

# Aerobic Endurance - Finding Optimal Rowing Ergometer Settings to Match Physiological Demands of Running

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## **ABSTRACT**

Assessing aerobic endurance is crucial for evaluating fitness levels, with the Cooper 12-minute test widely recognized as a benchmark. However, indoor rowing on the Concept2 rowing ergometer lacks a standardized equivalent, prompting this study to explore the potential of a 12-minute rowing test as an alternative. Despite differences in muscle groups, rowing shares foundational aerobic capacities with running. The investigation centers around the rowing drag factor, hypothesizing its role in aligning rowing performance with the physiological demands of running. The study involved 56 healthy male soldiers (age:  $22.89 \pm 2.28$  years) undergoing 12-minute running and three drag factor rowing tests. While basic anthropometrics showed limited influence, body height correlated positively with rowing performances, and body weight negatively affected both running and rowing at low resistance and positively at higher resistances. The closest correlation between running and various drag factor rowing tests, and also the only one with no statistically significant difference in distance covered, was found at damper setting 1 of the ergometer, representing the lowest drag factor. The highest association (.42) was found between 12-minute running and 12-minute row damper 1, but the coefficient of determination ( $r^2$ ) is only 0.18 (18%). Therefore, further analysis is needed before the rowing test can be considered a valid alternative to the Cooper test.

**Keywords:** Aerobic endurance; Concept2; Cooper test; Czech Army soldiers; physical performance

## INTRODUCTION

Aerobic endurance is one of the most significant markers of an individual's fitness. There are numerous possibilities for laboratory and field testing, with the Cooper 12-minute run (CRT) considered the flagship assessment in the field due to its extensively researched nature and ease of use (Cooper, 1968; Bandyopadhyay, 2015; Alvero-Cruz et al., 2019). There are cycling and swimming variants also, but not rowing one. The growing popularity and increased accessibility of indoor rowing on rowing ergometers provide an alternative to running for the general population. Its complex, whole-body movement pattern offers a convenient option when running is not feasible due to various reasons. Even though the dominant muscles in running and rowing differ (Hamner et al., 2010; Ogurkowska et al., 2015), rowing performance is strongly based on aerobic and anaerobic capacities (Hagerman, 1984; Secher, 1983). Therefore, rowing shares common foundations with running to a certain degree.

Various tests often yield formulas that relate test results to  $VO_2\max$ , considered a benchmark of aerobic endurance. However, even though  $VO_2\max$  strongly correlates with aerobic endurance performances, it is not the sole determining factor. Multiple other factors come into play, including technique, lactate accumulation, aerobic capacity, and others (Apte et al., 2022; Bosquet et al., 2012), including psychological ones (McCormick et al. 2015; Röthlin et al., 2022). For the reasons mentioned, utilizing any existing Concept2 rowing ergometer endurance test as an alternative to the Cooper running test is not ideal. Apart of different movement, these tests vary in other multiple parameters, such as work time, intensity, and measured values (Bensons & Connolly, 2020; Funch et al., 2021; Holmes et al., 2020; Klusiewicz et al., 2021; Sebastia-Amat et al., 2020). We advocate for the adoption of the 12-minute rowing test to closely mirror the parameters of the original test. Although a pilot study by Leuchter et al. (2023) demonstrated promising results regarding its applicability, differences in performance in the distance covered between running and rowing have prompted a reevaluation of the configurations of the new test.

Aerobic performance is positively influenced by maximal strength (Hoff et al., 2002), and rowing is powered by strength abilities (Izquierdo-Gabarron, 2010) to a greater extent than running, especially those of the upper body. Therefore, the resistance parameter in rowing might be a determining factor when approximating performances in rowing and running. According to Concept2 (2018a), resistance is created by pulling intensity and not by the ergometer; however, there is an adjustable setting that modifies another aspect of rowing, called the drag factor. In simple terms, the drag factor is represented by the damper setting. As the setting increases, the ergometer slows more rapidly between pulls, demanding greater power in the strokes and engaging more strength abilities. Our hypothesis revolves around the impact of damper settings on performance. It is our conjecture that these settings play a crucial role in approximating rowing to running. While a higher damper setting intensifies the strength component, our focus lies in investigating whether a lower damper setting aligns more closely with the physiological demands of running, aligning with our overarching goal of achieving a performance resemblance between rowing and running.

