Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 4), Art 114, pp. 1001 - 1008, April 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Comparative analysis of heart rate response in traditional rowing during short- and long-distance competitions

ALFONSO PENICHET-TOMAS[1], JOSE M. JIMÉNEZ-OLMEDO[2], JAVIER OLAYA-CUARTERO[3], SERGIO CALAVIA-CARBAJAL[4]
[1,2,3] Health, Physical Activity and Sports Technology (HEALTH-TECH), Department of General and Specific Didactics, University of Alicante, 03690 Alicante, SPAIN
[3] Faculty of Health Sciences, Isabel I University, 09003 Burgos, SPAIN
[4] Faculty of Education, University of Alicante, 03690 Alicante, SPAIN

Published online: April 30, 2024
(Accepted for publication April 15, 2024
DOI:10.7752/jpes.2024.04114

Abstract:
This study aimed to compare the heart rate responses of experienced traditional rowers during short- and long-distance competitions and to quantify and compare the workload associated with each modality during the competition. Thirteen highly trained traditional rowers participated in this study divided into two groups based on the competition modality: seven short-distance rowers (height 182.8 ± 6.5 cm, body mass 78.7 ± 4.4 kg,BMI 23.5 ± 1.2 kg/m²) competing in the 1400 m race, and six long-distance rowers (height 178.5±4.8 cm, body mass 75.0 ± 6.4 kg, BMI 23.5 ± 1.4 kg/m²) competing in the 5556 m race. To assess the heart rate workloads of the rowers, a 7×4-minute incremental step test was conducted on a rowing ergometer, and internal load data were collected during the respective competitions for each modality. The *z*-test was used to calculate the comparison of proportions based on the quotient resulting from dividing effect errors. Findings indicate that both short-distance and long-distance rowers spent significantly more competition time ($p<0.001$) in zone 6 (301.1 ± 48.2 s; 77.2 ± 12.4% and 1124.2 ± 127.5 s; 87.3 ± 9.9%, respectively) and in zone 5 (63.7 ± 49.6 s, 16.3 ± 12.7% and 113.8 ± 95.2 s, 8.8 ± 7.4%, respectively). Furthermore, significantly more competition time ($p<0.001$) at high intensity during their respective competitions was spent by both groups (short-distance group 349 ± 18.1 s, 89.5 ± 4.6% and long-distance group 1213.3 ± 64 s, 94.2 ± 5%). Conversely, a higher percentage of time in both low zones and low intensity was spent by the short-distance group ($p<0.05$). However, a higher percentage in zone 6 and at high intensity was spent by the long-distance group ($p<0.001$). Finally, a significantly higher workload was exhibited by the long-distance competition compared to the short-distance competition ($p<0.001$). These findings hold significant value for coaches and athletes as they provide essential information regarding the percentage of time spent in each work zone, enabling the design of individualized training programs based on the type of competition being prepared for.
Key Words*:* **rowers, performance, training zones, heart rate, fixed seat rowing, competition load.**

Introduction

Rowing is a sport involving the movement of a boat through the water using one or more oars attached to the boat (Penichet-Tomas et al., 2021), with athletes utilizing their entire bodies to propel the boat (Sebastia-Amat et al., 2020). Two main modalities in traditional rowing, where the seat of the athletes remains fixed, are described by the Spanish Rowing Federation. On one hand, the Trainera, with a minimum weight of 200 kilograms, is propelled by 13 rowers and a coxswain in long-distance competitions covering 5556 meters with 4 lengths and 3 tacks (Larrinaga-Garcia et al., 2023; Lorenzo-Buceta et al., 2014). On the other hand, the Llaüt, with a minimum weight of 150 kilograms, is operated by 8 rowers and a coxswain in short-distance races spanning 1400 meters with 4 lengths and 3 tacks (Spanish Rowing Federation Code of Regattas, 2011).

The strokes parameters in a Trainera team during a rowing competition were studied by Lorenzo-Buceta et al. (2014). Differences between lengths were observed, with the second length recording the lowest number of strokes and a wider span. The third and fourth lengths, however, saw a higher number of strokes, with the last length witnessing the application of the highest average force. Lorenzo-Buceta et al. (2014) reported a total power average of 20544 W and an average force of 4586 N for this crew during the competition.

