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Kinetics of ventilatory and mechanical parameters of novice male rowers on the rowing ergometer

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ABSTRACT
Maximal oxygen consumption (VO_{2max}) and maximal power output (P_{max}) play a preponderant role in the performance of rowers. This study aims to describe and analyse the kinetics of ventilatory and mechanical parameters in novice male rowers on the rowing ergometer. Twelve male novice rowers were part of the study – descriptive with a selective non-probabilistic cross-sectional design. The variables were VO_{2max} and P_{max}. The kinetics of the variables were observed in an Incremental Test (IT) and a 2,000 m time trial (2,000m_{TT}). The differences between the tests were established by Student's t-test ($p < 0.05$). In both protocols, the VO_{2max} reached 330–345 s. Between IT and the 2,000m_{TT} there were significant differences in the VO_{2max} (52.7 ± 3.3 vs 55.9 ± 3.4 $mLO_2{\cdot}kg^{-1}{\cdot}min^{-1}$, $p < 0.01$) and P_{max} (334.7 ± 20.2 vs 269.5 ± 31.3 W, $p < 0.001$). The novice rowers' low physiological capacity and efficiency generated instability in the power output kinetics. A very large delta was observed between the maximum and minimum power output. Exploring tests with a shorter duration for novice rowers (360 s) and improving power output control in the different tests are suggested.

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KEYWORDS
Rowing; novice rowers; maximal power output; maximal oxygen uptake; 2,000 m time trial

1. Introduction

Competitive rowing requires a high physical and technical demand (Huntsman et al., 2011). In this sense, one of the considerations to achieve optimal execution and thus a good sporting performance is the proper stabilisation of the boat (Muniesa & Díaz, 2010). Likewise, another critical component in the outcome of a regatta is the synchronisation between all the boat members (Rich et al., 2020). At the same time, from a physiological and metabolic point of view, competitive rowing has a sizeable aerobic contribution and a more minor but equally important anaerobic contribution (Hagerman et al., 1978; Pripstein et al., 1999; Secher, 1993). In effect, some research

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has reported that the contribution of aerobic metabolism ranges between 70% and 88%, while the contribution of anaerobic metabolism fluctuates between 12% and 30% (Hagerman et al., 1978; Pripstein et al., 1999; Secher, 1993).

For decades, the ventilatory parameters in elite category rowers have been well documented (Hagerman et al., 1978; Secher, 1993; Turnes et al., 2020). These ventilatory parameters, in most cases, have been evaluated through gas analysis on a rowing ergometer, a test considered the gold standard (Wagner, 1996) for elite rowers (Kendall et al., 2012; Klusiewicz et al., 2011). Concerning the maximal oxygen consumption (VO_{2max}) in competitive rowing, it has been observed that during a regatta, this component goes from ~0.25–0.5 litres of oxygen per minute ($LO_2{\cdot}min^{-1}$) at rest to individual maximum values (Das et al., 2019). These values can easily exceed 6 $LO_2{\cdot}min^{-1}$ in elite rowers (Hagerman et al., 1978). A strong background that should be considered is that elite rowers can reach VO_{2max} between 330 and 360 s and go below 360 s in the 2,000 m time trial (2,000m_{TT}; Hagerman et al., 1978; Mahler et al., 1984; Silva, 2016). In fact, the 2,000 m_{TT} on the rowing ergometer is the most commonly used test to assess the actual sports performance of rowers (Gillies & Bell, 2000; Klusiewicz & Faff, 2003; Klusiewicz et al., 1999; Russell et al., 1998; Silva, 2016). This test is a simulated race on a rowing ergometer but may reflect the demands of actual sports performance of rowers (Silva, 2016). However, in estimating VO_{2max} through the 2,000 m_{TT} in rowers, Klusiewicz et al. (2016) reported a lower total error rate when the athletes' capacity was higher. Therefore, to achieve a high degree of reliability in the assessment of VO_{2max} through the 2,000m_{TT}, rowers should be able to go under 6 min (Ingham et al., 2013). However, there is evidence that only 2% of the male rowers in the heavyweight category, aged 20–29 years, go below 360 s in the 2,000m_{TT} (Silva, 2016). In that same study, Silva (2016) reports that only 2% of the male rowers in the lightweight category, aged 22–28 years, go below 370 s in the 2,000m_{TT}. Indeed if we consider that "novice" category rowers take more than 420 s to complete the 2,000m_{TT}, any test used to estimate ventilatory parameters based on "elite" category results would be inaccurate (Kendall et al., 2011; Klusiewicz et al., 2016).

