

## INDIRECT METHODS OF ESTIMATING MAXIMAL OXYGEN UPTAKE ON THE ROWING ERGOMETER

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**Abstract.** The aim of the present study was to develop an indirect method of estimating maximal oxygen uptake in oarsmen and oarswomen on the rowing ergometer based on both the submaximal exercises and the commonly used in this sport maximal exercise-type test that simulates rowing the distance of 2000 m. Forty-four oarsmen and 27 oarswomen from both the national team and the direct back-up were enrolled in the investigations. Two exercise tests on the Concept II rowing ergometer were employed: the submaximal test with incremental power output (anaerobic threshold test) and the maximal test, simulating rowing the distance of 2000 m in the shortest possible time (2-km test). During both tests, oxygen uptake and heart rate were recorded and the highest values of these parameters registered during the 2-km test were regarded as the  $\text{VO}_2\text{max}$  and  $\text{HRmax}$  indices, respectively. The linear relation of the oxygen uptake to the power output (W) on the ergometer was detected in both the male ( $\text{VO}_2=1.1328+0.0113W$ ) and female ( $\text{VO}_2=0.6652+0.0128W$ ) athletes. Comparison of the regression lines demonstrated statistically significant differences between the oarsmen and oarswomen with respect to the intercept and the slope of the lines. Mean values of the directly measured  $\text{VO}_2\text{max}$  equaled to  $5.48\pm 0.59$  and  $3.68\pm 0.31$   $\text{l}\cdot\text{min}^{-1}$  in the groups of oarsmen and oarswomen, respectively. The most accurate predicted values of  $\text{VO}_2\text{max}$  were obtained based on the linear regression of  $\text{VO}_2\text{max}$  against the mean power output (WM) in the 2-km test using the following formulas:  $\text{VO}_2\text{max}$  ( $\text{l}\cdot\text{min}^{-1}$ ) in the males =  $1.682+0.0097$  WM;  $\text{VO}_2\text{max}$  ( $\text{l}\cdot\text{min}^{-1}$ ) in the females =  $1.631+0.0088$  WM. In the males, the difference between the measured and predicted  $\text{VO}_2\text{max}$  ( $\Delta\%$ ), correlation coefficient (r), standard estimation error (SEE), and total error (TE%) equaled to  $0.12\pm 4.96$  (NS), 0.889 ( $P<0.001$ ), 0.274, and 4.9, respectively. In the females, these values equaled to  $0.43\pm 5.02$  (NS), 0.801 ( $P<0.001$ ), 0.19 and 4.95, respectively. Based on the submaximal exercises, the relatively accurate predicted values of  $\text{VO}_2\text{max}$  were obtained from the linear regression of  $\text{VO}_2\text{max}$  against  $\text{PWC}_{170}$  using the following formulas:  $\text{VO}_2\text{max}$  ( $\text{l}\cdot\text{min}^{-1}$ ) in the males =  $3.2131+0.0076$  ( $\text{PWC}_{170}$ );  $\text{VO}_2\text{max}$  ( $\text{l}\cdot\text{min}^{-1}$ ) in the females =  $2.4138+0.0071$  ( $\text{PWC}_{170}$ ). In the males, the accuracy of prediction of  $\text{VO}_2\text{max}$  was defined by the

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following indices:  $\Delta\%=0.37\pm 6.15$  (NS),  $r=0.826$  ( $P<0.001$ ),  $SEE=0.279$ ,  $TE\%=6.03$ . In the females, the respective values were as follows:  $\Delta\%=0.30\pm 6.22$  (NS),  $r=0.711$  ( $P<0.001$ ),  $SEE=0.158$ ,  $TE\%=5.82$ . The obtained results indicate that it possible to relatively precisely predict maximal oxygen uptake from the results of submaximal and maximal (2-km test) exercises performed on the rowing ergometer. *(Biol.Sport 20:181-194, 2003)*

*Key words:* Oarsmen – Rowing ergometer – Maximal oxygen uptake – Indirect methods