The purpose of this study is to investigate the impact of the drag factor and anthropometric data on rowing performance and determine the setting that most closely replicates the physiological

requirements of running. This will be achieved through a comparison of the CRT and three variants of a 12-minute rowing test.

## **METHOD**

### ***Participants***

The research sample comprised 56 male soldiers from the Army of the Czech Republic with an average age of  $22.89 \pm 2.28$  years, body height  $182.04 \pm 4.87$  cm, and body weight  $81.57 \pm 8.54$  kg. Participants were healthy, possessed a sufficient fitness level to serve in the Army, and were accustomed to various physical testing. While rowing was not a common component of their physical training, they had been introduced to it in previous years and underwent at least one rowing test before participating in this research. The study received approval from the Ethical Board of the University of Defence, and all participants were informed of the objectives, procedures and risks of the study and provided written informed consent. Additionally, all volunteers were instructed not to perform any demanding physical activity before the test sessions.

### ***Study design***

The data collection spanned four days over a two-week period, with one day allocated for the Cooper 12-minute run test (CRT) and anthropometric data, and three days for 12-minute rowing sessions. The order of disciplines was randomized for each participant. Before the initial testing session, participants received detailed information about the study design and instructions for their individual testing schedule.

### ***Procedures***

For this study, anthropometric data were collected using the InBody 970 (InBody Co., Ltd. InBody Bldg, 625, Eonju-ro, Gangnam-gu, Seoul, 06106 Korea). Rowing tests were conducted on the Concept2 rowing ergometer model E (Concept2, Inc., 105 Industrial Park Drive, Morrisville, VT 05661, USA). CRT took place on a 300m athletic running track. All tests were conducted by physical education professionals at the University of Defence, each possessing a minimum of five years of teaching experience. Participants were explicitly instructed to exert their best effort during each testing session.

#### ***Cooper 12-minute run test (meters)***

Participants were provided with a race bib and a 10-minute individual warm-up preceding the test. The run commenced with a mass start, and the time remaining was displayed at the track's start. A loud signal was sounded one minute before the conclusion of the allotted time. The distance covered during the 12-minute interval was meticulously recorded. Participants were allowed to use watches for personal tracking.

#### ***12-minute rowing test (meters)***

Prior to each rowing test, participants completed an individual warm-up, followed by a 5-minute warm-up row, and adjustments to the ergometer. Subsequently, a 12-minute interval was set on the ergometer's performance monitor, allowing participants to initiate the test at their discretion

and monitor their progress throughout. The damper settings used, based on each participant's individually randomized schedule, were 1, 5, and 10, corresponding to drag factors 62 – 65, 113 – 114, and 204 – 205. The damper, a lever on the side of the flywheel cage, adjusts the resistance by controlling the amount of air, influencing the drag factor. This drag factor reflects the rate of deceleration of the ergometer flywheel, with higher drag factors indicating faster deceleration. The resistance itself is primarily created by the pulling intensity of the participant, not by the ergometer (Concept2, 2018b). After the interval concluded, the distance covered was recorded.

### Data analysis

The research data were processed using descriptive statistics (arithmetic mean, standard deviation, coefficient of variation, minimum and maximum value), descriptive statistics (two-sample t-test, paired) and correlation analysis (Pearson correlation coefficient). The Shapiro Wilk test was used to test the normality of the frequency distribution of each variable (a normal frequency distribution was demonstrated). The statistical significance level is set at  $\alpha = 0.05$ , with a critical value  $p = 0.27$  ( $n = 56$ ). The effect size (ES), as per Cohen (1988), is denoted by  $r = 0.1$  for small, 0.3 for medium, and 0.5 for large. Hopkins (2016) expanded the scale beyond these values as follows: trivial (0.0), very large (0.7), nearly perfect (0.9), perfect (1.0). The data were processed using the licensed software IBM SPSS Statistics (version 28.0, SPSS Inc., Chicago, IL USA) and Microsoft Excel.