Both rowers and coaches know that it is difficult to ensure a controlled load output on rowing ergometers with wind brake because neither the resistance nor stroke rate is externally adjustable but depends on the rower (Treff et al., 2018). However, the importance of measuring and evaluating ventilatory parameters accurately and individually for all categories of rowers is highlighted since, regardless of the category, training loads in rowing are increasingly specific and complex (Muniesa & Díaz, 2010). In this sense, during evaluations and training sessions in any sport, it is necessary to observe and describe external (Scott et al., 2016; Treff et al., 2018) and internal loads (Coutts et al., 2017; Marcora et al., 2008, 2009). Indeed, the entire scientific community, coaches, and athletes recognise that the physiological responses to a stimulus are different in each athlete, differing according to the level of training, sex, and years of experience (Scott et al., 2016). For this reason, in each rowing category, tests should be applied according to the level of sport achieved and not only replicate physical tests that present reliable indicators in the elite category (Hagerman et al., 1978; Secher, 1993; Turnes et al., 2020).

According to the background presented, ventilatory parameters have a preponderant role in rowers' performance, especially VO_{2max} (Hagerman et al., 1978; Wagner, 1996). However, despite the importance of measuring and evaluating both internal loads (VO_{2max} or Heart Rate [HR]) (López Chicharro et al., 2013; Muniesa & Díaz, 2010) and external loads (maximal power output [P_{max}] (Bourdin et al., 2017; Bourdin, Messonnier, Lacour et al., 2004), there are no updated studies that report the kinetics of ventilatory and mechanical parameters in novice rowers. Consequently, the main objective of this study was to describe and analyse the kinetics of ventilatory and mechanical parameters in novice male rowers on the rowing ergometer.

2. Materials y method

2.1. Participants

Twelve male novice rowers, belonging to the Naval Academy "Arturo Prat", volunteered to participate in this study (age: 20.3 ± 1.56 years, weight: 77.5 ± 5.74 kg, height: 176 ± 6.80 cm, body mass index [BMI]: 25.0 ± 2.14 kg/m^2, body fat percentage: 12.1 ± 3.37%, VO_{2max}: 52.7 ± 3.66 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$). The main inclusion criterion was the VO_{2max} assessed in the initial test (Incremental Test [IT]) on a rower-ergometer (Mekhdieva et al., 2019). In this sense, all participants in the study presented a $VO_{2max} \leq 60$ $mLO_2 \cdot kg^{-1} \cdot min^{-1}$. In contrast, the exclusion criterion was the inability to execute the IT to evaluate ventilatory parameters and the 2,000m_{TT}. Prior to applying the evaluation protocols, all participants were informed of the aim of the study and the possible risks of the experiment. All novice rowers signed the informed consent before the application of the protocols. The study and the informed consent were approved by the Scientific Ethical Committee of the Universidad Mayor, Santiago, Chile (registration number: 197_2020) and developed under the ethical standards for exercise and sports sciences (Harriss et al., 2019).

2.2. Research design

A descriptive study was used with a non-probabilistic cross-sectional selective design (Ato et al., 2013) to describe and analyse ventilatory and mechanical parameters in novice rowers. The design included an anthropometric evaluation (day 1), IT (day 2), and 2,000m_{TT} (day 3), the last two on a rower-ergometer. Between the three evaluations, there was a separation of 72 hours (Figure 1(a)).

2.3. Anthropometric measurements

For the characterisation of the sample, evaluation of weight, height, BMI, and body fat percentage were performed (day 1). The body fat percentage was evaluated using a Tanita Inner Scan BC-554® digital scale.

2.4. Nutritional timing

The nutritional timing is intended to prevent athletes from starting evaluations with a low blood glucose level (Huerta-Ojeda et al., 2019). For this study, before the IT and the 2,000m_{TT}, the nutritional timing consisted of 2 g of rapidly absorbed carbohydrates per kg of body weight. All participants were available 2 hours before the tests in a fasting condition. At that time, they received carbohydrate loading. Ninety minutes after the nutritional timing, they started the standardised warm-up (Figure 1(b)).