In contrast, during a simulated race on a rowing ergometer, rowers applied an average individual power of 250 W (León-Guereño et al., 2018), although these data may vary based on the duration and intensity of the warm-up (Mujika et al., 2012). Regarding lactate concentration, regattas showed an average lactate level of 10.2 mmol/l (González, 2014), with individual lactate peaks of rowers typically ranging between 10 and 18 mmol/L

Corresponding Author: JOSE M. JIMÉNEZ-OLMEDO, E-mail: j.olmedo@ua.es

(León-Guereño et al., 2018). These characteristics of the competition push lactic and alactic anaerobic capacity to their limits (Mejuto et al., 2012). Physiological values indicate that competition occurs above the anaerobic threshold, with maximal aerobic potency and lactate being the determining variables to identify the competitors' levels (Larrinaga-Garcia et al., 2023). Rowers in this discipline typically exhibit an endomesomorphic anthropometric profile, with an average fat level of 8% and muscle mass of 43.3% (León-Guereño et al., 2018). For this modality, power tests maintained at 4 mmol/l of lactate, the lactate-velocity ratio, or average power over 20 minutes, have been used as predictors of performance (Larrinaga-Garcia et al., 2023).

Furthermore, to compare improvements with different types of high-intensity interval training in Trainera rowers, the dynamics of oxygen volume during 6-minute high-intensity efforts and their recoveries have been employed (Mujika et al., 2023).

Currently, there is scant scientific evidence regarding physiological details in Llaüt competitions. However, studies on rowing competitions of similar duration demonstrate that aerobic metabolism predominates at a rate of 67%, with the remaining 33% attributed to anaerobic processes, consisting of 21% from alactic metabolism and 12% from lactic metabolism (Akça, 2014). Oxygen volume exceeds 75% at approximately 6 l/minute (Mäestu et al., 2005). Progressive tests of effort to exhaustion on indoor rowing machines have shown a correlation between total watts achieved and VO2max, although this correlation is not as strong for rowers in W/Kg and VO2max (Penichet-Tomas et al., 2023).

From a biomechanical standpoint, Llaüt rowers exhibit a greater isometric contraction in their lower limbs. Furthermore, they display greater explosive force in their lower limbs compared to other modalities. However, the other modalities demonstrate superior force generation ability over a longer duration. Llaüt rowers who can sustain force generation for an extended period while maintaining force levels tend to perform at a higher level (Penichet-Tomás et al., 2019). Finally, in terms of anthropometric data, Llaüt rowers tend to be ecto-mesomorphic with a low-fat percentage. Height and muscle mass index have been employed as predictors of performance in this modality (Penichet-Tomas et al., 2021). It has also been observed that good results in CMJ (Countermovement Jump) and bench pull tests are related to rowing performance (Sebastia-Amat et al., 2020).

Other cyclic sports use heart rate to monitor effort. Romero-Ramos et al. (2024) measured maximum and average heart rate for competitions lasting 35 minutes. The result was a mean heart rate of 162 bpm and a maximum of 182 bpm. Cherkesov et al. (2020) also focused on heart rate in athletes before and after exercise.

They found a significant post-exercise increase in heart rate, which does not return to previous levels until 1-minute post-exercise. Other authors such as Dong (2016) go a step further and talk about heart rate variability as a fundamental tool for training and recovery in cyclic sports. Dong says that this tool is a step beyond heart rate monitoring to understand the athlete's responses.

Despite the multitude of parameters considered in traditional rowing, scientific evidence regarding heart rate remains limited (González, 2014; Mujika et al., 2023; Penichet-Tomas et al., 2023), and it often serves as a complementary rather than a primary or thoroughly studied parameter. Therefore, the objective of this study is to compare the heart rate responses in experienced traditional rowers during long-distance and short-distance competitions, while also quantifying and comparing the workload associated with each modality during the competition.

Material & methods

Participants

For this study, a total of 15 highly trained traditional rowers were selected (McKay et al., 2022). The subjects engaged in training sessions six days a week, with each session lasting approximately 2 hours. These rowers were categorized into two groups: the short-distance rowers (n=7) participating in the 1400 m competition, and the long-distance rowers (n=6) involved in the 5556 m competition. Two of the rowers had to be excluded due to issues with their measuring devices. Physical and physiological data were collected from the athletes on the day of the competition and subsequently monitored using an H7 Bluetooth Smart Band (PolarInc., Kempele, Finland) to record heart rate data during each competition, following the method described by Okuno et al. (2013).

Various anthropometric aspects, including height, weight, and Body Mass Index (BMI), were measured and averaged for the subjects in both groups. The average maximum heart rate was determined using a step test protocol, as outlined by Turner et al. (2021). Additionally, the average loads associated with the competitions in each modality were calculated, following the methodology of Lucia et al. (1999). All rowers voluntarily provided informed consent to participate in this study, and the research protocol adhered to the ethical principles outlined in the Declaration of Helsinki.

The study received approval from the Human Research Ethics Committee of the University of Alicante (IRB UA-2023-06-14_1).

Table 1 shows the rower's descriptive characteristics.

Table 1. Rower's descriptive characteristics.

