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INFLUENCE OF TWO DIFFERENT CYCLIC LOADS ON THE MUSCLE FATIGUE AND THE MUSCLE ENDURANCE ABILITY

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UČINEK DVEH RAZLIČNIH CIKLIČNIH OBREMENITEV NA MIŠIČNO UTRUJENOST IN VZDRŽLJIVOST

ABSTRACT

On the basis of a selected sample of 8 middle and long distance runners and the chosen measurement method, we tried to determine the influence of a 6-km long continuous run at the speed V_{OBLA} and interval anaerobic lactate running loads of 5 x 300m in sub-maximal velocity with one minute breaks, on the endurance ability of the neuromuscular system.

The most significant conclusions are:

1. The decrease in the endurance ability of the neuromuscular system is, after a continuous duration of aerobic load, greater than after a more intensive anaerobic lactate interval loading.

2. The effect of central mechanisms on the state of muscle fatigue increases after cyclic monostructural loading, but in well trained subjects the influence of central fatigue does not dominate under any condition.

Key words: endurance, running, fatigue, neuromuscular system

POVZETEK

Na podlagi izbranega vzorca osmih kakovostnih tekačev na srednje in dolge proge in izbranega merilnega postopka smo ugotavljali vpliv 6km dolgega neprekinjenega teka pri hitrosti V_{OBLA} in intervalne anaerobno laktatne tekaške obremenitve 5 krat 300m v submaksimalni hitrosti z minuto vmesnega odmora na vzdržljivostno sposobnost živčno-mišičnega sistema.

Najpomembnejša zaključka sta:

1. Zmanjšanje vzdržljivostne sposobnosti živčno-mišičnega sistema je po neprekinjeni dolgotrajni aerobni obremenitvi večje kot po intenzivnejši anaerobno laktatni intervalni obremenitvi.

2. Vpliv centralnih mehanizmov na mišično utrujenost se po ciklični monostrukturni obremenitvi poveča, toda pri dobro treniranih preiskovancih vpliv centralne utrujenosti v nobenem primeru ne prevladuje.

Ključne besede: vzdržljivost, tek, utrujenost, živčno-mišični sistem

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I. INTRODUCTION

The decrease in muscle function efficiency (decrease of different motoric abilities: strength, speed, endurance, etc.) during intensive sport activity is the result of biochemical changes in the central nervous system (central mechanisms of fatigue), biochemical and biophysical changes in efficiency of other organic systems (7,9, 12,18). The condition of muscle fatigue is a complex biological phenomenon influenced by various and numerous physiological and psychological factors. Different types of sport activities (regarding intensity, duration, technical complexity, etc.) not only cause different degrees of muscle efficiency (fatigue) decrease, but considering data and finds of lab researches (2, 3, 4, 5, 9, 10, 11, 15, 20), in which the principles of muscle fatigue were studied on the population (not selected) under non-typical sport loads, muscle fatigue, after various exertions, also has different origins (influence of central and peripheral mechanisms of fatigue is different under different loads).

In this paper we want to establish the degree of the neuromuscular system endurance abilities drop caused by different cyclic monostructural (running) loads – a continuous 6-km long run at the speed of the anaerobic threshold (criterion V_{OBLA}) and an interval run of 5 times 300 m in sub-maximal speed with one minute breaks. We also want to determine the effect of the neuromuscular activity of central mechanisms on the decrease in endurance abilities. Our point of interest are also the possible differences between individual characteristics of muscle fatigue (degree and origin) after typical sport loads.

II. METHODS

Subject sample

The subject sample comprised 8 well trained middle and long distance runners. Their average age was 25.3 ± 4.1 years, body weight 62.5 ± 4.1 kg and body height 176 ± 3.6 cm. All are experienced athletic runners, being in training from 5-15 years, in average 9 ± 3 years.

Process and organisation of the experiment

The experiment was executed in two phases. The initial phase of the experimental procedure was carried out in a laboratory as preparation for further field measurements.

