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# MAXIMAL INTERMITTENT EXERCISE - THE LIMITATIONS OF PERFORMANCE; COMPARISON THE TRAINED AND UNTRAINED SUBJECTS

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**Abstract.** The purpose of this study was to investigate during repeated short, high-intensity exercise (1) what limitations makes the repetitions of this exercise difficult, (2) does specialist training consisting mainly anaerobic elements decreased these limitations. Two groups of subjects (n=22) –untrained group and trained one performed three-time repeated 30 s Wingate Test with 7- min rest after each bout of exercise. This work was supramaximal –intensity because average power output during first second of 30 s test was approximately two-three times higher than that required to elicit maximum oxygen uptake. Our result has shown that about 15% and 67% of total work in both groups was performed at the cost of phosphagens and glycogenolytic yielded ATP, respectively. Three times repeated exercise resulted in the decline of values of peak power output in 5.3% and 6.8% in control group and 6.2% and 8.4% in trained group during the second and third repetitions of exercise bout, respectively. Also the amount of mean power during repetitions of exercise bout declined, but the changes were more pronounced in the control group. The recovery rate of the mean power compared to peak power was slower in the control group than the trained one. After seven minutes of recovery peak power was recovered to 94.7% and 93.2% and means power to 92.7% and 88.6% in second and third repetition of exercise bouts. The recovery rate of mean power in the trained group was faster probably due to the training-changes in sensitivity of glycogenolysis to the inhibitory effect of acidification or/and another negative factors. Based in our results we can suggest no changes in phosphagenic system caused by training containing mainly an anaerobic programme.

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*Key words:* Repeated high-intensity exercise - Total work - Peak power - Mean power – Acidification - source of energy

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## Introduction

Many sports require the repeatedly engagement in high intensity exercise of athletes. They have to repeat a high intensity exercise with varying (often short) amounts of recovery time between bouts. Most of the energy for short bout of high-intensity exercise is derived from anaerobic metabolism. The sources of ATP are store of phosphagens (ATP, ADP, PCr) and anaerobic pathway of glycogenolysis [5,9,11]. It is very practical and important problem to be able to measure anaerobic capacity of athletes. Direct measurement of substrates, intermediates and products of anaerobic energy pathway needs accurate and invasive techniques, for example muscle biopsies. Due to invasiveness of direct methods, a less invasive, so more practised, indirect techniques for measuring anaerobic capacity we required. But it is problem, because indirect approach should be validated against the direct approach. Some authors realising the difficulties of whole-body comparisons [1,2] The good model for investigation of power output during exercise is maximal cycle ergometer test introduced by Bar-Or [3,4] in which the exercise is performed at a maximal rate from the onset of exercise. In our work we based on the 30 s Wingate Test three times repeated with 7-min rest after each bout of exercise.
We examined: - performance responses to intermittent high-intensity exercise - effect of specialist training on the anaerobic capacity

## Material and Methods

Twenty-two male physical education students (mean age 22±3 years) divided into two groups: trained and untrained –control group, performed three bouts of maximal cycloergometric exercise (3 x 30- s Wingate Test). Each bout of exercise was lasting 30- s and was interspersed with 7 min of recovery. Athletes group assembles eleven students who have been training 1.5 – 3 years of javelin throw, shot put, high jump. Wingate Test lasting 30-s was performed on a Monark mechanically braked cycle ergometer. After warning up, the subjects begin pedalling as rapidly as possible during 30 s against a heavy resistance of 0.74 N/kg body mass. The load was applied before the subject starts his work. Flywheel revolutions were counted after over 3-s intervals ideally by a photocell. During each exercise we measured: value of total work, peak and mean power output in watt and watt per kg b.m., fatigue index, time during subject was approaching to peak power, time during subject sustained the peak power output.

Before and 4 min after each bout of exercise we drew arterialized blood sample, to determine parameters of acid-base equilibrium.

The Ethical Committee of Scientific Researches in University of Medical School approved this study.

Conventional statistical methods used to analyse the data. Significantly different from the respective values in following bout of exercise and difference from values in untrained and trained group being considered at the level of $P<0.05$.

