LOCAL – CENTRAL FATIGUE AFTER CONTINUOUS AND INTERVAL RUNNING

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LOKALNO CENTRALNA UTRUJENOST PO NEPREKINJENEM IN INTERVALNEM TEKU

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Abstract

The research objective was to establish the influence of central fatigue on the efficiency of muscular function after two different cyclic running loads.

Seven well-trained runners carried out two running loads, differing in method and intensity: an intensive interval training 5 x 300 m (INT) and a continuous 6 km run (CON) at sub-maximal speed. The subjects carried out the test protocol for establishing the influence of central fatigue in the state of resting and after running. The index of central fatigue (In CF) was defined as the difference between the index of decrease in torque of voluntary muscular contraction (In T_{MVC}) and the index of decrease of torque of voluntary muscular contraction with additional electrical stimulation (In $T_{MVC + ES}$).

After INT $T_{MVC +ES}$ decreased by 6.6 ± 3.9 % (P < 0.05), after CON by 8.3 ± 10.1 % (P < 0.05), while T_{MVC} decreased much less. The decrease in muscular contractile ability was the consequence of peripheral fatigue for both running loads. In CF increased after both loads (after INT by 52 ± 78 % - P < 0.05, after CON by 48 ± 83 % - P < 0.05) but remained less than 0 after both loads. This research showed that central fatigue can be an important cause of decrease in the efficiency of muscular function also for well-trained individuals.

Keywords: central fatigue, interval runs, continuous tempo running, electrical stimulation

Izvleček

Cilj raziskave je bil ugotoviti vpliv centralne utrujenosti na učinkovitost mišične funkcije po dveh različnih cikličnih dinamičnih obremenitvah.

Sedem dobro treniranih tekačev je opravilo dve po metodi in intenzivnosti različni tekaški obremenitvi: intenzivni intervalni trening 5 x 300m (INT) in neprekinjen 6km dolg tek (CON) v submaksimalni hitrosti. V mirovanju in po teku so preiskovanci opravili testni protokol ugotavljanja vpliva centralne utrujenosti. Indeks centralne utrujenosti (In CF) smo definirali kot razliko med indeksom upadanja navora zavestne mišične kontrakcije (In T_{MVC}) in indeksom upadanja navora zavestne mišične kontrakcije ob dodatni električni stimulaciji (In $T_{MVC +ES}$).

Po INT se je navor $T_{MVC +ES}$ znižal za 6,6 ± 3,9 % (P 0,05), po CON pa za 8,3 ± 10,1 % (P 0,05), medtem je bil padec navora T_{MVC} izrazito nižji. Upad mišične kontraktilne sposobnosti je bil po obeh tekaških obremenitvah posledica periferne utrujenosti. In CF se je po obeh obremenitvah povečal (po INT za 52 ± 78 % (P 0,05), po CON pa za 48 ± 83 % (P < 0,05), vendar je po obeh obremenitvah ostal manjši od 0. Raziskava je pokazala, da je tudi pri dobro treniranih posameznikih lahko centralna utrujenost pomemben vzrok za padec mišične kontraktilne učinkovitosti.

Ključne besede: centralna utrujenost, intervalni teki, neprekinjen tempo tek, električna stimulacija

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INTRODUCTION

The processes of fatigue development are the result of a reduced efficiency of an individual link/individual links in the chain of the regulation of muscle function - the activation - contraction chain (Gibson and Edwards, 1985; Mc Comas, 1996). Thus, the decline in muscle function can be the consequence of peripheral fatigue which denotes disturbances in the various mechanisms from the neuromuscular junction up to the actin-myosin bond and central fatigue, which is primarily the consequence of the reduced effect of cortical motor centres and subcortical areas in the central nervous system (Gandevia, Allen and Mc Kenzie, 1995; Gibson and Edwards, 1985; Bigland-Ritchie, Jones, Hosking and Edwards, 1978). Gandevia, Allen and Mc Kenzie (1995) defined central fatigue as the difference between a decrease in voluntary and in electrically stimulated contractile muscle force. Gibson and Edwards (1985), however, define the presence of central fatigue as a condition in which the force of voluntary contraction is lower than the force of contraction obtained with additional electrical stimulation.