Characteristics	Short-distance (n = 7)			Long-distance (n = 6)		
	Mean ± SD	IC 95%		Mean ± SD	IC 95%	
Height (cm)	182.8 ± 6.5	176.8	188.9	178.5 ± 4.8	173.1	183.5
Body mass (kg)	78.7 ± 4.4	74.5	82.8	75.0 ± 6.0	68.7	81.3
BMI (kg/m²)	23.5 ± 1.2	22.3	24.7	23.5 ± 1.4	22.0	25.0
HRmax Test (bpm)	184.7 ± 6.1	179.0	190.3	183.8 ± 8.4	174.9	192.6
HRmax Competition (bpm)	183.0 ± 6.7	176.7	189.2	178.0 ± 6.4	171.2	184.7
HRmean (bpm)	173.1 ± 3.9	169.5	176.8	172.7 ± 9.0	163.3	182.2
TRIMPS	18.7 ± 0.3	18.4	18.9	63.0 ± 1.1	61.8	64.2

Test procedure

To determine the maximum heart rate of the rowers, a 7×4-minute incremental step test was conducted on a rowing ergometer (Concept 2, Model D, monitor PM5, Morrisville, VT, USA) equipped with an H7 Bluetooth Smart Band (PolarInc., Kempele, Finland) for heart rate data collection, following the method described by Okuno et al. (2013). This test, tailored for rowing, is individualized and takes into account various factors, including heart rate, as outlined by Turner et al. (2021). The initiation of the test and the increments in intensity are determined based on the best time achieved in the last performance test. In this particular case, all the athletes fell within the same time range in the last performance test, resulting in uniform test conditions. The test commenced at 140 watts and proceeded with increments of 30 watts, culminating in the seventh step at the highest possible intensity. Submaximal heart rates were recorded during the final 30 seconds of each submaximal workload. The maximum heart rate corresponds to the highest bpm (beats per minute) value attained during the test, sustained for a minimum duration of 5 seconds, in accordance with the criteria established by Rice & Osborne (2013).

Intensity Zones

The heart rate zones were defined as follows: zone 0 (Active recovery): <60% of HRmax, zone 1 (Endurance): 60–72% of HRmax, zone 2 (Tempo): 72–82% of HRmax, zone 3 (Threshold): 82–87% of HRmax, zone 4 (Transportation): 88–92% of HRmax, and zone 5 (VO2max): 93–100% of HRmax, based on the classification by Seiler (2010). Exercise intensity was categorized into three zones: low intensity, defined as <70% of FCmax (maximum heart rate), moderate intensity ranging from 70% to 90% of FCmax, and high intensity exceeding 90% of FCmax, following the criteria established by Neumayr et al. (2004) and Penichet-Tomás et al. (2018). The workload was calculated using the simplified TRIMPS (TRaining IMPulse) method as outlined by Lucia et al. (1999) and Muñoz et al. (2014). This model employs a three-phase zone and multiplies the time in minutes by the corresponding zone value (1, 2, or 3). The values obtained for all zones are then summed together.

Statistical analysis

Descriptive data were presented using the mean, standard deviation (SD), and 95% confidence intervals (CI) determined through bootstrapping. The z statistical test for comparing proportions was executed. This statistical technique assesses whether observed differences between two proportions or percentages in distinct samples or groups are statistically significant. The analysis involves subtracting one sample proportion from the other to ascertain the observed difference between the proportions. Furthermore, it computes the standard error of the difference between the sampling proportions, taking into consideration the sample sizes and the underlying population proportions. The formula below was employed to calculate the value of the z-statistic, where p_1 and p_2 represent the sample proportions of each group, p is the weighted sampling proportion, and n_1 and n_2 denote the sample sizes of each group. This formula measures how many standard deviations the observed difference between the proportions is from the mean.

$$z = \frac{(p_1 - p_2)}{\sqrt{p(1-p)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Finally, the calculated value of the z-statistic was compared with the critical value corresponding to the desired significance level, which was set at 0.05 for a 95% confidence level. If the calculated value exceeded the critical value, the null hypothesis was rejected, indicating a significant difference between the population proportions. The confidence interval of the difference in proportions was computed by adding the value of z times the standard error of the difference in proportions (SEDP) to the absolute difference for the upper limit and subtracting it for the lower limit.

