Central European Journal of Sport Sciences and Medicine | Vol. 37, No. 1/2022: 101–114
ISSN (print): 2300-9705 | ISSN (online): 2353-2807 | DOI: 10.18276/cej.2022.1-09

1,000-M ROWING ERGOMETER TIME TRIAL PERFORMANCE IN FEMALE AND MALE COLLEGIATE ROWERS

Oliwer Huzarski[A, B, D]

Student Research Club at the Department and Unit of Functional Diagnostics and Physical Medicine, Pomeranian Medical University, Szczecin, Poland
ORCID: 0000-0001-7644-4810

Waldemar Pluta[A, C, D]

Department and Unit of Functional Diagnostics and Physical Medicine, Faculty of Health Sciences, Pomeranian Medical University, Szczecin, Poland
ORCID: 0000-0002-6760-199X

Anna Lubkowska[A, C, D]

Department and Unit of Functional Diagnostics and Physical Medicine, Faculty of Health Sciences, Pomeranian Medical University, Szczecin, Poland
ORCID: 0000-0002-5378-5409 | e-mail: anna.lubkowska@pum.edu.pl

[A] Study Design; [B] Data Collection; [C] Statistical analysis; [D] Manuscript Preparation; [E] Funds Collection

Abstract **Introduction.** The purpose of this study was to evaluate the time of covering a distance of 1,000 m on a rowing ergometer by competitors of the Academic Sports Association of the Pomeranian Medical University and to relate the achieved results to the best results from the Polish Rowing Ergometer Academic Championships.
Methods. 28 rowers were tested in the 1,000 m "maximum" test (1,000 TM/t). In addition, correlations were sought between the time and power values obtained in the 1000 TM/t with the values of selected anthropometric indices (height and weight, body mass index BMI), hand grip strength, heart rate and body composition components (free fat mass FFM, skeletal muscle mass SMM).
Results. The significant correlation between the time and power output in 1,000 TM/t and values of FFM, SMM, handgrip strength test as well as resting HR have been observed.
Conclusion. The results obtained at 1,000 TM/t can be considered promising for the further training stage due to the fact that the study was conducted on a rowing ergometer under training conditions prior to a special training mesocycle shaping strength and speed, while the athletes competing at the event to which our results were related were in peak competitive performance.

Key words: performance rowing, indoor rowing, ergometer, "1,000 m maximal test"

Introduction

In testing rowers on water, the main limitations are the lack of technical possibilities to perform some physiological measurements, the high costs of portable apparatus and the variability of environmental conditions.

Therefore, conducting diagnostic exercise tests in the laboratory using a rowing ergometer enables standard test conditions to be maintained and sufficiently fulfils the postulate of test specificity. The rowing ergometer is an indispensable training tool in rowing, due to the fact that it most closely reflects the biomechanics of movement in a rowing boat (Sablic, Versic, Uljevic, 2021). The Concept II rowing ergometer was used for this study, allowing a simulation model for starting conditions that reproduces with due accuracy the relationships between the dominant sources of muscle metabolism during the rowing cycle. The use of such an apparatus during periods of preparation on land makes it possible to isolate individual stroke sequences, which allows athletes to better prepare physically and technically for rowing competitions.

Optimal performance on an ergometer involves proper technique and engages all major muscle parts (Secher, 2007; Hennig, 2003). The rowing stroke can be divided into 4 stages: the catch, the drive, the finish and the recovery. The catch is the starting point of the stroke. On a rowing boat this is the moment when the oar feather is immersed in the water. The counterpart to this on an ergometer is the retraction of the chain of the ergometer's acceleration handle. The correct posture during the catch is: arms straight, head in natural position, shoulders lowered, torso leaning forward, knees bent, shins upright. The drive is the force generating part of the pull. The drive can be divided into an early phase and a late phase. In the early phase, the straightened arms and shoulders passively transfer the force generated by the legs, hips and lower back. The force transferred to the ergometer comes first from straightening the legs and then from bending the torso backwards. In the late phase of the ride after the handle pass the knees, there is a pull from the arms. The finish on a rowing boat is the moment when the oar feather is pulled out of the water. On the ergometer this is the final stroke position in which the legs are straightened at the knees, the torso is slightly bent backwards (at an angle of 110 degrees) and the arms are pulled towards the ribcage. The recovery is passive and consists of returning to the starting position and preparation for the next pull. First the arms are straightened, then the torso is returned to 70 degrees, leg flexion begins when the torso is at 90 degrees.

The endurance preparation season during the rower's annual training cycle consists of the athlete performing 3 workouts per week on the ergometer (3 × 20 min continuous pace of 26–28 strokes per minute) for a period of 5 months. The rules of the academic competition differ from other championships in the distance to be covered by the rowers, which is 1,000 m instead of 2,000 m. For this reason, a 1,000 m test on a rowing ergometer is used for ongoing evaluation of the level of training in relation to the times achieved over this distance. Each season's annual preparation of rowing students culminates with the Polish Rowing Academic Championships (AMP in rowing), usually held in May, and the Polish Rowing Ergometer Academic Championships (AMP in rowing ergometer), held earlier, usually in April. The examined rowers competing at the national academic level achieved medal successes in the 2020/2021 season: women a silver medal in the 2021 Polish Rowing Academic Championships, men a bronze medal in the 2021 Polish Rowing Academic Championships.