The mechanisms of central fatigue are numerous and various. The common consequence of disturbances in individual mechanisms of central fatigue is the reduction in output (central drive) of the -motor neuron (Bigland-Ritchie, Furbush and Woods, 1986; Gandevia, Allen and Mc Kenzie, 1995; Mc Comas, 1992). This means disturbances in the recruitment and frequency modulation of motor units. These disturbances can be a consequence of lower excitation of the CNS (lower output of the motor cortex) (Gandevia, Allen and Mc Kenzie, 1995) as a result of afferent effects from the periphery or mental processes. The reduced efficiency of the -motor neurone can also be the consequence of disturbances in the transmission of electrical impulses from the motor cortical centres over subcortical centres and spinal cord into the muscle (Astrand and Rodahl, 1986; Gibson and Edwards, 1985; Guyton, 1980).

From the researches dealing with the role that the mechanisms of central fatigue play in the decrease in muscle contractile function, above all during the voluntary or electrically stimulated isometric loads, it can be concluded that the involvement and level of the influence of the mechanisms of central fatigue in the decrease in muscle function depends on the type of load, its duration and intensity (Bigland-Ritchie, Jones, Hosking and Edwards, 1978; Gandevia and Mc Kenzie, 1987; Linnamo, Hakkinen and Komi, 1988; Newham, Mc Carthy and Turner, 1991); the muscle involved (Bigland-Ritchie, Furbush and Woods, 1986; Gandevia, Allen and Mc Kenzie, 1995; Mc Kenzie, Bigland-Ritchie, Gorman and Gandevia, 1992), and the psychophysical abilities of the tested subjects (the training status attained by an individual athlete, gender). (Bigland-Ritchie, Jones, Hosking and Edwards, 1978; Bigland-Ritchie, Furbush and Woods, 1986; Hakkinen, 1994; Hakkinen, 1995).

Cyclic loads of long duration differ from short-term isometric and dynamic loads in movement structure, duration and intensity. In long-term cyclic loads it is necessary to maintain the activity of the CNS at a certain submaximal level also in the state of destroyed internal homeostasis. To improve endurance abilities by suitable training means to reduce fatigue - it means to exert influence on all possible forms of fatigue development, thus also on the reduction of the influence of central fatigue (Bigland-Ritchie, Furbush and Woods, 1986). In endurance sports those athletes have an advantage who are able to maintain a satisfactory level of the activity of the CNS also in extremely demanding physiological states of the organism. A higher tolerance to pain further contributes to the said advantage (Shephard and Astrand, 1995).

The objective of the research has been to establish if - and to what extent - is fatigue after continuous dynamic loading also the consequence of a lowered efficiency of the neural drive – central fatigue. We were interested in whether these loads exert influence on the level of activation and the ability of maintaining the activation level; at the same time we were also interested in how the signs of central fatigue show in individual athletes who are well trained in endurance.

METHODS

Sample of subjects. The sample of subjects consisted of 7 well-trained middle and long distance runners. The average result of the test subjects in running over 1500m was 3 minutes and 54.5 s (from 3:43 to 4:02). Their average age was 25.3 years ± 4.1 years (mean ± SD), the body weight 62.5 kg ± 4.1 kg, and body height 176 cm ± 3.6 cm.

The study has been approved by the National Committee for Medical Ethics.

Experimental procedure. The subjects participated in trial measurements performed in a laboratory, over the period of one week. The aim of the trial measurements was that the subjects become used to the measurement procedures in which percuate electrical stimulation is used. These trial measurements were followed by the tests for the determination of the intensity - speed of running in both experimental running tasks. The experimental protocol comprised of two experimental tasks - different long-duration dynamic (cyclic): (1) interval runs 5 x 300 m (INT) at a sub-maximal speed (10% lower than in the

400-m-test) with a recovery period of one minute between individual runs and (2) continuous running at a steady pace over 6 km (CON) at the speed of anaerobic threshold (criterion V_{OBLA}).

Both running loads were performed on an athletic track in the time before competition season. Before each test loading, the test subjects performed a warm-up: 10 minutes of easy running and stretching.

