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MEAN POWER OUTPUT, TIME AND SPEED OF THE 2000 M DISTANCE IN SCHOOLBOY ROWERS DURING LABORATORY TESTS IN DIFFERENT PERIODS OF THE ANNUAL TRAINING CYCLE OVER 3 YEARS OF TRAINING

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Abstract

Introduction: There is a wealth of studies concerning elite rower training. However, data concerning sport-specific training in schoolboy rowers are scarce and incomplete.

Aim of the study: This study was aimed at examining of the mean power output, time and speed of 2000 m distance in different annual training periods over three years of training in boys starting their sport-specific training.

Methods: All participants underwent "all out" 2000 m laboratory rowing using a Concept II ergometer. The tests were repeated four times - in November, January, March and June over three years of training.

Results: Mean power output increased significantly (P<0.001) in the second and third year of training vs. the first year, however, no differences were noted between the second and third year. In contrast, the improvement in time and speed was found in each year of training (P<0.001) in comparison with the preceding year. Ergometer speed was not correlated with the mean power output at any of the training period.

Conclusions: Our data suggest that when the Concept II ergometer is used for the evaluation of training effects time of simulated 2000 m rowing and rowing speed are better indices of training progress then the mean power output.

Key words: *youth sportsmen, ergometry rowing, training*

Introduction

Rowing is a sport placing high demands on both the aerobic and anaerobic energy systems since during a typical 2-km rowing competition muscles are called to perform at high power output for 6-7 minutes [1,2]. In consequence, numerous studies have revealed that physiological determinants of aerobic performance such as maximal oxygen uptake ($\dot{V}O_2$max), lactate and ventilatory thresholds in rowers yield high values and during competitive 2-km rowing the aerobic energy is responsible for about 70-86% of total energy demands [2,3]. Moreover, data concerning the lactate threshold in elite rowers confirm their high aerobic capacity [4]. In addition, close relationships between rowing performance and $\dot{V}O_2$max have been noted [5].

However, there is a wealth of studies suggesting a significant contribution of anaerobic capacity to the overall rowing performance. In high performance rowers a significant and positive correlation between time of simulated 2000 m rowing and maximal power output during 5 s all out exercise has been noted [6]. Additionally, it has been found that time of simulated 2000 m distance is in 75.7% related to peak power output during 30 s all out exercise [7]. Furthermore, isokinetic and isometric knee and hip extension strength and power during simulated rowing are also correlated with ergometric rowing performance [8]. A recent study of Shimoda et al. [9] has indicated that laboratory rowing performance can be evaluated by $\dot{V}O_2$max, leg extension power and stroke power consistency at the highest workload.

In order to reach high aerobic capacity competitive rowers are engaged mostly in prolonged extensive on water and/or ergometric training, which makes up the largest part of training volume [10,11]. In addition, during the competitive season a speed training including repeated bouts of high intensity exercise interspersed with short rest intervals is frequently used to improve anaerobic capacity [12]. It should be stressed that high training volume characteristic for rowers induces metabolic disturbances which increase the risk of depressed adaptability, overtraining and oxidative stress [13,14].

It is worth noting that most studies concerning physiology, biomechanics and training in rowing focused on high performance junior and senior sportsmen. Data concerning schoolboy rowers starting their sports career are scarce and incomplete. Russel et al.

[15] have indicated that in schoolboy rowers (mean age 18 years) the time of simulated 2000 m distance is positively related to body mass, maximal oxygen uptake and negatively to body fat. Similarly, in rowers aged less than 14 years the 1000 m ergometer rowing performance is significantly and positively correlated with maximal oxygen uptake and body size [16]. In addition, it has been noted that training of adolescent rowers is stressful for muscle cells inducing a significant elevation in plasma creatine kinase (CK) activity and fatty acid binding protein levels [17].

It is worth noting that young athletes are at higher risk of overload and overtraining than experienced ones [18]. For that reason studies concerning the responses to training of the youngest athletes are of special importance for sport practice. According to our best knowledge there are no longitudinal studies which evaluated the response of schoolboy rowers to training from the very beginning of sport-specific activity.