Due to the lack of opportunity to participate in last year's rowing ergometer competition it seems purposeful to compare actual rowing performance with the rivals from the last year competition. Consequently, the aim of the study was to evaluate the time of covering a distance of 1,000 m on a rowing ergometer by competitors of the Academic Sports Association of the Pomeranian Medical University (KU AZS PUM) and to relate the achieved results to the best results from the Polish Rowing Ergometer Academic Championships.

In addition, correlations were sought between the time and power values obtained in the 1,000 m test with the values of selected anthropometric indices (height and weight, body mass index BMI), hand grip strength and body composition components (free fat mass FFM, skeletal muscle mass SMM).

Material and methods

Test group

A total of 28 rowers (12 women and 16 men) competing on rowing eights (W8+ women's eight M8+ men's eight) training in the college club rowing section of KU AZS PUM took part in the study. In the men's group there were 9 rowers of the first rowing team (technically advanced) and 7 rowers of the reserve rowing team (beginners). In the women's group there were 8 rowers from the first rowing team (technically advanced) and 4 rowers from the reserve rowing team (beginners). The average rowing experience in the male group was 26.25 months (range 12 to 60 months) and in the female group 35.5 months (range 6 to 80 months). None of the study participants, both men and women, except for the participation in regular training sessions and in seasonal competitions of the rowing section of AZS PUM, had previously practised any sport discipline on a competitive basis.

All subjects and the trainer agreed to use the results obtained during the tests, which are part of the routine rowing training unit, for the scientific elaboration.

Maximum speed' exercise test (TM/t)

The study was conducted during a single training unit.

Prior to the speed tests, athletes had their resting heart rate (HR_{rest}) measured by palpation on the radial artery and internal carotid artery and body mass composition was analysed by electrical bioimpedance using a TANITA DC-430 S MA. The global grip strength of the hand (both right and left) handgrip test was also investigated, using a hydraulic handgrip dynamometer (BASELINE). For each upper limb, 3 repetitions of the measurement were made, from which the mean values were calculated for analysis.

Then each competitor was subjected to a speed test: The "maximum" test (TM/t) consisted of an assessment of the athlete's special fitness by simulating a 1,000 m race distance on a Concept II ergometer in as short a time as possible.

The load (drag factor) was set at 120 N s^2/m^2, which best corresponds to the resistance offered by the water when rowing in real conditions. During the test, heart rate was monitored using a Polar H10 heart rate monitor. Data were collected on average heart rate, maximum heart rate and minimum heart rate throughout the test and for each 100 m split. HR_{rest} was used to analyse the determinants of performance (power values [W] and time to complete the distance [s] as well as the calculated average exercise heart rate and maximum heart rate values obtained during the test.

Statistical Analysis

Statistical analyses were performed with the use of STATISTICA 13.3 software (StatSoft. Poland). All variables met normality assumptions using a Shapiro-Wilk test. The data distribution met the conditions of normal distribution, therefore the examined variables were presented in the form of arithmetic means and minimum and maximum values. A comparative analysis of the significance of difference in the temperature values of selected areas between groups was carried out using the Student's t-test. Additionally, the correlations between all of the examined parameters were calculated in studied groups.

Table 1. Anthropometric characteristics of the participants

	Men (n = 16)		Women (n = 12)		Student's t-test *p* t
	mean	min–max	mean	min–max	
Age (years)	22	20–24	22	20–25	NS
Body height (m)	186.19	178–198	172.17	159–183	*p* = 0.0000 t = 5.4
Body weight (kg)	82.66	63.4–98.4	63.98	50.30–86.6	*p* = 0.0003 t = 4.66
BMI (kg/m^2)	23.8	18.9–28.4	21.55	18.60–28.6	*p* = 0.0274 t = 2.18
BF (kg)	9.81	4.8–21.1	15.82	10–30.9	*p* = 0.0114 t = 5.39
PBF (%)	11.49	5.5–23.5	24	16.6–39.2	*p* = 0.0002 t = 2.5
FFM (kg)	72.84	58.3–85.4	48.16	40.3–52.7	*p* = 0.0000 t = 9.43
SMM (kg)	69.43	55.4–81.2	45.72	38.2–50s	*p* = 0.0000 t = 9.66
Rowing training experience (months)	26.25	12–60	35.5	6–84	NS

Legend: BMI – body mass index; BF – body fat; PBF – percent body fat; FFM – free fat mass; SMM – skeletal muscle mass.
Statistically significant difference at *$p < 0.05$, ** $p < 0.01$, ***$p < 0.001$.

Table 2. The mean as well as the minimum and maximum values of the results obtained in the cycloergometer speed test (1,000 m TM/t) and the values of heart rate indices (HR)

	Men (n = 16)		Women (n = 12)		Student's t-test *p* t
	mean	min–max	mean	min–max	
1000 m test time (s)	200.58	183.9–243.7	241.58	224.2–264.7	*p* = 0.0001 t = 7.0
1000 m test (W)	3236.3	1832–4072	1810	1356–2231	*p* = 0.0002 t = 5.04
HRrest (BPM)	61	48–75	64	60–72	NS
Avg HR (BPM)	178.13	164–193	177.17	169–199	NS
highest exercise HR (BPM)	186.63	175–199	184	174–202	NS
HGt_{left} left side rowing	51.4 * vs HGt_{right}	33.3–78	26.6 * vs HGt_{right}	21–34.3	*p* = 0.000884 t = 4.29
HGt_{left} right side rowing	51.29 * vs HGt_{right}	36.7–67	30.2 * vs HGt_{right}	27.3–33	*p* = 0.004704 t = 3.62
HGt_{right} left side rowing	52.73	33.7–69.7	28.73	23.7–38.7	*p* = 0.000778 t = 4.36
HGt_{right} right side rowing	53.96	41–65.7	32.4	29.3–36	*p* = 0.000620 t = 4.90

Legend: HR_{rest} – heart rate measured in rest; HGt_{left} – handgrip test left hand; HGt_{right} – handgrip test right hand; Avg HR – average exercise HR; *significance of differences between HGt strength for contralateral upper limbs within competitors from the same rowing side at $p < 0.05$.