Determination of the intensity of continuous running. The test was carried out on a treadmill. It consisted of 6 to 8 runs lasting 5 minutes each. The speed of an individual run was steady and constant, and it increased from one run to the next by 0.2 m . s^{-1}. Between individual runs there was a break of up to 45 seconds for taking blood samples. Using the method devised by Beaver, Wasserman and Whipp (1985), the running speed at the anaerobic threshold (OBLA criterion) was calculated on the basis of the lactate kinetics.

Determination of the intensity of interval runs. The speed of interval runs was determined on the basis of a test run over 400 m at the maximal possible speed. The test on a treadmill and the test run over 400 m were carried out in two consecutive days.

Between the tests for the determination of the speed of running and the first experimental task, namely continuous running over 6 km, four or five days elapsed, and after a subsequent three days, the test subjects also performed interval training. The test subjects were asked not to carry out intensive training loads at least two days before the experimental task.

To establish the initial state (after the warm-up), the tests were conducted in the following order: taking a blood sample, recording the heart rate and maximal voluntary isometric extension at the knee with an additional electrical stimulation of the quadriceps femoris muscle. The same protocol was used after the completed running load. The last measure – measurement of the maximal voluntary isometric extension at the knee with an additional electrical stimulation was finished 4 minutes after the completed running load.

Electrical stimulation. A custom-made computer-controlled four-channel electrical stimulator was used. During measurements with electrical stimulation and maximal voluntary isometric extension at the knee, the test subjects were in a lying position fixed at the pelvis and over the distal part of the thigh to a specially adapted bench, so that the trunk and the thigh of the fixed leg could not be moved. The distal part of the shank was fixed to a bar connected to a force transducer. A strain-gauge transducer was used with linear properties inside 0 – 5000 N, with hysteresis less than 1%. Stiff lower leg – bar connection was secured with an intermediate plate (as used by football players to secure tibia and fibula) and a bandage that prevented any movement between the bar and lower leg. The angle at the knee of the fixed leg was 45°.

Direct electrical stimulation of the muscle was used. Self-adhering neurostimulation electrodes (6x8 cm; Axelgaard, USA) were placed over the vastus lateralis and vastus medialis. Distal electrodes were placed over the distal part of the muscle belly, and proximal electrodes were placed over the middle part of the muscle belly. Electrodes remained fixed for the whole time of the experimental procedure by the addition of a medical net.

Data was sampled at 1kHz using a 12 bit AD converter (Burr-Brown, ZDA) and stored in a computer.

Measurement of the level of activation (AL) and dynamic changes the torque of voluntary and electrical stimulated contractions. During maximal isometric contraction of the quadriceps femoris muscle in the duration of 25 seconds we additionally stimulated the vastus lateralis muscle and the vastus medialis muscle with a short 0.8 s long train of electrical impulses with a frequency of 100 Hz (Figure 1). The first impulse was triggered after three seconds of voluntary concentric muscle contraction and the second at 24th second isometric contraction. The strength of electrical impulses was determined separately for each test subject with respect to his level of ability of tolerating electrical stimulation and was constant during the entire time of measurements. The amplitude was sufficiently large to completely activate the quadriceps femoris muscle (Strojnik, 1995).

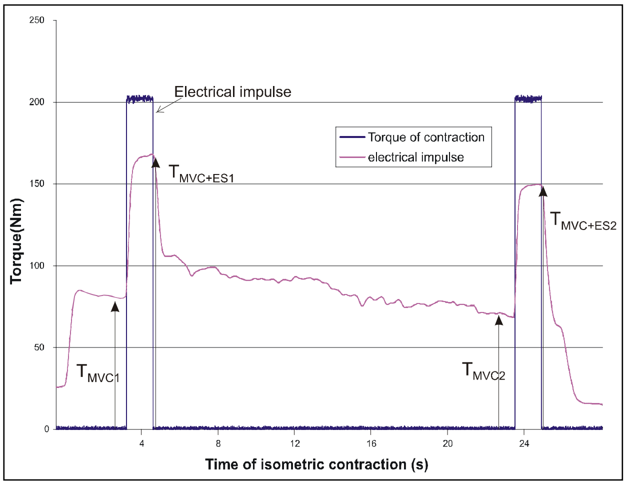


Fig. 1. Torque in the knee during a 25 s maximal isometric contraction with additional electrical stimulation.