## RESULTS

Basic descriptive statistics of the measured variables are presented in Table 1. The results indicate that the testing sample is adequately homogeneous in terms of age, body height, and body weight ( $CV = 2.67 - 10.46\%$ ). Results from the three variants of the 12-minute rowing test show a statistically and practically significant increase in performance from damper 1 to damper 5 and damper 10. The difference in the mean values of the Cooper 12-minute run test (CTR) is statistically insignificant only in the case of RD1 ( $p = .32$ ;  $d = .19$ ). In comparison with RD5 and RD10, there are statistically and practically significant differences ( $p = 0.00$ ;  $d = .58$ , resp. 1.02).

**Table 1.** Basic statistics characteristics of measured variables

MR/BD	M	SD	min	max	CV (%)
Age (years)	22.89	2.28	20.20	33.90	9.94
Height (cm)	182.04	4.87	171.00	199.00	2.67
Weight (kg)	81.57	8.54	65.70	101.00	10.46
CRT (m)	2831.16	188.50	2600.00	3300.00	6.66
RD1 (m)	2863.23	150.65	2511.00	3218.00	5.26
RD5 (m)	2929.77	148.06	2620.00	3219.00	5.05
RD10 (m)	3002.68	144.84	2744.00	3390.00	4.82

**Legend:** MR = measured variables; BD = Basic descriptive characteristics; M = mean; SD = standard deviation; min = minimum; max = maximum; CV = coefficient of variation; Height = body height, Weight = body weight, CRT = Cooper 12-minute run test; RD1 = 12-minute row damper 1; RD5 = 12-minute row damper 5; RD10 = 12-minute row damper 10

Table 2 presents the correlation matrix, indicating that age exhibited minimal influence on other variables. Body height demonstrated positive correlations with body weight and all performance metrics. Body weight showed a negative correlation with CRT but a positive correlation with high-resistance rowing. Notably, all three rowing disciplines exhibited strong correlations with each other and moderate correlations with CRT, with damper 1 rowing demonstrating the strongest correlation with the run.

**Table 2.** Correlation matrix for individual variables

Correlation	Age	Height	Weight	CTR	RD1	RD5	RD10
Age (years)	1	-0.06	0.09	0.01	0.06	0.07	0.10
Height (cm)	tri	1	0.45	0.18	0.23	0.32	0.26
Weight (kg)	tri	med	1	-0.16	-0.02	0.16	0.33
CTR (m)	tri	sm	sm	1	0.42	0.32	0.29
RD1 (m)	tri	sm	tri	med	1	0.79	0.63
RD5 (m)	tri	med	sm	med	vlg	1	0.74
RD10 (m)	sm	sm	med	med	lg	vlg	1

**Legend (see Table 1):** Statistically significant correlations are shown in bold; assessment of effect sizes for individual correlation coefficients are noted in the bottom part of the correlation matrix: tri = trivial, sm = small; med = medium; lg = large; vlg = very large. Statistical significance level:  $\alpha = 0.05$ ; critical value  $p$  ( $n = 56$ ;  $p_{krit} = 0.27$ )

## DISCUSSION

The primary focus of this study was to examine the impact of drag factor on rowing performance and identify the damper setting that best approximates rowing to running. Basic anthropometrics did not emerge as critical factors influencing performances.

The correlation between participant body height and body weight, with a value of  $r = 0.45$ , aligns with the findings of Islam et al. (2017) who reported a similar correlation of  $r = 0.44$  among university students. Although participant body height corresponds to the average body height in the Czech Republic 181 cm according to WorldData (2020), the body weight of 81.6 kg is notably lower than the Czech average of 91.9 kg. These data reinforce the notion that young soldiers tend to have lower obesity levels compared to their civilian peers. From an age perspective, a statistically insignificant yet discernible trend indicates a positive influence on rowing performance with higher resistance, but not in running. This trend aligns with the fact that muscle mass peaks around the age of 30 – 35 years (NIH, 2022), supporting the assertion that rowing is more strength-based than running, and reinforcing the theory of damper setting and strength abilities requirements. Body weight exhibits a similar pattern in rowing at higher resistances, negatively influencing running, consistent with the findings of Vanderburgh (2006). Noteworthy, damper 1 rowing seems to be almost completely negating influence of individual's body weight on performance. Body height, on the other hand, positively correlates with all performances, but with significance observed only in damper setting 5. Weak correlations of anthropometrics found in this study contrast with the findings of Cerasola et al. (2020), who discovered strong correlations of body height ( $r = -0.88$ ) and body weight ( $r = -0.82$ ) with 2000-m rowing. Even though the 12-minute and 2000-m rowing are

