Modeling of anthropometric determinants of rowing ergometer performance on a distance of 500 meters for physically inactive males

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Abstract
The evaluation of the relationships between anthropometric parameters and endurance abilities when covering various distances on the rowing ergometer has been carried out, but mainly on trained athletes. The purpose of studies conducted among students of the University of Warmia & Mazury in Olsztyn was to determine the relationships between selected somatic parameters and the time taken to cover a distance of 500 m on a rowing ergometer. An attempt was also made to determine which body parts, in the study subjects' opinion, are "most engaged" during this motor activity. The research was conducted in 2008 and encompassed 204 male students. The diagnostic survey method along with techniques of measuring anthropometric parameters and the time required to cover 500 m on a rowing ergometer were used. The independent variables, i.e., body mass and height of students, length of lower and upper limbs, and BMI, SI and CPI indices, had a significant effect on the time taken to cover a distance of 500 m. The best results were achieved by students 185 to 190 cm tall, weighing 90 to 95 kg, and with arms measuring from 80 to 90 cm. Approximately 50% of students reported that their legs were worked the hardest with slightly less indicating their whole body and arms (approx. 45.5% and 44%, respectively). Over 45% of the participants stated that all parts of their bodies were worked to the same extent. Nearly 27% indicated three intensively working parts, significantly less (approx. 21.5%) two, and fewest (approx. 6%) one.

Key words: rowing ergometer, anthropometric parameters, male students

Introduction
In 2004, studies regarding the possibility of applying the rowing ergometer in the assessment of endurance abilities among students (male and female) not actively involved in any sport or physical activity were commenced (stage I). (Choszcz et al., 2009; Podstawski et al., 2006). It should be noted that these types of young adults constitute the large majority of students attending the University of Warmia & Mazury in Olsztyn (Podstawski, 2006). The results of preliminary research serve as a reference to analogous studies conducted in the following years among university students, as well as a basis for more the complete analysis of the "500 m on a rowing ergometer" trial. In the second stage of the studies, the above mentioned method was subjected to analysis in order to determine whether it met the basic criteria of selecting tests for studies concerning motor abilities, such as: accuracy, validity, and objectiveness. Within these studies, the effects of covering a distance of 500 m on the rowing ergometer at a frequency of one motor task per week on the human body were also assessed (Podstawski et al., 2009).

As a result of the above mentioned studies, a motion was put forward to expand them so that a greater number of anthropometric and physiological parameters (golden standards) which may affect the time taken to cover 500 m on a rowing ergometer could be established.

A review of literature relating to the subject matter at hand revealed numerous articles which, however, focused mainly on anaerobic and aerobic efforts, with particular attention paid to rowing stretches completed by rowers at high-ranking sports competitions and during sports training (Ingham et al., 2008; Jürimäe et al., 2002; Miculic, 2009; Mikulić & Ružić, 2008; Mikulić et al., 2009; Nevill et al., 2010; Sprague et al., 2007). As indicated above, the studies concerned mainly people who are actively and professionally involved in sport and use the rowing ergometer for training or as a means of assessing one's level of motor fitness, in order to aid preparatory training and participation in future sport competitions.

Studies focused on aspects of health such as aerobic capacity and endurance were also confirmed. They

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pertained to, among others, children's level of endurance measured by means of the rowing ergometer (Gibson et al., 2000), the influence of rowing ergometer training on the function of the left chamber of the heart, and the morphology of the human organism (duManoir et al., 2007), as well as the relationship between the age and sex of study subjects and their abilities to achieve maximum force on the rowing ergometer (Seiler et al., 1998).

The available literature, however, lacks data regarding the ability to apply the rowing ergometer for measuring the level of endurance in university students who are not actively involved in any physical activity. Studies focused on the health aspects of such students have social wide scope since these young adults play major roles in various areas of social, political, economical, and cultural life.

It should also be noted that the capacity of the cardiovascular and respiratory systems is considered to be one of the most important components of motor fitness having a positive influence on health (Bouchard & Shehard, 1994). The efficiency of the cardio-respiratory system prevents the development of various cardiovascular diseases, improves the ability to work, and counteracts fatigue (Sharkey, 1997).