The first task of the experiment was to acquaint the subjects with the measurement technology and methods, to come to know and get accustomed to the sensation of electrical excitation of the muscle as well as to determine the fundamental parameters of loads of current intensity stimulation impulses at the chosen frequency of 100 Hz. Determining the parameters of the current intensity of the high frequency electrical impulses trains was done by gradual increase of current intensity. Such intensity of electrical impulses of frequency 100 Hz was chosen that each individual subject could just tolerate.

The second significant task in this phase of the experiment was the establishing of the basic functional and motoric parameters of the runner's present condition. The results of these measurements were used for an objective starting point in planning of individual subject's suitable – relatively equal test loads.

The second phase of the experiment presented the measurements on an athletic stadium. Each subject was measured by a series of experimental methods (functionally-biochemical and biomechanical) in the rest phase, after warm-up – preparation for loading – and 5 minutes after test loading on the athletic track (the functional and biochemical parameters were followed also during the test load itself and also after its termination). Each subject had to perform two measurements; once with interval and once with continuous long lasting running test load. Between the two tests of the same subjects at least 3 days passed.

Tests, measurements and criteria for formation of individual parameters

Determining the subject's running condition

For the assessment of the present efficiency of runners, two tests were used:

a) 400-m run test: The test was performed on the athletic stadium on plastic tracks. The subject tried to run the 400-m track as fast as possible. The run duration was measured with accuracy of up to ± 0,1 second.

b) test of repetitive 5-minute runs with gradual speed increase. The test was performed on a treadmill and consisted of 5-8 five minute runs. The speed of individual runs was regular and constant, but gradually increased from run to run for 0,2 m/sec. With the help of the Beaver & collaborators (1,22) method, on the basis of the lactate kinetics (LA) in the test of repetitive 5 minute runs, we can calculate the running speed which is defined by the lactate (LP) and the anaerobic (Onset of Blood Lactic Acid – OBLA) thresholds criterion.

For the experimental aerobic load, a continuous 6 km long run, at the speed of the anaerobic threshold (V_{OBLA}) was selected, and measured for each individual subject on a treadmill.

For the test training of the lactate anaerobic load we selected repetitive 300-m runs. The load decided on was 5 x 300 m in sub-maximal speed with short, one minute intervals. The time of repeated runs was longer for 10 % than three quarters of the 400-m test run time.

T300 m = (T400 m / 4) x 3 + 10 % (equation 1)

Functional and biochemical parameters

a) Heart rate
The heart rate frequency was measured by pulsimeters PE 3000 (Polar Electro, Finland). The values were recorded every 15 seconds.

b) Lactate concentration in the blood after the running load
The concentration of lactate in the blood was measured by Konton 640 Lactate Analyser (Konton, Austria) always directly after taking a blood sample from the earlobe. In interval loading the blood sample was taken after every 300-m run, while in the 6-km long continuous run it was taken at 3600 m and at the end of the run.

Biochemical parameters of different muscle contractions

The efficiency of muscle contractions was measured by the torque in the knee joint with a suitable support. For measuring the torque with a constant handle we used a compress-strain tensor and an alternating voltage amplifier (both constructed by MES, Maribor)

Electrical stimulation

A two-channel current stimulator (home made) was used. All impulses were bi-phasal and rectangular in shape. The following experimental procedure by use of electrical stimulation was performed:

Procedure presentation:

During maximal isometric contraction of the quadriceps femuris muscle, which lasted for 25 seconds, the muscles vastus lateralis and vastus medialis were additionally stimulated by three short 0,8-second trains of electrical impulses of frequency 100 Hz. The first impulse was released in the 3rd second of the voluntary concentric muscle contraction, while the other two followed at intervals of 10.2 seconds. A contextually similar measurement procedure is known from the research of Biglad-Ritchie & collaborators, 1978 (2).