## Results

Twenty-two physical education students volunteers between the age of 20 and 25 years participated in the study. All subjects were assigned to either control group (n=11 untrained subjects) or experimental group (n=11 athletes involved in a regular specialist training programme). The physical characteristics of the subjects are presented in Table 1. There were significant differences in weight between the groups. Weight of athletes group is 21.6% greater than untrained one. Performance variables are shown in Tables 2 – control group and 3 – athletes group.

**Table 1**
Antropometric and physiological characteristics of subjects of control group (n=11) and trained group (n=11)

| Parameters | Control group | | | Trained group | | |
|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range |
| Age (years) | 23.9 | 1.8 | 22-26.5 | 23.0 | 2.16 | 20-27.1 |
| Body mass (kg) | 78.7* | 11.7 | 62-1.5 | 97.0* | 12.9 | 80-120 |
| $VO_2$max (l/min) | 3.8 | 0.4 | 3.1-.9 | 4.5 | 0.4 | 4.2-5.4 |
| $VO_2$max(ml/min/kg | 46.8 | 6.0 | 39.3-9.2 | 46.7 | 7.5 | 39.3-61.4 |

*Difference between values is statistical significant, $P<0.05$

We can see that in both group power output during 30 s Wingate Test was approximately two to three times higher during first 5 s of exercise and about 1.5 times higher during last seconds of the test duration, than that required to elicit maximal oxygen uptake ($VO_2$ max). On the basis of these findings, we can qualify employing exercise as supramaximal intensity. During such the work is assumed

that anaerobic metabolism provides a large amount of ATP required. Because we did not measure the oxygen uptake during repeated high-intensity test, we accepted Bangsbo *et al.* (1990) result obtained in direct study. According their result, during a Wingate cycling test lasting 30 s 20% and 80% of the required energy is yielded by aerobic and anaerobic metabolism, respectively [2,5]. Our result shown that in bouts 2 ad 3 of exercise total amounts of work decreased in both groups. In control group drops of total work were 3.5% and 5.6% after second and third bout of exercise, respectively (Table 2). There were no significant changes in measurement of total work for the trained group in second bout of test, but during third bout decreased by 15.9% from 24.2 kJ to 20.3 kJ (Table 3). Three times repeated exercise resulted decline in value of peak power output in 4.1% and 5.7% during second and third bout, respectively in control group and 10% and 1.5% in trained group.

**Table 2**
Mean values of mechanical variables recorded in control group performing 3-times repeated 30 s Wingate Test

| Parameters | Test I | | Test II | | Test III | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Total work (kJ) | 18.9* | 2.8 | 18.23 | 2.3 | 17.91* | 2.4 |
| Total work (J/kg) | 240.8 | 21.7 | 238.7 | 19.0 | 242.0 | 20.6 |
| Peak power (W) | 828.7 | 131.7 | 794.4 | 100.1 | 740.0 | 113.5 |
| Peak power (W/kg) | 10.5 | 1.8 | 10.1 | 1.5 | 9.42 | 1.44 |
| Mean power (W) | 799.8 | 117.0 | 785.9 | 97.1 | 722.4 | 112.3 |
| Lowest power (W) | 475.4 | 64.9 | 448.3 | 64.3 | 498.0 | 120.6 |
| Time in which peak power was attained (s) | 3.28 | 0.84 | 3.38 | 0.84 | 3.0 | 0.93 |
| Time of sustaining peak power (s) | 2.53* | 1.46 | 2.28* | 1.02 | 4.05* | 1.30 |
| Fatigue index (%) | 24.6* | 6.6 | 26.2* | 6.2 | 22.5* | 6.11 |
| Maximal power required to elicit $VO_2$max | 331.4 | 32.0 | 331.4 | 32.0 | 331.4 | 32.0 |

