Biology of Sport, Vol. 21 N^{o}2, 2004

EFFECT OF ECCENTRIC AND CONCENTRIC EXERCISE ON PLASMA CREATINE KINASE (CK) AND LACTATE DEHYDROGENASE (LDH) ACTIVITY IN HEALTHY ADULTS

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Abstract. The aim of the research was to determine the influence of concentric and eccentric muscular work on plasma creatine kinase (CK) and lactate dehydrogenase (LDH) activity during a graded exercise protocol. The research material included 10 students of physical education. All of them performed the treadmill exercise protocol twice, under different conditions (test I – uphill run-concentric work, test II – downhill run – eccentric work). Oxygen uptake was registered during both tests. Blood samples were taken from the antecubital vein before, during and 2, 7 and 24 h after the test. The effort with a predominance of concentric muscular work elicited a significantly ($P<0.01$) higher blood acidosis in comparison to the eccentric one. Both efforts caused a significant ($P<0.05$) increase in plasma CK and LDH activity. After 24 h of rest CK activity continued to rise while plasma LDH activity returned to pre exercise value. After 7 and 24 h of recovery plasma CK activity was significantly ($P<0.05$) higher following the eccentric form of exercise. Simultaneously, increase of CK activity during recovery after the eccentric work, pointing at the deterioration of muscle cells, was stated just after 7 h of rest. It proves proper functioning of adaptive mechanisms and that the level of CK activity in plasma immediately after effort does not reflect muscles functioning disturbances.

(Biol.Sport 21:193-203, 2004)

Key words: Concentric work - Eccentric work - CK activity - LDH activity

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Introduction

The plasma increase in creatine kinase (CK) and lactate dehydrogenase (LDH) activities after exercise is connected with changes of cell membrane integrity and mechanical damage of muscle fibres. Changes in myocyte membranes might be caused by the decrease of a cellular ATP concentration, cell anoxia, cell lipid peroxidation and ion administration disturbances, and the intracellular proteins liberation in depended on particles size [16,17,19,21,30]. The intra-muscle enzyme activity increase after exercise is probably elicited by a derivative degradation processes initiated by the loos of intracellular homeostasis caused among others by the calcium ion concentration increase activating numerous proteolytic reactions [23]. It is also believed that it can be depended on protein transport from intracellular space to blood. Research confirms that interstitial fluid accumulates transitory and osmotic cellular metabolites as the speed of their removal is too slow in comparison to the pace of their delivery from cells and plasma [10,28]. The fluid surplus infiltrates lymphatic vessels and goes further to the blood. The above mechanisms present the excessive growth of tissue fluid pressure and allow for its constant interchange [10]. The flow of lymph is aided by skeletal muscle contractions, negative pressure inside the chest during inspiration, a suctorial effect produced by fast blood flow in veins and the regular twitch of large lymphatic vessels. The above factors influence the intracellular enzymes activity in blood plasma, especially during physical effort, for, over 90% of CK is transferred this course to the plasma [12].

The post exercise enzyme activity in plasma measured in the morning is higher than activity measured in the evening. This is do to the fact that the speed of the lymph flow during the night presents 20-25% of a 24 h flux [10] what is the cause of the interstitial liquid gathering in tissue. The intensive oozing of the interstitial liquid to lymphatic vessels and the growth of lymph flow with cellular metabolites to blood occurs during eccentric work of muscle [28]. It is believed that the eccentric work, preceded by similar exercise and conducted after full restitution, elicits much smaller post exercise changes of the CK activity in comparison to those caused by the first one [2,7,11,22,27,29,32]. It may be the evidence of the removal of surging interstitial liquid during the first effort, and changes of CK activity after the second effort should be regarded as the reflection of realistic liberation of CK or LDH from cells. The eccentric work of muscles, during which mechanical injuries of muscle may take place, induces greater disruption of cell membranes than concentric work does [9,24]. Previous research projects concentrate mainly on changes of intra-muscle enzyme activity in plasma, while

restitution after the eccentric or concentric effort is rarely considered. The main objective of this paper was the determination of concentric and eccentric muscular work on exercise and post exercise CK and LDH activity in men.