Position of the subject during measurement

During measurement the subject lay on the back on a special bench in such a position that the shanks fell freely (Figure 1). The position of the pelvic girdle was additionally fixed with a special band. Prior to the start of the experiment the subject was only leaning the push-off leg on the support (knee angle was 45 degrees) and on signal started to exert pressure onto it with all force, trying to maintain the maximal force for 25 seconds.

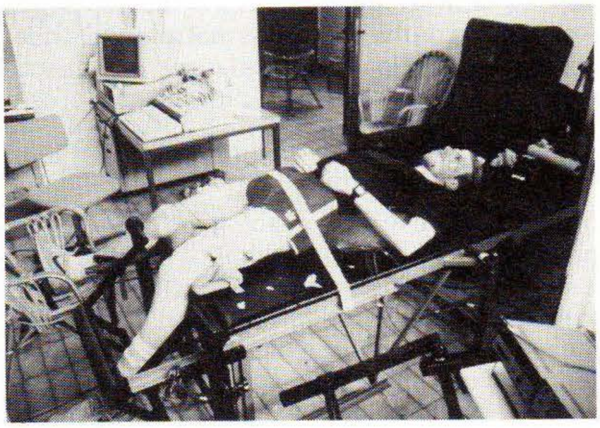

Figure 1: Position of subject during measurement

The surface stimulation of the vastus lateralis and vastus medialis muscles was carried out by electrodes of 5 x 8 cm in size. One electrode was attached onto the motoric spot of the muscle, the other onto its distal part. Both electrodes were additionally fixed by a medical net. The intensity of electrical impulses was determined for each subject separately according to his/her level of electrical stimulation tolerance ability and was constant all through the measurement.

Analysis of the 25-second long voluntary isometric contraction with intermediate periodical electrical impulse trains

Endurance ability of the muscle contractile system is described by two parameters:

a) Index of the decrease of voluntary contraction force Uz

$Uz = (F_{M3} - F_{M2}) \times F_{M2}^{-1} \times 100$ (equation 2)

The Uz index represents the dynamics of contraction force decrease of the muscle during the 25-sec-

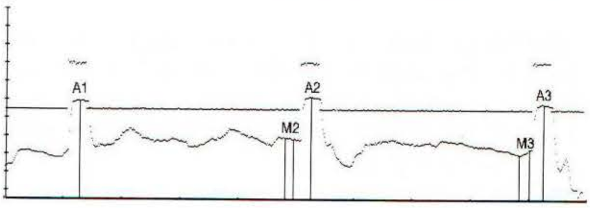

Figure 2: Recording of the muscle force during the 25-second long maximum isometric contraction with an additional periodical electrical stimulation (for symbols see text)

ond maximal isometric contraction in the interval between the 12th and 25th second.

b) Contraction force at the end of the 25-second isometric contraction (F_{M3}):
The average value of the force (F_{M2} and F_{M3}) in the time interval of 0.5 seconds directly before the additional stimulation of the muscle by a short electrical impulse of 0.8 seconds and of frequency 100 Hz (A2 and A3), was selected (Figure 2).
The influence of central mechanisms on muscle fatigue is defined by the difference between index Uz and index Us (equation 3), which represents the dynamics of the decrease of electrically stimulated muscle force during the 35-second period.

$$Us = (F_{A3} - F_{A2}) \times F_{A2}^{-1} \times 100 \quad \text{(equation 3)}$$

$$I_{CU} = Uz - Us \quad \text{(equation 4)}$$

In case of the drop of the central fatigue index bellow zero ($I_{CU} < 0$), in cases when the drop of voluntary muscle force is greater than the drop of the electrically stimulated muscle force (in case of the presence of the decrease of muscle force – fatigue, the fatigue index has a negative fore-sign), all points to the presence and predominant influence of central fatigue mechanisms on neuromuscular fatigue.