Results

The results of the study are presented in tables and charts. The characteristics of the studied group including body composition indices are presented in Table 1. Due to natural and expected and statistically confirmed inter-gender differences for anthropometric values and body composition, the results were analysed independently for women and men. The mean height and weight values for women were respectively: 172.17 cm and 63.98 kg and for men respectively: 186.19 cm and 82.66 kg. Mean BMI showed significant inter-sex variation, being 21.55 kg/m^2 for females and 23.8 kg/m^2 for males. Similarly, intersex differences were observed for all analysed body composition indices: BF, PBF, FFM and SMM, whose mean values were 15.82 kg, 24%, 48.16, 45.72 for women and 9.81 kg, 11.49%, 72.84 kg, 69.43 kg for men, respectively.

Mean HR_{rest} values measured before the speed test were 64 BPM in women and 61 BPM in men, sequentially calculated from the whole exercise period mean heart rate values were 177 BPM for women and 178 BPM for men.

The mean value of maximum heart rate obtained during exercise was 184 BPM in women and 186 BPM in men. The values for heart rate did not show inter-sex variation.

Table 2 summarises the mean as well as the minimum and maximum values of the results obtained in the cycloergometer speed test (1,000 m TM/t) and the values of heart rate indices. The results of simulation studies (starting conditions) conducted at the end of a mesocycle shaping the general endurance of rowers (Hagerman, Staron, 1983), indicate a significant range of variation in individual power indices obtained in the 1,000 m test. The mean power generated by the subjects was 1,810 W for women (range 1,356–2,231) and 3,236 W for men (range 1,832–4,072). The mean time to cover 1,000 m was 241.58 s for women and 200.58 s for men.

Competitors at the AMP in rowing ergometer compete in one of two weight categories: light weight with a weight limitation in the starting suit for women of up to 61.5 kg and for men of up to 75 kg and open weight with no weight limit for either women or men. In the study group the lightweight criterion was met by 5 men and 5 women the rest were qualified to the open weight category. If we relate the results of times in TM/t test by rowers of KU AZS PUM to the results of individual classification in AMP in the year 2020/21 in lightweight men would take respectively 6th, 28th, 66th, 71st and 95th place out of 98 competitors and in open weight 27th, 33rd, 39th, 45th, 46th, 62nd, 67th, 75th, 76th, 123th and 146th place out of 146 competitors. The women would be ranked 45th, 54th, 59th, 76th and 77th out of 92 athletes in the light weight and respectively 31st, 48th, 50th, 56th, 59th, 61st and 62nd out of 84 athletes in the open weight (Table 3). The results of the best 3 female athletes and the best 6 male athletes of a given university, apart from the individual classification, are also taken into account in the overall team classification for women and men. Considering the obtained results and places, men would take the 6th place out of 28 universities while women would take the 17th place out of 29 universities.

Table 3. Relating the rowers' TM/t results to the results and placed positions in the individual classification from the 2020/2021 AMP in Rowing Ergometer

Category	Number of KU AZS PUM athletes surveyed, whose current results correspond to locations			Number of participants in AMP in Rowing Ergometer 2020/21
	1st–10th	11th–50th	>50th	
Men's lightweight	1	1	3	98
Men's open weight	0	5	6	146
Women's lightweight	0	3	2	92
Women's open weight	0	3	4	84

An additional aim of the study was to search for correlations between anthropometric indices, body composition, handgrip test results, resting and exercise heart rate values and total time in 1,000 m TM/t as well as values of generated power. Statistical analysis did not confirm a statistically significant correlation between Avg HR and highest exercise HR with generated power and test time. Interestingly, the male group showed a statistically significant correlation between the results obtained and values of resting heart rate ($r = –0.506$, $p = 0.0455$). A lower resting heart rate determined higher values of generated power and shorter times. Women showed a similar trend but without statistical significance.

