Charles University | Faculty of Physical Education and Sport

SMAS

PILOT ANALYSIS OF TRAINING ZONE SETTING IN ROWERS USING 2000-METER ERGOMETER OUTPUTS

Jaroslav Hellebrand[1*], Jan Busta[2], and Miroslav Petr[1]

[1]Biomedical department, Faculty of Physical Education and Sport, Charles University in Prague, Prague, Czechia,
[2]Department of Swimming, Water and Technical Sports, Faculty of Physical Education and Sport, Charles University in Prague, Prague, Czechia
*Corresponding author

jaroslav.hellebrand@ftvs.cuni.cz

INTRODUCTION

From a physiological standpoint, the success of endurance training depends on the manipulation of several key variables, including duration, frequency, and—critically—exercise intensity (Seiler, 2010). The implicit objectives of athletic training are to maximize performance, minimize the risk of negative outcomes, and ensure peak performance occurs at the right time. In endurance sports, intensity is typically defined as a percentage of maximum heart rate, fixed or individualized blood lactate or ventilatory thresholds, critical power (CP), various forms of functional threshold power (FTP), or other threshold-based markers. However, prescribing training at precise intensity levels is particularly challenging in outdoor sports due to the variability of environmental conditions and the dynamic nature of physiological thresholds. As a result, heart rate training zones— specific intensity ranges during endurance type physical activity —are commonly used in practice to guide the planning, execution, and analysis of endurance training. These zones, however, are often specific to the modality of movement (Carey et al., 2009) i.e. they differ based on the type of activity ("sport").

Ideally, training should be guided by individually determined zones tailored to each athlete's physiological profile. Evidence supports the effectiveness of training models based on ventilatory thresholds (VT1 and VT2), which better reflect individual metabolic responses in endurance sports (Wolpern et al., 2015). While individualized testing is standard practice at the elite international level, it is less common at the youth or club level—particularly in smaller sports with limited resources. Therefore, identifying a simple, standardized performance metric that could guide individual approach to the of setting of the training zones—such as the 2000-meter ergometer test commonly used in rowing—may be practical.

METHODS

OBJECTIVE

The aim of this study was to establish reference values for relative power output in determining training zones, expressed as the ratio (percentage) of ventilatory thresholds VT1 and VT2 to performance in the 2000-meter rowing ergometer test.

PARTICIPANTS

Data were collected from 12 adolescent rowers: 5 females (mean age 17.6 ± 0.54 years) and 7 males (mean age 17.9 ± 0.9 years), all classified at Level 3 according to McKay et al. (2022). Each athlete had a structured training history of at least 3 years and was familiar with the Concept2 rowing ergometer as both a training and competition tool.

PROTOCOL

All athletes performed:

- A 2000-meter rowing test on a Concept2 Model D ergometer (Morrisville, USA)
- A graded CPET protocol on the same ergometer, using gas analysis via Cortex Metamax 3B (Leipzig, GER).

The initial workload for the CPET was set at 30% of the athlete's 2k performance (W) and rounded to the nearest whole number. Load increments were 15–20 W for females and 35–40 W for males. The test was conducted without rest intervals between stages and terminated upon reaching VO_2Peak—defined as the point where oxygen uptake plateaued—or voluntary exhaustion.

- **VT1** was identified as the point at which ventilation and CO_2 output (VCO_2) began to rise disproportionately relative to oxygen uptake (VO_2).
- **VT2** was determined using the V-slope method, indicating the deflection point in VCO_2 relative to VO_2.

DATA ANALYSIS

All data were recorded and analysed using Analyse-It plugin (Analyse-It Software Ltd., Leeds, UK) in Microsoft Excel. The 2000-meter time was converted to power (W) using the standard Concept2 formula: $\mathbf{W = 2.80 / pace_2}$.

Power outputs at VT1 and VT2 were recalculated as relative values—expressed as a percentage of 2k performance (VT1%2k, VT2%2k).

Statistical analysis included: Variance to quantify measurement variability, Interquartile range (IQR) to assess data distribution, Standard deviation (SD) to assess dispersion, Confidence intervals (CI99, CI95) to estimate population-level reliability, CI50 to identify ranges where dispersion was ≤5% (limit of practical field usability) in both sexes for each threshold.

RESULTS

	t2000m	Wavg500	VT1W	VT2W	VT1%2K	VT2%2K	MINVT1	AVGVT1	MAXVT1	MINVT2	AVGVT2	MAXVT2
W1	07:34.0	240	110	142	46%	59%	43%	49%	55%	59%	69%	75%
W2	07:15.0	272	150	190	55%	70%						
W3	07:51.7	214	105	150	49%	70%						
W4	07:42.8	226	120	165	53%	73%						
W5	07:25.0	254	110	190	43%	75%						
						VARIANCE		12%			16%	
						IQR		7%			3%	
						SD		5%			6%	
							CI-LL	CI-VARIANCE	CI-UL	CI-LL	CI-VARIANCE	CI-UL
						CI99	39%	20%	59%	57%	25%	82%
						CI95	43%	12%	55%	62%	15%	77%
						CI50	48%	3%	51%	67%	4%	71%

	t2000m	Wavg500	VT1W	VT2W	VT1%2K	VT2%2K	MINVT1	AVGVT1	MAXVT1	MINVT2	AVGVT2	MAXVT2
M1	06:08.0	449	240	320	53%	71%	32%	46%	53%	49%	61%	71%
M2	06:55.3	313	165	195	53%	62%						
M3	06:36.1	360	115	190	32%	53%						
M4	06:48.7	328	140	215	43%	66%						
M5	06:48.9	328	130	160	40%	49%						
M6	06:55.1	313	150	180	48%	58%						
M7	06:37.0	356	190	240	53%	67%						
						VARIANCE		21%			22%	
						IQR		12%			11%	
						SD		8%			8%	
							CI-LL	CI-VARIANCE	CI-UL	CI-LL	CI-VARIANCE	CI-UL
						CI99	34%	23%	58%	49%	23%	72%
						CI95	33%	20%	53%	53%	15%	68%
						CI50	43%	5%	48%	59%	4%	63%