### Introduction

Maximal oxygen uptake ( $VO_2\max$ ) is generally regarded as the best indicator of the cardiopulmonary fitness of the organism. However, the existing methods of direct estimation of this index employ expensive measuring equipment and qualified staff necessary to carry out the exercise test. Hence, indirect methods of estimating  $VO_2\max$  are often used, especially in studies of large population samples when direct measurements of  $VO_2\max$  are not feasible due to the time needed to carry out the tests and the necessity to assure safe conduct of the tested subjects (who are forced to exercise with the maximal intensity). In the indirect methods, the linear relation between heart rate and oxygen uptake as well as the relation between power output and oxygen uptake are generally utilized as are the relations between  $VO_2\max$  and the total work output in a given time or between  $VO_2\max$  and intensity of the exercise. As indicated by Carey [4], applicability of different indirect methods, such as the Astrand- Ryhming test on a cycloergometer, the Rockport Walk Test, the George-Fisher Jog Test or the 2.4-km running, to estimation of the training-induced changes is limited, especially in the intensely-trained subjects in whom alterations caused by the several-week training might be lower than the prediction error. In spite of this, the indirect methods are still considered to be very useful not only for investigations of people not engaged professionally in sports but also of athletes, particularly in the field and pre-selective studies aimed at the initial determination of predispositions to exercising in large groups of athletes.

Aerobic capacity is one of the major determiners of a success in rowing [9,14,17]. However, only one attempt has been made thus far to determine maximal oxygen uptake using the indirect method on a rowing ergometer [10]. The authors of that study predicted  $VO_2\max$  from the results of the sub-maximal exercises



according to the Astrand-Ryhming method [2]. However, this interesting investigation was carried out on the relatively small group of men (11 oarsmen and 14 subjects who did not practice rowing), making it difficult to evaluate the accuracy of the method. To date, we have not found any evidence in the literature of an attempt to indirectly estimate  $\text{VO}_2\text{max}$  on the rowing ergometer in women.

The aim of the present study was to elaborate the indirect method of estimation of maximal oxygen uptake on the rowing ergometer not only in oarsmen, like in the investigation cited above, but also in oarswomen. In addition, we attempted to develop a method of the indirect determination of  $\text{VO}_2\text{max}$  based on both the submaximal exercising and the commonly used in oarsmanship maximal exercise-type test that simulates rowing the distance of 2000 m.

### Material and Methods

Forty-four oarsmen and 27 oarswomen, including 18 males and 4 females from the national team and 26 males and 23 females the direct back-up of the national team, participated in the studies. Characteristics of the examined athletes is shown in Table 1. The subjects expressed their informed consent to participate in the investigations by signing the appropriate forms. The programme of the study was approved by the Ethical Research Committee at the Institute of Sports in Warsaw.

**Table 1**

Basic characteristics of the examined oarsmen (n=44) and oarswomen (n=27)

Group	Age (years)	Height (cm)	Body mass (kg)	Period of training (years)	Mean power output 2000 m (W)
Oarsmen	21.03±3.2	192±5	87.7±8.7	6.1±3.0	390±54
Oarswomen	19.4±1.6	176±4	72.1±7.9	5.0±2.2	234±28

Two exercise tests on the Concept II rowing ergometer were employed. First, after the 8-min. warm-up the athletes were subjected to a specific test involving maximal exercising which simulated rowing the distance of 2000 m (the 2-km test). On the following day, the anaerobic threshold test was performed which included three sub-maximal exercises at the power output of 50, 70, and 85% of the mean maximal power output (WM) determined in the 2-km test. Each exercise lasted 5 min and the exercises were separated by the 5-min. breaks.



During both tests: pulmonary ventilation (VE), oxygen uptake (VO<sub>2</sub>), and exhalation of carbon dioxide were recorded using the MMC Beckman detector (Beckman Instruments, Inc. USA), and heart rate (HR) was measured with use of the Polar Sport Tester recorder (Electro Oy, Finland). The highest values of VO<sub>2</sub> and HR registered within 30 s in the maximal test were regarded as the VO<sub>2</sub>max and HRmax indices.

The obtained results were statistically analysed by calculating the following: mean values of the examined parameters (x), standard deviation (SD), the Pearson's linear correlation and multiple regression coefficients, standard error of estimation (SEE), and total error (TE). SEE was calculated according to the

$$\text{formula: } SEE = Sy \cdot \sqrt{1 - r^2}$$

where: Sy – standard deviation of the VO<sub>2</sub>max value calculated indirectly,  
r – coefficient of correlation between VO<sub>2</sub>max values measured directly and calculated indirectly.

$$\text{TE was calculated according to the formula: } TE = \sqrt{\frac{\sum (y - Y)^2}{n}}$$

where: y – the value of VO<sub>2</sub>max calculated indirectly for each subject,

Y – the measured value of VO<sub>2</sub>max,

n – number of subjects.