On the other hand, indices characterising the muscular components of body composition and handgrip strength values showed a high correlation with generated power both in women (FFM: $r = 0.7030$, $p = 0.0108$; SMM: $r = 0.7050$, $p = 0.0104$; $HGtright_{left}$ side rowing: $r = –0.0063$, $p = 0.9919$; $HGtleft_{left}$ side rowing: $r = 0.4037$, $p = 0.4273$; $HGtleft_{right}$ side rowing: $r = 0.3300$, $p = 0.5230$; $HGtright_{right}$ side rowing: $r = 0.0311$, $p = 0.9605$) as well as in men (FFM: $r = 0.7713$, $p = 0.0005$; SMM: $r = 0.7414$, $p = 0.0010$; $HGtright_{left}$ side rowing: $r = 0.7053$, $p = 0.0767$; $HGtleft_{left}$ side rowing: $r = 0.6057$, $p = 0.0839$; $HGtleft_{right}$ side rowing: $r = 0.8737$, $p =0.0021$; $HGtright_{right}$ side rowing: $r = 0.8222$, $p = 0.0232$) and with the results of the times obtained in both women (FFM: $r = –0.7127$, $p = 0.0093$; SMM: $r = –0.7149$, $p = 0.0090$; $HGtright_{left}$ side rowing: $r = –0.0304$, $p = 0.9613$; $HGtleft_{left}$ side rowing: $r = –0.3940$, $p = 0.4396$; $HGtleft_{right}$ side rowing: $r = –0.3549$, $p = 0.4900$; $HGtright_{right}$ side rowing: $r = –0.0748$, $p = 0.9049$) as well as in men (FFM: $r = –0.7201$, $p = 0.0017$; SMM: $r = –0.6898$, $p = 0.0031$; $HGtright_{left}$ side rowing: $r = –0.6859$, $p = 0.0889$; $HGtleft_{left}$ side rowing: $r = –0.6020$, $p = 0.0863$; $HGtleft_{right}$ side rowing: $r = –0.8258$, $p = 0.0061$; $HGtright_{right}$ side rowing: $r = –0.8128$, $p = 0.0263$). The fat components of body composition did not show significant relationships with power and time values in the 1,000 mTM/t test.

Statistically significant correlations by gender are presented in figures from 1 to 6.