The purpose of the studies conducted among students of the University of Warmia & Mazury in Olsztyn, was to determine the relationship between selected somatic parameters (independent variables) and the time (T) taken to cover a distance of 500 m on a rowing ergometer (dependant variable), in order to establish the potential endurance abilities of students, as mature individuals who do not actively partake in any sports. An effort was also made to establish which parts of the body, in the subjective opinion of the men participating in the study, are "most engaged" when rowing the simulated distance.

The following independent variables were accepted:
- body mass (M) and body height (H) of students,
- year of studies (R),
- height/mass indices, such as: BMI, slenderness (SI), and CPI (Choszcz-Podstawski Index)
- arm length (L_A) and lower limb length (L_L).

The time required to cover the simulated distance of 500 m on the "Concept II Indoor Rower" rowing ergometer was accepted as the dependent variable.

An effort was also made to determine which of the applied height/mass indices are characterized by the highest determination coefficient for these types of studies.

Material and Method

Participants
The studies were conducted in 2008 and included 204 students attending the University of Warmia & Mazury in Olsztyn (UWM). The research was approved by the Bioethical Committee and governing bodies of the UWM, and all participants who gave written consent to take part in the research were tested. A description of students who participated in the experiment is presented in table 1.

| Table I. Specification of statistical parameters for the accepted independent variables with respect to the year of studies |
|---|---|---|---|
| | Mass M [kg] | Height H [cm] |
| | mean ± stand. dev. | Vi | mean ± stand. dev. | Vi |
| | (range) | [%] | (range) | [%] |
| I | 61 | 29.90 | 81.2 ± 10.46 (67–102) | 12.88 | 183.4 ± 6.49 (169–196) | 5.34 |
| II | 59 | 28.92 | 80.1 ± 9.89 (63–102) | 12.35 | 182.1 ± 6.54 (173–201) | 3.59 |
| III | 39 | 19.12 | 81.1 ± 7.32 (68–98) | 9.03 | 181.3 ± 4.67 (173–193) | 2.58 |
| IV | 45 | 22.06 | 80.7 ± 9.93 (65–98) | 12.30 | 182.6 ± 5.84 (176–198) | 3.20 |
| | BMI [kg · m⁻²] | SI [cm·kg⁻²] | CPI (height/mass) [cm · kg⁻¹] |
| | mean ± stand. dev. | Vi | mean ± stand. dev. | Vi | mean ± stand. dev. | Vi |
| | (range) | [%] | (range) | [%] | (range) | [%] |
| I | 24.2 ± 3.55 (19.8–35.4) | 14.67 | 42.6 ± 2.11 (36.3–45.9) | 4.95 | 2.3 ± 0.28 (1.7–2.7) | 12.17 |
| II | 24.2 ± 3.26 (18.4–31.5) | 13.47 | 42.4 ± 2.12 (38.3–46.6) | 5.00 | 2.3 ± 0.27 (1.8–2.9) | 11.74 |
| III | 24.7 ± 2.09 (19.8–28.4) | 8.46 | 41.8 ± 1.41 (39.4–45.7) | 3.37 | 2.2 ± 0.19 (1.9–2.7) | 8.64 |
| IV | 24.3 ± 2.77 (19.9–29.9) | 13.46 | 42.4 ± 2.11 (39.3–46.4) | 4.98 | 2.3 ± 0.28 (1.9–2.7) | 12.17 |
| | Arm length [cm] | Leg length [cm] |
| | mean ± stand. dev. | Vi | mean ± stand. dev. | Vi |
| | (range) | [%] | (range) | [%] |
| I | 78.4 ± 4.06 (72–89) | 5.18 | 89.0 ± 5.63 (79–103) | 6.32 |
| II | 76.5 ± 4.20 (65–85) | 5.49 | 88.3 ± 5.35 (76–101) | 6.05 |
| III | 76.8 ± 5.30 (70–92) | 6.90 | 87.8 ± 5.07 (77–99) | 5.77 |
| IV | 78.1 ± 7.50 (67–98) | 9.60 | 89.3 ± 5.10 (80–101) | 5.71 |

