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Body Mass and Aerobic Capacity are Robust Predictors of the 2000m Ergometer Rowing Performance: A Laboratory Study

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ABSTRACT

Purpose: Predicting performance in sports competitions is a popular topic in research. However, only a few studies exist in rowing sports, which suggest that some anthropometric and performance indices might predict performance in various situations. **Methods:** This work expands past research by examining the effects of five anthropometric measures, such as body mass index (BMI), height, weight, fat, and muscle, and three performance indicators, such as aerobic capacity, maximum speed, and force, while also considering the training history of 38 elite rowers (M_{age} = 16.89 ± 1.85, range 14.7 to 22.6 years, 61% males) participating in a national championship. **Results:** Apart from BMI, all measures correlated statistically significantly with the 2000m rowing time. A bootstrapped forward multiple regression yielded the best model with only two predictors (R^2=.995), aerobic capacity and body mass, accounting for 99.5% variance in the 2000m rowing time. **Conclusions:** While the results support previous findings, such robust prediction has not been reported in the literature. We conjecture that the differences from other past works rest with the high-pressure 2000m performance *preceding* a national championship. If these findings could be replicated, their practical implication is substantial in preparatory training for rowing contests.

Key words: Anthropometry, Athletes, Competitive Behavior, Rowing, Oxygen Consumption

INTRODUCTION

Rowing is a cyclic type of strength-endurance sport that requires the body's ability to sustain effort for a longer period. (Baudouin & Hawkins, 2004; Shaharudin & Agrawal, 2016). Rowing was already well-known as a means of transport in ancient times, while modern rowing sport developed in the 18th century. From there on, many rowing regattas have been established, and the sport's popularity has increased steadily. Nolte (2023) recently described the scientific aspects of rowing, highlighting the unique nature of this sport. Indeed, technical and equipment differences distinguish rowing from other paddling sports. For example, athletes sit in the opposite direction of forward movement on a rolling seat, while the oars are connected to the boat with spurs (oarlocks). The two main rowing disciplines are sculling (one oar in each hand of the rower) and sweeping (one athlete uses one oar), and there are different techniques to propel the boat effectively (e.g., Adam, DDR, Grinko, and Rosenberg style).

Rowing races take place in various boat classes, depending on the number, gender, and weight of the rowers. The presence or absence of a coxswain further increases the options for classification. Rowing competitions are organized at diverse levels: school, regional, national, continental, and international races. World Rowing Championships are held separately for the age categories (elite rowers, juniors, masters, U23), and World Rowing Cups are also critical challenges for elite rowers.

Research on predicting 2000m rowing performance proliferates continuously to select the best athletes and predict the best performance. However, it is difficult to measure and compare the 2000m rowing performance on water due to external factors (wind, water flows, temperature, etc.), while simulating official competitions can be an effective way to

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evaluate athletes' performance (Alföldi et al., 2023). Therefore, over the years, more often, the 2000m indoor ergometer time is the standard used for developing prediction models allowing for a controlled environment and mimicking the movement on water (Akça, 2014; Brett & Hopkins, 2012; De Campos Mello et al., 2009; Giroux et al., 2017). However, despite this practice, the most reliable way to evaluate an athlete's rowing performance is to measure the time required to complete a given rowing distance (2000m) on water (Mäestu et al., 2005).

Extant performance prediction models involve psychophysiological characteristics like body mass index (BMI), height, weight, body fat, and muscle mass, along with performance indicators like aerobic capacity (VO_2 max), maximum speed, and force. These measures are assumed to be predictors of rowing performance to a lesser or greater extent (Akça, 2014; Silva et al., 2021). However, most studies failed to homogenize the level at which the studied rowers compete (skill level), which is essential for the reliability and replicability of the results.