Material and Methods

Ten non-athletes, students of the physical education, aged 22.4±1.4 years, with body mass 75.5±1.4 kg and height 177.0±5.7 cm took part in the study. They performed 2 different kinds of physical effort with graded intensity until volitional exhaustion. Tests were performed on the treadmill (Jaeger) with a one week period between them. The first test (concentric work of muscles) was based on uphill running (+15° angle) with the initial speed of 5 km/h. The speed was increased every 3 min by about 1 km/h. During the second test (eccentric work) subjects were downhill running (-15° angle) with the initial speed of 9 km/h. The speed was increased every 3 min by about 3 km/h. Intervals lasting 1 min between next loads were adapted in both tests. Oxygen uptake was monitored during exercise using a gas analyser (Beckman Company) and expressed in ml/min/kg.

Blood samples were taken from the antecubital vein to heparinized test-tubes before and during every test, during intervals between next loads and after 2, 7 and 24 h of rest. Creatine kinase (CK, EC 2.7.3.2) and lactate hydrogenase (LDH, EC 1.1.1.27) activity was evaluated in plasma, without hemolysis, in a temperature of 37° C, using a spectrophotomertic method (prepared Analco kits - Poland). CK and LDH activities, corresponding to growing for 5 ml/kg/min values of oxygen uptake, were read from the above parameters co-dependence graph.

The lactate (LA) concentration was determined in plasma using commercial kits (BioMerieux Company, France). Results were analysed using Statistica 5.0 (StatSoft, Inc., 1995) softwere programme. Average values (X) and standard deviations (SD) were calculated. A non-parametric test of Wilcoxon and Mann-Whitney was used for the examination significances of differences. Differences were accepted as significant at the level of $P \leq 0.05$.

The research was approved by the Ethics Committee at the Medical University of Silesia in Katowice.

Results

The concentric effort (test I) elicited a significantly higher acidification of blood than the eccentric one (test II; Fig. 1). However, despite the fact that the concentric work caused higher blood and muscles acidification, examined subjects performed it longer (until oxygen uptake of 60 ml/kg/min) than the eccentric work (till 55 ml/kg/min).

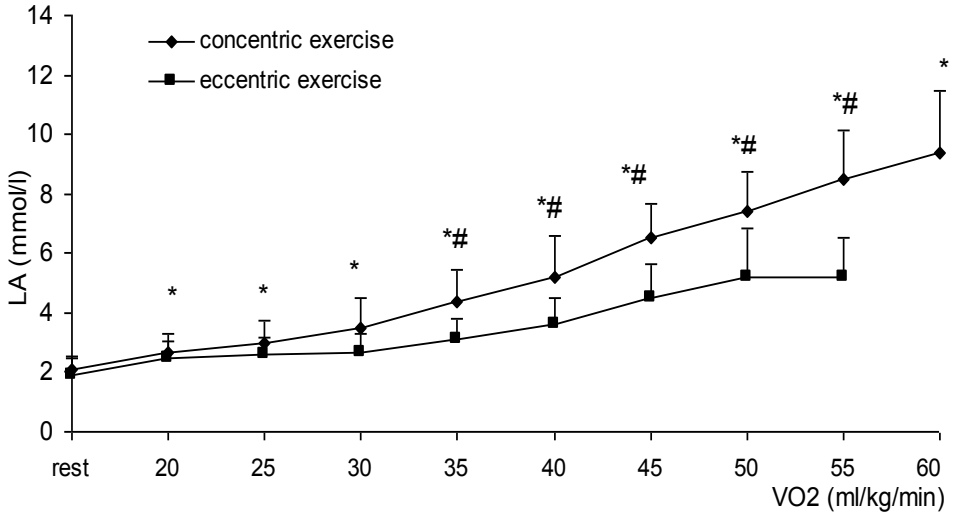

Fig. 1
The dependence of the lactate (LA) concentration in plasma upon the intensity of exercise characterised by concentric and eccentric work of muscles
*Statistically significant differences ($P<0.01$) in comparison to resting values in both kinds of muscular work; #Statistically relevant differences ($P<0.01$) between concentric and eccentric effort