In addition, the percentage value of TE (TE%) was determined according to the

$$\text{formula: } TE\% = \frac{TE}{Y} \cdot 100, \text{ where Y – measured value of VO}_2\text{max.}$$

In order to compare the regression lines, the differences in the slopes and the intercepts were analysed. Significance of the differences between the measured and calculated VO<sub>2</sub>max values was estimated using the Student's t test for dependent data.

All the calculations and statistical analyses were performed using the Statistica 5.1 for Windows (StatSoft) and Statgraphics Plus V. 3.0. (Statistical Graphics Corp.) software.



## Results

As indicated in Fig. 1, linear relations between the workload on the rowing ergometer (submaximal and maximal exercises) and the oxygen uptake were determined for both the female and male subjects. Importantly, statistically significant differences ( $P < 0.001$ ) were noted between the regression lines obtained for the females and males. As shown by the data presented in Table 2, the recorded HRmax values were, on the average, by  $6 \pm 6$  beats/min (oarsmen) and by  $6 \pm 5$  beats/min (oarswomen) lower than the expected values calculated according to following most often used formula:  $\text{HRmax} = 220 \text{ beats} \cdot \text{min}^{-1} - \text{age}$  (in years).

**Table 2**

Mean values ( $\pm$ SD) of maximal heart rate (HRmax) measured and predicted using the indicated formulas in the tested oarsmen ( $n=44$ ) and oarswomen ( $n=27$ )

		HRmax (beats $\cdot$ min <sup>-1</sup> )				
		Measured	220-age	214-age	*220-age (differences)	*214-age (differences)
Oarsmen	x $\pm$ SD	193 $\pm$ 8	199 $\pm$ 3***	193 $\pm$ 3	-6 $\pm$ 6	0 $\pm$ 6
	Min	177	188	182	-22	-16
	Max	205	202	196	5	11
Oarswomen	x $\pm$ SD	195 $\pm$ 6	201 $\pm$ 2***	195 $\pm$ 2	-6 $\pm$ 5	0 $\pm$ 5
	Min	184	197	191	-16	-10
	Max	204	203	197	3	9

\*differences between the measured and predicted HRmax;

\*\*\*indicates significance ( $P < 0.001$ ) of the difference from the measured value

To estimate  $\text{VO}_2\text{max}$  by the indirect method we used the following regression formulas obtained from the linear relation between the calculated indices:

A./ Based on the mean power output (WM) obtained in the 2-km test, expressed in watts:

- A.1.  $\text{VO}_2\text{max}$  ( $l \cdot \text{min}^{-1}$ ) in males =  $1.1328 + 0.0113 \text{ WM}$   
 $\text{VO}_2\text{max}$  ( $l \cdot \text{min}^{-1}$ ) in females =  $0.6652 + 0.0128 \text{ WM}$
- A.2.  $\text{VO}_2\text{max}$  ( $l \cdot \text{min}^{-1}$ ) in males =  $0.711 + 0.106 \text{ WM} + 0.0037 \text{ HR}_{\text{max}}$   
 $\text{VO}_2\text{max}$  ( $l \cdot \text{min}^{-1}$ ) in females =  $0.0215 + 0.0107 \text{ WM} + 0.006 \text{ HR}_{\text{max}}$
- A.3.  $\text{VO}_2\text{max}$  ( $l \cdot \text{min}^{-1}$ ) in males =  $1.682 + 0.0097 \text{ WM}$   
 $\text{VO}_2\text{max}$  ( $l \cdot \text{min}^{-1}$ ) in females =  $1.631 + 0.0088 \text{ WM}$



B./ Based on the sub-maximal exercises after estimation of  $PWC_{170}$ :