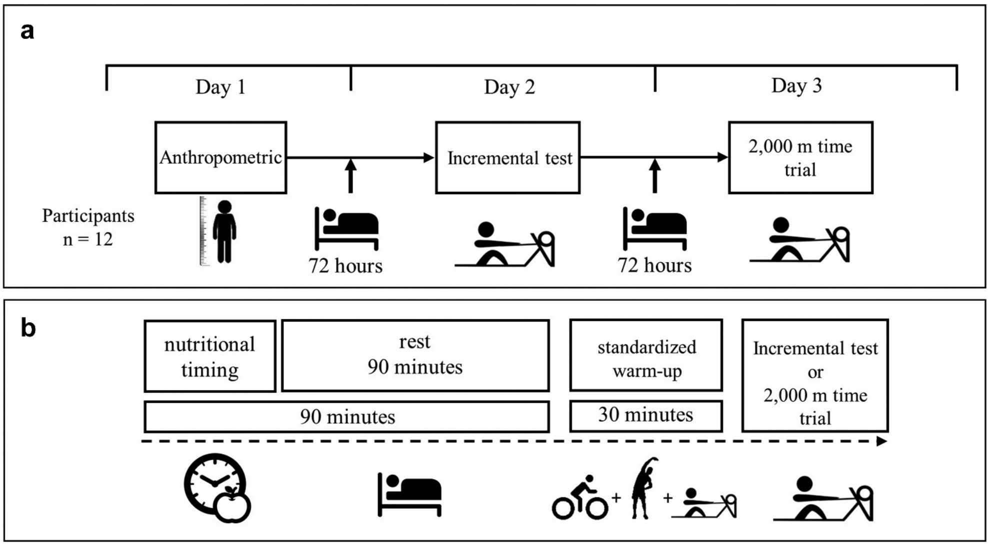

Figure 1. Research design.

2.5. Standardised warm-up

A standardised warm-up preceded all tests. This warm-up consisted of 10 minutes on an Airbike Xebex® resistance ABMG-3, USA. The warm-up intensity was between 60% and 70% of the theoretical maximum HR, calculated by the 208 – (0.7*age) formula (Tanaka et al., 2001). Then, 5 min of ballistic movements of the upper and lower extremities were included, and finally, the athletes rowed for 5 min between 60% and 70% of the theoretical maximum HR (Figure 1(b)) (Tanaka et al., 2001).

2.6. Incremental test

The evaluation of ventilatory parameters: VO_{2max}, respiratory quotient (RQ), minute ventilation (VE), and carbon dioxide production/oxygen consumption (VCO_2/VO_2) was performed with an IT in a rower-ergometer (Mekhdieva et al., 2019). Each step lasted 1 min in this IT, starting with 100 watts (W) and increasing 50 W in each step until exhaustion or the impossibility of maintaining the requested power. The rower machine used was a Concept2 Model D, monitor PM5, USA. Ventilatory parameters were measured using an automatic gas analyser system (Cosmed, model Quark CPET, Italy). The analyser was calibrated strictly according to the manufacturer's recommendations before testing. The data were processed through a laptop computer that calculated the results using software developed by the manufacturer (Cosmed, model Quark CPET, Italy). VO_{2max} was considered when VO_2 kinetics generated a plateau at the end of the test. This implied a stabilisation of VO_2 despite the increase in load. When considering a plateau, the criterion used was an increase of less than 150 $mLO_2 \cdot min^{-1}$ between intervals of 15 s (Howley et al., 1995). The latter intensity was also considered as the P_{max} of each subject. Power data were recorded in the ErgData V1.4.4® app, USA, and downloaded from an account created at https://log.concept2.com/.

2.7. 2,000 m time trial

The purpose of the $2{,}000m_{TT}$ is rowing 2,000 metres on a rower-ergometer in the shortest possible time. The time in this test was recorded in seconds (s). For the $2{,}000m_{TT}$, a Concept2 Model D rower machine, monitor PM5, USA. The drag factor used was 111–114 (the same drag factor used in the IT). During the $2{,}000m_{TT}$, the rowers were asked to try to obtain their personal best; to do so, each rower used a personal strategy based on experiences. For this reason, the powers performed by each rower were the result of both the stroke rate and the force generated in each stroke (Held et al., 2019). Power data were recorded in the ErgData V1.4.4® app, USA, and downloaded from an account created at https://log.concept2.com/. Ventilatory parameters for this test: VO_{2max}, respiratory quotient (RQ), minute ventilation (VE), and carbon dioxide production/oxygen consumption (VCO_2/VO_2) were also evaluated through an automatic gas analyser system (Cosmed, model Quark CPET, Italy).

2.8. Heart Rate

In the IT and the $2{,}000m_{TT}$, HR was evaluated with a Polar monitor model H10®, Finland. This device was synchronised via Bluetooth with the Concept2 Model D, monitor PM5, USA. HR data were recorded in the ErgData V1.4.4® app, USA, and downloaded from an account created at https://log.concept2.com/.

2.9. Rating of perceived exertion and post-exertion lactate

At the end of the IT and $2{,}000m_{TT}$, post-exertion capillary lactate ([La]) concentrations were measured. For this measurement, an h/p/cosmos®, Germany, lactometer was used. This lactometer generates an enzymatic-amperometric detection of lactate with an accuracy of ± 3% (minimum standard deviation of 0.2 $mmol{\cdot}L^{-1}$), sample volume 0.2 μL with a measuring range of 0.5–25.0 $mmol/L^{-1}$. In addition, the subjective perception of the effort (RPE) was evaluated at the end of both tests. The RPE was assessed on a scale of 1–10 (Borg, 1990).