Vi – percentage of variance explained
When validating the choice of the population it should be stated that university students compromise a group which is fully anatomically and physiologically developed, therefore the age of the study subjects completely eliminates the influence of developmental factors on the results of measurements taken on such individuals. This age is also characterized by relative stability as far as the functioning of the central and peripheral nervous systems is concerned (Gierat & Górska, 1999). If the study subjects had been highly engaged in sports activity this fact could have significantly altered the obtained results, as sports groups are characterized by the highest index of biological development among university students (Juras & Waśkiewicz, 1998). Students who took part in the study participated only in the obligatory physical education classes, which lasted 90 minutes and took place once per week, and were not involved in any other physical activity. Moreover, the vast majority of students attending UWM in Olsztyn reside in the Warmia & Mazury region, in the country or in small towns (typically with a population of 20-30 thousand inhabitants). Such a group can be considered to be uniform and, therefore, optimal for studies of this nature.

Data collection
The diagnostic survey method was applied in our studies, along with a technique of measuring anthropometric parameters and the time needed to cover a distance of 500 m on a rowing ergometer. The study tools applied in the experiment consisted of a set for measuring body mass and height as well as the length of the lower and upper limbs, and a Concept II model C rowing ergometer. Prior to conducting the trial, each participant took part in a 20 minute warm up. The results achieved on the rowing ergometer were sent to a computer, via the internet, in the form of the time (s) taken by the study subjects to cover the given distance. All students taking part in the study were instructed how to row and given opportunities to practice proper technique during P.E. lessons preceding the experiment.

Statistical Analysis
The results were subjected to statistical analysis using the Statistica PL suite (Stanisz, 2000; Stanisz, 2001; STATISTICA PL, 1997). Statistical calculations were conducted at a significance level of $\alpha = 0.05$. Before attempting to verify the basic hypotheses, the registered data was checked for the presence of gross errors (Kreft & Choszcz, 2000). Research hypotheses, which postulated that the time it takes to cover a distance of 500 m on a rowing ergometer depends on: the year of studies, the students' height and mass, and the length of their lower and upper limbs, were all subjected to verification.

It was also tested whether the amount of students included in the research was adequate enough to be considered representative. The following formula was applied to determine whether or not the trial is representative (1):

$$n = \frac{\mu_2^2 \cdot S^2}{\alpha^2}.$$ (1)

For the assumed level of significance $1 - \alpha = 0.95$ it was presumed that the error of estimating the average does not exceed 1.5% (Krefft & Choszcz, 2000; Nowak, 2002).

Due to the fact that reality can be described equally effectively by a few significantly different models (Osowski, 1997; Sztuff, 1996), the following forms of functions were tested in the study:

$$y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 \quad (2)$$
$$y = a_0 + a_1 x_1^2 + a_2 x_2^2 + a_3 x_3 + ... + a_7 x_1 x_2 + ... + a_9 x_2 x_3 \quad (3)$$
$$y = a_0 x_1^{b_1} x_2^{b_2} x_3^{b_3} \quad (4)$$

The choice of the tested function forms was determined by the following criteria: they should be as simple as possible while still containing as much information as possible (Oktaba, 1998).

Upon deriving regression equations (multiple, second degree polynomial, and exponential) an analysis of stepwise regression with the a posteriori procedure of eliminating insignificant variables and stepwise selection was carried out. The calculations were performed by means of Winstat (Mikołajczak, 2001) and Statistica PL (Stanisz, 2001) statistical packages. The calculated statistical value (F), the value of the probability of exceeding it, the multiple correlation coefficients, the percentage of explained variance, residual standard deviation, and the random variation coefficient were assumed as the criteria for assessing the suitability of a model for a given set of empirical data. The influence of the significance of structural parameters was also determined (Zieliński, 2001).

