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¿Los remeros novatos y experimentados adoptan diferentes estrategias de ritmo y sus respuestas fisiológicas y metabólicas muestran optimización?

Do novice and experienced rowers adopt different pacing strategies and do their physiological and metabolic responses show optimisation?

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Resumen: El objetivo fue evaluar las estrategias de ritmo y las respuestas metabólicas y fisiológicas de remeros novatos y experimentados, en distancia de 2000m. La muestra estuvo compuesta por 7 remeros universitarios y de clubes, 5 de los cuales eran novatos (edad 22.4±2.6 años, altura 182.6±8.4 cm, peso 79.7±8.9 kg), y 2 experimentados (edad 23.0±4.2 años, altura 194.1±4.1 cm, peso 90.3±2.0 kg). Todos los participantes realizaron una prueba de 2000m en un ergómetro de remo, seguidos por 3 pruebas en orden aleatorio (500m, 1000m, 1500m) a la velocidad y tiempo de carrera establecidos según la primera prueba de 2000m. La última sesión fue un test de $\dot{V}O_{2max}$. Durante estas pruebas se realizó análisis de gases, hematología, frecuencia cardiaca, tiempos parciales, velocidad de carrera y distancias. La acumulación de lactato en sangre (BLa) en los remeros novatos se incrementó progresivamente y se estabilizó en los últimos 500m. Los remeros experimentados aumentaron gradualmente la acumulación de lactato, pero lo mantuvieron en el tercer cuarto (1000-1500m), lo que les permitió mayor acumulación en el cuarto final (1500-2000m). El volumen de consumo de oxígeno ($\dot{V}O_2$) aumentó linealmente hasta los 500m finales en los remeros experimentados, mientras que en los remeros novatos fluctuó durante toda la prueba. Respecto al ritmo, los remeros novatos siguieron la estrategia "all-out" esperada, mientras que, inesperadamente, los remeros experimentados disminuyeron la velocidad progresivamente hasta el punto medio (1000m), en el que mantuvieron una velocidad de 5.10m·s^{-1}. Estos resultados sugieren que a un determinado nivel fisiológico y metabólico, los remeros experimentados están más adaptados a las demandas de una regata de remo de 2000m. Sin embargo, parece que no siempre siguen una estrategia "J-Shaped".
Palabras clave: Remo, Resistencia, Lactato, Frecuencia Cardiaca, Frecuencia Respiratoria.

Abstract: The aim was to evaluate the pacing strategies and metabolic and physiological responses of novice and experienced rowers, over a 2000m racing profile. The sample was composed of 7 male university and town boat club rowers, 5 of which were novice (age 22.4±2.6 yr, height 182.6±8.4 cm, mass 79.7±8.9 kg), and 2 experienced (age 23.0±4.2 yr, height 194.1±4.1 cm, mass 90.3±2.0 kg). All participants performed a 2000m racing profile on the rowing ergometer followed by 3 trials in randomised order (500m, 1000m, 1500m) at the stroke rate and split time set from the original 2000m test. The last session consisted of a $\dot{V}O_{2max}$ test. During these tests, gas exchange, haematology, heart rate, split times, stroke rate and distances were recorded. Blood lactate (BLa) accumulation in novice rowers was continuously increased and plateaued in the final 500m quarter. Whereas, experienced rowers gradually increased in lactate accumulation, but maintained in the third quarter (1000-1500m) which allowed room for further accumulation in the final quarter (1500-2000m). The volume of oxygen uptake ($\dot{V}O_2$) increased linearly until the final 500m quarter for the experienced group, while novice rowers fluctuated throughout the time trial. In terms of pacing, the novice rowers followed an expected "all-out" strategy whereas, unexpectedly, the experienced rowers continuously dropped in speed until the mid-point (1000m) where they maintained a speed of 5.10m·s^{-1}. The current findings suggest that at a physiological and metabolic level, the experienced rowers are more adapted to the demands of rowing a 2000m race. However, it appears that they do not always follow a "J-Shaped" strategy.
Keywords: Rowing, Endurance, Blood Lactate, Heart Rate, Breath frequency.