2.10. Statistical analysis

Data on the kinetics of ventilatory, mechanical, HR, [La], and RPE parameters, from the IT and the $2{,}000m_{TT}$ were sorted on a spreadsheet designed for the study. Before the analysis, all data were averaged at 15 s intervals. The normal distribution of the results was determined with the Shapiro–Wilk test. Descriptive statistics expressed the individual values, means, and standard deviations (SD) of the variables studied. Differences between the IT and the $2{,}000m_{TT}$ (relative VO_{2max}, absolute VO_{2max}, power output at VO_{2max}, HR at VO_{2max}, VE at VO_{2max}, RQ at VO_{2max}, VCO_2/VO_2, HR at finish, [La] at finish, and SPE at finish) were performed using Student's t-test for related samples (Hopkins et al., 2009). All analyses' effect size (ES) was calculated using Cohen's d test. The latter analysis considers an insignificant ($d < 0.2$), small ($d = 0.2$ to 0.6), moderate (d = 0.6 to 1.2), large (d = 1.2 to 2.0) or very large (d > 2.0) effect. Excel 2013® software and a customised spreadsheet were used for tabulation and data analysis (Hopkins, 2000). The level of significance for all statistical analyses was $p < 0.05$.

3. Results

3.1. Incremental test

When the incremental protocol was applied, the male novice rowers obtained a VO_{2max} equivalent to 52.25 ± 3.3 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ between 330 and 345 s. Likewise, in this same time interval (330–345 s), absolute VO_{2max} was 4.07 ± 0.26 $LO_2 \cdot min^{-1}$, power output at VO_{2max} was 334.7 ± 20.2 W, HR at VO_{2max} reached 194.2 ± 6.6 beats per minute (bpm), VE at VO_{2max} was 161.2 ± 22.2 litres per minute ($L \cdot min^{-1}$) and RQ at VO_{2max} reached 1.25 ± 0.06 VCO_2/VO_2 (Figure 2). At the end of the IT, HR was 196.5 ± 6.3 bpm, [La] equivalent to 14.84 ± 1.31 $mmol \cdot L^{-1}$, while RPE was 8.50 ± 0.52.

3.2. 2,000 m time trial

The analysis showed that the male novice rowers took 431.4 ± 12.7 s to perform the $2{,}000m_{TT}$. Likewise, VO_{2max} equivalent to 55.9 ± 3.4 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ was observed during the test. This VO_{2max} was observed between 330 and 345 s. in the same period