Plasma CK activity before tests was at the upper level of referential values [24 to 195 U/l (Table 1)]. Changes of CK activity during exercise depended on the character of muscles contraction. In test I (concentric work) statistically significant growth of CK activity was noticed at the intensity corresponding to oxygen uptake 45 ml/kg/min. In test II (eccentric work) the significant increase of this enzyme

activity was observed at a much smaller load (VO_2 at the level of 25 ml/kg/min). Significantly higher plasma CK activity in comparison to resting values were maintained in both tests until the end of exercise and 2 h after. For next 7 and 24 h CK activity was statistically higher in comparison to its level after 2 h of restitution. After the concentric work it returned to the value obtained before the test. The activity of this enzyme was significantly higher during the restitution (7 and 24 h) after eccentric work.

Table 1
Plasma creatine kinase activity (CK) during concentric and eccentric exercise with progressive intensity and in recovery

Oxygen uptake (ml/kg/min)	CK activity (U/l) Concentric work			Eccentric work		
	X	SD	N	X	SD	N
Resting	160	68	10	183	83	10
20	160	68	10	183	83	10
25	164	75	10	195*	81	10
30	171	85	10	197*	83	10
35	170	78	10	205	85	10
40	169	71	10	193*	77	9
45	177*	75	10	192*	79	9
50	183*	76	10	180*	76	8
55	184*	89	9	189*	77	6
60	192*	96	8	-	-	-
After 2 h rest	185*	94	10	262*	110	10
After 7 h rest	164#	113	10	594*	376	9
After 24 h rest	154#	93	10	504*	389	10

*Statistically significant difference in comparison to the respective resting values ($P<0.05$); #Statistically significant difference between the CK activity after the concentric and eccentric work ($P<0.05$)

Table 2
Plasma lactate dehydrogenase (LDH) during concentric and eccentric exercise with progressive intensity and after recovery

Oxygen intake (ml/kg/min)	LDH activity (U/l)					
	Concentric work			Eccentric work		
	X	SD	N	X	SD	N
Resting	272	53	10	286	65	10
20	272	53	10	286	65	10
25	282	51	10	297	61	10
30	310	46	10	307	52	10
35	329	58	10	331*	61	10
40	327	50	10	337*	62	9
45	322*	40	10	351*	79	9
50	332*	35	10	331*	56	8
55	337*	36	9	348*	55	6
60	344*	57	8	-	-	-
After 2 h rest	286	44	10	313	53	10
After 7 h rest	294	50	10	302	85	9
After 24 h rest	226#	27	10	278	48	10

*Statistically significant difference in comparison to the respective resting values ($P<0.05$); #Statistically significant difference between the LDH activities after the concentric and eccentric work ($P<0.05$)

Resting lactate dehydrogenase (LDH) activity in plasma did not exceed the physiological value amounting for men from 200 to 400 U/l. The statistically significant growth of this enzyme activity was noticed during the concentric work (test I) at the intensity corresponding to oxygen uptake of 45 ml/kg/min. During eccentric work (test II) its activity grew significant ($P<0.05$) at a lower intensity – 35/ml/kg/min. The increased activity of LDH in plasma maintained until the end of exercise. After 2 h of rest LDH activity decreased in both tests and did not differ significantly from the respective values reached before tests. This tendency was observed also after 7 h of rest. LDH activity went down to the initial value after 24 h of restitution. The work character did not differentiate significantly the LDH

activity after 2 and 7 h of rest. After 24 h of restitution the activity of this enzyme was significantly higher after the eccentric work in comparison to activity noticed after concentric effort.