Research hypotheses regarding the engagement of different areas of the body during the rowing ergometer trial on a distance of 500 m were also subjected to verification. Variance analysis was applied for their verification (Oktaba, 1998).
Results

Results which had been subjected to statistical analysis were compiled into tables and graphically illustrated. The results of the analysis of variance regarding the influence of the students’ year of studies on the average time it took to cover a simulated distance of 500m are presented in table 2.

Table II. Results of variance analysis of the average time taken to complete the trial

<table>
<thead>
<tr>
<th>Year of studies</th>
<th>Number [n]</th>
<th>Time T [s]</th>
<th>mean ± stand. dev. (range)</th>
<th>Vi [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>61</td>
<td>111.7 ± 11.90 (92.1±140.8)</td>
<td>10.65</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>59</td>
<td>112.6 ± 11.50 (90.5±140.2)</td>
<td>10.21</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>39</td>
<td>109.5 ± 7.79 (94.0±126.4)</td>
<td>7.11</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>45</td>
<td>110.8 ± 10.39 (94.7±132.7)</td>
<td>9.37</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>204</td>
<td>111.3 ± 10.75 (90.5±140.8)</td>
<td>9.61</td>
<td></td>
</tr>
</tbody>
</table>

Calculated value of (F) $F = 0.6911$
Probability of exceeding the calculated (F) statistics $p(F) = 0.5585$
Accepted level of significance $\alpha = 0.05$

As $p(F) > \alpha$, there are no grounds for rejecting the $H_0$ hypothesis.

$V_i$ – percentage of variance explained

The accepted level of significance ($\alpha=0.05$) did not provide grounds for rejecting the hypothesis that the average time it takes to cover the simulated distance of 500 m does not depend on the year of studies the participants of the trial are in. The largest differences in the average time taken to cover the simulated distance were noted between second and third year students, however, even these were not statistically significant. Therefore, in further deliberations, the "year of studies" was excluded as a variable and all students taking part in the studies were treated as a homogenous group. The necessary amount of students calculated from the formula (1), at an accepted 1.5% level of error in estimating the average, amounted to 160 students and was lower than the number of people who took part in the experiment. The trial was, therefore, accepted as representative of the population of students attending the University of Warmia & Mazury in Olsztyn.

For the remaining assessed variables, i.e., body height and mass, and the length of arms and legs, the assumed hypotheses had to be rejected in favor of alternative hypotheses. This is why these variables were accepted as factors which have a significant effect on the dependent variable. The results of analyses regarding the mathematical relationship between the dependant variable (T) and the independent variables (M, H, BMI, SI, CPI, L_R and L_N) have been compiled in table 3

Table III. Results of multivariate analysis of regression

<table>
<thead>
<tr>
<th>Feature</th>
<th>mean ± stand. dev. (range)</th>
<th>Vi [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time T [s]</td>
<td>111.3 ± 10.75 (85.0±140.8)</td>
<td>9.61</td>
</tr>
<tr>
<td>Mass M [kg]</td>
<td>80.8 ± 9.59 (63 ± 102)</td>
<td>11.87</td>
</tr>
<tr>
<td>Height H [cm]</td>
<td>182.5 ± 6.06 (169±201)</td>
<td>3.32</td>
</tr>
<tr>
<td>BMI [kg \cdot m^{-2}]</td>
<td>24.3 ± 3.15 (18.4±35.4)</td>
<td>12.96</td>
</tr>
<tr>
<td>SI [cm\cdot kg^{-0.5}]</td>
<td>42.3 ± 2.01 (36.3±46.6)</td>
<td>4.75</td>
</tr>
<tr>
<td>CPI (height/weight) [cm \cdot kg^{-1}]</td>
<td>2.3 ± 0.26 (1.7±2.9)</td>
<td>11.30</td>
</tr>
<tr>
<td>Arm length L_a [cm]</td>
<td>77.5 ± 5.30 (65±98)</td>
<td>6.84</td>
</tr>
<tr>
<td>Leg length L_n [cm]</td>
<td>88.6 ± 5.32 (76±103)</td>
<td>6.00</td>
</tr>
</tbody>
</table>

