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ESTIMATION OF ONE-YEAR ROWING TRAINING EFFICACY ON THE BASIS OF AEROBIC CAPACITY CHANGES

Key words: training, rowers, aerobic capacity.

ABSTRACT

The aim of the study was to estimate one-year rowing training efficacy on the basis of aerobic capacity changes, expressed by maximal oxygen uptake, individual anaerobic threshold, maximal power and mean power achieved during a 2000 m ergometer test. Six male junior rowers were examined twice at a one-year interval. Two ergometric tests were performed during the first and the second study: an incremental exercise test and a 2000 m all-out test. During the progressive test maximal values of power, blood lactate concentration (LA) and VO₂ were recorded. During the 2000 m rowing ergometer performance mean power was determined. On the basis of LA changes power and VO₂ at the individual anaerobic threshold were determined.

The results revealed statistically significant differences between the values of most parameters, measured at a one-year interval. Besides, significant correlations between results of an incremental test and a 2000 m all-out test were noted. In conclusion, after one-year rowing training, aerobic capacity increased significantly.

INTRODUCTION

Rowing is a sport which requires a high level of endurance (related to aerobic capacity) and force. The beginning of a rowing race, dependent on the efficiency of ATP anaerobic resynthesis and on force developed during accelerating of the boat (1000-1500 N) [5,16], requires from rowers a high anaerobic capacity. However, rowing performance over 2000 m depends primarily on the aerobic capacity, because more than 70% – 80% of energy during rowing originates from aerobic metabolism and only 20-30% from anaerobic changes [7, 12, 14]. The specificity of rowing makes rowers achieve high values of maximal oxygen uptake (6.0-7.0 l/min; 65-70 ml/kg/min) [5,15,16], which is decisive in this sport [4,8,18]. High values of VO_2max result certainly from the high content of slow twitch fibers in rowers' muscles (often exceeding 70%) [15, 16].

The predominance of aerobic ATP resynthesis during rowing causes that training loads increase the oxidative capacity of muscle fibers and significantly improve the cardiorespiratory transport system. This improvement can be obtained by using the individual anaerobic threshold (IAT) [12] determined blood lactate concentration changes during an incremental exercise test. In Steinacker's [16] view, successful rowers' training intensity is 70% - 90% of the training time below the anaerobic threshold. In practise, the heart rate at IAT (measured in laboratory) is used to determine the intensity of training sessions [12]. This parameter can be used during rowing training,

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because the HR determined in laboratory is valid for monitoring of training in highly trained rowers [2]. VO₂max and oxygen consumption at the anaerobic threshold are admittedly good predictors of 2000 m rowing ergometer performance in elite rowers [4], but some other predictors have also been found. Bourdin and Ingham [1, 8] stated that peak power output sustained during maximal incremental testing is the best predictor of performance during 2000 m rowing on an ergometer and an overall index of physiological rowing capacity and rowing efficiency.

The aim of the study was to estimate oneyear rowing training efficacy on the basis of aerobic capacity changes, determined by maximal oxygen uptake, individual anaerobic threshold, maximal power and mean power achieved during a 2000 m ergometer test.

METHODS

The subjects were six male junior rowers, who were examined twice at a one-year interval. Tests were carried out in the same training period. Tables 1 and 2 present the rowers' characteristics and the training loads applied during one year between the two studies. All subjects agreed to participate in the study and give blood samples for research purposes. The experiment was given approval by the Committee of Research Ethics of the Poznan University of Medical Sciences (1744/03). To evaluate aerobic capacity changes two ergometric tests were performed during the first and the second study: an incremental exercise test and a 2000 m all-out test. The tests were carried out during separate measurement sessions (after 2-3 days of recovery).