From the analysis of the torque at the knee (Figure 1) the following bio-mechanical parameters were selected and calculated:

1) Magnitude of peak torque at the knee in the 3rd second (T_{MVC1}) and in the 24th second (T_{MVC2}) during 25-second maximal voluntary muscle contraction.

2) The index of the decrease of the magnitude of the maximal torque at the knee between the 3rd and 24th second of maximal voluntary muscle contraction (equation 1) is

$In\ T_{MVC} = (T_{MVC1} - T_{MVC2})/ T_{MVC1}\ 100$ equation 1

3) Magnitude of torque at the knee during maximal voluntary muscle contraction with additional electrical stimulation after the 3rd second ($T_{MVC1 + ES1}$), and in the 24th second ($T_{MVC2 + ES2}$).

4) The index of the decrease of the magnitude of the maximal torque at the knee for an electrically stimulated contraction between the 3rd and 24th second (equation 2) is

$In\ T_{MVC + ES} = (T_{MVC1 + ES1} - T_{MVC2 + ES2}) / (_{TMVC1 + ES1}) \cdot 100$ equation 2

5) The level of muscle activation (proportion of T_{MVC} relative to the total muscle force capacity $T_{MVC +ES}$) in the 3rd (AL1) and 24th second (AL2) of the test protocol (equation 3 and equation 4) is

$AL\ 1 = T_{MVC1} /T_{MVC1 + ES1} \cdot 100$ equation 3

$AL\ 2 = T_{MVC2} /T_{MVC2 + ES2} \cdot 100$ equation 4

On the basics of above parameters we defined the index of central fatigue as:

$In\ CF = In\ T_{MVC} – In\ _{TMVC+ES}$ equation 5

Central fatigue was defined for the cases when $In\ T_{MVC} > In\ T_{MVC+ES}$ or when $In\ CF > 0$. This would occur in the case when the decrease in the torque of voluntary muscle contraction was larger than the decrease in the torque of electrically stimulated muscle contraction (D1 < D2 or AL1 > AL2) (Figure 2).

Heart rate. The heart rate frequency was measured with heart rate meters of the type Polar PE 3000 (Oulu, Finland).

Concentration of lactate in blood (LA). The concentration of lactate in blood was measured with a Kontron 640 lactate analyser (Vienna, Austria). A sample of 20 ìl of blood was taken from the hyperaemic earlobe before (after warm-up) the running load and 3 minutes after completed running loads. The accuracy of the measurement of lactate concentration in fresh blood was $\pm$ 0.2 mmol . l^{-1}.

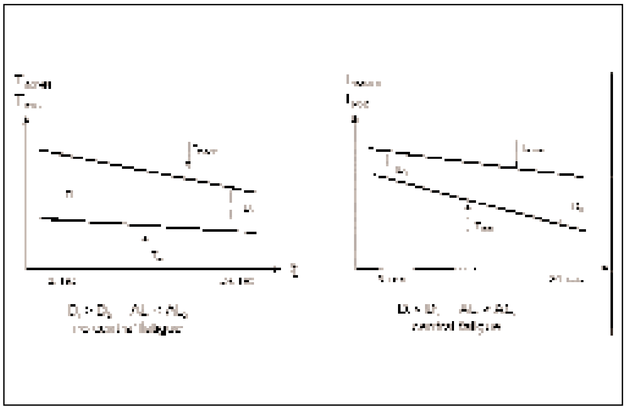


Fig. 2. Schematic representation of the model defining the presence of central fatigue. Legend: D = differences between TMVC±ES and TMVC (D1 - measures at 3rd second and D2 - measures at 24th second of 25-second isometric contraction; AL = level of muscular activation (AL1 - measures at 3rd second and AL2 - measures at 24th second of 25-second isometric contraction

Statistical methods. For the calculation of statistical significance of the differences in the individual parameter before and after the running load, the t-test for dependent samples was used. For the calculation of statistical significance of the differences between individual test subjects as regards the presence of central fatigue, a one-way ANOVA - analysis of variance was used. The statistical significance was accepted with an alpha error of 5% in two-tailed testing. To calculate the correlation between the individual parameters, the Pearson correlation coefficient was used.