Muscle activation index

The muscle activation index contributes greatly to the elucidation of the problem of the muscle endurance ability as well as of the problem of assessing the presence of muscle fatigue central mechanisms.

The index of muscle activation is expressed as the ratio of the size of voluntary muscle force and the muscle force stimulated by electrical impulse.

$$I_{MA} = F_{M2} \times F_{A2}\text{-}1 \quad \text{i.e.} \quad F_{M3} \times F_{A3}\text{-}1 \quad \text{(equation 5)}$$

Statistical methods

For determining statistical significance among the results of individual parameters in various steps of measurement and among the results of parameters of different loads, the Student T-test was used.

All results were relativised according to the parameter value before loading – warm-up state, which we chose as criterial value. The value of the relativised parameter (Rp) was determined by the ratio of the difference in the values of the parameter at an individual point of measurement (Rx) and before loading (Rpred), and the value before loading (Rpred):

$$Rp = (Rx - Rpred) \times Rpred^{-1} \times 100 \quad \text{(equation 6)}$$

III. RESULTS

BIOCHEMICAL AND FUNCTIONAL PARAMETERS BEFORE, DURING AND AFTER VARIOUS TYPES OF CYCLIC LOADS

Continuous load

The average speed of the 6-km run is 4.96 m/s, for the selected sample of subjects, which is in accordance with the speed chosen on the basis of test loading. The average speed at the anaerobic threshold by the V_{OBLA} criterion was, for the selected sample of runners, 5.02 m/s. In spite of the fact that the subjects ran at the speed of the anaerobic threshold by the V_{OBLA} criterion, the concentration of lactate exceeded 4 mmol/l. After running 3600 m the average concentration was between 5 and 5.5 mmol/l, at the end of the run it increased to 6.3 mmol/l (Figure 3).

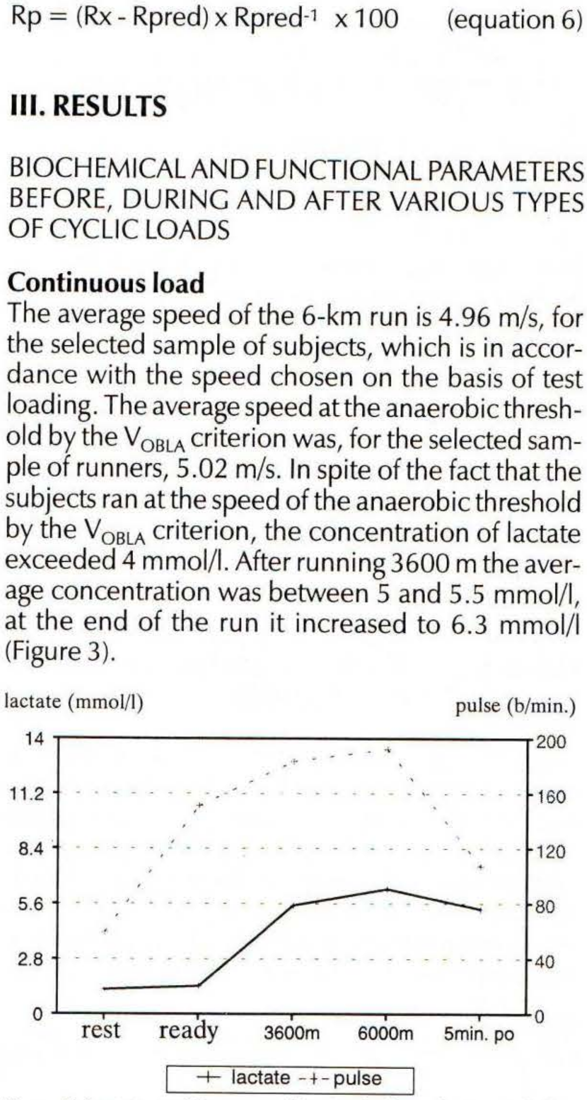

Figure 3: Lactate and heart rate kinetics before, during and after continuous running.