DISCUSSION

From a methodological perspective, this study represents a pilot investigation, which is reflected in the relatively small sample size. This limitation reduces the statistical power of the analysis and restricts the generalizability of the findings to the broader rowing population. The study employed a one-time, cross-sectional measurement, without repeated testing. Therefore, intraindividual variability over time—particularly in response to training adaptations—could not (by design) be assessed. Given the dynamic nature of physiological responses to training, the specificity of the measured values should be interpreted considering the athletes' current fitness levels. Athlete performance level is very likely a factor, undoubtedly higher performing athletes will have both threshold values closer to their individual 2k performance. We expect that relative threshold values will vary across performance levels, as suggested by McKay et al. (2022). Additionally, participant age must be considered. Prior research shows that age influences maximum heart rate (Ozemek et al., 2017), and the adolescent age group in this study may limit the transferability of results to other age or performance categories.

Another limitation is the use of a rowing ergometer as the testing modality. While ergometers provide a valid and reliable alternative to laboratory diagnostics in rowing (Mentz et al., 2020), notable biomechanical differences exist between ergometer rowing and on-water conditions (Fleming et al., 2014). Despite these differences, the rowing ergometer remains a widely accessible and practical training tool. Individual physiological responses between ergometer and on-water testing may vary, but previous studies suggest that training prescriptions derived from ergometer tests are applicable and at least somewhat effective for most rowers (Vogler et al., 2010).

The physiological variables analysed—particularly power output at VT1 and VT2—are widely recognized in practice. However, interpreting their relative values to 2000-meter performance requires further validation in larger and more demographically diverse samples. Unsurprisingly, the results confirmed that male rowers achieved higher absolute and relative power outputs than females. The broader range of values in the male group indicates greater interindividual variability in training status, whereas the narrower VT1 range in females suggests a more homogeneous group.

Overall, the analysis demonstrated clear sex-based differences in performance metrics and their variability. Identifying VT1 and VT2 based on relative power output enables more precise training zone planning and more effective load management.

CONCLUSION

The results of this pilot study suggest that prescribing training zones based on 2000-meter rowing ergometer performance may be a viable approach in practical training settings, especially if athletes can be accurately classified by performance level and normative values are established for each category. The identified threshold values may serve as a reference for further research and as a preliminary guide for training intensity prescription in contexts where detailed laboratory diagnostics are not available.

Future research should aim to validate this methodology in a larger and more demographically diverse sample, while accounting for performance classification levels or raw performance as a factor.

REFERENCES

- Carey, D. G., Tofte, C., Pliego, G. J., & Raymond, R. L. (2009). Transferability of running and cycling training zones in triathletes: Implications for steady-state exercise. Journal of Strength and Conditioning Research, 23(1), 251–258. https://doi.org/10.1519/JSC.0b013e31818767e7
- Fleming, N., Donne, B., & Mahony, N. (2014). A comparison of electromyography and stroke kinematics during ergometer and on-water rowing. Journal of Sports Sciences, 32(12), 1127–1138. https://doi.org/10.1080/02640414.2014.886128
- McKay, A. K. A., Stellingwerff, T., Smith, E. S., Martin, D. T., Mujika, I., Goosey-Tolfrey, V. L., Sheppard, J., & Burke, L. M. (2022). Defining Training and Performance Caliber: A Participant Classification Framework. International Journal of Sports Physiology and Performance, 17(2), 317–331. https://doi.org/10.1123/ijspp.2021-0451
- Mentz, L., Engleder, T., Schulz, G., Winkert, K., Steinacker, J. M., & Treff, G. (2020). The mechanical rower: Construction, validity, and reliability of a test rig for wind braked rowing ergometers. Journal of Biomechanics, 106, 109833. https://doi.org/10.1016/j.jbiomech.2020.109833
- Ozemek, C., Whaley, M. H., Finch, W. H., & Kaminsky, L. A. (2017). Maximal heart rate declines linearly with age independent of cardiorespiratory fitness levels. European Journal of Sport Science, 17(5), 563–570. https://doi.org/10.1080/17461391.2016.1275042
- Seiler, S. (2010). What is best practice for training intensity and duration distribution in endurance athletes? International Journal of Sports Physiology and Performance, 5(3), 276–291. https://doi.org/10.1123/ijspp.5.3.276
- Vogler, A. J., Rice, A. J., & Gore, C. J. (2010). Physiological Responses to Ergometer and On-Water Incremental Rowing Tests. International Journal of Sports Physiology and Performance, 5(3), 342–358. https://doi.org/10.1123/ijspp.5.3.342
- Wolpern, A. E., Burgos, D. J., Janot, J. M., & Dalleck, L. C. (2015). Is a threshold-based model a superior method to the relative percent concept for establishing individual exercise intensity? A randomized controlled trial. BMC Sports Science, Medicine and Rehabilitation, 7(1), 16. https://doi.org/10.1186/s13102-015-0011-z

International Conference on Science and Medicine in Aquatic Sports (SMAS)
May 9 – 10, 2025