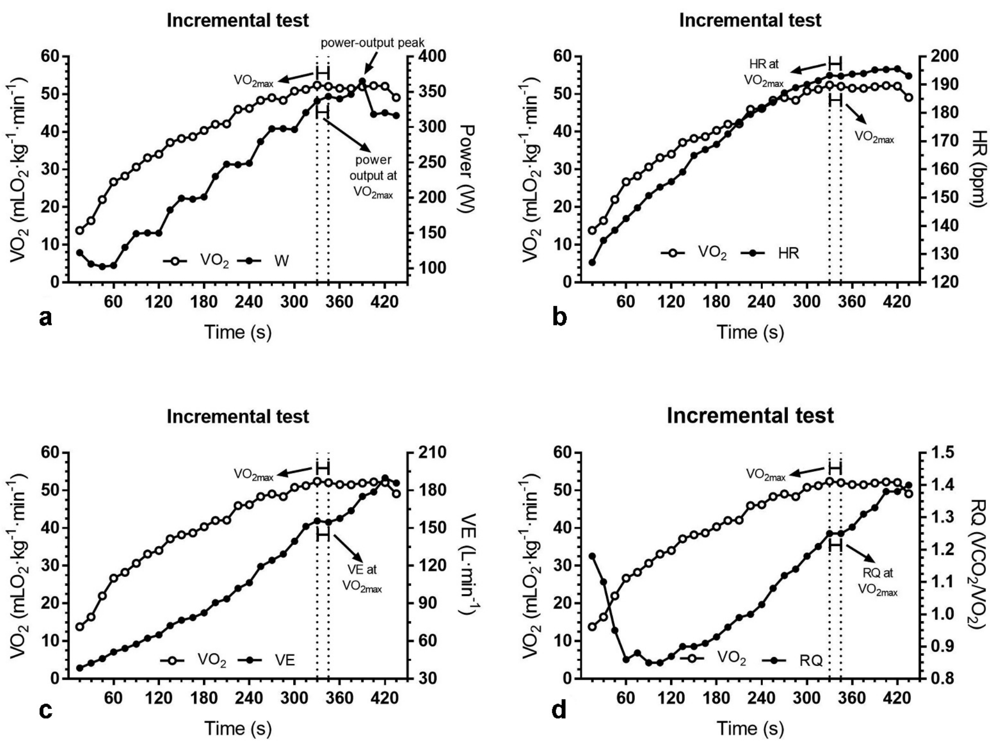

Figure 2. Kinetics of ventilatory, mechanical, and cardiac parameters in the Incremental Test on the rowing ergometer.

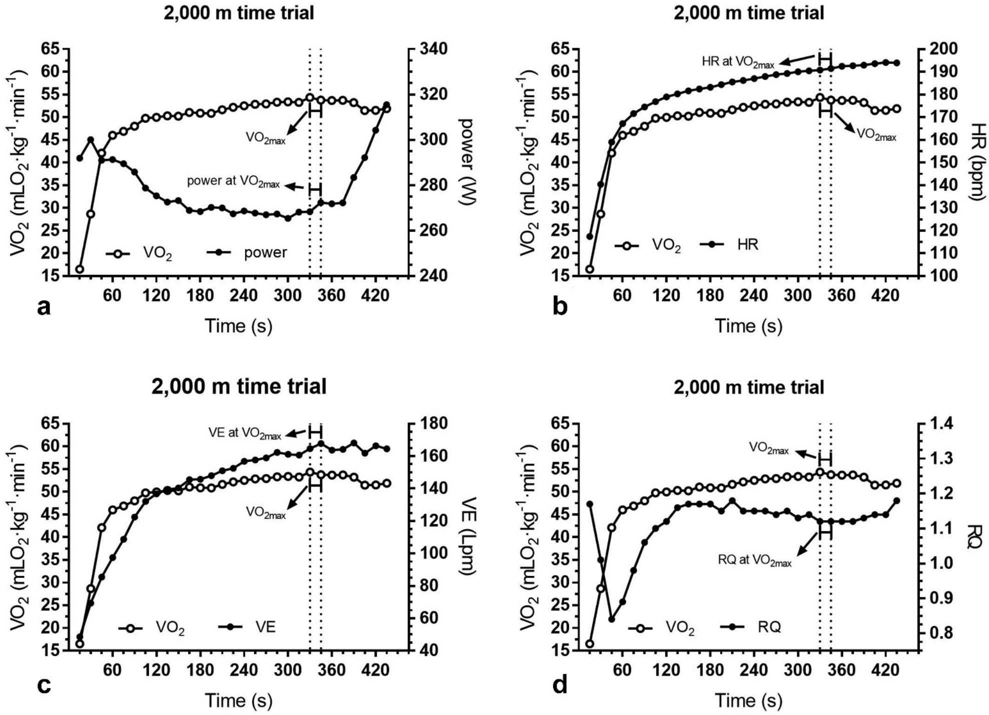

Figure 3. Kinetics of ventilatory, mechanical, and cardiac parameters in the 2,000m_{TT} on the rowing ergometer.

(330–345 s), absolute VO_{2max} was 4.31 ± 0.18 $LO_2 \cdot min^{-1}$, power output at VO_{2max} was 269.5 ± 31,3 W, HR at VO_{2max} reached 189.7 ± 7.8 bpm, VE at VO_{2max} was 160.9 ± 18.7 $L \cdot min^{-1}$, and RQ at VO_{2max} reached 1.12 ± 0.03 VCO_2/VO_2 (Figure 3). In parallel, the mean values for the 2,000m_{TT} were as follows: relative VO_{2max} = 49.70 ± 1.89 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$, absolute VO_{2max} = 3.83 ± 0.17 $LO_2 \cdot min^{-1}$, mean power output (P_{mean}) = 276.25 ± 23.97 W, HR = 181.25 ± 4.88 bpm, VE = 140.07 ± 15.72 $L \cdot min^{-1}$ y RQ = 1.11 ± 0.03 VCO_2/VO_2. At the end of the 2,000m_{TT}, HR was 194.7 ± 5.4 bpm, there were measured [La] equivalent to 14.63 ± 1.44 $mmol \cdot L^{-1}$, while RPE was 8.66 ± 0.65.

When a comparison was made between IT and 2,000m_{TT}, it was observed that relative and absolute VO_{2max} were higher in the 2,000m_{TT} than in the IT ($p < 0.01$). Conversely, power output at VO_{2max}, HR at VO_{2max} and RQ at VO_{2max} were statistically lower in the 2,000m_{TT} than IT ($p < 0,05$). VE at VO_{2max}, HR, [La], and RPE did not show significant differences between both tests ($p > 0.05$). The mean values of both tests are reported in Table 1.