Discussion

Some significant disturbances in muscle cell metabolism and the flow of specific cellular enzymes to the structure fluids occurred during the physical exercise, especially eccentric, in nature [4,13,18]. The post exercise increase of CK and LDH activity is widely documented and regarded by many researchers as a specific marker of muscle fibres disruption [13,18,19]. However, considering the large personal diversification and physiological condition of muscles (training level, sex, intensity and type of muscle contractions). The sensitivity of this index is frequently questioned [8,15,26,31]. In this research, the increase of CK and LDH activity immediately after test I equalled respectively 20 and 26% and after test II - 8 and 22% of resting values. Significantly higher growth, especially of the CK activity in plasma, was noticed after the perpetual effort with large and stable intensity [19,30].

Physical efforts performed in this research, independently on muscle contraction character, had similar intensity measured through oxygen uptake. Obtained data show that the statistically significant growth of CK and LDH activity in plasma manifested itself by lower intensity of eccentric work in comparison to work with concentric character. It cannot be excluded that eccentric work elicits faster filtration of the interstitial liquid and earlier occurrence of enzymatic protein in blood as a consequence [20]. Stretched muscle fibres produce higher tension during the eccentric than concentric contractions. It favours liberation of metabolites from muscle cells and its further transport in lymphatic vessels is aided by the concentric work of muscle when shortening and thickening of fibres takes place. The increase of work intensity is the impulse for the intensification of blood flow, what causes the enforcement of the blood suctorial effect in relation to lymph from main lymphatic vessels and next to the growth of cellular enzymes activity in plasma [1,6,14,25].

Plasma CK and LDH activity grew significantly after the eccentric exercise with increasing intensity. Notwithstanding, only CK activity grew significantly during restitution. Similar results were obtained by Chen *et al.* [3] who observed congenial reaction of CK in plasma after 2 and 24 h after eccentric work. On the other hand, after several days of eccentric training they noticed an adaptation to this kind of work. The post exercise and recovery changes of CK activity were not

statistically significant. In this research, differences between plasma CK activities after the concentric and eccentric work were significantly after 7 and 24 h of restitution. The activity of this enzyme was essentially higher after eccentric work (test II). Differences among the LDH activities occurred after 24 h of rest in both tests. The LDH activity after the eccentric work was significantly higher in comparison to concentric values. One of the causes of different course of CK and LDH activity changes might be the disparity of enzymatic protein particles size. Creatine kinase is smaller protein (dimer with mass of 84000) comparing to the lactate hydrogenase (tetramer with mass of 150000), consequently it may easier penetrate through, muscle cell membrane disrupted by exercise [33].

According to the obtained data it may be presumed that eccentric effort performed with graded intensity did not cause mechanical injuries of muscle cells and elicited only an increase of myocyte membranes penetrability. On the other hand, plasma lactate concentration during the concentric effort was higher in comparison to the concentric work despite of the fact that the concentric work lasted longer. It may be expected that changes of the functional state of muscles not connected with lactate production were the reason for the difference in the length of the effort. It cannot be excluded than, that the increase in plasma CK activity during restitution after eccentric work was the consequence of the secondary degradation processes because some amount of muscle fibres were under irreversibly damaged [5]. The highest CK activity presented in this research after 7 h of restitution (594 U/l) was lower than that registered after 6 h restitution from a 18 km run amounting to 900 U/l [10]. Significantly higher CK and LDH activities in plasma, respectively over 10000 and 400 U/l were obtained by Chen *et al.* [3] after eccentric work of the elbow joint flexors.

Data gathered in this paper show that the type of muscle contractions character in exercise with growing intensity did not elicit differences in CK and LDH activity during the performance of test regarding the adaptive mechanisms function. Simultaneously, as a consequence of the derivative adaptation processes, CK activity increase in plasma during the restitution pointing at the existence of muscle cells damage was stated only after 7 h of rest. It indicates that the CK activity in plasma immediately after effort does not reflect the disruption of muscle cell membranes.