Thus, this study was undertaken to examine mean power output, time and speed of 2000 m simulated distance in four annual training periods during three years of training, starting from the selection of boys for rowing training.

Materials and Methods

Subjects

Prospective subjects were recruited among male students aged about 15 years. Because of their age each subject's parents (or legal guardians) were asked to give their informed consent prior to further procedures. All the participants underwent a medical examination including resting and post-exercise (30 sit ups with maximal speed) electrocardiography, and anthropometric measurements. The procedures took place in March, in August all accepted subjects participated in a training camp where they were engaged in different types of physical activity such as running, games, gymnastics, but also ergometer and on-water rowing. Final selection of subjects for rowing training was performed by a coach and was based mainly on their skills in rowing technique. A total of 23 boys were accepted for further participation in rowing training and all of them completed the study. All experimental procedures were in compliance with internationally accepted policy statements regarding human subjects.

Exercise protocol

The subjects were asked not to participate in any physical activity in the 24 h before testing and to abstain from eating for 2 h before testing. All the participants were familiarized with the laboratory procedures during the training camp in September of the first year of training. In each of the 3 years of training simulated rowing was performed four times - in November (transition phase), in January (general preparation phase), in March (specific preparation phase) and in June (competitive phase) as a part of routine testing of sportsmen supervised by the coach. All tests started at 9:00 a.m. Before testing the subjects' weight and height were measured using medical scales. The warm-up using Concept II ergometer (Morsville, VT, USA) and damper setting 4-5 lasted 14 min and consisted of 10 min rowing at heart rate 130-150 bpm, 1 min rowing at 180 bpm repeated 2 times and 2 min rowing at 130-150 bpm. Thereafter all the participants underwent simulated "all out" 2000 m rowing with verbal encouragement to provide a maximal effort. The readings of mean power and time of the distance were taken from the registration system of the ergometer and speed over 2000 m simulated distance was calculated and expressed in m/s.

Training load

Throughout the study training load expressed as hours of training was precisely registered by the coach. Training intensity was evaluated as heart rate registered using sport tester Vantage NV (Polar Electronics, Finland).

Statistical analysis

Data distribution was evaluated using the Shapiro-Wilk test. One-way ANOVA for repeated measures and the post-hoc Tukey test were used for data comparison. Correlations between ergometric speed and mean power output and body mass were calculated according to Pearson. Data are presented as means and standard deviations. Statistical significance was set at $P<0.05$. All calculations were performed using Statistica v. 7.1 software (StatSoft, USA).

Results

Total training volume gradually increased in each year of training (Table 1). In the first year of training low-intensity work constituted 61.2% of all training volume, however it markedly decreased in the second and third year of training. On the contrary, in the second and third year of training a marked elevation in training intensity was noted. In the first year of the study training of schoolboy rowers consisted mostly of non-rowing activities such as games, swimming, running and gymnastics which made up 43% of the total volume (Table 2). In the subsequent two years of training on-water and ergometer rowing volume increased, however, other activities still made up 26-27% of total training volume.

The subjects' anthropometric characteristics are presented in Table 3. Their weight and height significantly increased in successive years of training being greater in the second year vs. the first ($P<0.001$) and in the third vs. first ($P<0.001$) and second ($P<0.02$) year of training. Similarly, the subjects' BMI increased in

Table 1. *Volume and intensity of training in schoolboy rowers during three years of the study*

Training intensity (bpm)	Training experience		
	I*	II	III
120-140	278 (61.2%)^	211 (43.5%)	245 (48.4%)
130-160	94 (20.7%)	155 (31.9%)	104 (20.6%)
160-180	73.5 (16.2 %)	50 (10.3%)	102 (20.1%)
170 – 190	1.1 (0.2%)	60 (12.4%)	25 (4.9%)
> 190	7,4 (1.6%)	9,0 (1.8%)	30 (5.9%)
Total volume (h)	454	485	506

* denotes years of training ; ^ denotes percent of total training volume in respective year of training

Table 2. *The contribution of different training modalities to overall training volume during three years of training in schoolboy rowers*