Interval load

The planned average running speed in this test load was 6.6 m/s, while the actual speed of interval runs was for 0.2 m/s faster. Lactate concentration in the blood increased linearly from run to run. At each following run the lactate increase was approximately 2 mmol/l. In this way, at the end of the 5th run, the lactate concentration reached the value of 11, or 11.5 mmol/l (Figure 4).

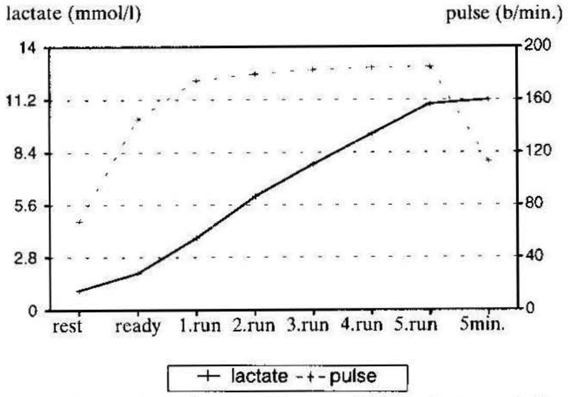

Figure 4: Lactate and heart rate kinetics before, during and after interval load

From the viewpoint of the intensity of the metabolic processes, the two experimental loads differ (although the differences in lactate concentrations before and 5 minutes after different loading do not reach statistical significance P = 0.125), in regard to the exercise of the cardiovascular system, illustrated by the heart rate, there were no differences between the interval lactate training and continuous running tempo (P = 0.807). The frequency of the heart rate in both types of exercise reached its maximal values (Figures 3,4).

INFLUENCE OF THE CYCLIC MONOSTRUCTURAL EXERCISE ON THE ENDURANCE ABILITY OF MUSCULAR CONTRACTION

The decrease dynamics of the muscle contraction force during the 25-second maximal isometric contraction Uz, after the 6 km long continuous run, is 4.7 % and is more distinct than after the interval run exercise, where the decrease in muscle endurance ability is only 2.7 % (Table 1). None of these differences reach the threshold of statistical significance. Also the second parameter of the endurance ability,

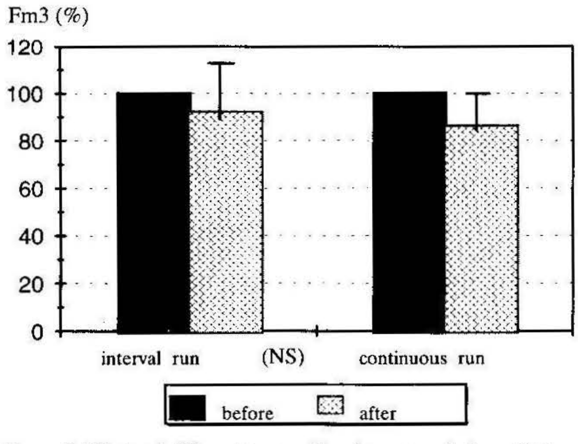

Figure 5: Effects of different types of loads on muscle force FM3

force FM3 is, after continuous exercise running, for 13.7 ± 12 % smaller than the force before exertion (the difference is statistically significant), while the interval load causes only 7.6 ± 21,4 % drop of the isometric force (Figure 5).

The difference of 6.1 % between the influences of continuous and interval exercise on the voluntary muscle force FM3 is not statistically significant (P = 0.239).

AN ATTEMPT AT ASSESSING THE PRESENCE OF CENTRAL FATIGUE AND THE EFFECT OF CYCLIC MONOSTRUCTURAL EXERCISE ON CENTRAL FATIGUE MECHANISMS

Dynamics of voluntary and electrically stimulated muscle force before loading

The index of decrease in voluntary muscle force Uz, was in the phase before the interval workout loading 2,2 % (increase of force) and after the continuous run – 4.1 % (Table 1).