Results

Table 3 displays the comparison between both modalities. The long-distance group spent a duration of 1124.2 ± 127.5 s (87.3 ± 9.9%) in zone 6, whereas the short-distance group allocated 301.1 ± 48.2 s (77.2 ± 12.4%) to this zone, revealing significant differences ($p<0.001$). In zone 5, the long-distance group spent 113.8 ± 95.2 s (8.8 ± 7.4%), while the short-distance group utilized 63.7 ± 49.6 s (16.3 ± 12.7%), again demonstrating significant differences ($p<0.001$). No differences were observed in zones 4 and 3. However, significant differences were identified in zone 1 ($p=0.021$) and zone 2 ($p=0.038$). Regarding the three-phase zone, the short-distance group spent 349 ± 18.1 s (89.5 ± 4.6%) in the high-intensity zone, while the long-distance group invested 1213.3 ± 64 s (94.2 ± 5%), revealing significant differences between the modalities ($p=0.001$). At moderate intensity, the short-distance group dedicated 34.3 ± 18.7 s (8.8 ± 4.8%), whereas the long-distance group allocated 69.2 ± 60.4 s (5.4 ± 4.7%), once again displaying significant differences between modalities ($p=0.014$). Finally, the short-distance group spent 6.7 ± 1.5 s (1.7 ± 0.4%) at low intensity, whereas the long-distance group devoted 5.5 ± 4 s (0.4 ± 0.3%) to low intensity, and significant differences were observed between the groups ($p=0.009$).

Table 3. Comparative analysis of time by HR zone and exercise intensity between Llaüt and Trainera rowers.

			Short-distance (n = 7)			Long-distance (n = 6)			z test		
		HR max (%)	Time (%) Mean±SD	Time (s) Mean±SD	HR (bpm) Mean±SD	Time (%) Mean±SD	Time (s) Mean±SD	HR (bpm) Mean±SD	p	CI 95%	
Heart rate zone	Active recovery	< 60	0.4±0.5	1.6±1.9	104.4±5.1	0.0±0.0	0.0±0.0	0.0±0.0	0.021*	-0.002	0.010
	Endurance	60-72	1.7±0.4	6.7±1.6	122.7±4.7	0.6±0.4	7.8±5.1	123.1±8.9	0.038*	-0.002	0.025
	Tempo	73-82	1.8±0.7	7.0±2.8	144.7±5.4	1.4±1.2	18.3±15.9	144.2±6.4	0.595	-0.011	0.018
	Threshold	83-87	2.5±2.0	9.9±8.0	158.1±5.5	1.9±1.7	23.8±22.1	157.2±6.7	0.394	-0.010	0.024
	Transportation	88-92	16.3±12.7	63.7±49.6	168.0±6.2	8.8±7.4	113.8±95.2	167.8±8.4	<0.001†	0.035	0.106
	VO_2max	93-100	77.2±12.4	301.1±48.2	176.8±4.7	87.3±9.9	1124.2±127.5	174.4±7.9	<0.001†	-0.146	0.849
Exercise intensity	Low	< 70	1.7±0.4	6.7±1.5	116.7±6.2	0.4±0.3	5.5±4.0	120.6±9.3	0.009*	0.000	0.007
	Moderate	70-90	8.8±4.8	34.3±18.7	156.6±7.4	5.4±4.7	69.2±60.4	154.6±6.0	0.014*	0.004	0.065
	High	> 90	89.5±4.6	349.0±18.1	175.8±4.0	94.2±5.0	1213.3±64.0	174.0±8.2	0.001*	-0.080	-0.014

HR: Heart Rate; HRmax: Maximum Heart Rate; s: seconds; bpm: beats per minute: SD: Standard desviation; CI: confidence interval VO_2max: maximum oxygen volume; $^*p<0.05$; $^{\dagger}p<0.001$

Figure 1 illustrates the distinctions between zones in the long-distance and short-distance groups. On one hand, the long-distance group dedicated the majority of its time to zone 6 (1124.2 ± 127.5 s; 87.3 ± 9.9%) during the competition, revealing significant differences compared to the other zones (p<0.001). Zone 5 also exhibited significant differences ($p<0.001$) in comparison to the lower zones (113.8 ± 95.2 s; 8.8 ± 7.4%). However, no significant differences were observed among the lower zones themselves. Concerning the three-phase zones, high intensity demonstrated significant distinctions ($p<0.001$) in terms of both percentage (94.2 ± 5.0%) and time (1213.3 ± 64 s) when compared to lower intensities. Moderate intensity also displayed significant differences ($p<0.001$) in relation to low intensity (69.2 ± 60.4 s; 5.4 ± 4.7%) during the competition. On the other hand, the short-distance group also allocated the majority of its time to zone 6 (301.1 ± 48.2 s; 77.2 ± 12.4%), where significant differences were identified in comparison to the other zones ($p<0.001$). Zone 5 (63.7 ± 49.6 s; 16.3 ± 12.7%) also exhibited significant differences ($p<0.001$) when compared to the lower zones. In terms of the three-phase zones, the short-distance group predominantly spent its time at high intensity (349.0 ± 18.1 s; 89.5 ± 4.6%), revealing significant differences ($p<0.001$) with regard to other intensities. Similarly, moderate intensity showed significant differences ($p<0.001$) when compared to low intensity (63.7 ± 49.6 s; 16.3 ± 12.7%) during the competition.