References

1. Balnave C.D., M.W.Thompson (1993) Effect of training on eccentric exercise-induced muscle damage. *J.Appl.Physiol*. 75:1545-1551

2. Brown S.J., R.B.Chil, S.H.Day, A.E.Donnelly (1997) Exercise-induced skeletal muscle damage and adaptation following repeated bouts of eccentric muscle contractions. *J.Sports Sci*. 15:215-222

3. Chen T.C., S.S.Hsieh (2001) Effects of a 7-day eccentric training period on muscle damage and inflammation. *Med.Sci.Sports Exerc*. 33:1732-1738

4. Clarkson P.M., W.C.Byrnes, K.M.McCormik, L.P.Turcotte, J.S.White (1986) Muscle soreness and serum creatine kinase activity following isometric, eccentric and concentric exercise. *Int.J.Sports Med*. 7:152-155

5. Clarkson P.M., C.B.Ebbeling (1988) Investigation of serum creatine kinase variability after muscle-damaging exercise. *Clin.Sci*. 75:257-261

6. Clarkson P.M., K.Nosaka, B.Braun (1992) Muscle function after exercise-induced muscle damage and rapid adaptation. *Med.Sci.Sports Exerc*. 24:512-520

7. Ebbeling C.B., P.M. Clarkson (1990) Muscle adaptation prior to recovery following eccentric exercise. *Eur.J.Appl.Physiol*. 60:26-31

8. Evans W.J., C.N.Meredith, J.G.Cannon, C.A.Dinarello, W.R.Frontera, V.A.Hughes, B.H.Jones, H.G.Knuttgen (1986) Metabolic changes following eccentric exercise in trained and untrained men. *J.Appl.Physiol*. 61:1864-1868

9. Fitzgerald G.K., J.M.Rothstein, T.P.Mayhew, R.L.Lamb (1991) Exercise-induced muscle soreness after concentric and eccentric isokinetic contractions. *Phys.Ther*. 71: 505-513

10. Havas E., J.Komulainen, V.Vihko (1997) Exercise-induced increase in serum creatine kinase is modified by subsequent bed rest. *Int.J.Sports Med*. 18:578-582

11. Hyatt J.P., P.M.Clarkson (1998) Creatine kinase release and clearance using MM variants following repeated bouts of eccentric exercise. *Med.Sci.Sports Exerc*. 30:1059-1065

12. Lindena J., W.Küpper, I.Trautschold (1984) Enzyme activities in thoracic duct lymph and plasma of anaesthetized, conscious resting and exercising dogs. *Eur.J.Appl.Physiol*. 52:188-195

13. Lu S.S., S.K.Wu, J.J.Chen (1992) The effects of heavy eccentric contractions on serum creatine kinase levels. *Clin.J.Physiol*. 35:35-44

14. Mair J., M.Mayr, E.Müller, A.Koller, C.Haid, E.Artner-Dworzak, C.Calzalari, C.Larue, B.Puschendorf (1995) Rapid adaptation to eccentric exercise-induced muscle damage. *Int.J.Sports Med*. 16:352-356

15. Manfredi T.G., R.A.Fielding, K.P.O'Reilly, C.N.Meredith, H.Y.Lee, W.J.Evans (1991) Plasma creatine kinase activity and exercise-induced muscle damage in older men. *Med.Sci.Sports Exerc*. 23:1028-1034

16. Melin B., L.Bourdon, C.Jimenez, A.Charpenet, O.Bernard (1997) Plasma myosin and creatine kinase time-course after a concentric-eccentric field exercise. *Arch.Physiol.Biochem*. 105:27-31

17. Newham D.J., D.A.Jones, R.H.Edwards (1986) Plasma creatine kinase changes after eccentric and concentric contractions. *Muscle Nerve* 9:59-63