*Difference between values is statistical significant, $P<0.05$

**Table 3**
Mean values of mechanical variables recorded in trained group performing 3 times repeated 30 s Wingate Test

| Parameters | Test I | | Test II | | Test III | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Total work (kJ) | 24.2* | 3.5 | 21.4 | 2.7 | 20.3* | 3.3 |
| Total work (J/kg) | 244.2* | 13.8 | 242.0 | 86.4 | 224.3* | 24.6 |
| Peak power (W) | 1052.4 | 163.8 | 947.2 | 186.4 | 934.5 | 114.4 |
| Peak power (W/kg) | 10.9 | 1.7 | 9.8 | 1.9 | 9.6 | 2.2 |
| Mean power (W) | 1020.4* | 142.9 | 941.2 | 181.2 | 928.7* | 211.9 |
| Lowest power (W) | 579.0 | 82.9 | 506.3 | 69.0 | 459.4 | 93.1 |
| Time in which peak power was attained (s) | 4.12 | 0.72 | 3.86 | 0.37 | 4.02 | 0.58 |
| Time of sustaining peak power (s) | 3.41* | 0.87 | 2.77* | 1.0 | 3.09 | 2.04 |
| Fatigue index % | 26.0 | 5.0 | 26.0 | 10.2 | 30.0 | 14.9 |
| Maximal power required to elicit $VO_2$max | 374.1 | 27.3 | 374.1 | 27.3 | 374.1 | 27.3 |

*Difference between values is statistical significant, $P<0.05$

The decrease of peak power output during repeated bouts of high-intensity exercise could be explained by a reduction in availability of PCr and/or by change in enzyme activity contributed in resynthesis of PCr. An explanation of a reason for the reduction in the values of peak power , can be supported by the measures of the time in which peak power was attained and the time of sustaining peak power by subject (Tables 2 and 3). It is surprising the fact that trained group needed the longer time to obtain peak power than untrained group. This difference we could explain by higher flywheel resistance (correspond with higher body mass of athletes) which they had to surmount starting the test. To define the glycogenolytic activity during lactic component of work, we measured mean power output and power drop index - named also fatigue index. Fatigue index in control group decreased from 24.6% to 22.5% during bout of high-intensity of exercise 1 and 3, respectively (Table 2). The opposite changes we stated in trained group. Fatigue index in athletes increased from 26.0% to 30.0% during the first and third bout of exercise, respectively (Table 3). The result obtained in this part of experiment can indicate that the glycogenolysis is inhibited during repeated bout of high-intensity

exercise in control group, but not affected in trained group. Inhibition of glycogenolysis can be due to decrease of keys enzyme activity and/or reducing level of muscle glycogen. In our experiments was one of the important questions regarding the proportion between the work in which energy is yielded by phosphagens degradation and by anaerobic glycogenolysis. In our calculations we accepted following the results of same authors [5,11,13], that the contribution of aerobic and anaerobic metabolism to the provision of ATP during the short-term high-intensity exercise is about 20% and 80%, respectively. Our results have shown that the about 15% and 67% of total work was performed at the cost of phosphagens and of glycogenolytic/glycolytic yielded ATP, respectively (Tables 2 and 3; Fig 1 and Fig 2 ). During repeated bouts of exercise, values of phosphagenic work increased about 2% and values of glycogenolytic work decreased about 5% in control group. Training affected changes regarding metabolism during repeated high-intensity work.