Verifying the hypothesis of the significance of the regression equation indices

Hypothesis $H_0$: the regression equation indices differ insignificantly from zero
Hypothesis $H_1$: the regression equation indices differ significantly from zero

Calculated value of (F) $F = 142.49$, $F = 85.74$, $F = 63.39$, $F = 135.57$
Probability of exceeding the calculated (F) statistics $p(F) < 0.0000$

<table>
<thead>
<tr>
<th>Accept level of significance</th>
<th>M, H, L_a, L_n</th>
<th>BMI, L_a, L_n</th>
<th>SI, L_a, L_n</th>
<th>CPI, L_a, L_n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accepted level of significance</td>
<td>$\alpha = 0.05$</td>
<td>$\alpha = 0.05$</td>
<td>$\alpha = 0.05$</td>
<td>$\alpha = 0.05$</td>
</tr>
<tr>
<td>Percent of explained variability</td>
<td>81.27</td>
<td>72.31</td>
<td>58.74</td>
<td>67.04</td>
</tr>
<tr>
<td>Multiple correlation index</td>
<td>0.9015</td>
<td>0.8503</td>
<td>0.7664</td>
<td>0.8188</td>
</tr>
<tr>
<td>Standard deviation of the tests</td>
<td>4.7117</td>
<td>5.7293</td>
<td>7.7363</td>
<td>6.2042</td>
</tr>
<tr>
<td>Random variation coefficient</td>
<td>4.23</td>
<td>5.15</td>
<td>6.95</td>
<td>5.57</td>
</tr>
<tr>
<td>Regression equation</td>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td>(d)</td>
</tr>
</tbody>
</table>

When $p(F) < \alpha$, the zero hypothesis $H_0$ is rejected in favor of the alternative hypothesis $H_1$

\[
\begin{align*}
T &= 0.0068 H^2 + 0.0569 M^2 - 0.0489 L_a^2 - 0.0647 H M + 0.0325 H L_a + 0.0215 M L_a + 161.9032 \\
T &= \cdot -0.463883 \cdot 0.0610 L_a^2 - 0.0296 L_a^2 + 0.53466 \cdot 0.0611 L_a L_n + 0.1550 L_a \cdot BMI + 667.7404 \\
T &= -62.4900 SI + 0.7722 SI^2 - 0.0067 L_a L_n + 1416.3792 \\
T &= -238.1661 CPI + 58.1029 CPI - 0.0039 L_a L_n + 375.0660
\end{align*}
\]

$V_i$ – percentage of variance explained
The conducted regression analysis enabled the formulation of a few important equations describing the influence of independent variables on the time taken to cover a distance of 500 m on a rowing ergometer.

Among the mathematical equations introduced, the regression analysis (a), in which the body mass and height of students as well as the length of their lower and upper limbs were assumed as the independent variables, proved to be the best suited for the given set of empirical data. For this relationship, the percentage of variance explained exceeded 81%, with a very low coefficient of random variation (approx. 4%). Equations (b) and (c) are also characterized by relatively high compatibility, with the percentage of variance explained equal to 72% and 67%, respectively, and a relatively high coefficient of random variation of approx. 5%. The length of the lower limbs ($L_N$) had relatively the least influence on the amount of time it took to cover a distance of 500 m, followed by the length of the upper limbs ($L_R$). The described relationships are presented as graphic illustrations of the results (fig. 1-4), at average values of the parameters.