RESULTS

Dynamics of the heart rate frequency and the kinetics of lactate in blood before and during interval runs and continuous running. The dynamics of the heart rate frequency and the kinetics of lactate in blood in the state of resting, during and after continuous run, and during and after interval runs is shown in Figure 3a,b.

The speed attained by the test subjects during running over 6 km on an athletic track amounted to 4.96 $\pm$ 0.29 m . s^{-1}. The concentration of lactate in blood at the end of the run was 5.8 $\pm$ 1.8 mmol. 1^{-1} and differed statistically significantly from the value before the loading ($P < 0.001$). The average value of HR was 192 $\pm$ 8 beats . min-1. The average speed of five 300-m runs with recovery intervals of one minute in-between was 6.8 $\pm$ 0.4 m . s^{-1}. The concentration of lactate in blood immediately after the com-

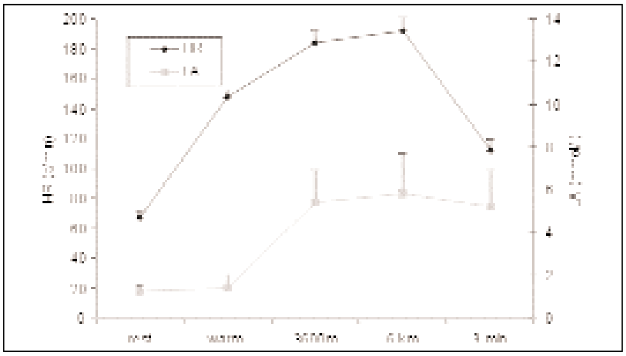
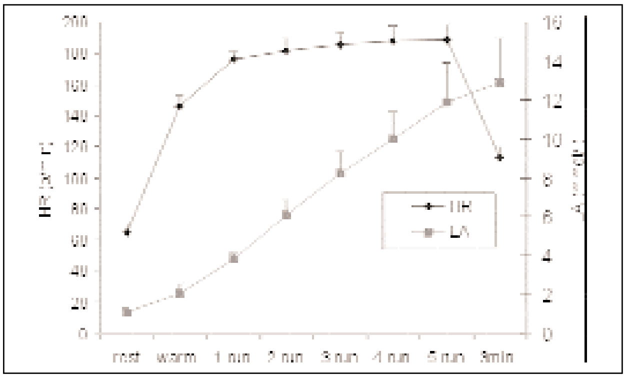


Fig. 3. Dynamics of the heart rate frequency and the kinetics of lactate in blood in continuous run (left) and in interval runs (right). Values are means ± SD



pleted interval runs was 11.9 ± 2.3 mmol. 1^{-1}, while in three minutes after the completed loading it increased to 12.9 ± 2.7 mmol .1^{-1}. The heart rate after interval runs was 189 ± 11 beats . min^{-1}. The difference (6.1 mmol.1^{-1}) in the concentration of lactate in blood after different running loads is statistically significant ($P < 0.001$). The differences in the value of the heart rate after completed running loads do not, however, reach the level of statistical significance ($P = 0.102$).

The influence of running loads on the decrease of voluntary and electrically stimulated muscle contraction. The changes in the torque T_{MVC} and T_{MVC+ES} during a voluntary isometric contraction in the duration of 25 seconds in the state of resting and after various running loads are shown in Table 1.

In all measurements, except in resting - before interval runs, the torque T_{MVC} decreased during the 25-second isometric contraction. The changes in the torque T_{MVC} attained the level of statistical significance in no measurement. In contrast to the dynamics of the torque T_{MVC}, the decrease in the torque T_{MVC+ES} during the isometric contraction lasting 25 seconds was more pronounced. The decrease in the torque by 6,6 ± 3,9 after INT , 7.7 ± 6.3 % before, and by 8.3 ± 10.1 % after the continuous load were also statistically significant ($P < 0.05$). In all measurements, the dynamics of the decrease of the torque T_{MVC+ES} was more pronounced than the decrease in the torque of voluntary muscle contraction.