4. Discussion

Concerning the main objective of the study, during the performance of the IT, the mean VO_{2max} in the novice male rowers was 4.07 ± 0.26 $LO_2 \cdot min^{-1}$, reached between 330 and 345 s of the test; in the same test, the mean power output at

Table 1. Mean values and Student's t-test for the incremental test and 2,000 m time trial.

	Incremental Test			2,000 m time trial			*t*-test			
variables	mean ± SD	min	max	mean ± SD	min	max	*t*	gl	*p*	*ES*
VO_{2max} $LO_2·min^{-1}$	4.07 ± 0.26	3.41	4.35	4.31 ± 0.18	3.93	4.62	−3.389	11	**	1.10
VO_{2max} $mLO_2·kg^{-1}·min^{-1}$	52.7 ± 3.3	49.0	59.9	55.9 ± 3.4	51.8	63.7	−3.264	11	**	0.96
power output at VO_{2max} W	334.7 ± 20.2	289.4	360.8	269.5 ± 31.3	222.3	330.4	8.155	11	***	2.53
HR at VO_{2max} bpm	194.2 ± 6.6	184.1	202.3	189.7 ± 7.8	171.1	198.9	2.994	11	*	0.63
VE at VO_{2max} $L·min^{-1}$	161.2 ± 22.2	118.8	192.8	160.9 ± 18.7	136.5	205.3	0.072	11	ns	0.01
RQ at VO_{2max} VCO_2/VO_2	1.25 ± 0.06	1.15	1.35	1.12 ± 0.03	1.10	1.20	7.505	11	***	2.58
HR at finish bpm	196.5 ± 6.3	289.0	205.0	194.7 ± 5.4	185.0	204.0	1.745	11	ns	0.31
[La] at finish $mmol·L^{-1}$	14.8 ± 1.3	13.6	17.2	14.6 ± 1.4	12.7	17.8	0.528	11	ns	0.15
SPE at finish 1–10	8.50 ± 0.52	8.0	9.0	8.66 ± 0.65	8.0	10.0	−0.616	11	ns	0.28

bpm, beat per minute; HR, heart rate; $L·min^{-1}$, litres per minute; $mLO_2·min^{-1}$, millilitres of oxygen per minute; $mLO_2·kg^{-1}·min^{-1}$, millilitres of oxygen per kilogram per minute; SD, standard deviation; RQ, respiratory quotient; SPE, subjective perception of effort; VE, minute ventilation; VCO_2/VO_2, carbon dioxide production/oxygen consumption; $mmol·min^{-1}$, millimoles per litre; VO_{2max}, maximal oxygen consumption; W, watts; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; ns, no significative.

VO_{2max} was 334.7 ± 20.2 W. In parallel, in the $2{,}000m_{TT}$, the mean VO_{2max} was 4.31 ± 0.18 $LO_2·min^{-1}$, reached between 330 and 345 s, while the mean power output at VO_{2max} was 269.5 ± 31.3 W. Based on the VO_{2max} (55.9 ± 3.4 $mLO_2·kg^{-1}·min^{-1}$), the cardiorespiratory fitness of participants was “excellent” when compared to healthy and physically active individuals (Herdy & Caixeta, 2016). However, due to the scant evidence of ventilatory parameters with novice rowers (Kendall et al., 2011), it was difficult to compare our findings with studies of similar characteristics. Indeed, only the research presented by Kendall et al. (2011) assessed VO_{2max} in novice female rowers (2.88 $LO_2·min^{-1}$). In this sense, the researchers carried out the analysis of variables by dividing and comparing the sample into two categories according to rowing experience (more than one-year collegiate experience [varsity] and less than one-year collegiate experience [novice]). At the end of that study, it was concluded that shorter tests (like *the critical velocity test*) might be more appropriate for assessing performance in novice rowers (Kendall et al., 2011). Despite this background, it is difficult to compare the results obtained in the present study (novice men) with those reported by Kendall et al. (2011) (novice women). On the other hand, elite male rowers have described the ventilatory parameters from the 1970s (Hagerman et al., 1978) to the present day (Van der Zwaard et al., 2018). Concerning this, it has been shown that in the elite men category, VO_{2max} values easily exceed 6.0 $LO_2·min^{-1}$, regardless of the evaluation protocol used (Hagerman et al., 1978; Klusiewicz & Faff, 2003; Van der Zwaard et al., 2018). For this reason, and considering that the VO_{2max} values of elite rowers are much higher than those of novice rowers, it is difficult to compare the two categories.