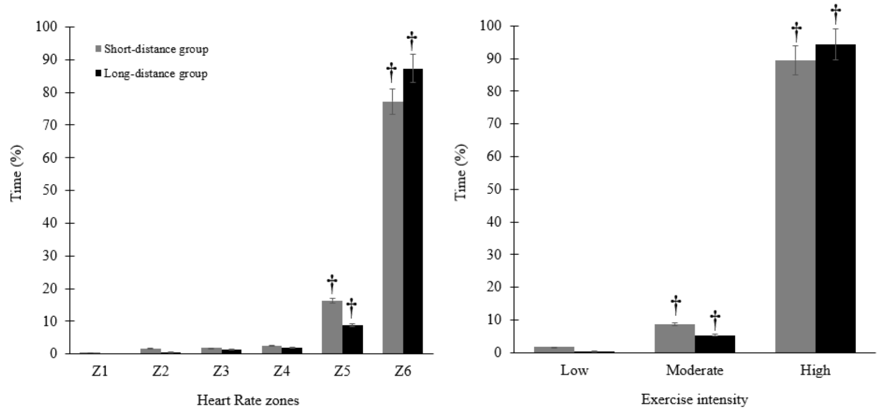

Figure 1. Amount of TRIMPS corresponding to short-distance and long-distance competition. $^{\dagger}p<0.001$

In Table 1, it is observed that the short-distance competition exhibited an average workload of 18.7 ± 0.3 TRIMPS. In contrast, rowers who participated in the long-distance competition experienced a workload of 63.0 ± 1.1 TRIMPS, revealing significant differences between the two groups (p<0.001).

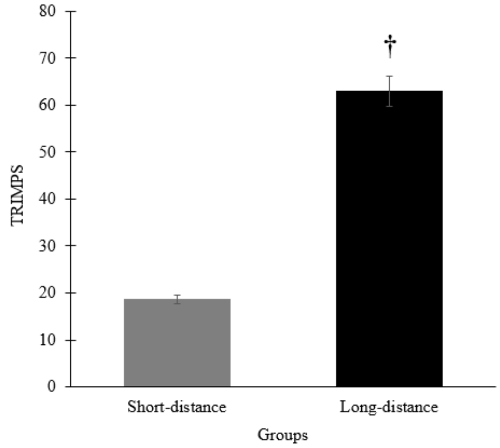

Figure 2. TRIMPS corresponding to short-distance and long-distance competition. †p<0.001

Discussion

The purpose of this study was to conduct a comparative analysis of intensity zones during both long-distance and short-distance rowing competitions. The study aimed to determine the duration and proportion of time spent in each intensity zone during these competitions, shedding light on the significance of each zone within the context.

The long-distance rowing group completed the competition within a total duration of 1288 seconds. Notably, the majority of this time was spent in intensity zone 6, accounting for a substantial portion of 1124.2 ± 127.5 seconds (equivalent to 87.3 ± 9.9% of the total competition time). These findings diverge from the results obtained by Penichet-Tomás et al. (2018) in their long-distance rowing test, where they reported that athletes allocated the highest proportion of their time to zone 4 in one subject (135.4 seconds; 35.5%) and to zone 5 in another (84.3 seconds; 22.1%). It is worth noting that these disparities may arise from the fact that Penichet-Tomás et al. (2018) conducted relay-style tests. In accordance with the study by González (2014), long-distance rowing competitions are associated with an average accumulation of blood lactate levels at approximately 10.23 mmol/l, which corresponds to intensity zone 5 as defined by Seiler (2010). In this regard, our study aligns with this observation, as the highest percentage of time during the competition was indeed spent in zone 6 (1124.2 ± 127.5 seconds; 87.3 ± 9.9%), which corresponds to high-intensity zone, zone 5 (1213.3 ± 64.0 seconds; 94.2 ± 5.0%).

In the case of the short-distance rowing group, we were unable to find previous studies for direct comparison of our results. However, it's important to consider that the shorter duration of the competition likely allows rowers to approach and potentially exceed the high-intensity zones as defined by Seiler (2010), even at certain points during the competition. Nevertheless, relying solely on heart rate data, we cannot definitively determine if rowers reached the maximum intensity set by VO2max. Nonetheless, it is worth noting that the average maximum heart rate observed during the short-distance competition differs from the average maximum heart rate recorded during the 7×4 test (Rice & Osborne, 2013). When we compare our results for short-distance rowers with a study on rowers, we can observe that the intensity zone we have identified corresponds to a VO2max range between 75% and 100%. These zones align with the high-intensity zone in the three-phase measurement, where rowers spent a considerable amount of time (349.0 ± 18.1 seconds; 89.5 ± 4.6%) (Mäestu et al., 2005). However, if we break down the intensity zones into the six categories, as indicated by Mäestu et al. (2005) based on VO2max, we find that our data shows significant differences in zone 5 compared to the other zones (301.1 ± 48.2 seconds; 77.2 ± 12.4%; p<0.001). Assessing aerobic and anaerobic zones based solely on heart rate can be challenging, as it may not provide a complete picture of the underlying physiological processes. The significant differences found in low intensity zones between the short-distance group and the long-distance group may be due to different factors. On the one hand, the type of warm-up used, in long distance as indicated by Mujika et al. (2012), an excessively long and intense warm-up is usually performed, which can cause this increase in heart rate. Furthermore, as indicated above, the greater habit of competing over short distances can lead to a relaxation that favors keeping the heart rate in low zones.