Introduction

The term 'pacing' is associated with the regulation of exercise intensity throughout an exercise bout based on circumstantial factors, in order to maintain internal homeostasis and/or to avoid early exhaustion (Abbiss, 2008; Smits, 2014). Pacing is considered to be a function of a perceptually mediated algorithm which is continuously compared to a sub-conscious template which itself has been derived from previous exposure to an exercise challenge (Stone et al 2012, Gordon et al 2017). Thus the modulations in pace occur in order to preserve the finite anaerobic capacity and so prevent a depletion of associated substrates and accumulation of associated metabolites (Gordon et al 2017, Foster et al 2004). The template is based upon associated sensations of pain and fatigue in reflection to the exercise duration. By understanding what pacing is, it also allows scientist to research the given sports optimal strategy, and in turn optimize performance, because only small variations in the pacing strategy can dictate competitive results. Additionally, by understanding the physiological demands of the sport, it aids in the development of athlete training (de Koning, 2011; López et al, 2015, 2016, 2017).

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There are many different pacing strategies used in different sports. St Clair (2006) describes 4 broad categories as: an 'all out' approach, a 'slow start' approach, an 'even paced' approach and a 'variable' approach, however Abbis (2008) also added 'negative', 'positive', and, 'parabolic-shaped' strategies to the list.

The type of strategy an athlete may choose to adopt is affected by the length and duration of the event. For example, a rowing race typically lasts 6-7 minutes across a 2000 m course and has previously been reported to adopt a "parabolic-shaped" and more precisely as a reverse "J-shaped" pacing strategy (Brown, 2010). Also, a pacing strategy could be interrupted by environmental factors such as weather, terrain and the racing course. Furthermore, experience has previously been highlighted as being of significance to the success of a pacing strategy (Green et al 2010, Scruton et al 2014).

The pacing strategy adopted by elite rowers is typically "reversed J-shaped" (Brown, 2010). However, the response and profile for non-elite rowers is presently un-clear. Therefore, the current study will approach this issue and investigate the pacing strategies whilst testing and comparing against experienced rowers.

In addition, whilst pacing strategies can be described, it does not offer an explanation of the underlying physiological mechanisms that regulate the consequent pacing of the event. Understanding this would explain whether current strategies are driven or adopted because they are beneficial physiologically.

Therefore, the aim of the current study is to evaluate pacing strategies adopted by novice and experienced rowers over 2000 m rowing ergometer trial and to understand if experience is linked to the optimal pacing strategy. In addition, another issue addressed by this study will be to examine the performance outcomes in relation to the physiological and metabolic responses.

Methods

Ethical Approval

The present study gained ethical approval from the Faculty of Science and Technology Research Ethics Panel (FREP), Anglia Ruskin University. Participants completed consent forms and a health-screening questionnaire that contained the physical activity readiness questionnaire (PAR-Q), the high intensity questionnaire and a blood-sampling questionnaire. Any participants who reported any issues with the health-screening questionnaire were excluded from the study.

Participants

Nine male rowers aged 18-30 volunteered to take part in the study. Four experienced rowers and five novice rowers. All the rowers were recruited from the University and town Rowing Clubs in Cambridge, UK.

The inclusion criteria to participate was they were male, aged 18-30 years old, have rowed across a 2000 m race profile previously and consider themselves to be physically active on a day-to day basis. The rowers were placed in either a novice or experienced category based on the length of time they have been rowing. Criteria for the experienced category rowing for at least 4 years and competed regularly within the British Rowing season. Owing to life commitments, two experienced rowers withdrew from the study prior to completion; therefore their data was not included in the results.

Procedure

Participants were informed to arrive to testing well hydrated and wearing suitable clothing and shoes. The participants attended the laboratory on five separate occasions and all participants were tested individually. All sessions took place within 3 weeks, at the same time of the day and all the tests were carried out on the same Concept II model D rowing ergometer (Concept 2 – Nottingham, UK).

The first session was a self-paced 2000m-time trial, in which participants were encouraged to reach their personal best (PB). The second, third and fourth sessions were randomly assigned 500m, 1000m and 1500m tests. During those tests, the participants were asked to maintain a given stroke rate and split time which was originally recorded in the initial 2000m test. The final session consisted of an incremental $\dot{V}O_{2máx}$ test, which was based around the total time of the initial 2000m.