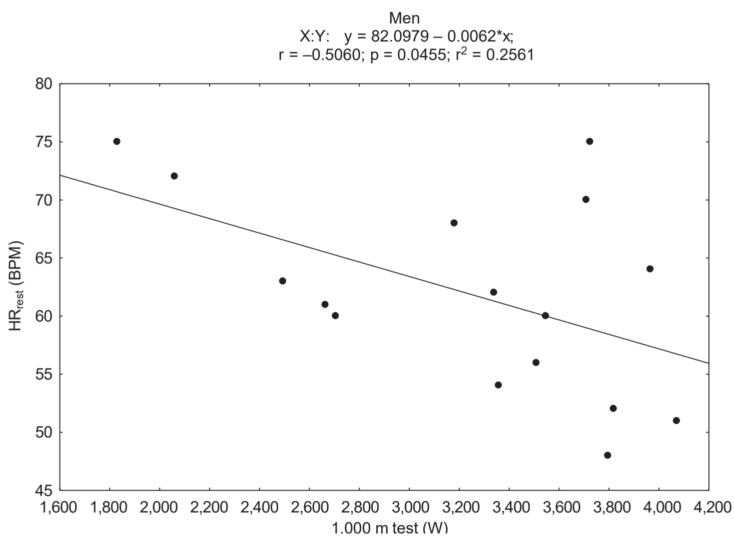

Figure 1. Relationship between rest heart rate and power from 1,000 m test

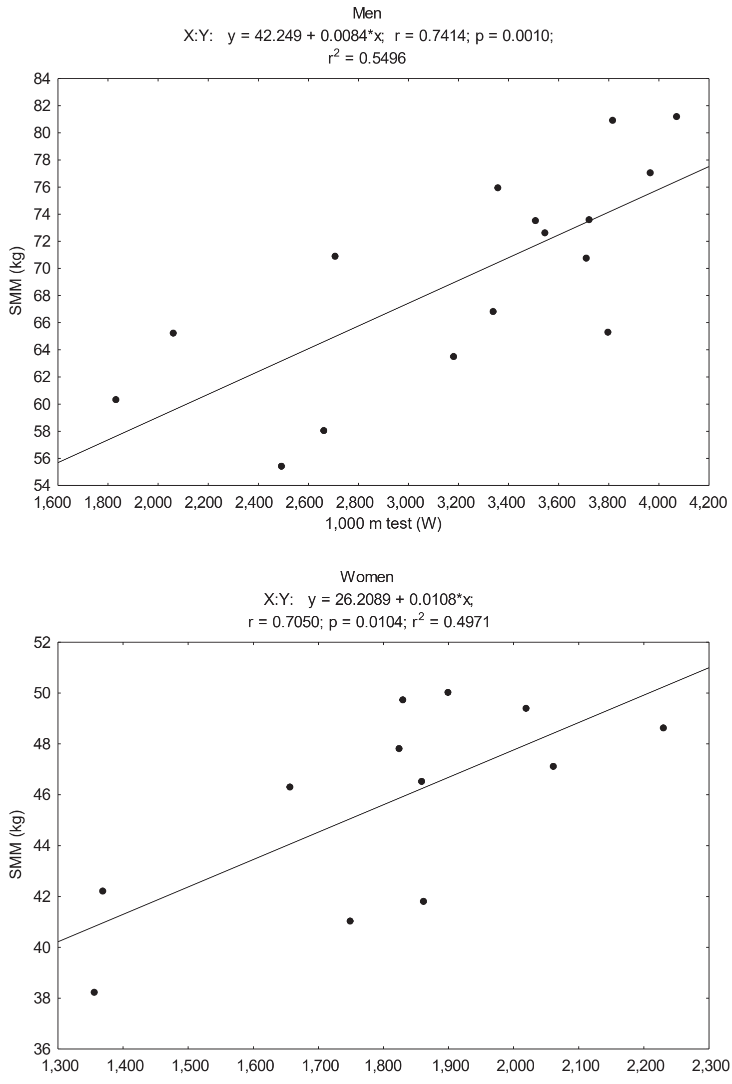

Figure 2. Relationship between skeletal muscle mass and power from 1,000 m test

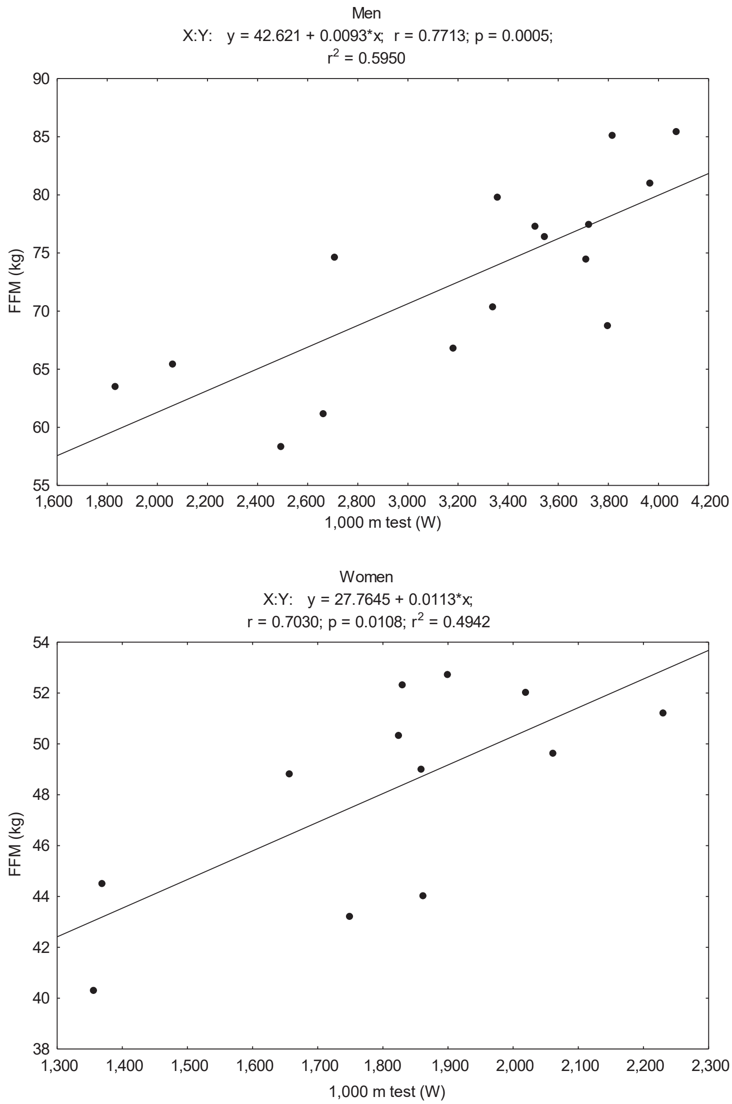

Figure 3. Relationship between free fat mass and power from 1,000 m test

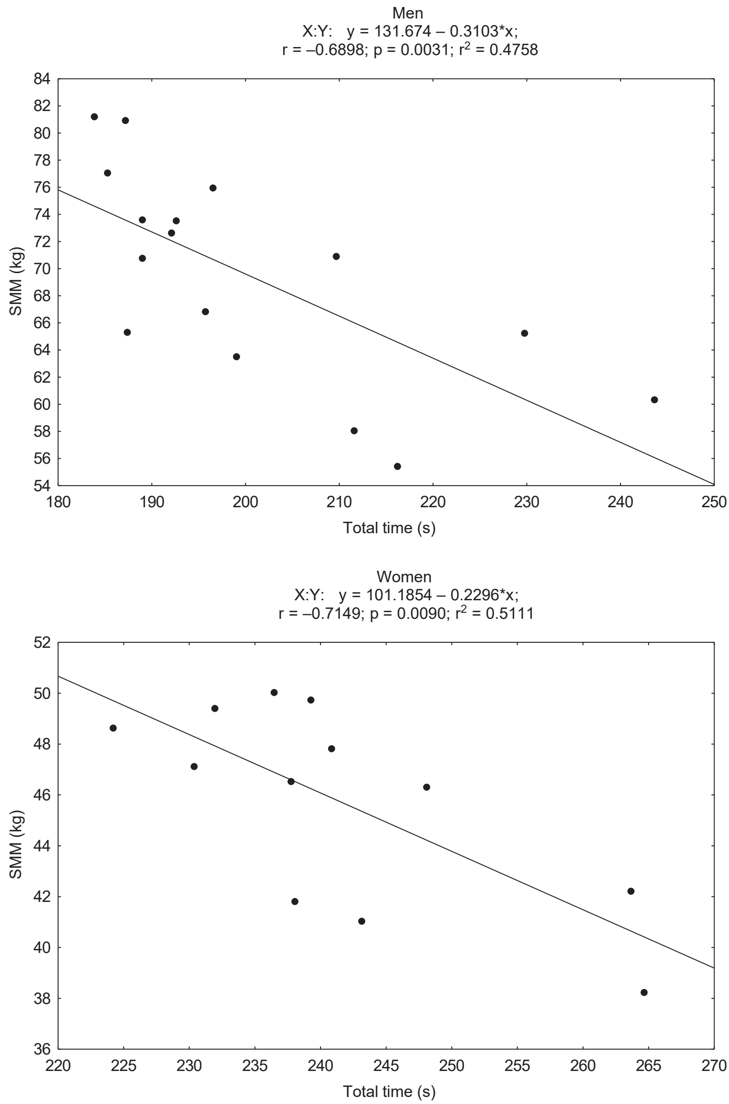

Figure 4. Relationship between skeletal muscle mass and total time from 1,000 m test