not extremely different, certain similarities can be found, particularly when comparing sprint vs marathon runs and their anthropometrics. It is important to note that this study's research sample comprised rowing beginners, often with poor technique.

For the analysis of performances, the results affirmed our hypothesis that a lower drag factor better mimics the physiology of running. The average CRT distance was  $2831 \pm 188$  m, slightly above the excellent fitness level threshold according to CRT norms (Cooper, 1968). The rowing distance covered increased along with a higher drag factor, with damper 1 averaging at  $2863 \pm 150$  m, damper 5 averaging  $2929 \pm 148$  m, and damper 10 averaging  $3002 \pm 144$  m. In considering the potential influence of a training effect, there is a possibility of small improvements. However, given the substantial differences between rowing distances, irrespective of their order (the three trials were randomized), the impact of the training effect can be deemed negligible. Due to the pilot nature of the present study ( $n = 56$ ), statistical testing (ANOVA) was not conducted to assess differences between the results of the three rowing tests. The correlations of running with damper settings 1, 5, and 10 were all statistically significant (medium), with  $r$  values of 0.42, 0.32, and 0.29, respectively. Therefore, with running, the damper setting that showed the closest correlation was damper 1, representing a drag factor of approximately 63. Notably, despite the statistically significant yet relatively low determination coefficient of damper 1 rowing on CRT ( $r^2 = 0.18$ ), suggesting the variability in the running and rowing performances explained by each other is relatively modest, the performance differences were still statistically indifferent. Interestingly, the highest drag factor (204 - 205) resulted in the best results in the 12-minute rowing trial. It's worth mentioning that the best results in rowing are generally achieved with a drag factor around 115 - 125 (Concept2, 2018), except for sprints where the maximum damper setting is typically utilized. The explanation might lie in the different populations reporting the settings; rowing specialists often possess high-quality and explosive techniques, whereas untrained individuals in rowing may lack sufficient technique and instead rely more on maximal strength than power. Despite statistically significant differences among various drag factors, particularly a substantial effect size ( $d = 0.94$ ) between damper 1 and damper 10, and medium-level differences ( $d = 0.45$  and  $d = 0.5$ ) between damper 5 and damper 1 and 10 respectively, it is noteworthy that all three rowing trials exhibited strong correlations. A higher correlation was consistently observed with more similar damper settings, indicating a nuanced relationship between drag factors and rowing performance and suggesting that damper setting might affect actual performance more than, for example, in cycling on flat versus uphill terrain where power output is statistically unaffected (Hovorka, 2022). Further research exploring the potential influence of lean muscle mass on this relationship could provide valuable insights into the complex dynamics of rowing performance.

## CONCLUSION

This study delved into the intricate relationship between drag factor, represented by damper settings, and the performance of rowing in comparison to running. Despite exploring anthropometric factors, they did not emerge as critical influencers in this context. Body height positively correlated with all performances, while body weight exhibited a pattern of negatively influencing running and

lower drag factor rowing. The findings confirmed our hypothesis that a lower drag factor better replicates the physiological demands of running. The lower the drag factor, the closer the rowing performance is to running. While the correlations between running and various rowing scenarios were statistically significant, the modest determination coefficient in the closest performances suggests an intricate interplay of various factors in both running and rowing exercises. In summary, our study provides valuable insights into the nuanced relationship between drag factor and the performance dynamics of rowing. The similarity of performances in CRT and the lowest drag factor 12-minute rowing suggests their possible interchangeability for aerobic endurance testing. This offers a foundation for further exploration and refinement of rowing protocols as an alternative to running, emphasizing the alignment of 12-minute rowing performance with the Cooper 12-minute run test.

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