The dynamics of isometric muscle force in the interval between two points of isometric contraction follow-through, is very different from subject to subject. With some, this force decreases, with others it increases. It is therefore impossible to form any general principles.

More distinctive and much more consistent are the changes in forces of the complete muscle potential represented by the greatest voluntary force together with the force caused by additional electrical impulse of high frequency alongside the biggest voluntary contraction. With one exception, the stimulation force decreased with all subjects. The index of the decrease in the complete contractile potential Us in a rested muscle was, before interval loading, –3.7 ± 4.3 % and –7.7 ± 4 % before continuous loading. From the analysis of results in table 1, it is possible to establish that the decrease in electrically

Table 1: Index of decrease in voluntary and electrically stimulated muscle force Uz and Us (AS ± SD) and the difference of the state before and after different load types (AS ± SD)

Load type	before load	after load	difference %	P
Parameter				
Uz (%)	2.2± 9.8	-2.7± 5.9	4.9± 13.9	*
Interval run				
Us (%)	-3.7± 4.3	-6.5± 4.9	2.7± 5.9	NS
Uz (%)	-4.1± 6.3	-4.7± 5.6	0.5± 5.5	NS
Continuous run				
Us (%)	-7.7± 4	-5.9± 2.5	1.9± 3.8	NS

stimulated muscle force, during the period of 25 seconds, is greater in comparison to the dynamics of the decrease of voluntary isometric force. This means that the reasons for muscle fatigue are mainly of peripheral character. The analysis of individual subjects also shows that the signs of central fatigue do not predominate in one single case. Quite the opposite. The subjects, even when tired, were able to activate the muscle even more and in this way lower the activation deficit (increase of "muscle advantage") (Table 3).

Dynamics of voluntary and electrically stimulated muscle force after loading

The decrease in voluntary muscle force is, in the state after interval loading, 2.7 ± 5.9 %, after continuous loading 4.6 ± 5.6 % (Table 1).

From the analysis of the result dynamics of individual subjects, we can establish that the trends of voluntary as well as of stimulated muscle force, after termination of the running load, are more consistent compared to the results before exertion. With only one subject the voluntary isometric muscle force increased, while with all others the voluntary as well as the stimulated force decreased as expected. The index of decrease in the stimulation force is, also after the running load, higher than the index of decrease of isometric muscle force, confirming that the basic reasons for the decrease in contractile muscle ability can be found mainly in peripheral mechanisms. But the results in Table 1 show that, after the end of the running load, the difference between indexes Uz and Us grew smaller. Before loading this difference was 5.9, i.e. 3.6 %, after loading it was 3.8 (after interval runs) and 1.2 % after continuous exertion. The decrease in the differences between the degree of fatiguing of voluntary and of stimulated muscle contractions after loading signifies an increase in the influence of central fatigue mechanisms. The index of central fatigue Icu decreased after both loads. But the values of (Icu) were, even after interval and continuous runs, distinctly greater than 0, which means that the main reasons of the decrease in isometric muscle force are still mostly biochemical and biophysical changes in the muscle contractile system – therefore the peripheral muscle mechanisms (Table 2).

Table 2: Index of central fatigue (Icu) before and after loading and the difference in state before and after load of different type (AS ± SD)

Measurment time.	before load	after load	difference %	P
Load type				
Interval run	5.9± 6.4	3.8± 6.2	2.2± 11.8	NS
Continuous run	3.6± 4.3	1.2± 4.8	1.4± 5	NS
Difference	1.4± 6.1	2.7± 8.4		

The confirmation of this assertion is also an increase in the index of muscle activation, the "muscle advantage" in the fatigue state. (Table 3).