**Figure I.** Relationship between time taken to complete the trial and the body height and mass of students

**Figure II.** Relationship between the time taken to complete the trial and the BMI index and length of the upper limbs

**Figure III.** Relationship between time taken to complete the trial and the SI index and length of the upper limbs

**Figure IV.** Relationship between time taken to complete the trial and the CPI index and length of the upper limbs
Based on the derived mathematical dependency (tab. 3, regression equation - a) and analysis of the graph (fig. 1), it can be stated that the decision variables in this model are the body mass and height of the study subjects. The length of the upper limbs also has a significant effect on the time taken to cover a distance of 500 m on a rowing ergometer. The variable which was not found to have a significant effect was the length of the lower limbs. The best results (under 100 s) were achieved by students weighing between 90–95 kg, 185 to 190 cm in height, and with upper limbs measuring between 80–90 cm in length. In the remaining models (tab. 3), the length of the upper and lower limbs was found to have a significant effect on the time it took to complete the simulated distance, in addition to the accepted indices (BMI - equation b, SI - equation c, and CPI - equation d). Upon analysis of the graphic illustrations presenting the described relationships (fig. 2, 3, and 4) it can be deducted that students characterized by an arm length between 80 and 90 cm, and leg length between 85 and 95 cm, as well as the following indices (derivatives of body mass and height): BMI (from 26 to 30 kg·m⁻²), SI (from 39 to 43 cm·kg⁻⁰·³³), and CPI (from 2.0 to 2.4 cm·kg⁻¹), are most predisposed for rowing.

Results regarding the "work put in" by the students' individual body parts under analysis have been presented in table 4.

| Table IV. Body parts claimed to be worked by students when covering a distance of 500 m on the rowing ergometer |
|---|---|---|---|---|---|
| Body part | I | II | III | IV | Total |
| n | % | n | % | n | % | n | % | n | % |
| 1. Arms | 25 | 40.98 | 26 | 44.06 | 19 | 48.72 | 20 | 44.44 | 90 | 44.12 |
| 2. Legs | 28 | 45.90 | 31 | 52.54 | 21 | 53.85 | 22 | 48.89 | 102 | 50.00 |
| 3. Buttocks | 9 | 14.75 | 11 | 18.64 | 6 | 15.38 | 8 | 17.78 | 34 | 16.67 |
| 5. Abdomen | 6 | 9.84 | 8 | 13.56 | 5 | 12.82 | 7 | 15.56 | 26 | 12.75 |
| 6. Whole body | 28 | 45.90 | 29 | 49.15 | 17 | 43.59 | 19 | 42.22 | 93 | 45.59 |

Calculated value of (F) statistic: F=161.2270
Probability of exceeding the calculated (F) value: p(F)=0.0000
Accepted level of significance: α=0.0500

Because p(F) < α - the H₀ hypothesis should be rejected in favor of an alternative hypothesis.
Results of the Duncan test: 1, 2, 6 > 3, 4, 5; 2 > 1, 6

<table>
<thead>
<tr>
<th>Number of indicated body parts</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>A - only one</td>
<td>3</td>
<td>4.92</td>
<td>4</td>
<td>6.78</td>
<td>2</td>
</tr>
<tr>
<td>B - only two</td>
<td>13</td>
<td>21.31</td>
<td>11</td>
<td>18.65</td>
<td>9</td>
</tr>
<tr>
<td>C - only three</td>
<td>17</td>
<td>27.87</td>
<td>15</td>
<td>25.42</td>
<td>11</td>
</tr>
<tr>
<td>D - all</td>
<td>28</td>
<td>45.90</td>
<td>29</td>
<td>49.15</td>
<td>17</td>
</tr>
</tbody>
</table>

Calculated value of (F) statistic: F=240.5741
Probability of exceeding the calculated (F) value: p(F)=0.0000
Accepted level of significance: α=0.0500

Because p(F) < α - the H₀ hypothesis should be rejected in favor of an alternative hypothesis.
Results of the Duncan test: D > A, B, C; C > A, B; B > A

- differences are statistically significant at the α=0.05 level
-** differences are statistically significant at the α=0.01 level

Statistical analysis regarding the number of times students indicated certain regions of their body as those which are worked the most intensely during the trial on the rowing ergometer showed that there are no grounds to accept the hypothesis that all analyzed body parts are worked equally hard. It was established that approx. 50% of students indicated that their lower limbs (legs) were worked the hardest, whilst slightly fewer (approx. 45.5%) indicated their whole body; a similar percentage of students (approx. 44%) stated that their arms were the most intensively worked. The remaining body parts, such as: the buttocks, back, and abdomen, were indicated much less frequently - in the few percent range.