Examining the anthropometry of athletes often highlights the physiological, functional, and biomechanical aptitudes required to excel in sports (Battista et al., 2007). In rowing, Russell et al. (1998) demonstrated that reliable performance prediction models could be based solely on anthropometric indices. Research on rowers' anthropometric characteristics underscores the significance of body mass (Maciejewski, 2019; Winkert et al., 2019), particularly lean body mass (Cosgrove et al., 1999) and body height (Bourgois, 2000; Penichet-Tomas et al., 2021). A lower BMI is associated with improved performance (Castañeda-Babarro, 2024). Muscle mass is a primary factor behind gender differences and maximal strength (Janssen et al., 2000; Mayhew et al., 2001; Miyashita & Kanehisa, 1979; Stefani, 2006). Finally, body fat percentage is also an essential predictor in performance models (Majumdar et al., 2017). These findings confirm that anthropometric measures play a pivotal role in rowing performance.

Although the predictive potential of anthropometric characteristics is significant, more effective models can be developed by combining them with selected physiological characteristics. During a rowing race, aerobic capacity contributes 75-80% of the required energy, making an exceptionally high aerobic capacity essential for successful rowing performance (Droghetti et al., 1991; Jurišić et al., 2014; Silva et al., 2021). Consequently, researchers often assess changes in maximal oxygen uptake (VO_2 max) and incorporate this index into the design of effective prediction models (Castañeda-Babarro, 2024; Cosgrove et al., 1999; Ingham, 2002; Lacour et al., 2009; Riechman et al., 2010). Fitness indices, including peak and mean power, maximum speed, maximum force, and other strength variables, have been shown to effectively predict 2000m rowing ergometer performance (Bourdin et al., 2004; Izquierdo-Gabarren et al., 2010; Riechman et al., 2010). While the relationship between rowers' force output and performance may be significant, the exact nature of this interaction remains unclear (Ingham, 2002; Warmenhoven et al., 2018).

As discussed above, studies indicate that models considering different anthropometric and physiological characteristics have greater predictive potential than using these measures individually. Based on the results obtained during past works, the question arises as to which characteristics or combinations are more robust predictors of 2000m rowing performance that could be applied in practice. Are the anthropometric characteristics or the aerobic capacity more effective measures of performance? Does training history have a significant effect on 2000m rowing performance? Which measures should be involved in a performance prediction model?

To address gaps in the extant literature, particularly the limited predictive power of individual anthropometric or physiological factors, we aimed to examine a more comprehensive model of 2000 m rowing performance by examining a wider range of variables. Specifically, we investigate key anthropometric (BMI, height, weight, body fat, and muscle percentage) and physiological (aerobic capacity [VO_2 max], maximum speed, and force) characteristics, while also considering training history. Our study is distinct in focusing on a homogeneous sample of elite rowers who competed in the Hungarian National Rowing Championship during their pre-competition training phase, thus reducing variability and increasing the reliability of findings. We hypothesized combining several anthropometric and performance-related indices would predict 2000 m performance more accurately than any single factor alone. This approach may contribute to more effective athlete selection and individualized training strategies.

METHODOLOGY

Participants and Study Design

With permission from club management and coaches, participants were recruited from the cohort of young athletes competing in the Hungarian National Rowing Championships. The three inclusion criteria were being a registered rower competing in the national championship, having medical clearance for competitive sports, and having a regular training record for at least three months (a national-level rower in Hungary trains at least five days per week). Exclusion criteria included acute or chronic injury, illness, or medical condition that could interfere with physical performance or testing.

A priori power analysis using the G*Power (v. 3.1) software (Faul et al., 2009) for multiple linear regression with 10 predictors, an alpha level of 0.05, and power of 0.80 to detect a medium effect size ($f^2 = 0.15$), indicated a required sample size of 118 participants. Due to the limited number of eligible elite rowing athletes, our final sample was only one-third of the calculated sample size. Therefore, we decided to compensate for the reduced statistical power by applying bootstrapping procedures (1,000 resamples) to estimate confidence intervals and enhance the robustness and generalizability of the regression coefficients. This resampling approach helps to mitigate potential bias from small sample sizes and strengthens the stability of the predictive models (Mooney et al., 1993).