18. Nicholson G.A., J.G.McLeod, G.Morgan, M.Meerkin, J.Cowan, A.Bretag, D.Graham, G.Hill, E.Robertson, L.Sheffield (1985) Variable distributions of serum creatine kinase reference values. Relationship to exercise activity. *J.Neurol.Sci*. 71:233-245

19. Nosaka K., P.M.Clarkson (1994) Effect of eccentric exercise on plasma enzyme activities previously elevated by eccentric exercise. *Eur.J.Appl. Physiol*. 69:492-497

20. Nosaka K., P.M.Clarkson (1995) Muscle damage following repeated bouts of high eccentric exercise. *Med.Sci.Sports Exerc*. 27:1269-1269

21. Nosaka K., P.M.Clarkson (1996) Variability in serum creatine kinase response after eccentric exercise of the elbow flexors. *Int.J.Sports Med.* 17:120-127

22. Nosaka K., P.M.Clarkson (1997) Influence of previous concentric exercise on eccentric exercise-induce muscle damage. *J.Sports Sci*. 15:477-483

23. Saxton J.M., A.E.Donnelly (1995) Light concentric exercise during recovery from exercise-induced muscle damage. *Int.J.Sports Med*. 16:347-351

24. Schwane J.A., S.R.Johnson, C.B.Vandenakker, R.B.Armstrong (1983) Delayed-onset muscular soreness and plasma CPK and LDH activities after downhill running. *Med.Sci.Sports Exerc*. 15:51-56

25. Seger J.Y., B.Arvidsson, A.Thorstensson (1998) Specific effects of eccentric and concentric training on muscle strenght and morphology in humans. *Eur.J.Appl.Physiol*. 79:49-57

26. Sherwood R.A., A.Lambert, D.J.Newham, W.S.Wassif, T.J.Peters (1996) The effect of eccentric exercise on serum creatine kinase activity in different ethnic groups. *Ann.Clin.Biochem*. 33:324-329

27. Smith L.L., M.G.Fulmer, D.Holbert, M.R.McCammon, J.A.Houmard, D.D.Frazer, E.Nsien, R.G.Israel (1994) The impact of repeated bout of eccentric exercise on muscular strength, muscle soreness and creatine kinase. *Br.J.Sports Med*. 28:267-271

28. Sorichter S., A.Koller, C.Haid, K.Wicke, W.Judmaier, P.Werner, E.Raas (1995) Light concentric exercise and heavy eccentric muscle loading: effects on CK, MRI and markers of inflammation. *Int.J.Sports Med*. 16:288-292

29. Sorichter S., J.Mair, A.Koller, P.Secnik, V.Parrak, C.Haid, E.Müller, B.Puschendorf (1997) Muscular adaptation and strength during early phase of eccentric training: influence of the training frequency. *Med.Sci.Sports Exerc.* 29:1646-1652

30. Tanada S., T.Higuchi, T.Nakamura, M.Imaki, K.Matsumoto, T.Miyoshi (1993) Evaluation of exercise intensity indicated by serum lactate dehydrogenase activity in healthy adults. *Acta Biol.Hung*. 44:153-160

31. Vincent H.K., K.R.Vincent (1997) The effect of training status on the serum creatine kinase response, soreness and muscle function following resistance exercise. *Int.J.Sports Med*. 18:431-437

32. Whitehead N.P., T.J.Allen, D.L.Morgan, U.Proske (1998) Damage to human muscle from eccentric exercise after training with concentric exercise. *J.Physiol*. 15:615-620

33. Wyss M., J.Smeitink, R.A.Wavers, T.Wallimann (1992) Mitochondrial creatine kinase: a key enzyme of aerobic energy metabolism. *Biochim.Biophys.Acta* 1102:119-166

Accepted for publication 24.09.2003

Acknowledgement
Research was realised as own study and DS.-50 financed by the Scientific Research Committee