The differences between the influence of the various running loads on the level of decrease T_{MVC} in T_{MVC+ES} during of 25 second isometric contraction were very small and statistically non-significant.

The influence of running loads on the level of muscle activation. The influence of INT and CON on the level of muscle activation AL1 and AL2 is shown in Table 1.

Increase of AL1 after both running loads was very similar and close to statistical significance. After INT AL1 increased by 5 ± 12% ($P = 0.067$) and after CON by 4.6 ± 13.5% ($P = 0.087$). The level of activation AL2 in all measurements was higher than AL1.

The increase in the level of muscle activation AL2 (compared with AL1) was statistically significant ($P < 0.05$) in both measurements before load, while after the runs the rise of muscle activation during isometric contraction was lower and statistically non-significant.

The increase in the activation level of AL1 after both running loads and higher values of AL2 in comparison with AL1 are the consequence of a more rapid

TABLE 1: The influence of interval runs (INT) and continuous run (CON) on changes of torque of voluntary (T_{MVC}) and electrically stimulated muscle contraction (T_{MVC+ES}), on level of muscle activation (AL) and index of central fatigue (In CF).

	INTERVAL RUNS (INT)								
	T_{MVC1} (Nm)	**T_{MVC2}(Nm)**	**InT_{MVC}(%)**	**$T_{MVC+ES1}$(Nm)**	**$T_{MVC+ES2}$ (Nm)**	**InT_{MVC+ES}(%)**	**AL1(%)**	**AL2(%)**	**InCF**
Before	132 ± 27	137 ± 31	-4 ± 6.9	186 ± 36	175 ± 43	5.6 ± 4.1	70.9 ± 11	**78.2 ± 12P**	-9.6
After	131 ± 33	129 ± 29	1.8 ± 3.1	176 ± 32	**164 ± 32±**	**6.6 ± 3.9***	74.4 ± 7	78.1 ± 9	-4.4
	CONTINUOUS RUN (CON)								
	T_{MVC1} (Nm)	**T_{MVC2}(Nm)**	**InT_{MVC}(%)**	**$T_{MVC+ES1}$(Nm)**	**$T_{MVC+ES2}$ (Nm)**	**InT_{MVC+ES}(%)**	**AL1(%)**	**AL2(%)**	**In CF**
Before	134 ± 31	132 ± 23	1.3 ± 2.1	187 ± 29	**174 ± 32±**	**7.7 ± 6.3***	71.7 ± 9	**75.9 ± 13 P**	-6.4
After	135 ± 26	128 ± 27	4.8 ± 2.9	180 ± 33	**165 ± 32±**	**8.3 ± 10.1***	75 ± 6	77.6 ± 9	-3.5

Values are means SD; n = 7 subjects; ± = significant differences (P 0,05) between $T_{MVC\pm ES1}$ and $T_{MVC\pm ES2}$; * = significant differences (P 0,05) between In $T_{MVC\pm ES1}$ and $T_{MVC\pm ES2}$ (relative changes); **P** = significant differences (P 0,05) between AL1 and AL2.

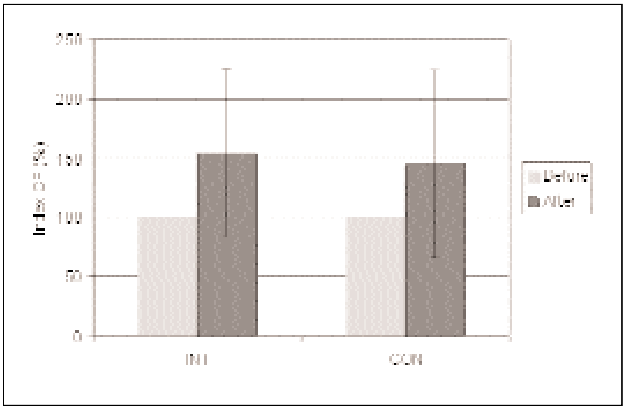


Fig. 4. The influence of interval (INT) and continuous (CON) loading on the relative change (means ± SD) of the import of central fatigue on the muscular function.

decrease of torque TMVC±ES in comparison with the dynamics of T_{MVC} decrease.

