieškrūvis veikia kvėpavimo dujų apykaitos rodiklius ir EMG pokyčius, yra nedaug, be to, jie palyginti prieštaringi. M. Burnley su bendraautoriais (2002) nustatė, kad padidėjusi VO2 kaitos amplitudė yra susijusi su EMG pokyčiais. J. U. Gonzales ir B. W. Scheuermann (2006) pateikia opozicišką teoriją ir nerodo ryšio tarp EMG pokyčių ir VO2 kaitos ilgo krūvio metu, po didelio intensyvumo prieškrūvio. Dirbančių raumenų elektrinio aktyvumo analizė leistų geriau suprasti metabolizmo pokyčius ir jų mechanizmą, kadangi raumenų EMG pokyčiai dirbant atspindi jų nuovargį, raumenų grupių ir motorinių vienetų rekrutavimo pokyčius (Scheuerman et al., 2001; Green et al., 2010). Raumenų pažaida taip pat gali prisidėti prie metabolinių sąnaudų padidėjimo krūvio metu. Egzistuoja prielaida, kad pažeistos raumeninės skaidulos dirbančias skaidulas veikia kaip papildomas mechaninis krūvis (Lieber et al., 1996, Sandercock, 2000). Analizuojant literatūrą, nerasta duomenų apie tai, koks yra ūminis ir liekamasis skirtingų ekscentrinių prieškrūvių poveikis raumenų elektriniam aktyvumui ir kvėpavimo dujų apykaitos rodikliams skirtingo intensyvumo krūvių veloergometru metu.

Tyrimo tikslas – nustatyti ekscentrinio koncentrinio prieškrūvio ūminį ir liekamąjį poveikį kvėpavimo dujų apykaitos rodiklių ir raumenų elektrinio aktyvumo kaitai. atliekant skirtingo intensyvumo krūvius veloergometru.

Tyrimo uždaviniai:

1. Nustatyti ekscentrinio koncentrinio prieškrūvio poveikį kvėpavimo dujų apykaitos rodiklių kaitai ir keturgalvio šlaunies raumens elektriniam aktyvumui, atliekant vidutinio ir didelio intensyvumo krūvį.
2. Nustatyti ekscentrinio koncentrinio prieškrūvio poveikį kvėpavimo dujų apykaitos rodiklių kaitai ir keturgalvio šlaunies raumens elektriniam aktyvumui, atliekant nuosekliai didinamą krūvį.
3. Nustatyti vienos kojos ekscentrinio prieškrūvio poveikį kvėpavimo sistemos rodiklių kaitai ir keturgalvių šlaunies raumenų elektriniam aktyvumui, atliekant didelio intensyvumo krūvį.

Tyrimo naujumas ir originalumas

Ekscentrinio koncentrinio bei vienos kojos ekscentrinio prieškrūvio ūminis ir liekamasis poveikis kvėpavimo dujų apykaitos, aerobinio darbingumo rodikliams bei raumenų elektriniam aktyvumui pastovaus intensyvumo ir nuosekliai didinamo krūvio veloergometru metu buvo ištirtas ir palygintas pirmą kartą. Tyrimu nustatyta, kad po ekscentrinio koncentrinio ir ekscentrinio prieškrūvio pasireiškia ūmus poveikis kvėpavimo dujų apykaitos rodikliams, o poveikio darbo efektyvumui nesama. Abiejų kojų ekscentrinis koncentrinis prieškrūvis padidina pažaidos paveiktų raumenų elektrinį aktyvumą, o po vienos kojos ekscentrinio prieškrūvio pasireiškia nelauktas raumenų elektrinio aktyvumo atsakas, kai ekscentrinio prieškrūvio paveiktos kojos EMG nepakinta, o nepaveiktos kojos EMG amplitudė sumažėja.

Teorinė ir praktinė tyrimo reikšmė

Tyrimo rezultatai papildo žinias apie ekscentrinių koncentrinių fizinių pratimų ūminį ir liekamąjį poveikį kvėpavimo dujų apykaitos ir raumenų funkcijai sekančių fizinių pratimų metu. Atsižvelgiant į funkcinių sistemų pokyčius po struktūrinį nuovargį sukėlusių pratimų, praktikoje galima geriau prognozuoti sekančių atliekamų aerobinių krūvių darbingumo pokyčius, efektyviau planuoti pramankštą bei pasirengimą sporto varžyboms.

IŠVADOS

1. Ekscentrinis koncentrinis prieškrūvis padidino plaučių ventiliaciją ir širdies susitraukimų dažnį vidutinio, bet ne didelio intensyvumo krūvio metu, po prieškrūvio praėjus 45 min. Minėti rodikliai vidutinio ir didelio intensyvumo krūvių metu nepakito praėjus 24 val. po prieškrūvio. Praėjus 45 min, šoninio plačiojo raumens EMG amplitudė nepakito, o, praėjus 24 val. po prieškrūvio, vidutinio intensyvumo krūvio metu padidėjo. Didelio intensyvumo krūvio metu minėtų raumenų EMG buvo nepakitusi. Ekscentrinis koncentrinis prieškrūvis neturėjo poveikio darbo efektyvumui vidutinio ir didelio intensyvumo krūvio metu nei po 45 min, nei po 24 val.