IV. DISCUSSION

The decrease in muscle endurance ability means an increased sensitivity of the neuromuscular system towards the change of the homeostatic state - the worsening of biochemical and biophysical conditions (fatigue) in individual organic systems (7, 14, 18). The fatigue of the neuromuscular system is, after intensive sport burdening such as interval and continuous running, in our research, mainly the result of the accumulation of metabolic products, increased acidosis, also the exhaustion of the energy deposits, i.e. disturbance in the functioning of individual energetic processes (7, 12, 13, 14, 17, 18, 19, 21) Increased acidosis (high level of H+ ion concentration) weakens the re-phosphorisation (processes of glycolysis) and by this causes the obstruction of the restoration of ATP (14,19,21). The decrease in pH also causes, through the weakening of the Na+K+ATP-iasis functioning, a changed electrolytic balance which provokes disturbances in circulation of action potential into the muscle cell (8,16,21). Increased concentration of H+ ions, which develops during the formation of lactate, with glycogenolysis inhibits certain active parts of myosin and through this directly lowers the efficiency of muscle contraction (19, 21).

In different intensity of run loading, the activity of various motoric units with different muscle tissues, differs. Due to this, the magnitude of biochemical and biophysical changes – disturbances, in individual muscles varies.

The results of the research show that the decrease in the endurance ability of the muscle contractile system, after long and continuous aerobic burdening, is greater than after more intensive anaerobic lactate exertion.

Table 3: Index of muscle activation IMA (AS ± SD) and the difference in state before, after loading and load of different type (AS ±SD)

Load type	before load	after load	difference	P
Parameter				
M2/A2	68.8%± 21.8	68%± 23.7	1.1%± 4.4	NS
Interval run				
M3/A3	71.9%± 21.3	71.8%± 26.2	0%± 7.7	NS
Difference	3.2%± 4.1	3.8%± 4.6		
M2/A2	74.6%± 15.5	66.6%± 13.8	9.8%± 13.9	*
Continuous run				
M3/A3	77.2%± 14.9	67.8%± 15.9	11.1± 12.1	*
Difference	2.5%± 3.2	1.2%± 2.6		

On the basis of the research results and data from other studies (3, 4, 5, 8, 15, 16), it appears that the continuous 6-km run and the sustainment of maximal isometric contraction over a longer period of time, cause fatigue of motoric units with a similar frequency of triggering and those differing from the ones in more intensive interval runs.

At the beginning, electrical impulses of high frequency take care of maintaining the 25-second maximal isometric contractions, at the end of the load, when the value of the muscle force FM3 and the decrease in the contraction force Uz have been measured, by lowering the frequency of the action potential, muscle force is sustained by electrical impulses of lower frequency.

Jones and Bigland-Ritchie & collaborators, in their researches, found, with the aid of electromyographic technology (3, 4, 15, 16), that the maximal isometric contraction of the adductor pollicis muscle is achieved by the nervous impulse with a frequency of about 60 Hz. The frequency of nervous impulses rapidly diminishes after only a few seconds of maximal contraction. Bigland-Ritchie (4, 5) discovered that, during maximal isometric contraction, the frequency of motoric units' stretching decreased in less than one minute by 50 % (from 27 Hz to 14 Hz). With the lowering of the excitation frequency, muscle force decreases as well, but not in complete interdependence.

Maximal isometric forces are triggered by high frequency nervous impulses. Lasting sustainment of maximal force on the same level is prevented by a relatively fast fall of the action potential (lower frequency) as well as by changes in the muscle cell (changes of the Ca_{2+} accumulation in the T-tubules and inter-tissue space of the muscle, changes of ion concentration in the extracellular fluid (12, 13, 14). Taking into account that in both types of running loads, the motoric units with low triggering frequency are probably more active, these motoric units, due to fatigue under special running loads, by the end of the 25-second isometric contraction, when the force FM3 and the index Uz are measured, contribute a lesser part to the common contractile force. If this hypothesis holds then the following question is in place: is the frequency of motoric units' stretching in both running loads and during the 25 second maximal isometric contraction really completely equal (about 20 Hz – low-frequency peripheral fatigue)(20)? By use of available experimental technology, we could not assess these differences in our research. Regarding a greater decrease in voluntary muscle force after continuous lasting load, it is possible to conclude that, in continuous lasting run, as well as after the end of the 25 second maximal isometric contraction, motoric units with similar frequency of stretching, which is lower than the stretching of motoric units in faster interval runs, are probably activated.