All the participants were healthy elite rowers with medical clearance for sports competitions. They (and their parents if they were minors) provided informed consent and completed a General Data Protection Regulation (GDPR) data handling form before participating in the study. In total, 42 elite rowers agreed to participate, but only 38, including 23 men (M_{age} = 16.2 years; SD = 1.4; range = 14.7–22.6), completed the study (Table 1). The four dropouts found testing distracting in their preparation for the competition. The study, conducted over four days, was approved by the Research Ethics Board (Permission No. SZE/ETT-11/2024 [IX.11.]). Participants (and their parents in case of minors) were informed about the study's objectives and the potential risks, measurement methods, and motor test techniques. The research followed the Helsinki Declaration's principles (World Medical Association, 2013) for human participant studies.

The research employed a cross-sectional (correlational) design with laboratory-based assessments to examine how anthropometric and physiological variables predict 2000 m rowing performance in elite athletes.

Materials

Anthropometric and body composition measures

A trained ISAK-accredited expert (level 1) measured anthropometric characteristics according to the standardized procedures of the International Society of Kinanthropometry. Demographic questions included age, training age, and training experience. Body height (BH) was measured to the nearest 0.1 cm using a height rod scale (Seca 217, Hamburg, Germany) without shoes. Body mass (BM) was measured to the nearest 0.1 kg after removing shoes and heavy clothing. Body mass index (BMI) was calculated by dividing body weight in kilograms by the square of body height in meters [body mass (kg)/BHm^2]. Body composition characteristics (fat mass percentage, FMP [%], and muscle mass percentage, MMP [%]) were measured in the standing position using the InBody 720 tetrapolar 8-point tactile electrode system (Biospace Co., Ltd., Seoul, Korea) (Gibson et al., 2008).

Table 1. Anthropometric and physiological measures, and 2000m rowing results of 38 participants

	Mean	SD	Min	Max
Age (years)	16.91	1.91	14.69	22.57
Training history (years)	4.85	2.39	0.41	9.92
Height (cm)	175.91	9.43	158.70	194.00
Weight (kg)	68.46	7.95	53.60	87.20
Body fat percent (%)	18.69	8.30	8.10	40.80
Body muscle percent (%)	38.77	5.80	26.00	46.40
Body Mass Index (BMI)	22.17	2.32	17.80	28.00
Time 2000m (min)	7.57	0.67	6.08	9.30
Aerobic capacity (VO2 max)	63.13	11.41	30.59	81.39
Maximum speed (m/s)	2.46	0.31	1.93	3.33
Maximum force (N)	1,521.95	262.78	950.00	2,036.00

2000-meter maximal rowing ergometer test

Competitors completed a 2000 m total effort test on a certified rowing ergometer (Concept 2 D, RowErg200, USA). The ergometer screen was set to display the number of meters remaining, the average 500 m time, and the overall time. Power in watts (W) was measured over 2000 m. The watts were calculated as follows: first, the distance was determined: distance = (time/number of strokes) × 500. The "split" was calculated in the next step: split = 500 × (time/distance). The watts were calculated as 2.8/(split/500). There were minor differences in intensity due to individual variations in stroke rate and the ability to hold the 500m split time constant. Before testing, participants warmed up for 6 min on a 500m run, rested for 6 min, and performed stretching exercises during this time. Estimated relative aerobic capacity ($ErVO_2$) was calculated using the formula $ErVO_2$ = (Y × 1000)/BM for women (McArdle et al, 2007), where BM is body mass and Y = [BM <61.36 kg; 14.6.1-(1.5 × time)]; BM => 61.3 kg; 14.6 - (1. 5 × time)]; for men, ErVO2 = (Y × 1000)/BM, where BM is body mass and Y = [BM <75 kg; 15.1- (1.5 × time)]; [BM => 75 kg; 15.7- (1.5 × time)].