The observed differences in the moderate and high-intensity zones, particularly in intensity zones 5 and 6, can likely be attributed to several factors. One possible explanation is the phenomenon known as cardiovascular drift, where during prolonged exercise, heart rate tends to gradually increase even at a constant exercise intensity. This could have occurred during the warm-up or due to the competition lasting more than 10 minutes, as suggested by Coyle and González-Alonso (2001). Additionally, in the case of long-distance rowers, there may be variations in different aspects of their stroke throughout the competition, as noted by Lorenzo-Buceta and García-Soidán (2015). Even if rowers experience a decrease in power output, it's possible that they maintain or even increase their pace, which can prevent the heart rate from fully recovering between different phases of the race. This continuous effort and variation in stroke dynamics can contribute to the differences observed in heart rate profiles among intensity zones. This is consistent with other studies such as that of Montalvo et al. (2021) where for the heart rate to reach 50% of the maximum heart rate, 3 min of total rest had to pass between sets of an exercise. In this line, Coelho et al. (2020) states that the heart rate recovers from the end of the exercise, and states that the rate at which the heart rate recovers depend on the energy expenditure of the exercise. Another study along these lines that reinforces our point is that of Cherkosv et al. (2020) in which the differences between pre- and post-competition heart rate do not attenuate until 1 minute after the end of exercise.

Regarding workload measurement, various methodologies are employed. Load can be quantified subjectively through the Rate of Perception of Effort (RPE) as suggested by DellaValle & Haas (2013), or objectively using metrics such as Excess Post Exercise Oxygen Consumption (EPOC) (Jobson et al., 2009), and Heart Rate Variability (HRV) (Saboul et al., 2016). Each method presents distinct advantages and limitations. The adoption of the simplified TRIMPS model (Lucia et al., 1999) in this study is attributed to its emphasis on heart rate as a primary factor.

This model is notable for its widespread application in various studies, minimal material requirement, and ease of implementation outside laboratory settings. In contrast, controlled environments often utilize VO2max measurements and diverse questionnaires to assess workload in time-constrained tests, as explored by Messonnier et al. (2005). These approaches yield results that differ from those obtained in this study, particularly regarding workload. A comparative analysis of these workload measurement methodologies could be beneficial in reducing discrepancies among them. Additionally, the observed variance in TRIMPS for short distances in this study is attributed primarily to test duration, as the percentage of time spent at different intensities was found to be similar. This finding aligns with the research of Mujika et al. (2012), which demonstrated that both duration and intensity influence heart rate, thus indicating that TRIMPS values are more dependent on test duration rather than intensity.

The main limitation of the study is the small sample size. However, it is pertinent to note that data collection occurred during actual competitive events, contrasting with other studies where data were predominantly gathered in laboratory settings. Participants in this study predominantly had greater exposure to short-distance competitions, influencing their familiarity and performance in these events. Furthermore, the timing of the tests during the season was varied and did not account for the weekly training load or the athletes' current form. Despite these limitations, the data offer substantial value for coaches and athletes. They provide insights into the distribution of time across various work zones, facilitating the design of tailored training programs suited to specific competition types. An additional dimension for future research would involve including athletes more accustomed to long-distance events, alongside an analysis of their warm-up routines for these competitions. Assessing the training load during the week and the fitness level of the rowers in preparation for competitions would also be beneficial. Moreover, it is important to acknowledge the possibility of variations in higher work zones that are not detectable through heart rate monitoring alone. These zones, as identified by several researchers and synthesized in the literature review by Muñóz (2016), warrant further exploration.

Conclusions

This study reveals that both short-distance and long-distance rowers predominantly spent the majority of their competition time in Zone 6 and at high-intensity levels based on heart rate monitoring. Zones 5 and medium intensity areas emerged as the second most occupied zones during competitions. A comparative analysis between the two modalities indicates that athletes in the short-distance category allocated a higher percentage of their time to lower intensity zones and activities. In contrast, participants competing in long-distance events demonstrated a greater inclination towards spending time in Zone 6 and engaging at high-intensity levels. Notably, the long-distance competitions were characterized by a significantly higher overall workload compared to their short-distance counterparts.