Whilst seated, they had two capillary samples taken from the finger, the site of which all bloods were taken. The smaller 20µl sample was for analysis of blood lactate and glucose and the larger sample, 100µl, for pH, blood gasses and, electrolytes.

Prior to all trials participants performed a warm-up on the rowing machine. They were allocated 5 minutes for their warm-up and they would repeat the same warm-up in all the following sessions.

The first session was a 2000m-time trial representing a real racescenario. During this trial, expired air was recorded on a breath-by-breath basis and heart rate was recorded using a 5s epoch, with split times, wattages and strokes rates were recorded every 30s.

The second, third, and fourth sessions required participants to row across 500m, 1000m and, 1500m distances based on their original split times and stroke rates from the initial 2000m time trial. On the final visit, the participants carried out a $\dot{V}O_{2max}$ test. The protocol for this test was adopted from Gore (2012). The participants completed up to 74 minute intervals with a minute rest between each interval. Upon completion of each stage a 20µl capillary blood sample was collected and heart rate and $\dot{V}O_2$ were recorded throughout. Each stage was separated by 60s recovery period, with each subsequent stage being completed at a rate that was 5s faster than the previous, based on the 2000m time trial result.

After the ergometer tests were carried out in sessions 1 to 4, two post capillary blood samples were collected. Again, a smaller sample was taken to analyse blood lactate and blood glucose, then a larger sample for pH, blood gasses and electrolytes.

Pulmonary gas exchange responses

Using a low resistance mouth piece and turbine assembly volumes and flow rate were determined. For the determination of expired gas concentration O_2 and CO_2 were analysed at a rate of 60 ml·min^{-1} while being drawn off directly from the mouth piece. Using custom metabolic cart software the gas concentrations and respiratory responses were aligned to reflect breath-by-breath gas exchange variables ($\dot{V}O_2$, VCO_2, VE and RER). Prior to all trials the metabolic cart was calibrated for both volume/flow and gas concentration in accordance with manufacturers specifications.

Cardiovascular responses

During all trials including the $\dot{V}O_{2max}$ trial HR responses were recorded using a 5s sampling frequency using a Polar 810s telemetric system (Polar, Kempele, Finland).

Bloodchemistry

Blood samples (150 µl) were collected for the analysis of key biochemical markers (OptiCCA-TS, Una Health, Cardiff, UK). Blood lactate/glucose sample (20µl) were recorded using an automated system (EKF, Biosen C, UK). All equipment was calibrated as per manufacturers' instructions.

Data Analysis

Breath data was recorded with the Metalyzer 3B-R2 and saved in MetaSoft Studio V4.60 (Cortex Ltd-Leipzig, Germany) and later exported to Excel (Microsoft Excel for Mac 2011-Version 14.5.5) for analysis.

After all testing was complete, the written data was then transferred to Excel too. Using conventional methods the data was used to calculate means, standard deviations (SD), changes from pre to post, percentage of max and to tabulate or graph data.

For statistical analysis, IBM SPSS Statistics (Version 24.0) was used to run paired t-tests for between groups and repeated measures ANOVA within groups. However, owing to the small sample, t-tests and ANOVAs were not appropriate therefore, means, standard deviations, and Cohen's d (1988) effect size were utilised.

Results

Throughout the results section, it is important to note that effect sizes were used and the effect sizes were deemed 0.0-0.2 small, 0.3-0.5 medium, >0.8 high. Additionally, in all the results where asterisks have been used, their meanings are: *small effect, **medium effect, ***large effect.

Table 1. Mean and standard deviations of participant characteristics.

Participants	2000 m time (min:s)	Age (years)	Height (cm)	Mass (kg)	VO_{2max} (L.min^{-1})
Novice (n=5)	07:17.0	22.4 ± 2.6	182.6 ± 8.4	79.6 ± 8.7	4.87 ± 0.6
Experienced (n=2)	06:32.0	23 ± 4.2	194.1 ± 4.1	90.3 ± 1.9	6.16 ± 0.9
Mean (n=7)	06:54.0***	22.7*	188.4**	85**	5.5**

The total time to complete 2000m for both categories is shown (Table 1). A large effect size was found between groups (Cohen's d = 0.81). Overall, the novice group were on average 45 seconds slower than the average total time in the experienced category.