When looking into the motor structure of "work" performed on the rowing ergometer in terms of the number of body parts engaged in the effort, it was noted that over 45% of the study subjects stated that all the specified body parts were worked. However, nearly 27% of people indicated three working body parts, significantly fewer - two body parts (approx. 21.5%), with the least indicating only one part (approx. 6%).

**Discussion**

During the first stage of the studies an effort was made to assess the construct validity of the "500 m on a rowing ergometer" test, based on the content analysis of literature pertaining to the subject matter at hand. It was assumed that work done on this equipment is typical of submaximal effort, lasting 50 – 120 s (Podstawski et al., 2006). During work done on the rowing ergometer, nearly all parts of a person's muscular system are
engaged (Secher, 2000; Yoshida & Higuchi, 2003). Statistical analysis of results obtained in the given experiment, conducted based on the subjective impressions of the study subjects, confirmed the above mentioned assumptions in the opinions of 45% of the respondents. A mere 5% of students who participated in the trial indicated that only one part of their body was worked when rowing on the rowing ergometer.

Moreover, it was found that not all the applied anthropometric parameters influence the obtained results equally. In the participants' opinion, the lower limbs (approx. 50%) and upper limbs (approx. 44%) were the most engaged body parts during exercise performed on the rowing ergometer. Surprisingly, the subjective assessment of the engagement of individual body parts was not reflected by the statistical analysis of results regarding the influence of independent variables on the time (T) it took to cover a distance of 500 m on the rowing ergometer. It was confirmed that the main factors which influence the final result (measured time T) are body mass (M) and height (H) as well as indices derived from these parameters. This is confirmed by mathematical models describing this variance, included in table 3. The significant influence of arm length (Lₐ) and leg length (Lₐ) was also shown to have an interactive nature in the majority of the individual equation components. This signifies that these features are a derivative of general body built and are generally reflected by height.

The observations have a significant meaning when it comes to applying the rowing ergometer in an effort to improve physical fitness, not only in athletes who regularly partake in sport, but also among those people who only sporadically take part in physical culture. Due to the fact that sport is a form of participation in physical culture, by people who possess the adequate somatic-motor predispositions and agonistic-perfectionist aspirations, the goal of whom is to meet the need of self-fulfillment by means of competition, aspiring to achieve maximum results in physical and motor ability, it pertains only to a small group of people within a given society (Grabowski, 1999). People, who aren't physically active along with those representing a low level of motor fitness, constitute the highest percentage in just about every society, including those of highly developed as well as underdeveloped nations (Francis, 1999; Kuntzelman & Reiff, 1992; Schlcker et al., 1994). This gives reason as to why the trial of covering a distance of 500 m on the rowing ergometer can be used to assess the level of endurance abilities in representatives of this social group, i.e., people who are less physically able and even partially physically handicapped. Equalizing the negative influence of body mass on the movement performed by relieving the lower limbs enables the person exercising to perform an effort of moderate intensity for a longer period of time. This poses an important argument for applying the rowing ergometer to increase the level of a person's endurance abilities.

Despite the fact that studies agree that VO₂max is the strongest indicator of rowing ergometer performance of all tested anthropometric and physiological parameters (Ingham et al., 2002; Jürimäe et al., 2002), body mass and lean body mass are also commonly indicated as important predictors (Cosgrow et al., 1999; Mikulić & Ružić, 2008; Russel et al., 1998). Studies conducted on a group of sportsmen who actively train rowing shows that, on the whole, the efficiency of rowing on given distances increases along with an increase in body measurements and activation of as many muscles taking part in the effort as possible (Ingham et al., 2008; Mikulić & Ružić, 2008; Russel et al., 1998). Professional rowers performing at a high level are tall, heavy, and have high values of VO₂max (Ingham et al., 2008; Jürimäe et al., 2002; Nevill et al., 2010; Riechman et al., 2002). A similar relationship was observed in our study conducted on people who are passive in terms of physical activeness, which is to say that the best results were obtained by individuals with a body mass in the range of 90-95 kg and a height of 185 to 190 cm.