The influence of running loads on central fatigue.

The influence of INT and CON on the index of central fatigue is shown in figure 4 and Table 1. Before the loads, the differences between the decrease in In T_{MVC} and In $T_{MVC + ES}$ were 9.6 % and 6.4 %, respectively ($P < 0.05$), while after the runs they reduced to 4.4 % and 3.5 %, respectively, and thus fell below the threshold of statistical significance. After the running loads, the drop in the torque of voluntary and electrically stimulated muscle contraction increased; however, the differences did not attain the level statistical significance. The index of central fatigue was smaller than 0 in the state of resting and after both loads. Compared with the values before the loading, In CF increased after the loads; however, the differences did not attain the level of statistical significance. The differences in the influence of the role of central fatigue in neuromuscular fatigue after the various running loads did not reach the threshold of statistical significance as well.

Central fatigue in individual test subjects. The values of the index of central fatigue for individual test subjects and individual measurements are given in Table 2. Although the average In CF of the sample of test subjects does not show the presence of central fatigue, it is possible to establish, by comparison of the results of individual test subjects, statistically significant ($P < 0.05$) differences in the role of central fatigue on the efficiency of their neuromuscular system. In two subjects, central fatigue did not occur in any measurement; in three subjects it occurred in one measurement; in two subjects it was possible to speak about the influence of central fatigue in two measurements. A pronounced presence of central fatigue after both running loads could be established in one test subject; in two subjects only after a prolonged continuous loading.

Table 2. Values of the index of central fatigue (In CF) for individual test subjects.

MEASUREMENT SUBJECT	In CF Before CON	In CF After CON	In CF Before INT	In CF After INT	AVERAGE In CF	P
1.	-12.5	11.59	-9	-7.54	-5.27	0.042
2.	-6.44	4.36	7.22	-9.43	-1.00	
3.	3.22	-10.1	-7.5	-14.56	-7.52	
4.	-4.08	8.34	-2.53	14.79	4.13	
5.	1.08	-9.9	-15.31	-8.78	-9.53	
6.	-8.5	-14.12	-17.11	-6.73	-11.65	
7.	-17.52	-12.09	-17.41	-0.57	-11.89	

DISCUSSION

The influence of running loads on the role of central fatigue on the efficiency of neuromuscular system.

On the basis of comparisons between the dynamics of the decrease in voluntary and electrically stimulated contraction and the dynamics of the changing of muscle activation during an isometric effort lasting 25 seconds it was possible to establish that the force during electrical stimulation was falling faster after running loads than the voluntary force and that during maximal isometric contraction of 25 seconds, the level of muscle activation increased. On the basis of these results it is possible to conclude with certainty that the decline in muscle function after both running loads was the consequence of peripheral fatigue.

Since the recuperation of the muscle's contractile abilities (twitch torque, MVC, torque of muscular contraction at high frequency stimulation) after intensive loads is quick (the twitch torque achieves the state before the intensive cyclic loading already after 6-7 minutes) (Škof, 1993; Vollestad, Sejersted and Saugen, 1997), is should be taken into account that the decrease in torque of voluntary muscular contraction, as well as the decrease of $T_{MVC + ES}$ during the 25 s isometric contraction immediately after the running loads, would be greater than that measured in this study (in the 4^{th} minute after the running). It is also possible to conclude that the ratio between both parameters would not change significantly in that case.

The values of decrease of T_{MVC} in endurance-trained test subjects in our study point to a different response than in untrained test subjects of various ages in the studies (Bigland-Ritchie, Jones, Hosking and Edwards, 1978; Bigland-Ritchie, Furbush and Woods, 1986; Gandevia, Allen and Mc Kenzie, 1995; Mc Kenzie, Bigland-Ritchie, Gorman and Gandevia, 1992).