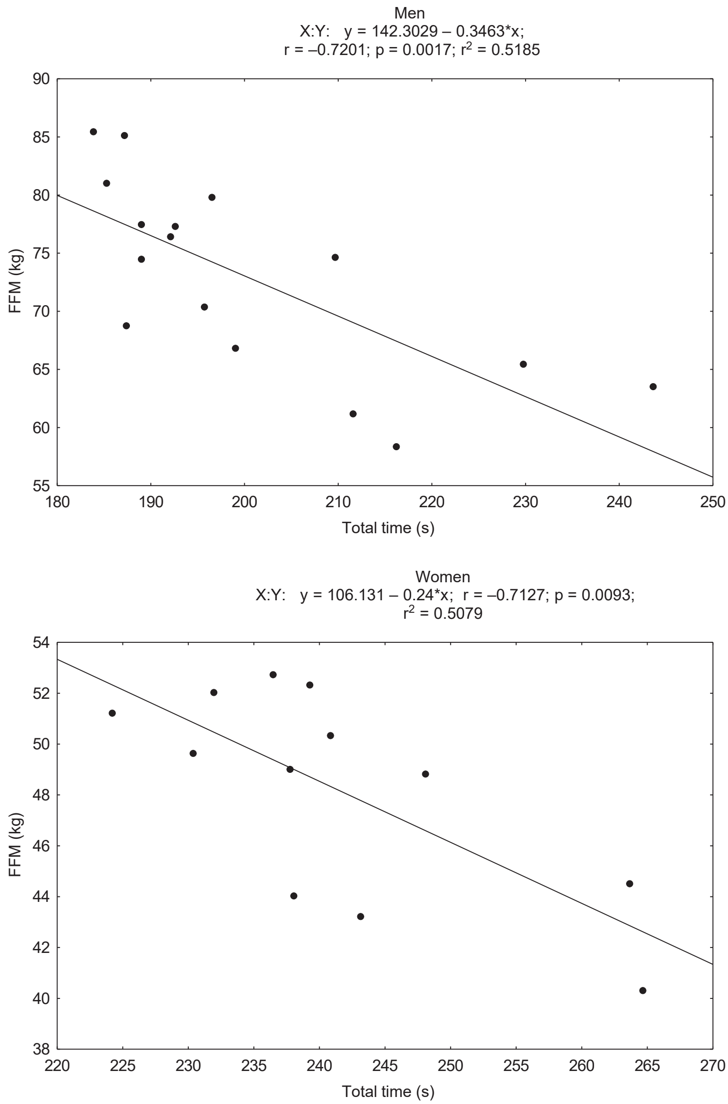

Figure 5. Relationship between free fat mass and total time from 1,000 m test

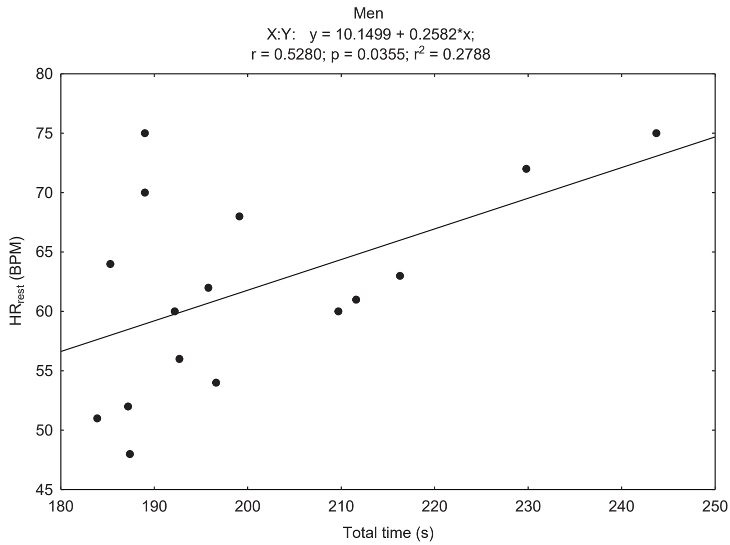

Figure 6. Relationship between rest heart rate and total time from 1,000 m test

Discussion

Rowing is a strength and endurance sport requiring the ability to generate both anaerobic power and aerobic capacity, it involves activation of almost all muscles in the body (Mikulic, Bralic, 2018), in which body size, strength, technique and rowing tactics play an important role in achieving sporting success. It is a cyclic sport containing a repeating sequence of four phases: the catch followed by the drive, the finish and the recovery phases, during which precise technique is required to maximise boat speed. The main objective of the sport is to cover a certain distance of the “run” in the shortest possible time. Assessing an athlete’s performance in both amateur and competitive sports is important for monitoring progress and evaluating the effects of training in both practice and research. The Concept II rowing ergometer can reliably physiologically simulate race conditions and is widely used to assess athlete performance outside the water (Soper, Hume, 2004). A recent study by Soper and Hume, comparing the reliability of rowing performance over distances of 500 m and 2,000 m on the Concept II and RowPerfect ergometer, found that the rowers’ mean power output was less variable on the Concept II ergometer (500 m = 2.8%, 95% CI 2.3, 3.4; 2000 m = 1.3%, 95% CI 0.8, 2.9) compared to the RowPerfect ergometer, which is not very popular in Poland (500 m = 3.0%, 95% CI 2.5, 3.9; 2,000 m = 3.3%, 95% CI 2.2, 7.0) (Soper, Hume, 2004). Independently, the accuracy of the measurement with the Concept II ergometer was confirmed by Boyas in his work (Boyas, Nordez, Cornu, Guével, 2006). According to his study on a group of rowers, the ergometer software’s mathematical algorithms underestimated the power generated by approximately 25 W relative to the actual values assessed using a strain gauge placed near the handle and a position sensor installed on the chain. The Authors concluded that the deletion of the first strokes following changes in power production allows to limit this phenomenon. The high accuracy of the ergometer and the possibility of conducting the test under controlled conditions make many studies use speed tests at 500 m, 1,000 m and 2,000 m on the ergometer as a criterion for predicting performance. However, it is important to note that the movement on the ergometer does not accurately reflect the hand movements you make on the water (you do not have to lower your arms to pull the oar out of the water) (Hume, 2018).

The main objective of the study was to evaluate the time taken by athletes of KU AZS PUM to complete a distance of 1,000 m on a rowing ergometer and to compare them to academic results from the national competition. On the basis of a comparative analysis of the speed results obtained in our own research in relation to the results from the AMP 2020/2021 in rowing ergometer, the male team consisting of the research participants would take 6th place out of a possible 28 and the female team would take 17th place out of a possible 29. For the team, the best 6 results in men and the best 4 results in women are scored. The high place in the retrospective prediction in the men's overall ranking, despite the lack of athletes fitting in the top ten, is due to the very small intra-group variation in the results of the times achieved. The difference between the best (03:03.9) and worst (03:09.0) times for the 1,000 m in the top 6 men was only 5.1 s. The impact of a small intra-group variation of results can be best explained on the example of the previous results of the competitors of the Gdańsk University of Technology at the AMP 2020/2021. Despite the fact that two leading competitors from Gdańsk took the 1st and the 7th position in the men's light category, the other 4 competitors scored much lower, the difference between the best and the worst result was as much as 23.2 seconds, which placed the Gdańsk University of Technology in the team classification outside the top 10, on the 12th position.