Counter-movement jump

We assessed lower limb explosiveness with the PJS-4P60S force plateau ("JBA" Zb. Staniak, Poland) with a sampling frequency of 400 Hz (Gajewski et al., 2008). In the calculations, the rower's body mass was taken as a point influenced by the vertical component of the gravitational force acting on the body and the reactive force of the platform. Three counter-motion jumps (CMJ) were performed, with each maximum force assessed. To perform a CMJ, participants performed a vertical jump from a standing, upright position, preceded by a countermovement of the upper limbs and a lowering of the center of mass prior to take-off. This study aimed to determine the maximum force (Forcemax [N]) and the maximum speed (Speedmax [m/s]).

Procedure

We conducted anthropometric and physiological tests in a temperature and humidity-controlled laboratory at the beginning of the competition season. On day one, anthropometric and body composition measurements were performed. The participants were asked to arrive on an empty stomach at the testing facility. On the second day, they completed the motor skills test (Countermovement Jump [CMJ]) in the morning, and in the afternoon, they performed the 2000m rowing ergometer test. The coaches were instructed not to perform strenuous training with the athletes participating in the research on the day before the study. The study was conducted during the preparation week for the national championship.

Data Availability

The data set on which this report is based is available from the authors in Excel or SPSS format upon reasonable request.

Statistical Analyses

First, we examined data normality by calculating skewness and kurtosis. Second, we calculated the correlations between the predictor variables and the dependent measure (2000 m rowing performance). Finally, we conducted a bootstrapped hierarchical multiple regression analysis to identify significant 2000 m rowing performance predictors.

Results

First, we examined the normality of the data by calculating the skewness and kurtosis of the measures. All skewness values obtained were between -1.00 and +1.00, and the kurtosis values were between -2.00 and +2.00. According to Hair et al. (2010) and Byrne (2010), the data are normally distributed if the skewness is between -2.00 and +2.00 and the kurtosis is between -7.00 and +7.00. Next, we calculated Pearson's product-moment correlation coefficients (r) between the dependent measure (2000m performance) and the independent variables (Table 2).

Subsequently, we employed bootstrapping with 5,000 resamples to calculate confidence intervals for the regression coefficients and improve the estimates' robustness, given the modest sample size, in a forward hierarchical multiple regression predicting 2000m rowing performance. We used all measures from Table 1 as predictors except the BMI, which did not correlate statistically significantly with the 2000m performance. The final model, with two significant predictors— aerobic capacity (β = -0.047, p <.001) and body mass (β = -.044, p <.001)—explained 99.5% of the variance in 2000m rowing performance before the national championship (adjusted R^2=.995; adjusted R^2=.995, see Table 3 A-D).

Table 2. Pearson's correlation between dependent and independent variables (n=38)

		2000m Time (min)	*p*	*R-squared* (R^2)
Training history (years)	r	-0.489**	0.002	0.239
Height (cm)	r	-0.635**	<.001	0.403
Weight (kg)	r	-0.652**	<.001	0.425
Body fat percent (%)	r	0.618**	<.001	0.382
Body muscle percent (%)	r	-0.721**	<.001	0.520
Body Mass Index (BMI)	r	-0.031	0.854	0.001
Aerobic capacity (VO_2 Max)	r	-0.862**	<.001	0.743
Maximum speed	r	-0.508**	0.001	0.258
Maximum force	r	-0.754**	<.001	0.569

**. Correlation is significant at the 0.01 level (2-tailed).

The bootstrap bias was minimal (<.001), and the unstandardized β coefficients were stable across the 5,000 bootstrap replicates. All assumptions (for calculating regressions) were met, including linearity, independence, homoscedasticity, and normality of residuals.