4.1. Kinetics of ventilatory parameters

Another essential component to analyse is VO_2 kinetics, specifically the time it takes for rowers to reach VO_{2max}. In this regard, a study developed by Mahler et al. (1984) showed that elite male rowers reach VO_{2max} between 330 and 360 s. This result was observed in both an IT and a 6-minute rowing test (6-min_{RT}). An important fact that should be considered when analysing the pioneering studies of Mahler et al. (1984) and Hagerman et al. (1978), is that the rower machines used in those decades have no relation to the devices used today (Turnes et al., 2020). However, the background described in these pioneering studies reliably describes the kinetics of ventilatory and mechanical parameters in elite rowers (Hagerman et al., 1978; Mahler et al., 1984). In a more recent study, Das et al. (2019) described, at 500-metre intervals, the VO_2 kinetics during the 2,000m_{TT} in elite rowers, showing that the lightweight category reaches VO_{2max} at 318 s (1,500 metres) and the open category at 309 s (1,500 metres). Likewise, these researchers observed that in the last 500 metres of the test, a decrease in VO_{2max} is generated (lightweight category −0.1% and open category −0.6%; Das et al., 2019). Concerning this, our findings evidenced that novice male rowers reach VO_{2max} between 330 and 345 s in both the IT and the 2,000m_{TT}. However, despite this similarity in time to reach VO_{2max} and the described kinetics between elite and novice rowers, the VO_{2max} values evaluated in the present study are considerably lower than those described for the elite category. From a different perspective, while the elite rowers can complete the 2,000m_{TT} in less than 360 s (Silva, 2016), reaching VO_{2max} (Hagerman et al., 1978; Mahler et al., 1984), the novice rowers could only cover an average of 1,670 m in the same period (360 s). Apparently, the pioneering studies in rowing by Hagerman et al. (1978) and Mahler et al. (1984) used the 6-min_{RT} in elite rowers because the kinetics of VO_2 is similar to that described in incremental tests for these athletes (Secher, 1993). For this reason, and to reliably assess $VO_{2max,}$ the athletes tested should be able to go under 360 s in the 2,000m_{TT}. On the contrary, if the rowers have a reduced physical level, which could be the case of novice or amateur rowers, tests should be applied according to the physical condition presented (Ingham et al., 2013). In the case of novice rowers, it is suggested that tests lasting 360 s be used (6-min_{RT}).

When analysing the intensity indicators at the end of each protocol, it was observed that HR, [La], and RPE post-exertion were maximal and without significant differences between both tests ($p > 0.05$; Table 1). However, the VO_{2max} achieved in the IT was lower than that observed in the 2,000m_{TT} ($p < 0.01$; ES = 1.10). In this sense, our research has not been the only one to report these differences (Turnes et al., 2020). Indeed, Turnes et al. (2020) also observed that the VO_{2max} reached in IT was lower than the observed in the 2,000m_{TT} (4.69 ± 0.61 vs. 4.86 ± 0.62 $LO_2 \cdot min^{-1}$, respectively). These same investigators reported that, despite the differences observed between the two tests (~5%), the 2,000m_{TT} is a valid assessment for estimating maximal cardiorespiratory fitness in regional- and national-level rowers (Turnes et al., 2020). Apparently, it would be expected to observe differences when evaluating the same participants with different protocols. Therefore, to ensure data reliability, the choice of the protocol must be conditioned to the athletes' capabilities when evaluating. In our case, the percentage difference calculated between the IT and the 2,000m_{TT} was 5.5%.

4.2. Rowing exercise tests

Eventually, the difference between both tests can be conditioned to the protocol used in the IT (Mekhdieva et al., 2019). In this sense, independent of the category, most of the incremental protocols used in male rowers start between 100 and 150 W but then vary with the increase in load and time per step (Bourdin et al., 2017; Gillies & Bell, 2000; Mekhdieva et al., 2019; Syrotuik et al., 2005; Turnes et al., 2020). For example, Turnes et al. (2020) propose, for national- and regional-level rowers, an IT from 130 W for 3 min and increase 30 W every 3 min until exhaustion. For international- and national-level rowers, Bourdin et al. (2017) propose an initial load of 115 W for rowers under 75 kg body mass and 150 W for rowers over 75 kg body mass for 3 min and increase 35 W every 3 min until exhaustion. This protocol includes a 30 s pause at the end of each step to evaluate [La]; finally, Syrotuik et al. (2005) and Gillies and Bell (2000) used, in university rowers, the same protocol used in the present study, Mekhdieva et al. (2019), but with steps of 2 min. Consequently, the correct protocol choice to evaluate VO_{2max} in rowers is fundamental to achieving reliability in the information. As a research team, we believe that protocols with larger load increments between each step should be used for elite rowers. In this case, the protocols used by Mekhdieva et al. (2019), Gillies and Bell (2000), and Syrotuik et al. (2005). In lower-level rowers, we believe that protocols with smaller load increments will allow athletes to reach VO_{2max} without experiencing muscle fatigue prematurely. In this case, we suggest the protocols used by Turnes et al. (2020) or Bourdin et al. (2017).