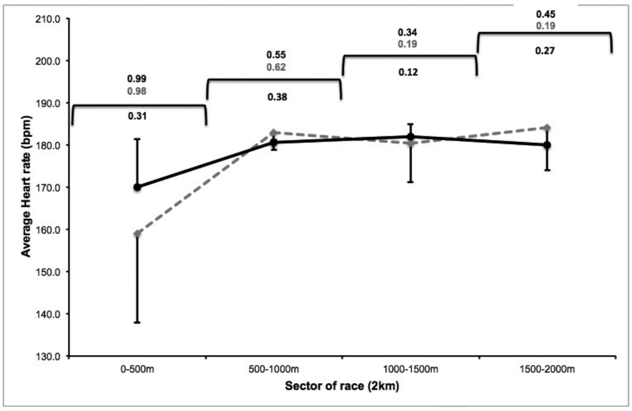

Figure 1. Average heart rate taken from the last 60s of each sector of the race.
The **Grey Dashed Line** represents novice rowers and the **Black Line** represents experienced rowers.

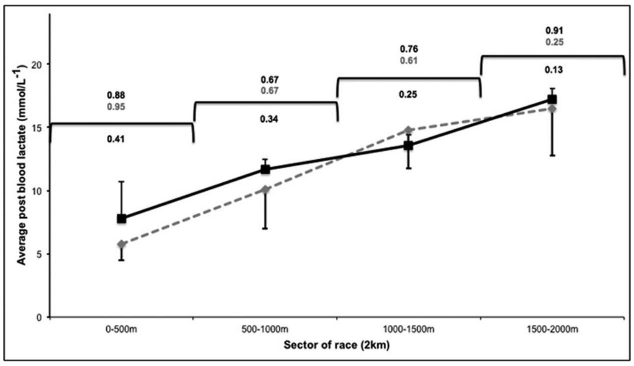

Figure 2. Average blood lactate taken from the finger tip at the end of each sector of the race.
The **Grey Dashed Line** represents novice rowers and the **Black Line** represents experienced rowers.

Heart rate for 2000m ergometer rowing is shown in Figure 1. A medium to small effect was found between the groups across each quarter of the 2000m rowing race (Cohen's d = 0.31, 0.38, 0.12, 0.27). A large to medium effect was found within the experienced group across the 2000m test (Cohen's d = 0.99, 0.55, 0.34, 0.45), whilst a large to small effect was found across the 2000m test within the novice group (Cohen's d = 0.98, 0.62, 0.19, 0.19).

Average post blood lactate concentrations are shown in Figure 2. There was a medium to small effect size found between the groups across the 2000m ergometer test (Cohen's d = 0.41, 0.34, 0.25, 0.13). A medium to large effect was found within the experienced group (Cohen's d = 0.88, 0.67, 0.76, 0.91), whilst a large to small effect was found in the novice group (Cohen's d = 0.95, 0.67, 0.61, 0.25).

Table 2. Metabolic components of the blood taken from the fingertip after each sector of the race.