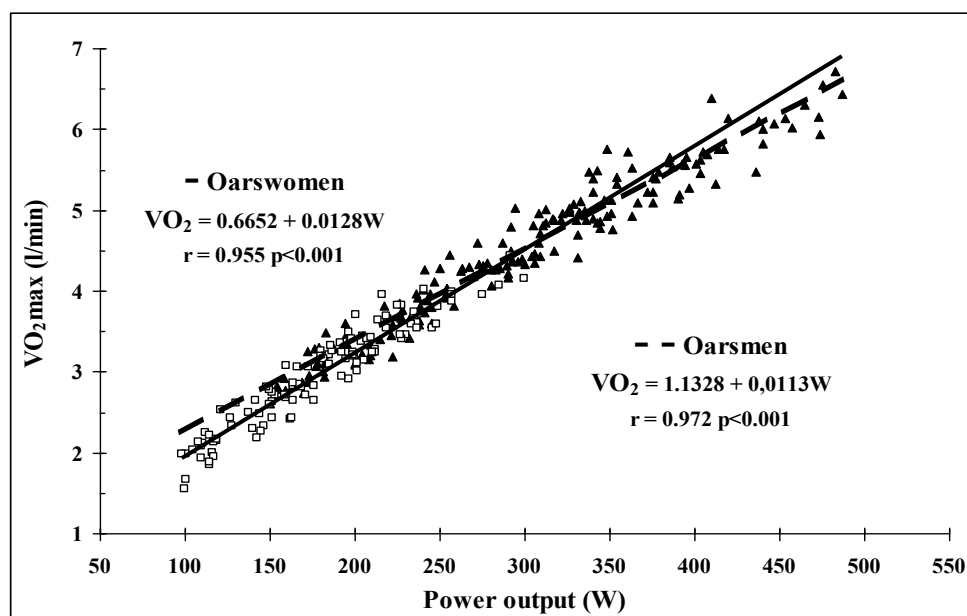
B.1.  $VO_2\max$  ( $l \cdot \min^{-1}$ ) in males =  $3.2131 + 0.0076 (PWC_{170})$

$VO_2\max$  ( $l \cdot \min^{-1}$ ) in females =  $2.4138 + 0.0071 (PWC_{170})$

B.2.  $VO_2\max$  ( $l \cdot \min^{-1}$ ) in males =  $3.2131 + 0.0076 (PWC_{170}) \times K$

$VO_2\max$  ( $l \cdot \min^{-1}$ ) in females =  $2.4138 + 0.0071 (PWC_{170}) \times K$

Formulas A.1. and A.2. were developed using the regression of  $VO_2$  against power output, based on the results obtained in both sub-maximal and maximal exercises (the anaerobic threshold test and the 2-km test) (Fig. 1). Formulas A.3. were established using the regression of  $VO_2$  against the power output attained exclusively in the maximal exercise during the 2-km test.



**Fig. 1**

Relation between oxygen uptake and power output in oarsmen ( $\blacktriangle$ ,  $n=44$ ) and oarswomen ( $\square$ ,  $n=27$ ) exercising on the Concept II rowing ergometer  
Comparison of the regression lines: intercept  $F=21.67$ ;  $P<0.001$ ; slope  $F=10.87$ ;  $P<0.001$

The value of  $PWC_{170}$  was calculated from the regression of HR against power output by interpolation to the HR value of 170 beats per minute. To formulas B.2.,

an additional coefficient K calculated from the regression: measured  $\text{VO}_2\text{max}$ /predicted  $\text{VO}_2\text{max}$  vs. age (in years) was introduced and the following formulas were obtained:

$$K (\text{males}) = 1.0037 - 0.000174 \text{ Age}$$

$$K (\text{females}) = 1.0896 - 0.004584 \text{ Age.}$$

**Table 3**

Comparison of maximal oxygen uptake measured directly and predicted in oarsmen (n=44). Indicated are mean values ( $\pm$ SD), mean differences ( $\Delta$ ), correlation coefficients (r), standard estimation errors (SEE), and total errors (TE). Percentages were calculated relatively to the directly measured values

Coefficient	Method					
	Direct	A.1.	A.2.	A.3.	B.1.	B.2.
$\text{VO}_2\text{max} \pm \text{SD}$ ( $\text{l} \cdot \text{min}^{-1}$ )	5.48 $\pm$ 0.59	5.54 $\pm$ 0.61	5.56 $\pm$ 0.56*	5.47 $\pm$ 0.53	5.48 $\pm$ 0.49	5.48 $\pm$ 0.49
$\Delta \pm \text{SD}$ ( $\text{l} \cdot \text{min}^{-1}$ )		0.07 $\pm$ 0.28	0.09 $\pm$ 0.27	-0.01 $\pm$ 0.27	0.00 $\pm$ 0.33	0.00 $\pm$ 0.33
$\Delta \pm \text{SD}$ (%)		1.36 $\pm$ 5.17	1.78 $\pm$ 5.06	0.12 $\pm$ 4.96	0.37 $\pm$ 6.15	0.37 $\pm$ 6.15
R		0.889***	0.889***	0.889***	0.826***	0.826***
$r^2$		0.790	0.791	0.790	0.682	0.682
SEE ( $\text{l} \cdot \text{min}^{-1}$ )		0.284	0.259	0.274	0.279	0.278
TE ( $\text{l} \cdot \text{min}^{-1}$ )		0.29	0.28	0.27	0.33	0.33
TE (%)		5.28	5.17	4.90	6.03	6.03