Training modality	%*		
	I^	II	III
On-water rowing	27	38	35
Ergometer rowing	4	14	17
Pool rowing	15	4	4
Strength training	11	17	18
Non-specific training[a]	43	27	26

*percent of total volume in each year of training; ^ year of training; [a] including gymnastics, games, running, and swimming,

Table 3. *Anthropometric characteristics of the subjects (means± SD)*

	I*			
	November	January	March	June
Age (years)	15.3 ± 0.3	15.5 ± 0.3	15.7 ± 0.3	15.9 ±0.3
Weight (kg)	70.4 ± 8.0	73.6 ± 6.5**	72.5 ±6.3**	72.5 ± 5.3**
Height (cm)	182.4 ± 0.4	183.5 ± 0.4§	184.4 ±0.4	184.7 ±0.3
BMI	19.4 ± 2.0	20.1 ±1.5††	21.3 ±1.4††	21.2 ± 1.5††
	II*			
Age (years)	16.3 ± 0.3	16.5 ± 0.3	16.7 ±0.3	16.9 ± 0.3
Weight (kg)	75.3 ± 6.4^	76.1 ± 5.9^	76.1 ± 5.2^	76.0 ± 5.4^
Height (cm)	186.6 ± 0.3‡	186.7 ± 0.4‡	187.0 ±0.4‡	187.6 ± 0.4‡
BMI	21.6 (1.3)§§	21.8 ± 1.4‡‡	21.8 ±1.3	21.6 ± 1.5
	III*			
Age (years)	17.3 ± 0.3	17.5 ± 0.3	17.7 ± 0.3	17.9 ±0.3
Weight (kg)	78.3 ± 6.3#,	78.6 ± 6.7#,	79.1 ± 6.7#,	78.5 ± 6.6#,
Height (cm)	187.9± 0.4†,^^	187.9 ± 0.4†,^^	187.9 ± 0.3†	188.0 ± 0.3†
BMI	22.2 ± 1.4***	22.3± 0.4***	22.4 ±1.5***,¶¶	22.2 ±1.3***, ¶¶

* denotes year of training; ** *P*<0.007 vs. November of the same year; ^ *P*<0.001 vs. respective months of the first year of training; # *P*<0.001 vs. respective months of the first year of training;
P<0.02 vs. respective months of the second year of training; § *P*<0.04 vs. November of the same year of training; ‡ *P*<0.001 vs. the first year of training; † *P*<0.001 vs. respective months of the first year of training; ^^ *P*<0.05 vs. respective months of the second year of training; †† *P*<0.006 vs. November of the same year of training; §§ *P*<0.001 vs. November of the first year of training; ‡‡ *P*<0.05 vs. January of the first year of training; *** *P*<0.001 vs. respective months of the first year of training; ¶¶ *P*<0.05 vs. respective months of the second year of training

Table 4. *Mean power output, time of 2000 m distance and rowing speed in schoolboy rowers during laboratory Concept II exercise performed over three years of training (means ± SD)*

	November	January	March	June
I *				
Mean power (W)	281.6 ± 22.8	301.8 ± 22.5	304.5 ± 18.6	311.7 ± 20.8
Time (s)	430.9 ± 11.4	421.9 ± 10.8	417.7 ± 8.5	414.5 ± 9.3
Speed (m/s)	4.64 ± 0.12	4.74 ± 0.12	4.79 ± 0.10	4.82 ± 0.11
II*				
Mean power (W)	323.8 ± 21.1*	327.2 ± 20.9*	334.8 ± 24.3*	349.6 ± 25.5*
Time (s)	410.4 ± 9.1*	408.6 ± 8.98*	404.5 ± 9.7*	400.4 ± 10.2*
Speed (m/s)	4.87 ± 0.11*	4.89 ± 0.10*	4.94 ± 0.12*	4.99 ± 0.12*
III*				
Mean power (W)	344.5 ± 23.3**	345.8 ± 23.1**	355.9 ± 26.6**	368.9 ± 27.3**
Time (s)	397.1 ± 10.9**,^	402.0 ± 9.1**,^	397.0 ± 9.0**,^	392.9 ± 9.6**,^
Speed (m/s)	5.04 ± 0.14**,^	4.97 ± 0.11**,^	5.04 ± 0.12**,^	5.09 ± 0.12**,^