The above mentioned relationships most likely stem from the fact that in the sitting position taken on a rowing ergometer the rowers body mass is supported by the seat of the device, and the athletes can afford to be heavier (Steinecker, 1993). Other authors’ studies on professional rowers revealed significant correlations between performance and body mass as well as dimensions (Battista et al., 2007; Bourgois et al., 2000; Hebbelnick et al., 1980; Shephard, 1998). These studies were however conducted mostly on longer stretches (2000 m and less often – 1000 m). The above research concluded that top rowers can be generalized as having higher values of anthropometric parameters and lean body mass when compared to average persons (Bourgois et al., 2000; Russel et al., 1998).

The positive influence of possessing longer limbs is connected with their levering effect and ability to perform longer strokes. The biomechanical advantage of longer legs is caused by the longer drive phase of the rowing stroke and further knee extensions (Battista et al., 2007; Mikulić & Ružić, 2008; Russel et al., 1998; Slater et al., 2005). Therefore, elite rowers are characterized by a shorter sitting height (relative to stature) but at the same time longer limbs, when compared to average people (Bourgois et al., 2001; Cleassens et al., 2005; Mikulić, 2008, 2009).

Attention should be paid, however, to the individual diversity that occurs in the basic anthropometric parameters (body mass and height) as well as height-mass indices calculated on the basis of these parameters in groups of fit (physically active) and unfit (physically passive) individuals. The body mass of rowers who train professionally is composed mainly of lean body mass, and the obtained results are largely influenced by a high
level of maximal oxygen uptake (in L/min). These factors are, in turn, determined by the genetic predispositions of the athlete and proper training. Therefore, individuals characterized by a well developed muscular system, a solid skeleton, an above average height, and oxygen capabilities (Mikulić & Ružić, 2008) will be more predisposed to achieve better results. On the other hand, the body mass of individuals who aren't physically active is largely made up of body fat (fatty tissue) as opposed to muscle, which significantly restricts the aerobic capabilities of an organism (Carter, 1985; Ingham et al., 2002; Mikulić & Ružić, 2008; Secher, 1983, 2000). The conducted research confirmed a significant relationship between anthropometric parameters and the results achieved in the trial of covering a distance of 500 m on a rowing ergometer by individuals leading a passive lifestyle.

Conclusions

The following conclusion can be formulated based on the conducted studies:

1. Statistically significant differences were not noted between the time it took to cover a distance of 500 m on a rowing ergometer and the year of studies of the participants. The group was, therefore, treated as homogenous.

2. The independent variables accepted in the study, i.e.: body mass and height of students, length of the lower and upper limbs, as well as BMI, SI and CPI indices, had a significant influence on the dependent variable (time taken to cover a distance of 500 m).

3. Among the tested models, the second degree polynomial proved to be the best suited model for describing the given phenomenon, whilst the body mass and height of students as well as the length of their upper limbs were confirmed as the decision variables. Students who completed the distance of 500 m on a rowing ergometer the fastest, were characterized by a height of 185 to 190 cm, a body mass of 90 to 95 kg, and an arm length of 80 to 90 cm.

4. In the respondents' opinion, the individual body parts were not equally engaged in the effort required to cover a distance of 500 m on the rowing ergometer. Approximately 50% of the students indicated that their lower limbs (legs) were worked the hardest, slightly fewer (approx. 45.5%) indicated their whole body, whilst about 44 % specified their upper limbs (arms). The remaining body parts, such as: the buttocks, back, and abdomen were indicated much less frequently - in the few percent range. Over 45% of the students who took part in the research stated that all of the analyzed body parts were worked during the ergometer trial. Nearly 27% indicated three working body parts, significantly fewer specified two (approx. 21.5%), with the fewest students indicating only one working body part (approx. 6%).

5. The research ought to be continued and its scope extended to include physiological parameters as well as other age groups (e.g., high school, middle school, and even elementary school students). The influence of training and its duration on the time taken to cover a simulated distance should also be taken under analysis. This would give researchers, P.E. teachers and physical therapists a better understanding of the possibility of applying this trial for health purposes.

Conflict of Interest: Nothing to declare

References