\* $P < 0.05$ ; \*\*\* $P < 0.001$ ; significance of the differences and correlation between the measured and predicted  $\text{VO}_2\text{max}$



**Table 4**

Comparison of maximal oxygen uptake measured directly and predicted in oarswomen (n=27). Indicated are means ( $\pm$ SD), mean differences ( $\Delta$ ), correlation coefficients (r), standard estimation errors (SEE), and total errors (TE). Percentage were calculated relatively to the directly measured values

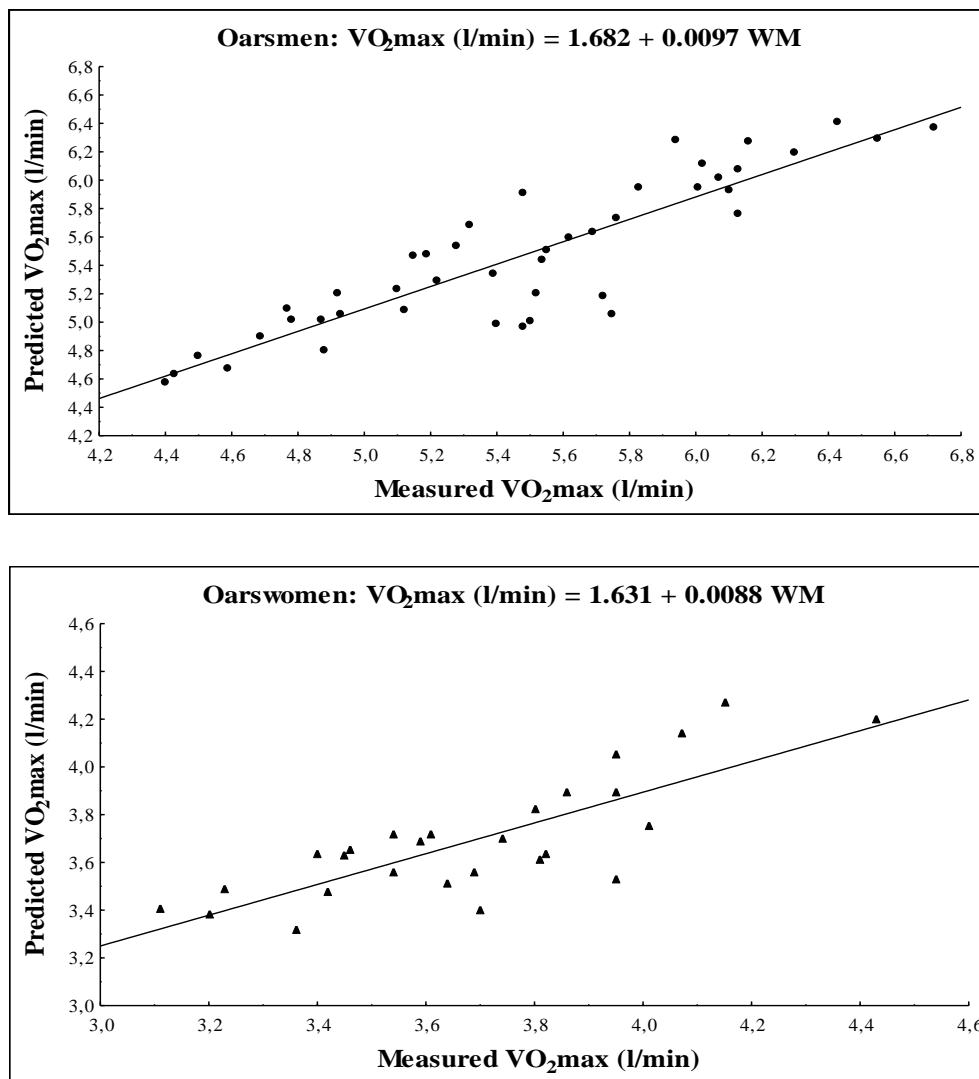
Coefficient	Method					
	Direct	A.1.	A.2.	A.3.	B.1.	B.2.
VO <sub>2</sub> max $\pm$ SD (l·min <sup>-1</sup> )	3.68 $\pm$ 0.31	3.66 $\pm$ 0.36	3.70 $\pm$ 0.30	3.69 $\pm$ 0.25	3.68 $\pm$ 0.22	3.68 $\pm$ 0.20
$\Delta\pm$ SD (l·min <sup>-1</sup> )		-0.02 $\pm$ 0.21	0.01 $\pm$ 0.20	0.01 $\pm$ 0.18	0.00 $\pm$ 0.22	0.00 $\pm$ 0.22
$\Delta\pm$ SD (%)		-0.57 $\pm$ 5.67	0.48 $\pm$ 5.27	0.43 $\pm$ 5.02	0.30 $\pm$ 6.22	0.36 $\pm$ 6.20
r		0.801***	0.793***	0.801***	0.711***	0.718***
r <sup>2</sup>		0.642	0.629	0.642	0.505	0.515
SEE (l·min <sup>-1</sup> )		0.222	0.184	0.190	0.158	0.141
TE (l·min <sup>-1</sup> )		0.22	0.19	0.18	0.21	0.21
TE (%)		5.85	5.22	4.95	5.82	5.80