The final model's RMSE (0.045) indicated extremely low error. The unstandardized coefficients were highly stable across 5,000 bootstrap samples, and the bias was negligible (< .001). The confidence intervals emerged to be narrow and consistent. The residuals did not show autocorrelation based on the Durbin-Watson statistic (1.435). Homoscedasticity, linearity, and normality of residuals were confirmed. The correlation between the two statistically significant predictors was r =.187, and the variance-inflated factor was 1.04. These results suggest no concern over multicollinearity between VO_2 max and body mass. Therefore, collinearity did not artificially inflate the high adjusted R^2 (.995). Consequently, the model is statistically well-justified.

DISCUSSION

The results of this study indicate that aerobic capacity (VO_2 Max) and body mass are the most critical parameters in predicting 2000m ergometer rowing performance in young elite rowers. In the current sample, these two variables together accounted for an exceptionally high 99.5% of the variance in performance time, as indicated by the final multiple regression model (adjusted R^2 = 0.995). This suggests that they function as near-complete predictors of ergometer rowing time under the specific testing conditions employed.

This finding reinforces past empirical works by substantiating the importance of aerobic power and body composition in rowing performance. However, it is important to highlight that past research has not typically reported such a strong predictive power. The unusually high level of explained variance in the current study may reflect unique features of the sample and testing protocol. Specifically, the data were collected in the immediate period leading up to a national championship, when athletes are likely to be near peak physiological and psychological readiness. This competition-specific context may have minimized performance variability due to extraneous factors and thus strengthened the predictive relationship between physiological capacity and rowing time.

Moreover, the low variance inflation factors (VIF ≈ 1.04) confirm that multicollinearity between VO_2 Max and body mass was negligible, supporting the statistical integrity of the regression model. The residuals met all standard assumptions for linear regression, and bootstrap resampling (5,000 iterations) revealed highly stable coefficient estimates with negligible bias, further enhancing the model's robustness in the sample studied.

It is also worth noting that other commonly studied predictors, such as muscle percentage, maximum strength, and training history, although significantly correlated with 2000m performance, did not contribute meaningfully to the final predictive model once VO_2 Max and body mass were accounted for. This underlines the dominant predictive role of aerobic fitness and overall body mass when peak competitive performance is the outcome of interest.

Table 3. A-D

A) Bootstrapped multiple linear regression

Model	R	R^2	Adjusted R^2	RMSE	R^2 Change	F Change	df1	df2	p	Durbin-Watson		
										Autocorrelation	Statistic	p
1	0.000	0.000	0.000	0.613	0.000		0	37		0.216	1.473	0.096
2	0.829	0.687	0.678	0.348	0.687	79.049	1	36	< .001	0.262	1.452	0.075
3	0.997	0.995	0.995	0.045	0.308	2128.873	1	35	< .001	0.191	1.435	0.060

B. ANOVA

Model		Sum of Squares	*df*	Mean Square	*F*	*p*
2	Regression	9.547	1	9.547	79.049	< .001
	Residual	4.348	36	0.121		
	Total	13.895	37			
3	Regression	13.824	2	6.912	3440.172	< .001
	Residual	0.070	35	0.002		
	Total	13.895	37			

The intercept model is omitted, as no meaningful information can be shown.

C. Coefficients

Model		Unstandardized	Standard Error	Standardized	*t*	*p*	95% CI	
							Lower	Upper
1	(Intercept)	7.529	0.099		75.735	< .001	7.327	7.730
2	(Intercept)	10.712	0.362		29.555	< .001	9.977	11.447
	VO_2	-0.050	0.006	-0.829	-8.891	< .001	-0.061	-0.038
3	(Intercept)	13.510	0.077		176.456	< .001	13.354	13.665
	VO2	0.047	7.248×10^{-4}	-0.778	-64.404	< .001	-0.048	-0.045
	BM	-0.044	9.437×10^{-4}	-0.557	-46.140	< .001	-0.045	-0.042

BM=Body mass (weight); VO_2=aerobic capacity. The following covariates were considered but not included: Training history, body height, body fat, maximum speed, and maximum force.