Success in competitive sport is determined by many factors, including psychological conditions, motor skills and body composition. Therefore, an additional aim was to look for those of the modifiable factors that may have the greatest impact on the performance of rowers.

One of the most important is muscle strength, the level of which is often used to identify predispositions in different sports. Of the many muscles of the limbs, the strength of the muscles that generate the global grip is most commonly assessed. The grip strength test is the simplest and least complex of the many instrumental measurements of muscle strength and there is some evidence that grip strength reflects global muscle strength (Bohannon, Magasi, Bubela, 2012) In this study, we divided the study group into the side on which they rowed in a rowing boat. In all subjects, the right upper limb was statistically significantly stronger in the HGt test. Moreover, each time, regardless of the side, the strength in the HGt_{right} test correlated more strongly with the results (generated power and time). Rowing with "one oar", as an asymmetric sport, is characterised by a higher power generated by the outside hand. For those rowing on the right it is the left hand and for those rowing on the left it is the right hand. Among our subjects, only the males showed a statistically significant very strong relationship ($r = 0.81$) between the force value in the HGt_{right} test, generated power and the total time of the test, regardless of the side on which they row. The results for HGt_{left} in men showed no statistically significant correlation. Interestingly, the outside hand correlates more strongly than the closer hand in individuals rowing on opposite sides. Based on this observation, it can be concluded that the grip strength of the left hand is a weak point for right-sided rowers (because this hand is then the outside hand) and they should pay special attention to developing the strength of this hand during training. HGt_{right} and HGt_{left} in women showed a significantly weaker, not statistically significant relationship with rowing performance. This can be explained by the lower upper body strength in women and the compensatory shift of the rowing effort to the lower, stronger body part.

A number of studies have attempted to establish the relationship between selected physiological variables and 500 m 1,000 m or 2,000 m performance, i.e. body mass, V_{O2}max (Secher, 1993); Cosgrove, Wilson, Watt, Grant, 1999; Majumdar, Das, Mandal, 2017; Penichet-Tomas, Pueo, Selles-Perez, Jimenez-Olmedo, 2021; Thiele, Prieske, Gäbler, Granacher, 2021; Purge, 2017). In young rowers a higher aerobic capacity and larger body size are beneficial for performance over 1,000-m rowing ergometer distance (Mikulic, Ruzic, 2008)

In our study, free fat mass and skeletal muscle mass had the greatest influence on 1,000 m TM/t performance in both men and women. Penichet-Tomas in his study (Penichet-Tomas, Pueo, Selles-Perez, Jimenez-Olmedo, 2021) also identified muscle mass in women as the best determinant of outcome. It should be noted that in the case of men, the analysis of the results showed a greater correlation of the values of FFM and SMM indices with the ability to generate power than with the time of the test. In women, on the other hand, these indices correlated more strongly with time than with power values.