4.3. Kinetics of mechanical parameters

Concerning this external load, it has been shown that the power output performed on the rowing ergometer is a predictive parameter of performance in rowers (Arend et al., 2015). In this sense, Bourdin, Messonnier, Lacour et al. (2004) concluded that power output, especially peak power output (P_{peak}), is a general index of physiological capacity and rowing efficiency in both heterogeneous and homogeneous groups. It has also been shown that this variable has the additional advantage of being easily measured in the field (Bourdin et al., 2017). Along the same lines, the P_{max}, which corresponds to the power output at VO_{2max}, is another external load that is easy to measure on the ergometer (Bourdin, Messonnier, Hager et al., 2004). At the end of the IT, we observed power output at VO_{2max} equivalent to 334.7 ± 20.2 W. Unfortunately, due to the limited evidence with novice rowers, it was difficult to compare our results; only Bourdin et al. (2017) reported a power output at VO_{2max} equivalent to 259 ± 24 W in novice female rowers. In parallel, during the performance of the $2{,}000m_{TT,}$ power output at VO_{2max} equivalent to 269.5 ± 31.3 W was observed. This power was lower than the P_{mean} observed during the performance of the $2{,}000m_{TT}$ (276.25 ± 23.97 W). Concerning the kinetics of power output during the development of the $2{,}000m_{TT}$, data reported in college-level male rowers describe kinetics similar to those observed in the present study (Purge et al., 2017). However, our findings show that novice rowers, compared to higher-level rowers, have lower P_{max} y P_{mean} in the $2{,}000m_{TT}$ (Ní Chéilleachair et al., 2017; Purge et al., 2017). For example, Purge et al. (2017) reported a P_{max} equivalent to 375.4 ± 44.0 W and a P_{mean}

equivalent to 302.4 ± 47.2 W in college-level male rowers. Similarly, Ní Chéilleachair et al. (2017) reported that well-trained rowers might reach a P_{mean} equivalent to 488.2 ± 72.0 W after 10 weeks of high-intensity interval training. These differences between categories may be conditioned by the low physiological capacity and rowing efficiency of novice rowers compared to higher-level rowers. Finally, to make a reliable comparison between different rowers and different categories, both P_{peak} and P_{max} should be analysed relatively and absolutely since, in general, rowers with greater muscle mass produce higher levels of power (Bourdin et al., 2017; Harat et al., 2020).

5. Limitations

The lack of descriptive information on ventilatory and mechanical parameters in novice rowers makes it challenging to compare our findings with those of other studies. However, during the research development, it could be observed that similar tests and evaluation systems are applied in the different categories. This situation could lead to a higher total error rate in lower-level categories (Klusiewicz et al., 2016).

6. Conclusions

At the end of the study, it could be observed that the VO_{2max} in both the IT and the $2{,}000m_{TT}$ was reached between 330 and 345 s. After this time, VO_{2max} starts to decrease. For this reason, we suggest exploring tests with a shorter duration for novice rowers (360 s). In parallel, it was evidenced that the power output kinetics of novice rowers is similar to that of higher-level rowers. However, the novice rowers' low physiological capacity and rowing efficiency in the present study generated instability in the power output kinetics, with lower P_{max} y P_{mean} than the higher-level rowers and a very large difference between the maximum and minimum power output in the $2{,}000m_{TT}$.

7. Perspective

The performance time in the 2,000 m_{TT} should be considered for the planning of training loads. If the rower can go under 7 minutes, we suggest an evaluation of VO_{2max} through ergospirometry. In this way, it will be possible to obtain the P_{max} (power output at VO_{2max}) with the kinetics of ventilatory parameters. On the other hand, if the rowers cannot go under 7 minutes in the $2{,}000m_{TT}$, we suggest a shorter test according to the rowers' capabilities.

Highlights

- The novice rowers run the $2{,}000m_{TT}$ on the rowing ergometer in more than 7 min.
- The novice rowers reached the VO_{2max} in the $2{,}000m_{TT}$ in 330–345 s.
- The 6-min test on the rowing ergometer is suggested for novice rowers to estimate VO_{2max} and maximal aerobic power.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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