	Sectors of race (2 km)			
	0-500m	500-1000m	1000m-1500m	1500-2000m
HCO_3 (mmol/L^{-1})	**19.54± 2.17**	**16.66 ± 2.55**	**13.96 ± 2.23**	**27.22 ± 2.01**
	23.30 ± 0.00 **	**16.40 ± 0.00***	**14.20 ± 0.14***	**10.45 ± 0.35 *****
pH	**7.35 ± 0.03**	**7.39 ± 0.21**	**7.24 ± 0.07**	**7.16 ± 0.07**
	7.39 ± 0.10*	**7.27 ± 0.00***	**7.19 ± 0.04 ****	**7.11 ± 0.00 ****
Glucose (mmol/L)	**4.04 ± 0.49**	**4.31 ± 1.25**	**5.54 ± 1.86**	**6.12 ± 1.18**
	4.59 ± 0.49**	**4.10 ±2.50***	**3.79 ± 2.16****	**6.23 ± 0.33***
RER	**0.89 ± 0.04**	**1.04 ± 0.04**	**1.04 ± 0.05**	**1.11 ± 0.15**
	0.90 ± 0.05*	**1.08 ± 0.49***	**1.09 ± 0.04****	**1.06 ± 0.01***
PCO_2 (kPa)	**4.83 ± 0.37**	**4.94 ± 0.70**	**4.41 ± 0.18**	**4.30 ± 0.36**
	5.00 ± 0.38*	**4.90 ± 0.00***	**5.09 ± 0.42****	**4.53 ± 0.10****
PO_2 (kPa)	**13.80 ± 1.21**	**13.43 ± 1.32**	**13.66 ± 0.73**	**13.15 ± 0.98**
	12.15 ± 0.65**	**13.20 ± 0.00***	**12.40 ± 0.44*****	**13.03 ± 0.24***

The **Grey Units** represent novice rowers and the **Black Units** represent experienced rowers

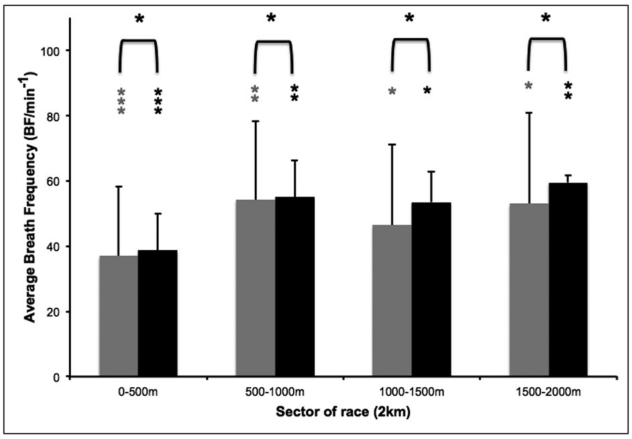

Figure 3. Average breath frequency taken from the last 60s of each sector of the race.
The **Grey Blocks** represents novice rowers and the **Black Blocks** represents experienced rowers.

There was a small effect size found between novice and experienced groups for average breath frequency across the entire 2000m test (Cohen's d = 0.05, 0.02, 0.18, 0.16). There was a large to small effect size within the novice group (Cohen's d = 0.78, 0.36, 0.16, 0.12) and a large to small effect size within the experienced group (Cohen's d = 0.92, 0.59, 0.07, 0.41).

Table 3. Changes in haematology factors for pre and post each sector of the race.

Pre Haematology factors	Sectors of race (2 km)			
	0-500m	500-1000m	1000m-1500m	1500-2000m
Na+ (mmol/L^{-1})	**143.0 ± 1.7**	**140.7 ± 2.6**	**142.3 ± 4.1**	**141.4 ± 3.1**
	143.6 ± 3.5*	**142.1 ± 0.0***	**143.2 ± 2.5***	**142.7 ± 1.1***
K+ (mmol/L^{-1})	**4.3 ± 0.2**	**3.9 ± 0.4**	**4.2 ± 0.2**	**4.0 ± 0.2**
	3.8 ± 0.3***	**4.4 ± 0.2****	**4.2 ± 0.2***	**4.1 ± 0.2***
tHb (g/Dl^{-1})	**15.0 ±0.7**	**14.6 ± 0.7**	**14.8 ± 1.0**	**15.0 ± 0.8**
	14.9 ± 1.3*	**15.1 ± 1.2***	**15.3 ± 0.5***	**15.5 ± 0.2***
Hct (%)	**45.1 ± 2.1**	**43.8 ± 2.3**	**44.5 ± 3.0**	**45.0 ± 2.5**
	44.7 ± 3.7*	**45.3 ± 5.0***	**45.8 ± 1.5***	**46.5 ± 3.8***

The **Grey Units** represent novice rowers and the **Black Units** represent experienced rowers