\*\*\*P<0.001; significance of the correlation between the measured and predicted VO<sub>2</sub>max

Comparisons of the measured VO<sub>2</sub>max values to those predicted from the above regression formulas is shown in Tables 3 and 4. Noteworthy, in all the examined cases only minor differences were detected between the measured and predicted mean values of VO<sub>2</sub>max. The dispersion plots of the measured values of this index v/s those predicted using the regression formulas A.3. and B.1. are presented in Figs. 2 and 3.

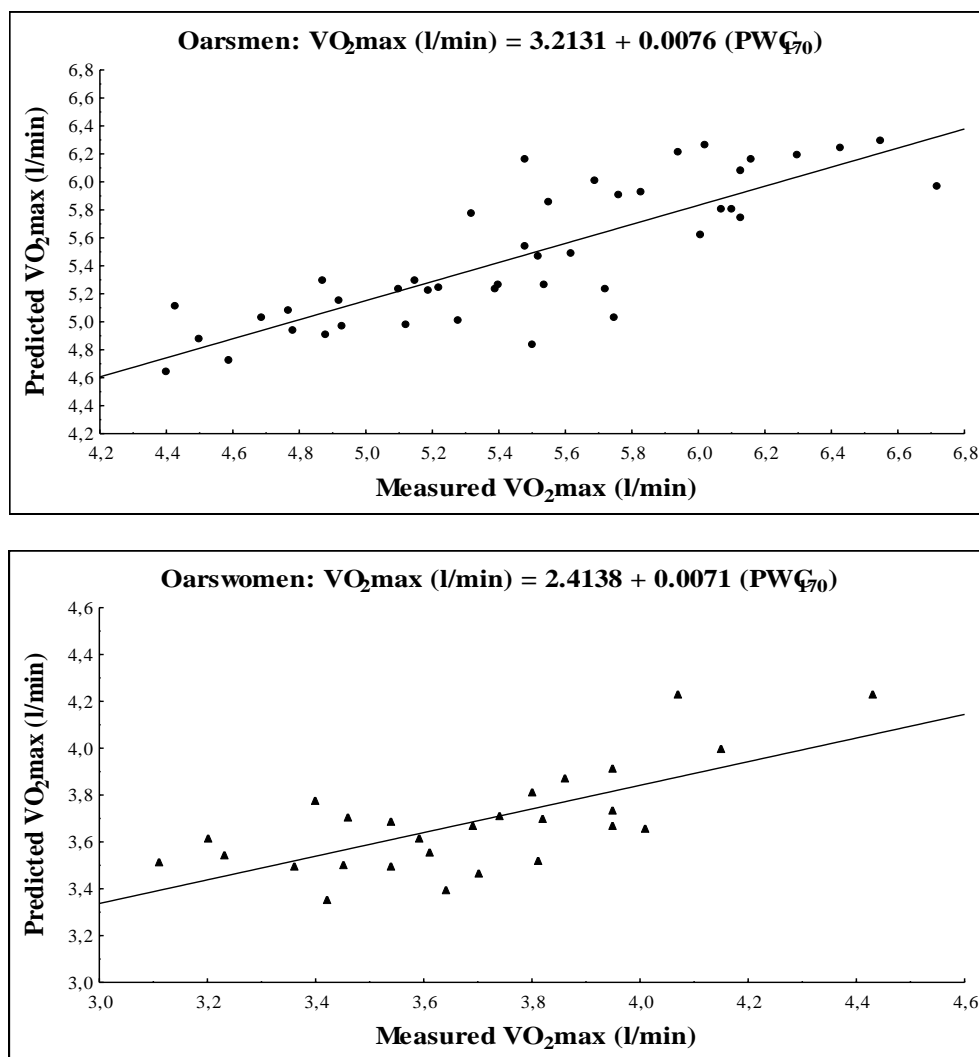




**Fig. 2**

Relation between  $\text{VO}_2\text{max}$  ( $\text{l}\cdot\text{min}^{-1}$ ) measured directly and predicted based on the mean power output (WM) obtained in the 2-km test (A.3. method) in oarsmen ( $n=44$ ) and oarswomen ( $n=27$ )



**Fig. 3**

Relation between  $VO_2\max$  ( $l \cdot \min^{-1}$ ) measured directly and predicted based on  $PWC_{170}$  (B.1. method) in oarsmen ( $n=44$ ) and oarswomen ( $n=27$ )



## Discussion

The original accomplishment of the present study is the demonstration that maximal oxygen uptake can be relatively accurately predicted based on the submaximal and maximal exercising on a rowing ergometer. The differences in the mean  $\text{VO}_2\text{max}$  values ( $\Delta\pm\text{SD}\%$ ) measured and predicted with use of the five presented methods in male and female athletes did not exceed 1.8%. The SEE and TE values were lower than 0.29 and 6.03%, respectively. The correlation coefficient values ranged from 0.711 to 0.899. Accuracy of all the presented methods was similar except for one case – in the A.2. method in males, the predicted  $\text{VO}_2\text{max}$  was significantly different from the measured value (Table 3). However, even in this method the differences of the means equalled to only 1.78% and the values of SEE, TE, and  $r$  were 0.259, 5.17% and 0.889, respectively. The most favourable configuration of the characteristic indices was obtained for the A.3. method. In fact, in this case predicted mean  $\text{VO}_2\text{max}$  values were almost identical to their measured equivalents in both the male ( $\Delta\pm\text{SD}\%=0.12\pm 4.96$ ) and female ( $\Delta\pm\text{SD}\%=0.43\pm 5.02$ ) athletes; the SEE, TE, and  $r$  values amounted to 0.274 and 0.190, 4.90% and 4.95%, and 0.889 and 0.801 in the males and females, respectively. Likewise, mean  $\text{VO}_2\text{max}$  values obtained with the method based on the submaximal exercising (B.1) were identical to their measured equivalents ( $\Delta\pm\text{SD}\%=0.37\pm 6.15$  and  $0.30\pm 6.22$  for the males for females, respectively) and the SEE values were similar to those obtained with the A.3. method. However, the correlation coefficients and total errors of the measurements obtained with the B.1. method in the oarsmen ( $r=0.826$  and  $\text{TE}=6.03\%$ ) and the oarswomen ( $r=0.711$  and  $\text{TE}=5.82\%$ ) were slightly less favourable than those calculated with the A.3. method. Overall, as judged by the values of the presented indices, the two methods seem to yield very precise results. In the studies of Lakomy and Lakomy [10],  $\Delta\%$  equalled to 2.4. In other investigations, the values of  $\Delta\%$  presented or calculated by the authors from the obtained results ranged from 1.2 to 11% [3,4,5,15]. Correlation coefficients ( $r$ ) obtained for men and women with the A.3. method and for men with the B.1. method were significantly higher than the average values calculated by Carey and Frommelt [3] from the results of 14 studies of other authors ( $r=0.69$ ) and by Adams [1] from the results of 13 investigations ( $r=0.64$ ). Similarly, the  $r$  value obtained for women with the B.1. method was slightly higher than the averages reported by these authors. Correlation coefficients of the measured vs. predicted values obtained with the Astrand-Ryhming method [2], over the past 50 years the most commonly used nomogram for predicting  $\text{VO}_2\text{max}$ ,



ranged from 0.63 to 0.85 [2-5,11,12,15] and the SEE values (in  $l \cdot \text{min}^{-1}$ ) usually exceeded 0.5 [11,12].