A progressive rowing ergometer (Concept II) test to exhaustion was performed to estimate the maximal oxygen uptake (VO₂max) and individual anaerobic threshold (IAT). During the test a number of gasometric parameters were analyzed by the Oxycon Mobile ergospirometric system (Viasys Healthcare Inc., USA) and heart rate (HR) was measured (sport-tester Polar T61 coded, Finland). The first load was determined individually. After each three-minute exercise, load (power) was increased about 30 or 40 W (individually), and between consecutive loads a one-minute pause was applied for blood sampling from the earlap. The test was performed until the maximal level of recorded parameters was achieved and was stopped when subjects could not continue exercise with the current load. The maximal values of VO₂, power (Pmax), heart rate (HRmax) and blood lactate concentration (LAmax) were recorded immediately after the incremental test. VO₂max and power were also expressed per kilogram of body mass.

On the basis of blood lactate concentration changes (Dr. Lange, Cat. No. LKM 140, Germany) values of the parameters at the individual anaerobic threshold were determined: $VO_{2 IAT}$, power (P_{IAT}), HR_{IAT}, LA_{IAT}. Oxygen uptake and power were also expressed per kilogram of body mass.

Table 1. Characteristics of the rowers

n=6	Age [years]	Height [cm]	Body mass [kg]	Years of training
1 st study	15.5 + -0.5	184.8+/-4.2	78.4+/-10.4	2.8+/-1.6
2 nd study	16.5 + -0.5	188.0+/-3.5	83.5+/-8.4	3.8+/-1.6

Table 2. Training loads applied during one year between two studies

	Effective training hours	Basic means	Directed means	Special means (on the water)	Loads at the anaerobic threshold
Off-season	6h/week	110 h	28 h	75 h	17 h
In-season	7.5h/week	10 h	40 min	106 h	6.5 h

During the 2000 m rowing ergometer test (Concept II) mean power (P_{2000}), expressed per kilogram of body mass was also calculated.

The results were reported as mean values with standard deviations. The t-test was used to calculate the differences between the groups and Pearson correlation was calculated to estimate the relationships between parameters. The level of statistical significance was set at $p \le 0.05$.

RESULTS

The results of our study showed statistically significant differences between values of the majority of parameters, measured at a one-year interval ($p \le 0.05$) (Fig. 1-6). Non-significant differences were found only for body mass, blood lactate concentration and heart rate at the IAT level and maximal heart rate (p>0.05). Besides, in the two studies significant correlation between VO₂ at the IAT (l/min) and VO₂max (l/min) and between VO₂max (l/min) and P_{2000 m} was observed. Power at IAT and the maximal power was also related to P_{2000 m} ($p \le 0.05$) (Tab. 3, 4).



Figure 1. Maximal oxygen uptake during the first and the second study



Figure 2. Maximal power achieved in an incremental exercise test during the first and the second study



Figure 3. Maximal blood lactate concentration during the first and the second study



Figure 4. Oxygen uptake at the individual anaerobic threshold during the first and the second study



Figure 5. Power at the individual anaerobic threshold during the first and the second study



Figure 6. Mean power achieved during the 2000 m rowing ergometer performance during the first and the second study

	VO ₂ max	P _{IAT}	Pmax	
$VO_{2 IAT}$	0.99**			
P _{2000m}	0.91*	0.96**	0.94**	
* $p \le 0.05$, ** $p \le 0.01$				

 Table 3. Correlation coefficients between parameters measured during the first study

 Table 4. Correlation coefficients between parameters measured during the second study

	VO ₂ max	P _{IAT}	Pmax
$VO_{2 IAT}$	0.97**		
P _{2000m}	0.88*	0.90*	0.96**
	.0.01		

* $p \le 0.05$, ** $p \le 0.01$

DISCUSSION

Values of maximal oxygen uptake (in liters and ml/kg) obtained during the second study were significantly higher than VO₂max values achieved during the first study. However, maximal oxygen uptake was lower than in Hagerman et al. [5] (6 l/min; 67.6 ml/kg/min), Secher [15] (6, 7–7 l/min) and Steinacker [16] (6-6.6 l/min; 65-70 ml/kg/min). Discrepancies between our findings and those of other authors could result from the subjects' different age - juniors (in our study) and seniors (in other studies). However, changes in the VO₂max level can occur in shorter time than it was in our study. Hagerman and Staron [6] noted a significantly lower maximal oxygen uptake (5.1 l/min; 56.5 ml/kg/min) off-season in comparison to the values in season (6 l/min; 69.1 ml/kg/min). These authors affirmed that although seasonal effects were expected, the unusually large differences in metabolic capacities between the studies reflect a high degree of training specificity.