The average decrease in T_{MVC} in our research amounted to 1.7 %, and in untrained subjects at the same duration it was 8 to 15 %. An even more essential difference between the results of our research and the mentioned ones shows the fact that the degree of decreasing of TMVC in trained subjects was by 6 % (in individual subjects even up to 15 %) lower than the degree of decreasing of electrically stimulated contraction. In the research by Bigland – Ritchie, Furbush and Woods (1986), the fall in the force of voluntary and electrically stimulated contraction of the quadriceps muscle was the same in untrained subjects.

It is possible to conclude that athletes trained in endurance are able to activate more adequately the CNS in the state of fatigue, thereby at least partly compensating the influences of the mechanisms of peripheral muscle fatigue. This hypothesis is confirmed (even if not statistically significantly) by the increase in muscle activation after both running loads.

A relatively good maintenance of the level of voluntary muscle contraction (high endurance, which shows through the low decrease in T_{MVC} during 25-second maximal isometric contraction) can, however, be explained with the »muscle wisdom« (Enoka, 1991) – the mechanism of regulation of the frequency of triggering - excitation of motor units (Bigland-Ritchie, Jones, Hosking and Edwards, 1978; Jones, Bigland-Ritchie and Edwards, 1979). From the results of the research it is possible to conclude that test subjects well trained in endurance are able to control the triggering of nervous impulses which ensures better maintenance of sub-maximal muscle contraction.

Although the decline in muscle function was also after running loads of a local nature - the consequence of peripheral fatigue, the increased dynamics of drop of T_{MVC} after running loads (decrease of T_{MVC} is bigger than $T_{MVC + ES}$) can also be connected with the increase in the influence of central fatigue.

Intensive loads which cause a pronounced increase of acidosis and a pronounced decrease in peripheral function of muscle contraction cause at the same time negative influences on the central mechanisms of the control of movement. A high acidosis, the function III and IV of afferent paths weakens, which can produce a decrease in the frequency in activation of motor units (Gandevia, Allen and Mc Kenzie, 1995; Mc Comas, 1992). At high-intensive loads, the oxidation of branched amino acids BCAA in muscles increases as an energy substitute for exhausted glycogen reserves in prolonged high-intensity loads due to which the quantity of tryptophane in the CNS increases. This can reduce the activity of thalamus and reticular formation (Newsholme, Leech and Duester, 1994; Snyder, 1998). A prolonged or intensive flow of nervous impulses can produce a decline in the efficiency of the transfer at synaptic places – central fatigue due to the various biochemical reasons (drop in pH, exhaustion of transmitters) (Astrand and Rodahl, 1986; Guyton, 1980).

Due to the transgressed threshold of acidosis in both running loads, it was not possible - despite a relatively high difference in the speed of running between the two running loads - to prove the differences in the influence of two different cyclic loads on the level of muscle activation, the ability of preserving isometric muscle contraction and the mechanisms of fatigue.

Central fatigue in individual test subjects.

Although a highly selected sample of well-trained runners was selected there was a significant difference between the subjects in the ability of maintaining a high muscle efficiency during test measurement causing fatigue before and after demanding running loads. From the analysis of the results of individual test subjects it is possible to establish a different influence of the mechanisms of central fatigue. The increase in the influence of central mechanisms on the fall of muscle function in our research could not be simply attributed only to elevated acidosis since the connection between the CF index and LA is low ($r = 0.15$ and 0.14). The differences in the threshold of occurrence of central fatigue are affected by a whole cluster of mechanisms (some are described at the beginning of this chapter), also of a psychological nature, especially the level of the threshold of sustaining pain and discomfort (Shephard and Astrand, 1995).

CONCLUSIONS

On the basis of the results of the research it has been possible to conclude:

1) The decline in muscle contractile abilities after running loads was a consequence of peripheral fatigue.

2) The influence of central fatigue increased after the running loads, but there were no differences bet-

ween INT and CON in their influence on central fatigue.

3) The research has also shown that central fatigue can be the cause of the decrease in the efficiency of muscular function in a well-trained individual. Sports training and psychological preparation of competitors in endurance sports develop the ability of maintaining high activity of central mechanisms also in the state of fatigue. Therefore the checking of the efficiency or the diagnosing of this kind of effects of training, and especially the identification of athletes with poorer performance (efficiency) of central mechanisms is appropriate and useful.

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