In the B.2. method, owing to the possible existence of the age-dependent differences in the maximal heart rate we introduced the coefficient (K) dependent on the age of the tested subjects. We presumed that these differences, in the method based on  $\text{PWC}_{170}$ , might affect the predicted  $\text{VO}_2\text{max}$ . As indicated by the obtained results, K did not influence the examined indices, presumably because of the narrow age range of the examined athletes.

One of the factors that favourably affected the accuracy of the prediction of  $\text{VO}_2\text{max}$  was undoubtedly the subjects' familiarity with the exercise tests employed in the present study. In fact, both the sub-maximal exercise test (anaerobic threshold test) and the maximal test simulating rowing the distance of 2000 m (2-km test) are widely used in the exercise examinations of oarsmen [13,14,18] and have for years been employed as routine physical fitness checkups in the leading Polish oarsmen and oarswomen [6,9]. As indicated earlier by us [8], there is a high reproducibility of the results obtained in both the sub-maximal and maximal exercise tests in subjects examined twice within a few days' period. In the cited investigations, the values of the correlation coefficient (test-retest) and the total measurement error expressed in percentages of the mean were as follows:  $r=0.91$  and  $\text{TE}=6.4\%$  for  $\text{VO}_2$  in the submaximal exercise,  $r=0.89$  and  $\text{TE}=5.8\%$  for  $\text{VO}_2\text{max}$ , and  $r=0.99$  and  $\text{TE}=2.7\%$  for the mean power in the maximal exercise.

In the method based on the relation between power output and heart rate during submaximal exercises (B.1. and B.2), the  $\text{PWC}_{170}$  value was used instead of the usually employed HR index for the given power output. Consequently, the possible errors associated with individual registration of HR at the particular power output were eliminated. The relation between  $\text{VO}_2\text{max}$  and  $\text{PWC}_{170}$  during exercising on a rowing ergometer was described in our previous reports [7].

In the present study, the highest values of oxygen uptake recorded in the maximal test which simulated rowing the distance of 2000 m were regarded as  $\text{VO}_2\text{max}$ . This test has for years been used as the most popular method of estimation of the aerobic capacity in oarsmen [9,13,18]. As indicated by Mahler *et al.* [13] and Pipstein *et al.* [16], no significant differences can be detected between peak oxygen uptake determined in the 2-km test on a rowing ergometer and maximal oxygen uptake registered in the incremental exercise until exhaustion.

Similar to the results of Lakomy and Lakomy [10], maximal heart rate of the oarsmen and oarswomen examined in the present study was lower than the expected value calculated from the most commonly used formula:  $220 - \text{age}$  (in years). This phenomenon may be, at least in part, related to the employment of a



rowing ergometer in our studies. In fact, as reported by Yoshiga and Higuchi [19] HRmax recorded on such an ergometer was by four contractions per minute lower than the one registered on a running track. The authors suggested that the reduced heart rate in the former case resulted from the engagement of a large mass of the muscles in a sitting position, the circumstances favouring return of the venous blood to the right atrium and thus making it possible to exercise at maximal intensity at lower HRmax. Moreover, the good fitness of the examined athletes associated with the relatively low maximal heart rate [17] may also be of importance. In fact, as shown previously by us [9], in oarsmen from the Polish national team the HRmax values were lower than those recorded in the direct backup athletes. Likewise, both the junior and senior oarsmen successful in international competition exhibited significantly lower values of HRmax than their unsuccessful counterparts.

In conclusion, the obtained results indicate that it is possible to relatively precisely predict maximal oxygen uptake (l/min) from the indices obtained in both sub-maximal ( $VO_{2max} = 3.2131 + 0.0076 PWC_{170}$  in the males,  $VO_{2max} = 2.4138 + 0.0071 PWC_{170}$  in the females) and maximal (the 2-km test:  $VO_{2max} = 1.682 + 0.0097 WM$  in the males,  $VO_{2max} = 1.631 + 0.0088 WM$  in the females) exercising on a rowing ergometer. From the two methods used, the one based on the maximal exercise simulating rowing the distance of 2000 m appeared to be more accurate for predicting  $VO_{2max}$ .

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