The results of this study can be applied in training for both modalities. As heart rate is a simple and non-invasive parameter to measure, coaches can use the competition data obtained in this article to increase the quality of their training and make it more similar to competition by having percentage and total time data for greater accuracy. This comparison can be made across all training sessions and competitions and improvements can be observed against an established benchmark.

Acknowledgments
This work was supported by Generalitat Valenciana (grant number CIGE/2022/15).

Conflicts of interest - If the authors have any conflicts of interest to declare.

References

Akça, F. (2014). Prediction of rowing ergometer performance from functional anaerobic power, strength and anthropometric components. *Journal of Human Kinetics*, *41*(1), 133–142. https://doi.org/10.2478/hukin-2014-0041

Cherkesov, T. Ingushev, C. Konopleva, A. Cherkessov, R. Gairbekov, M. Zhukov, A (2020). Features of the performance exposure in girls involved in cyclic and acyclic sports. *Journal of Medicine and Life, 14*(1), 105-110. https://doi.org/10.25122/jml-2020-0054

Coelho, T., Peçanha, T., De Oliveira, F., Cavinato, C., Mielli, V., Crivoi, E., & Campos, L. (2020). Effect of exercise intensity after a single session of isocaloric aerobic exercise on the heart recovery. *Journal of Physical Education and Sports, 20*(5), 2851-2858. https://doi.org/10.7752/jpes.2020.s5387

Coyle, E. F., & González-Alonso, J. (2001). Cardiovascular drift during prolonged exercise: new perspectives. *Exercise and Sport Sciences Reviews*, *29*(2), 88–92. https://doi.org/10.1097/00003677-200104000-00009

DellaValle, M., & Haas, D. (2013). Quantification of training load and intensity in female collegiate rowers. *Journal of Strength and Conditioning Research*, *27*(2), 540–548. https://doi.org/10.1519/JSC.0b013e3182577053

Dong, J. (2016). The role of heart variability in sports physiology. *Experimental and Therapeutic Medicine, 11*(5), 1531-1536. https://doi.org/10.3892/etm.2016.3104González, J. M. (2014). Olympic rowing and traditional rowing: biomechanical, physiological and nutritional aspects. *Archivos de Medicina Del Deporte*, *31*(1), 51–59.

Jobson, S. A., Passfield, L., Atkinson, G., Barton, G., & Scarf, P. (2009). The analysis and utilization of cycling training data. *Sports Medicine*, *39*(10), 833–844. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed9&NEWS=N&AN=2009496886

Larrinaga-Garcia, B., León-Guereño, P., Coca-Nuñez, A., & Arbillaga-Etxarri, A. (2023). Analysis of performance parameters of Traineras: a systematic review. *Retos*, *49*, 322–332. https://doi.org/10.47197/retos.v49.97626

León-Guereño, P., Urdampilleta, A., Zourdos, M. C., & Mielgo-Ayuso, J. (2018). Anthropometric profile, body composition and somatotype in elite traditional rowers: A cross-sectional study. *Revista Española de Nutricion y Dietetica*, *2*(4), 279–286. https://doi.org/10.14306/renhyd.20.2.204

Lorenzo-Buceta, H., & García-Soidán, J. L. (2015). Dynamic response analysis of a rowing fixed seat rowing (Trainerilla) by the application of accelerometry. *Journal of Sport and Health Research*, *7*(1), 55–64.

Lorenzo-Buceta, H., Pérez-Treus, S., García-Soidán, J. L., Arufe-Giraldez, V., Cornes, X. A., & Cornes, A. A. (2014). Dynamic analysis on the fixed seat rowing: trainera. *Retos*, *2041*(25), 120–123.

Lucia, A., Hoyos, J., Carvajal, A., & Chicharro, J. (1999). Heart Rate response to professional road cycling: The Tour de France. *International Journal of Sports Medicine*, *20*(3), 167–172. https://doi.org/10.1055/s-1999-970284

Mäestu, J., Jürimäe, J., & Jürimäe, T. (2005). Monitoring of performance and training in rowing. *Sport Medicine*, *35*(7), 597–617. https://doi.org/10.2165/00007256-200535070-00005

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

Mejuto, G., Arratibel, I., Cámara, J., Puente, A., Iturriaga, G., & Calleja-González, J. (2012). The effect of a 6-week individual anaerobic threshold based programme in a traditional rowing crew. *Biology of Sport*, *29*(4), 297–301. https://doi.org/10.5604/20831862.1019886

Messonnier, L., Aranda-Berthouze, S. E., Bourdin, M., Bredel, Y., & Lacour, J. R. (2005). Rowing performance and estimated training load. *International Journal of Sports Medicine*, *26*(5), 376–382. https://doi.org/10.1055/s-2004-821051