The specificity of our subjects' training had also an influence on the significant rise of oxygen consumption at the individual anaerobic threshold (IAT) after one year. However, changes in VO₂ at the anaerobic threshold level were not accompanied by changes in heart rate at the IAT. It is worthy to add that the maximal heart rate was also unchanged with training, which remains in agreement with results obtained by Hagerman and Staron [6] and Mahler et al. [10]. Despite the anaerobic threshold increase, oxygen consumption at the IAT (in percent) VO₂max did not enhance, which resulted from a similar percentage increment of VO₂max and VO_2 at the IAT level between the studies. However, the individual anaerobic threshold of our subjects (86% and 83% of VO₂max during the first and the second study, respectively) was high and similar to those presented by Mickelson and Hagerman [12] (83% of VO₂max) and Steinacker [16] (80-85% of VO₂max) for highly trained rowers. Besides, also Yoshida et al. [17] observed a strong correlation for VO₂max and oxygen consumption at the blood lactate threshold.

A significant increase of aerobic capacity, expressed by the VO₂max and IAT level, proves the efficacy of our rowers training. Certainly, it results from optimal training loads stimulating aerobic energy release, which playa a dominant role during rowing [7, 12]. Optimal training loads can be applied when the individual anaerobic threshold (but not 4 mmol/l threshold) is known. Bourgois and Vrijens [3] observed that a steady state of mean blood lactate concentration during the 30-min prolonged exercise test was found only for the power output at IAT and the blood lactate concentration at the end of this test was significantly lower at IAT as compared to 4 mmol/l threshold. Messonnier et al. [11] also noted that VO₂ corresponding to the 4 mmol/l blood lactate concentration was not related to the training load in the group of highly trained rowers.

Mean power achieved during two 2000 m ergometer tests (284.2 and 336.1 W) was lower than mean power presented by Hagerman [7] (390 W) and Jurimae and Jurimae [9] (354.3 W). Maximal blood lactate concentration was also lower than its concentration in Jurimae and Jurimae [9] (13.4 mmol x l(-1)). However, the subjects examined by those authors were a few years older than ours, which could have an impact on their higher anaerobic glycolysis efficiency and higher tolerance of homeostasis disturbances. Besides, in our study results revealed a positive correlation between mean power and maximal oxygen uptake. This is consistent with the findings of Peltonen and Rusko [13] studies, in which r = 0.87 ($p \le 0.01$) between power in 6-min all-out test and maximal oxygen uptake was noted.

The percentage increase of maximal power between two studies was similar to its rise in

Hagerman and Staron [6], although the time between these authors' studies (from in-season to off-season) was shorter than in our study. The statistically significant increase in maximal power and maximal blood lactate concentration (between the first and the second study) proves anaerobic capacity improvement, following a rise in the aerobic capacity. Similarly to our first study Bourdin et al. [1] affirmed that maximal power was significantly related to body mass. During the second study, this correlation was not significant. The reason might be that maximal power increased significantly between two studies, but body mass did not.

The results of our study show that after oneyear rowing training, aerobic capacity, estimated by maximal oxygen uptake, individual anaerobic threshold, maximal power and mean power achieved during a 2000 m ergometer test, increased significantly. The use of individual anaerobic threshold in training leads to an improvement in rowing performance. The obtained coefficients of correlation confirmed a positive correlation between the results of an incremental exercise test and a 2000 m all-out test.

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