The improvement of the experimental method for assessing the endurance functions of the muscle contractile system is certainly in the extension of the follow-through period of isometric force dynamics and in searching for a possibility to follow the influences of fatigue of individual sport loads with a test exercise which is, regarding load method, similar or equal to the sport exercise.

A more distinct decrease in voluntary muscle force after continuous lasting loading is also the result of an increased influence of central mechanisms. Muscle fatigue is a very complex state, which not only depends on biophysical, biochemical and other changes in the muscle itself, but also changes in other organic systems exert strong influence on this state, especially CNS (2, 9, 10, 12, 17). The decrease in muscle efficiency has, beside physiological and neurophysiological, also its psychological background (7,14). By the mentioned experimental method we tried to assess the presence of central mechanisms (mechanisms of fatigue outside the muscle) and their influence on muscle fatigue after various running loads. The increase of central mechanisms influence upon muscle fatigue ensues from the physiological and psychological factors. The fundamental recognition of this paper is that the influence of central mechanisms on the degree of muscle fatigue in fact increases after the running load, but in the sample of selected runners it does not exceed the influence of peripheral local mechanisms.

Mechanisms of central fatigue are represented mostly by the decrease in activation abilities of motoric centres in the CNS (Central Nervous System) and the drop of efficiency of the corticospinal connection (conductivity speed of nervous impulses through the nerve tissue and across the synapses) (12). The consequences of intensive or continuous running exertion are reflected in the oversaturation of the central nervous system by very intensive flow of signals from the proprioreceptors and chemoreceptors from active areas of the organism (12, 13, 14, 18, 19). Most probably also the high level of acidosis, that is transferred by the blood from the active muscle groups into the CNS, influences the decrease in the activation efficiency of the motoric centres of the CNS, as well as the speed of nervous impulses transfer (12, 14, 19). Quite certainly the psychological barriers have a significant effect on the level of central fatigue. All these mechanisms present a physiological and biochemical basis for certain psychological functions and can cause motivation decrease.

Although the differences in central mechanism's influence on muscle fatigue, after different running loads, do not reach the threshold of statistical significance, they are still interesting and worthy of comment. The portion of central fatigue in the degree of muscle efficiency decrease is, after a continuous load (run), in regard to the value after interval runs, greater (Table 1,2). Also after lasting aerobic loading, the increase in muscle advantage at the end of the 25-second isometric contraction, is smaller than after interval loading (Table 3). Although the acidation of the organism after a 20 minute run, at the speed of 5m/s is, in comparison to the 45-second long run, at the speed of 6.8 m/s, with one minute break, quite lower, a lasting exertion and its monotony can cause a certain level of saturation ("numbness" of the nervous system motoric centres), the decrease in the runner's motivation and by this a fall in muscle contractile ability.

From the viewpoint of psychical demand, a lasting, continuous and intensive workout is more fatiguing than a repetition of shorter workouts even if these contain more intensive loads with interval breaks. In planning workout units, especially with young sportsmen/women, it is sensible to avoid frequent use of long, continuous and highly intensive loads. It is better to use interval form of workouts.

The sustainment of 25-second long maximal isometric contraction certainly demands, as every endurance activity , especially in enduring problems ensuing from the overcoming of physical exertion. Also from the analysis of the results of individual subjects it is possible to conclude that the presence of central fatigue probably does not depend so much on the type of load, but more on the psychical ability of the subject (the ability to endure subjective problems and pain in overcoming physical exertion) and on his/her endeavour in performing test exercises.

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