*denotes years of training; * $P<0.001$ – significantly different vs. first year of training; **$P<0.001$ – significantly different vs. first year of training; ^ $P<0.001$-significantly different vs. second year of training

Table 5. *Pearson correlation coefficients between ergometer speed, mean power output and body mass in schoolboy rowers over three years of training*

	Ergometer speed (m/s)		
	I*	II	III
Mean power (W)	0.126	0.100	0.188
Body mass (kg)	0.191	0.470^	0.618^

* - denotes year of training; ^ $P<0.001$

the successive years of training. However, only minor changes in subjects' weight, height and BMI were noted in different training periods of the same year of training.

In the second year of training significant improvement in the mean power output, time of the distance and speed were noted in comparison with the first year of training ($P<0.001$) (Table 4). Similarly, in the third year of training all tested variables were markedly different vs. the first year of training ($P<0.001$). However, there were no differences in the mean power output between the second and third year of training. On the contrary, time of the distance and ergometer speed in the third year of training markedly improved vs. the second year of training.

Rowing speed was not associated with mean power output in any of the years of training (Table 5).

Discussion

This study is the first to report prolonged training effects in youth rowers. We had a unique possibility to examine the changes in mean power output, time and speed of simulated 2000 m distance in four different periods of the annual training cycle over three years of training in schoolboy rowers starting their sport career. However, our study had certain limitations. First of all the use of Concept II ergometer did not allow to measure maximal power output, an important determinant of rowing performance [19,20]. Secondly, the mean power output, time and speed of the distance reflect the physiological, technical and tactical adaptation to training, however, until now their contribution to sport-specific performance have not been precisely defined [21].

Despite the above constraints our data may be useful for coaches since the Concept II ergometer is routinely used for testing rowers [22,23]. Moreover, there are data indicating a close relationship between Concept II and competition performance due to a similar pattern of movement during ergometer and on-water rowing [24,25]. In addition, relative age effects (RAEs) in our study were of minor importance due to similar age of all participants at the beginning of the study [26].

Training characteristics of schoolboy rowers with respect to training modality and intensity were similar to those of successful rowers [27]. However, due to the young age of our subjects total training volume throughout three years of the study was more than 2 times lower than in international level rowers [28].

Moreover, the high contribution of non-specific training in the first year was in accordance with guidelines for youth athletes [29].

Mean power output in November of the first year of training, thus at the beginning of the study, was higher by 4%, but in June 15% higher than that reported in rowers aged 17 years [30]. In addition, time of simulated 2000 m rowing in our participants in the first year of training was similar to that found in 25 years old university and club rowers [31]. Furthermore, in March and June of the second year of training the ergometer speed of our subjects was similar to that reported by Nevill et al [32] in elite junior rowers.

The above data indicate appropriate subject selection for rowing training and efficacy of the training program. This assumption is further supported by constantly decreasing time and increasing speed of simulated 2000 m distance observed in subsequent annual periods and years of training.

However, it is worth noting, that in the second year of training insignificant changes in mean power output were accompanied by marked improvement in time and speed of simulated distance. These data possibly indicate that with training progression rowing economy and tactics became more important than overall work in determining simulated performance, a phenomenon well known in other sports [33,34]. Moreover, our findings are in agreement with other studies indicating that changes in mechanical variables decrease with training experience and even became insignificant in well-trained athletes [35]. This assumption was further supported by the lack of the relationship between rowing speed and the mean power output observed in our study.

Thus, it could be postulated that at the level of schoolboy rowers tested using the Concept II ergometer either time of the distance or rowing speed have to be used in the evaluation of training progress. Moreover, special attention has to be paid to rowing speed since it has been noted that this variable reflects on-water performance [32].

In conclusion, we demonstrated that in schoolboy rowers training modality characteristic for rowing induced an improvement in time of simulated 2000 m rowing and rowing speed, even when the mean power output did not change. Additionally, we noted that there were not relationships between rowing speed and the mean power output. Thus, it seems that when Concept II ergometer is used for evaluation of training effects time and speed are better indices of training progress than the mean power output.

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