This can be explained by the influence of factors other than muscle indices on the total distance covered during ergometer work, such as body height, limb length, rowing pace and technique. As a rule, a higher pace is observed in lightweight athletes (lower height, lower weight, lower muscle mass, lower free fat mass) than in open weight athletes. A higher tempo means more weaker pulls (generating less power) but a better time score. It seems that due to the greater rowing experience of the women's group (on average more than 9 months more than men) they have a better technique in the rowing ergometer test. This allows them to better (without losses) transfer the generated force to the ergometer, which translates into better time conversion rates.

Summary

The results of the research conducted should be interpreted with caution as the main limitation of this study is the size of the group. Therefore, they can be used as a reference but should be interpreted in the context of individual characteristics and needs. The results obtained at 1,000 TM/t can be considered promising for the further training stage due to the fact that the study was conducted on a rowing ergometer under training conditions prior to a special training mesocycle shaping strength and speed, while the athletes competing at the event to which our results were related were in the starting period and therefore by definition in top form. It would be interesting to re-determine the correlation of HGt in rowers rowing on the left and right side of the boat after targeted training on the outside hand.

References

Bohannon, R.W., Magasi, S.R., Bubela, D.J. (2012). Grip and knee extension muscle strength reflect a common construct among adults. *Muscle Nerve,* 46, 555–558.

Boyas, S., Nordez, A., Cornu, C., Guével, A. (2006). Power responses of a rowing ergometer: mechanical sensors vs. Concept2 measurement system. *Int J Sports Med.*, *27* (10), 830–833. DOI: 10.1055/s-2006-923774.

Cosgrove, M.J., Wilson, J., Watt, D. Grant, S.F. (1999). The relationship between selected physiological variables of rowers and rowing performance as determined by a 2,000 m ergometer test. *Journal of Sports Sciences*, *17* (11), 845–852.

Hagerman, F.C., Staron R.S. (1983). Seasonal variables among physiological variables in elite oarsmen. *Can J Appl Sport Sci*, *8*, 143–148.

Hennig, M. (ed.) (2003). *Wioślarstwo.* Warszawa: Polski Związek Towarzystw Wioślarskich.

Hume, P.A. (2018). Movement Analysis of Scull and Oar Rowing. In: B. Müller, S. Wolf (eds.), *Handbook of Human Motion.* Springer, Cham. DOI: 10.1007/978-3-319-14418-4_133.

Majumdar, P., Das, A., Mandal, M. (2017). Physical and strength variables as a predictor of 2,000 m rowing ergometer performance in elite rowers. *Journal of Physical Education and Sport ® (JPES)*, *17* (4), 2502–2507.

Mikulic, P., Bralic, N. (2018). Elite status maintained: a 12-year physiological and performance follow-up of two Olympic champion rowers. *Journal of Sports Sciences, 36* (6), 660–665. DOI: 10.1080/02640414.2017.1329548.

Mikulic, P., Ruzic, L. (2008). Predicting the 1,000 m rowing ergometer performance in 12–13-year-old rowers: the basis for selection process? *J Sci Med Sport*, *11* (2), 218–226. DOI: 10.1016/j.jsams.2007.01.008.

Penichet-Tomas, A., Pueo, B., Selles-Perez, S., Jimenez-Olmedo, J.M. (2021). Analysis of Anthropometric and Body Composition Profile in Male and Female Traditional Rowers. *Int J Environ Res Public Health, 18* (15), 7826.

Purge, P., Hofmann, P., Merisaar, R., Mueller, A., Tschakert, G., Mäestu, J., Jürimäe, J. (2017). The Effect of Upper Body Anaerobic Pre-Loading on 2,000-m Ergometer-Rowing Performance in College Level Male Rowers. *J Sports Sci Med.*, *16* (2), 264–271.

Sablic ,T., Versic, S., Uljevic, O. (2021). Association of Motor Abilities and Morphological Characteristics with Results on a Rowing Ergometer. *Sport Mont*, *19*, 3–6.

Secher, N.H. (1993). Physiological and biomechanical aspects of rowing. Implications for training. *Sports Med.*, *15* (1), 24–42. DOI: 10.2165/00007256-199315010-00004.

Secher, N.H. (ed.) (2007). *Handbook of Sports Medicine and Science Rowing.* Blackwell Publishing.

Soper, C., Hume, P.A. (2004). Towards an Ideal Rowing Technique for Performance. The Contributions from Biomechanics. *Sports Med*, *34* (12), 825–848.

Soper, C., Hume, P.A. (2004). Reliability of power output changes with ergometer type and race distance. *Sports Biomechanics*, *3* (2), 237–247.

Thiele, D., Prieske, O., Gäbler, M., Granacher, U. (2021). Zusammenhang von biologischer Reife, Körperkonstitution und körperlicher Fitness und der Leistung auf dem Ruderergometer bei Elite-Nachwuchsruderinnen [Association between biological maturity, body constitution and physical fitness with performance on a rowing ergometer in elite youth female rowers]. *Sportverletz Sportschaden.* German. DOI: 10.1055/a-1532-4597.

Cite this article as: Huzarski, O., Pluta, W., Lubkowska, A. (2022). 1,000-m Rowing Ergometer Time Trial Performance in Female and Male Collegiate Rowers. *Central European Journal of Sport Sciences and Medicine*, *1* (37), 101–114. DOI: 10.18276/cej.2022.1-09.