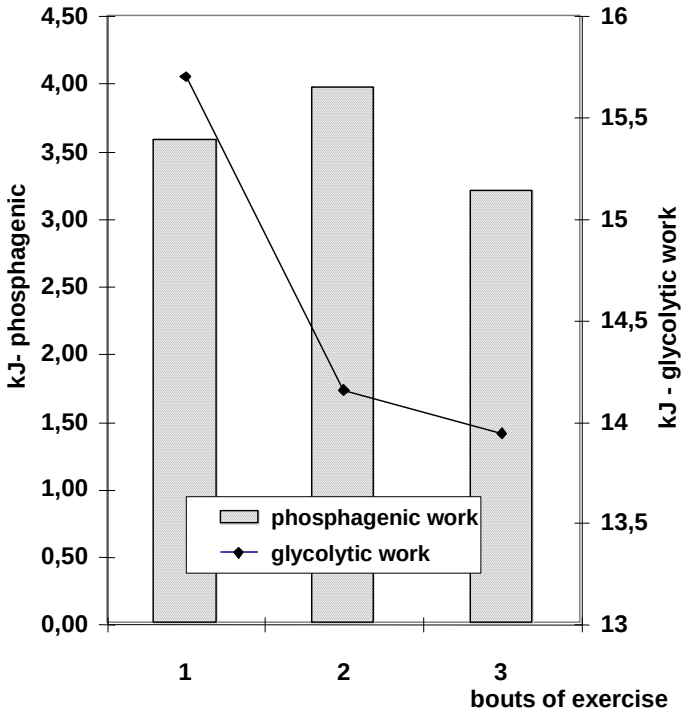


**Fig. 1**
Changes of phosphagenic and glycolitic components of total work performed by control group

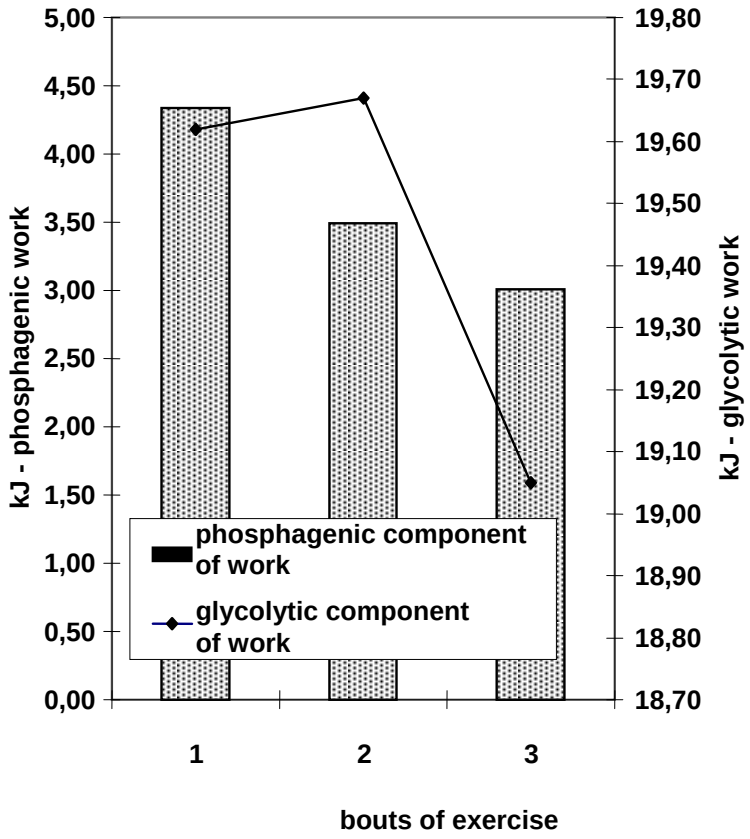


**Fig. 2**
Changes of phosphagenic and glycolytic components of total work performed by trained group

In trained group, level of phosphagenic work is slightly, but systematically decreased about 1.5% and 2% during second and third bout of exercise, respectively, while the values of glycogenolytic/glycolytic work increased about 5%.

**Table 4**
Blood acid-base status in control at rest and 4 min after each bout of 3 times repeated 30 s Wingate Test. Values are mean ±SD (n=11)

| Parameters | Rest | Test I | Test II | Test III | 15 min recovery |
|---|---|---|---|---|---|
| pH | 7.40± 0.01 | 7.20±0.04 | 7.15±0.06 | 7.11±0.06 | 7.19±0.05 |
| Bicarbonate mmol/l | 25.5±1.2 | 13.2±1.8 | 10.7±2.0 | 10.1±1.5 | 14.0±1.3 |
| pCO2 mm Hg | 41.6±3.9 | 32.2±3.8 | 26.2±4.2 | 24.2±3.6 | 28.90±5.1 |
| Base Excess (BE) mmol/l | 0.52±2.0 | -13.8±2.23 | -17.4±2.4 | -18.7±2.4 | -15.3±2.3 |

Differences between the rest's values and values of 3-bouts of exercise and recovery are statistical significant, $P<0.05$

The greater changes in blood parameters of acid-base equilibrium in athletes group during following bouts of exercise supported earlier findings testifying to increased contribution of glycolytic process after anaerobic training (Table 4).
Both value of plasma BE and [$HCO_3^-$] decreased progressively with repeated 30 s Wingate Test; from (-) 1.03±0.93 to (-) 18.9±2.2 mEq/l, and from 23.8±1.05 to 10.03±0.91 mmol/l value BE and [$HCO_3^-$], respectively. Plasma [$HCO_3^-$] reached a nadir of 8.7 mmol/l (Table 4). Comparing obtained results between control and athletes group, we can evaluate the adaptational changes caused by several years' training consisting mainly anaerobic programme. Training-induced changes we can interpreted as an increased tolerance to acidification or/and different negative factors and increased muscle glycogen stores. Another possibility is, that because the maximal workload is higher, the increased lactic acid production may represent a greater functional capacity to generate energy through anaerobic glycogenolysis/glycolysis. However, basing on our findings we can suggest no changes in phosphagenic system.