D. Bootstrap (5,000 samples) Coefficients

Model		Unstandardized	Bias	Standard Error	p*	95% CI*	
						Lower	Upper
1	(Intercept)	7.527	-2.398×10^{-4}	0.099	< .001	7.331	7.721
2	(Intercept)	10.710	0.016	0.297	< .001	10.221	11.403
	VO_2	-0.050	-2.300×10^{-4}	0.005	< .001	-0.062	-0.042
3	(Intercept)	13.504	-0.012	0.118	< .001	13.283	13.739
	VO_2	-0.047	1.107×10^{-4}	0.001	< .001	-0.049	-0.045
	BM	-0.044	7.936×10^{-5}	0.001	< .001	-0.046	-0.041

Bootstrapping based on 5000 replicates.
The coefficient estimate is based on the median of the bootstrap distribution.
* Bias-corrected accelerated.

Although these results are compelling, they should be interpreted with caution. While typical for elite athlete studies, the relatively small sample (n = 38) may limit generalizability. Additionally, because the measurements were taken in a high-performance training phase, the results may not be extrapolated to general training periods or rowers of different skill levels.

Consistent with our findings, VO2 max and lean body mass were highly correlated with velocity in a 2000m rowing ergometer time trial (r = 0.85) in a study by Cosgrove et al. (1999) involving 13 young male rowers (aged 19.9 ± 0.6 years). Stepwise multiple regression identified VO_2 max as the single most significant predictor, accounting for 72% of the variance in rowing performance. This value was exceeded in a study by Yoshiga and Higuchi (2003), who reported a r = -.90 correlation between the 2000m rowing sprint and VO_2 max (reflecting 81% shared variance between the two measures). Finally, Gillies and Bell (2000) reported an almost perfect correlation (*r* = -.96) between the 2000m rowing time and VO_2 max. Our model's predictive power of VO_2 max was comparable but lower than in these studies (R^2 =.68). However, adding body mass, the predictive power emerged as almost perfect, reflected in the 99.5% figure. The critical role of body mass is also supported by a more recent study (Cerasola et al., 2020) that found a stronger correlation between body mass (*r* = -.815) and 2000m rowing sprint than VO_2 max and 2000m rowing time (*r* = -.761) in national level young rowers.

Yoshiga and Higuchi (2003) have also substantiated the importance of body mass in the 2000m rowing sprint, in addition to the VO_2 max. These authors found that body mass was a significant predictor (r = -.85) of the 2000m rowing time in 191 rowers. Indeed, these authors concluded, "*This study suggests that individuals with large body size and aerobic capacity possess an advantage for a 2000-m row on an ergometer*" (p. 317), matching the conclusion of our study. However, this paper did not disclose the athletes' competition level despite mentioning that the participants trained at least 5 days a week.

The current study revealed a significant inverse relationship between body mass and 2000m ergometer rowing time (r = -.652; refer to Table 2). Comparable results emerged from other studies as well (*r*= -0.506, [Majumdar & Mandal, 2017]; *r* = -.680, [Nevill et al., 2010]; *r* = - 0.41, [Russell et al., 1998]). Together, these studies suggest that body mass has a moderate to strong relationship with the 2000m rowing ergometer performance. Therefore, besides VO_2 max, anthropometric measures should be included in performance prediction models of the 2000m rowing ergometer sprint time. However, considering past conjectures (i.e., Russell et al., 1998), anthropometric indices alone are not the best predictors of the 2000m rowing sprint.

Although VO_2 max and body mass, when considered together, are significant predictors of 2000m rowing sprint performance, other anthropometric and physiological measures may also serve as effective or even superior predictors, depending on the specific context of rowing. For example, recent research (Castañeda-Babarro, 2024) evaluated rowers' anthropometric and performance profiles based on their position in the boat. The study found that height, associated with longer arms and greater body mass, predicts performance. However, a lower BMI was explicitly associated with improved performance in the bow and stern positions.