Montalvo, S., Conde, D., Gonzalez, M., Diezte-Hermosa, M., Ibarra-Mejia, G., & Dorgo, S. (2021). Heart Rate percentage as a method for determing intra-set resting during a post-activation performance enhacement exercise to increase vertical jump performance. *Journa of Physical Education and Sport, 21*(5), 2730-2736. https://doi.org/10.7752/jpes.2021.05363

Mujika, I., Bourdillon, N., De Txabarri, R. G., & Millet, G. P. (2023). High-Intensity Interval Training, performance, and oxygen uptake kinetics in highly trained traditional rowers. *International Journal of Sports Physiology and Performance*, *18*(3), 326–330. https://doi.org/10.1123/ijspp.2022-0323

Mujika, I., de Txabarri, R. G., Maldonado-Martín, S., & Pyne, D. B. (2012). Warm-up intensity and duration's effect on traditional rowing time-trial performance. *International Journal of Sports Physiology and Performance*, *7*(2), 186–188. https://doi.org/10.1123/ijspp.7.2.186

Muñóz, I. (2016). Methods of quantification of the training load in cyclical endurance sports. *Revista Búsqueda*, *3*(16), 53–63. https://doi.org/10.21892/01239813.166

Muñoz, I., Cejuela, R., Seiler, S., Larumbe, E., & Esteve-Lanao, J. (2014). Training-intensity distribution during an ironman season: relationship with competition performance. *International Journal of Sports Physiology and Performance*, *9*(2), 332–339. https://doi.org/10.1123/IJSPP.2012-0352

Neumayr, G., Pfister, R., Mitterbauer, G., Maurer, A., & Hoertnagl, H. (2004). Effect of ultramarathon cycling on the heart rate in elite cyclists. *British Journal of Sports Medicine*, *38*(1), 55–59. https://doi.org/10.1136/bjsm.2002.003707

Okuno, N. M., Tricoli, V., Silva, S. B. C., Bertuzzi, R., Moreira, A., & Kiss, M. A. P. D. M. (2013). Postactivation potentiation on repeated-sprint ability in elite handaball players. *Journal of Strength and Conditioning Research*, *27*(3), 662–668. https://doi.org/10.1519/JSC.0b013e31825bb582

Penichet-Tomás, A., Jiménez-Olmedo, J. M., Pueo, B., & Fernández-Sáez, J. (2018). Physiological analysis of the 100 km indoor rowing world record. *Journal of Physical Education and Sport*, *18*(3), 1538–1543. https://doi.org/10.7752/jpes.2018.03227

Penichet-Tomas, A., Jimenez-Olmedo, J. M., Pueo, B., & Olaya-Cuartero, J. (2023). Physiological and mechanical responses to a graded exercise test in traditional rowing. *International Journal of Environmental Research and Public Health*, *20*(4), 3664. https://doi.org/10.3390/ijerph20043664

Penichet-Tomás, A., Pueo, B., & Jiménez-Olmedo, J. (2019). Physical performance indicators in traditional rowing championships. *The Journal of Sports Medicine and Physical Fitness*, *59*(5), 767–773. https://doi.org/10.23736/S0022-4707.18.08524-9

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. *International Journal of Environmental Research and Public Health*, *18*(15), 7826. https://doi.org/10.3390/ijerph18157826

Rice, A. J., & Osborne, M. A. (2013). Rowers. In R. K. Tanner & C. J. Gore (Eds.), *Physiological tests for elite athletes* (2nd ed., pp. 353–370). Australian Institute of Sport.

Romero-Ramos, O., Niznikowski, T., Litwiniuk, A., Fernández-Rodriguez, E., González, A. J., & Smuka, I (2024). Assessment of perceived exertion among runners: exploring the interplay of heart rate, performance, and sports habits. *Journal of Physiscal Education and Sports, 24*(2), 397-406. https://doi.org/10.7752/jpes.2024.02048Saboul, D., Balducci, P., Millet, G., Pialoux, V., & Hautier, C. (2016). A pilot study on quantification of training load: the use of HRV in training practice. *European Journal of Sport Science*, *16*(2), 172–181. https://doi.org/10.1080/17461391.2015.1004373

Sebastia-Amat, S., Penichet-Tomas, A., Jimenez-Olmedo, J. M., & Pueo, B. (2020). Contributions of anthropometric and strength determinants to estimate 2000 m ergometer performance in traditional rowing. *Applied Sciences*, *10*(18), 6562. https://doi.org/10.3390/APP10186562

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

Spanish Rowing Federation Code of Regattas. (2011). FER. www.federemo.org/

Turner, K. J., Pyne, D. B., Périard, J. D., & Rice, A. J. (2021). High-intensity interval training and sprint-interval training in national-level rowers. *Frontiers in Physiology*, *12*, 803430. https://doi.org/10.3389/fphys.2021.803430