**Table 5**
Blood acid-base status in trained group at rest and 4 min after each bout of 3 times repeated 30 s Wingate Test; values are mean ±SD (n=11)

| Parameters | Rest | Test I | Test II | Test III | 15 min recovery |
|---|---|---|---|---|---|
| pH | 7.40± 0.01 | 7.20±0.03 | 7.13±0.03 | 7.08 ±0.03 | 7.18±0.05 |
| Bicarbonate mmol/l | 23.8±1.05 | 12.6±1.36 | 10.7±2.0 | 10.03±0.91 | 14.50±1.6 |
| pCO2 mm Hg | 40.5±2.8 | 31.8±4.2 | 25.6±4.3 | 24.0±3.5 | 28.90±6.0 |
| Base Excess (BE) mmol/l | -1.03±0.93 | -14.0±1.42 | -17.4±1.6 | -18.9±2.2 | -14.9±2.4 |

Differences between the rest's values and values of 3-bouts of exercise and recovery are statistical significant, $P<0.05$

## Discussion

In our work we examined the possibility of performance of repeated high-intensity exercise by untrained man and athletes. We have tried to answer the questions:

- due to what limitations high-intensity exercise repetition is problematical
- does specialist training level these limitations.

Our subjects performed 30 s Wingate Test repeated three times with 7-min recovery time between each bout of exercise. It was supramaximal-intensity work, because average power output during first seconds of 30 s test was approximately two- three times higher than that required to elicit maximum oxygen uptake. During this exercise of 30-s duration anaerobic metabolism provides a large proportion of the ATP required. During first 10 s of exercise contribution of PCr to ATP resynthesis was the major source of energy and during the last 20 s of test, glycogenolytic pathway yielded ATP [8]. However, Bogdanis *et al.* [5] have shown, that during 30 s sprinting exercise approximately 20% of the total energy required was supplied by aerobic pathway. Our results shown that in athletic group during the first bout of 30 s Wingate Test, the phosphagenic system yield about 14.5% of energy and glycogenolytic system about 65.5%. Our measurement corespondent with results of another authors. Bangsbo *et al.* [2] in direct methods

stated the partitioning of anaerobic/aerobic systems yielding energy on the level 80%/20%, respectively. The data of Karlson and Saltin [6,9] shown that the average glycolytic ATP provision rate during 30 s of high-intensity exercise will be three to four times greater than the rate of ATP provided by PCr.

It is interesting,that the mean of the phosphagenic system contribution in control group was similar to the result of athletic group, but glycogenolytic power output is lower about 6%. We can suggest that PCr degradation and the ATP muscle store during 30 s of maximal dynamic cycling was not significantly changed by training, although the glycolytic contribution and average power output increased by 6%. Very few studies have determined whether the anaerobic capacity can be increased through right training. Same authors suggest that the greater power output following training was due to the recruitment of large muscle mass [7,10,12]. Repeated three times bout of exhaustive high-intensity exercise caused only slightly reduction of total work performance in both control and athletic groups in spite of a significant decline in the glycogenolytic rate in control group. This reduction in the glycogenolytic rate may be partly explained by the further reduction in muscle pH in the second high-exercise and following one. Due to the decline in glycogenolytic rate, the slower recovery of mean than peak power we have seen in control group. After seven minutes of recovery, peak power was recovered to 95.9% and 94.3% respectively after second and third repeated bout of exercise, but in the same time the mean power recovered to 89.8% and 91.8%. Less disturbed of recovery rate of mean power in trained group may be due to the changes in sensitivity of glycogenolysis to the inhibitory effect of acidification or another negative factors, caused by the training.

Taking in consideration our results, we can suggest that during the repeated high-intensity exercise:

- the energy supply and particularly PCr availability may be limiting performance such work,
- the reduction in the rate of glycogenolysis/glycolysis is more pronounced in untrained subject than trained one, but the reasons for the reduction is not clear,
- specialistic training does not significantly affect of PCr degradation and the ATP store, although the glycogenolytic contribution and average power increases about 6%.

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