2. Nuosekliai didinamo krūvio metu, praėjus 24 val. po ekscentrinio koncentrinio prieškrūvio, nepakito darbo efektyvumas, tačiau padidėjo plaučių ventiliacija, širdies susitraukimų dažnis, šoninio plačiojo raumens EMG amplitudė, o vidutinio plačiojo EMG galios spektro vidutinis dažnumas sumažėjo.

3. Didelio intensyvumo krūvio metu, praėjus 1 val. po vienos kojos keturgalvio šlaunies raumens ekscentrinio prieškrūvio, padidėjo plaučių ventiliacija, ekscentrinio prieškrūvio paveiktų raumenų EMG rodikliai nepakito, tačiau sumažėjo ekscentrinio prieškrūvio nepaveiktos kojos šoninio plačiojo raumens EMG amplitudė. Praėjus 24 val. po minėto prieškrūvio, šie rodikliai buvo nepakitę.

PUBLICATIONS

1. Dubininkaitė, Loreta; Stasiulis, Arvydas; Baranauskienė, Neringa. Įvairaus intensyvumo aerobinio prieškrūvio poveikis širdies susitraukimų dažnio kaitai kartotinio nuosekliai didinamo krūvio metu // Ugdymas. Kūno kultūra. Sportas. Kaunas : Lietuvos kūno kultūros akademija. ISSN 1392-5644. 2007, Nr. 2(65), p. 3-9.
2. Baranauskienė, Neringa; Stasiulė, Loreta; Raubaitė, Sandra; Stasiulis, Arvydas. The residual effect of prior drop jumps on EMG parameters of thigh muscles during moderate and heavy cycling // Ugdymas. Kūno kultūra. Sportas. Kaunas : Lietuvos kūno kultūros akademija. ISSN 1392-5644. 2012, Nr. 2(85), p. 3-9.
3. Baranauskienė, Neringa; Stasiulis, Arvydas. The residual effect of prior drop jumps on cardio respiratory parameters during moderate cycling in young women // Ugdymas. Kūno kultūra. Sportas. Kaunas : Lietuvos kūno kultūros akademija. ISSN 1392-5644. 2012, Nr. 3(86), p. 11-17.
4. Kvedaras, Mindaugas; Solianik, Rima Baranauskienė, Neringa. Mirror visual feedback impaction abductor pollicis brevis muscle electrical activity the stroke affected arm // Ugdymas. Kūno kultūra. Sportas. Kaunas: Lietuvos sporto universitetas. ISSN 1392-5644. 2013, Nr. 2 (89), p. 43-48.

Other publications

1. Baranauskienė, Neringa; Dubininkaitė, Loreta; Stasiulis, Arvydas. The residual effect of prior drop jumps on EMG of thigh muscles during heavy cycling exercise // Acta Kinesiologiae Universitatis Tartuensis=Abstracts of the First Baltic Conference in Exercise and Sports Sciences and the First Baltic Conference of Young Scientists in Exercise and Sport Sciences, Tartu, Estonia, 7-10 May 2008. Tartu: University of Tartu. ISSN 1406-9822. 2008, vol. 13 (Supplement), p. 31.
2. Baranauskienė, Neringa; Stasiulis, Arvydas. Changes in EMG of m. Vastus lateralis and medialis during heavy cycling one and 24 hours after one leg eccentric exercise // Acta Kinesiologiae Universitatis Tartuensis=Abstracts of the Fourth Baltic Conference in Exercise and Sport Sciences, Tartu, Estonia, 7-9 April, 2011. Tartu: University of Tartu. ISSN 1406-9822. 2011, vol. 16 (Supplement), p. 31.
3. Baranauskienė, Neringa; Raubaitė, Sandra; Stasiulė, Loreta;

Stasiulis, Arvydas. VO_2 during heavy cycling increases 45 minutes after drop jumps in men but not in women // Current Issues and New Ideas in Sport Science: 5th Baltic Sport Science Conference : Abstracts, Kaunas, 18-19 April 2012. Kaunas: Lietuvos kūno kultūros akademija, 2012. ISBN 9786098040708. p. 27.

4. Raubaitė, Sandra; Baranauskienė, Neringa; Stasiulis, Arvydas. The time course of oxygen uptake, heart rate and emg during two month of moderate interval endurance training: a case study // Current Issues and New Ideas in Sport Science: 5th Baltic Sport Science Conference: Abstracts, Kaunas, 18-19 April 2012. Kaunas: Lietuvos kūno kultūros akademija, 2012. ISBN 9786098040708. p. 175.
5. Raubaitė, Sandra; Baranauskienė, Neringa; Stasiulis, Arvydas. The effect of power endurance and high-intensity power training on aerobic capacity in sprinters // 6th Baltic Scientific Conference "Sport Science for Sustainable Society": Abstracts, Riga, Latvia, 23-25 April 2013. Riga : Latvian Academy of Sport Education. ISSN 1691-6220. ISBN 9789984920467. 2013, p. 63.
6. Baranauskienė, Neringa; Raubaitė, Sandra; Stasiulis, Arvydas. Changes in EMG of m. vastus lateralis and medialis during incremental cycling 24 hours after prior drop jumps exercise // 6th Baltic Scientific Conference "Sport Science for Sustainable Society": Abstracts, Riga, Latvia, 23-25 April 2013. Riga: Latvian Academy of Sport Education. ISSN 1691-6220. ISBN 9789984920467. 2013, p. 125-126.

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