In a 6000m rowing sprint, anthropometric and metabolic variables jointly were found to be the strongest predictors of performance (R^2 =.722), followed by models that included either anthropometric (R^2 =.575) or metabolic (R^2 =.530) measures alone (Mikulic, 2009). These differences imply that the 2000m ergometer performance predictors should not be extrapolated to other rowing situations, such as longer distances, co-acting or team rowing, and rowing on water. Consequently, the here-reported results are limited to the 2000m ergometer rowing, the most often adopted laboratory trial investigating rowing performance and related measures.

In Summary, our results align with previous research in confirming that VO_2 max and body mass are strong predictors of 2000m rowing ergometer performance. Like earlier works by Cosgrove et al. (1999), Yoshiga and Higuchi (2003), and Gillies and Bell (2000), we found that VO_2 max shows a substantial inverse correlation with rowing time. Furthermore, consistent with studies by Cerasola et al. (2020) and Yoshiga and Higuchi (2003), our results support the significant contribution of body mass to rowing performance.

What distinguishes our study from prior research is the combined predictive power of VO_2 max and body mass, which together explained 99.5% of the variance in 2000m performance—a level of predictive accuracy not previously reported. This suggests a near-total model of performance prediction when both physiological and anthropometric factors are considered. Additionally, the timing of our data collection—before a national championship—may have contributed to the powerful associations by capturing athletes at peak readiness, a factor not consistently reported in earlier studies. Thus, while our findings corroborate the central role of aerobic capacity and body mass highlighted in past research, they also add new knowledge by demonstrating their combined, near-complete predictive capacity under high-performance, competition-ready conditions.

Strengths and Practical Implications

A strength of the current study lies in its focus on a homogeneous sample of young elite rowers tested immediately before a national-level competition. This specific research context might have reduced variability, boosting the observed relationships' robustness. Furthermore, bootstrapped regression analysis further improved the reliability of statistical estimates despite the modest sample size. From a practical perspective, the findings offer valuable insights for coaches, sport scientists, and talent identification programs. Specifically, VO_2 max and body mass emerge as highly informative markers for assessing and monitoring rowing-specific performance potential. Routine evaluation of these parameters may support individualized training plans, guide athlete selection for competition, and help optimize resource allocation in athlete development programs.

Limitations

This study has a relatively small sample size, but the bootstrapping method strengthens the reliability of the findings. Rowers competing in the national championship may not represent all rowing athletes. Finally, even using the bootstrapping method, biological sex differences could not be examined in this study due to the small number of men and women in the sample.

CONCLUSIONS

This study found that aerobic capacity (VO_2 max) and body mass explained 99.5% of the variance in 2000m ergometer rowing performance among young elite athletes preparing for a national championship. While the predictive power is almost perfect, the findings are context-specific and may not generalize to other rowing populations or settings. Replication with larger, more diverse samples is needed to confirm these results and to explore potential sex-based differences. If validated, these findings may inform performance assessment and training strategies, emphasizing the integration of physiological and anthropometric measures, with VO_2 max and body mass emerging as the most reliable predictors of 2000m rowing performance.

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DATA AVAILABILITY

The data set on which this report is based is available from the authors in Excel or SPSS format upon reasonable request.

AUTHORS' CONTRIBUTION

Zoltán Alföldi: Conceptualization, methodology, software; *Ferenc Ihász:* Conceptualization, data curation, supervision; *Celal Bulgay:* Methodology, validation, writing, review, and editing; *Anna Pápai Horváth*: Conceptualization, data curation, software, verification; *Ádám Balog*: Conceptualization, data curation, methodology; *Zsolt B. Katona:* Methodology, data curation; *Angéla Somogyi:* Methodology, supervision, resources, investigation; *Attila Szabo*: Formal analysis, verification, writing, review, and editing.

ETHICAL APPROVAL

The research received ethical permission (Permission Number SZE/ETT-11/2024 [IX.11.]) from the Scientific Advisory Board of Széchenyi István University.

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