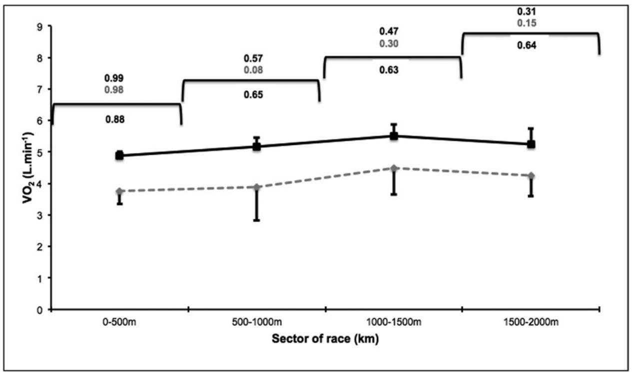

Figure 4. Volume of O_2 uptake taken as an average over the final 60s of each sector of the race.
The **Grey Dashed Line** represents novice rowers and the **Black Line** represents experienced rowers.

The $\dot{V}O_2$ response across the 2000m test shows a medium to high effect between the groups (Cohen's d = 0.88, 0.65, 0.63, 0.64). There was a large to medium effect in the experienced group (Cohen's d = 0.99, 0.57, 0.47, 0.31) and high to medium effect in the novice group (Cohen's d = 0.95, 0.08, 0.30, 0.15).

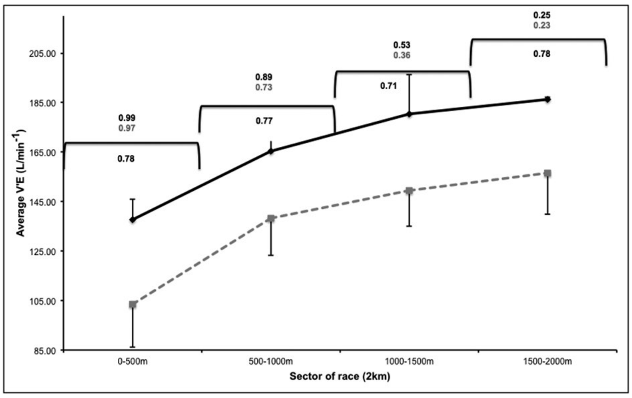

Figure 5. Average volume of air expired taken from the last 60s of each sector of the race.
The **Grey Dashed Line** represents novice rowers and the **Black Line** represents experienced rowers.

The V_E response shown in Figure 5 for the 2000m test showed a continuous large effect between the groups (0.78, 0.77, 0.71, 0.78). Within the experienced groups, there was found to be a large to small effect size (Cohen's d = 0.99, 0.89, 0.53, 0.25) whilst also finding a large to small effect within the novice group (Cohen's d = 0.97, 0.73, 0.36, 0.23).

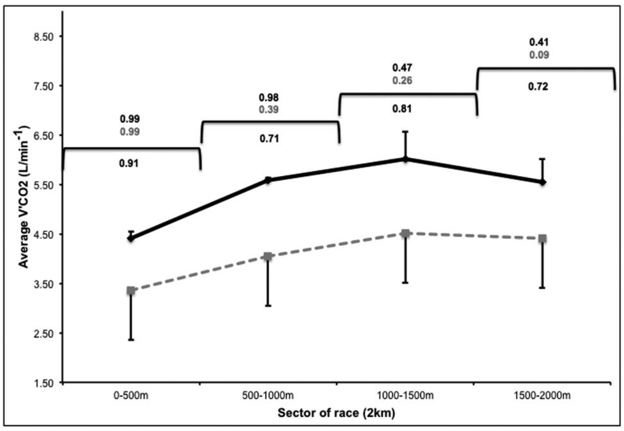

Figure 6. Average volume of CO_2 uptake during the last 60s of each sector of the race.
The **Grey Dashed Line** represents novice rowers and the **Black Line** represents experienced rowers.

The $\dot{V}CO_2$ was found to have a medium to large effect size between the groups (Cohen's d = 0.91, 0.71, 0.81, 0.72). A large and medium effect was found within the experienced group (Cohen's d = 0.99, 0.98, 0.47, 0.41) and a large to small effect within the novice group (Cohen's d = 0.99, 0.39, 0.26, 0.09).

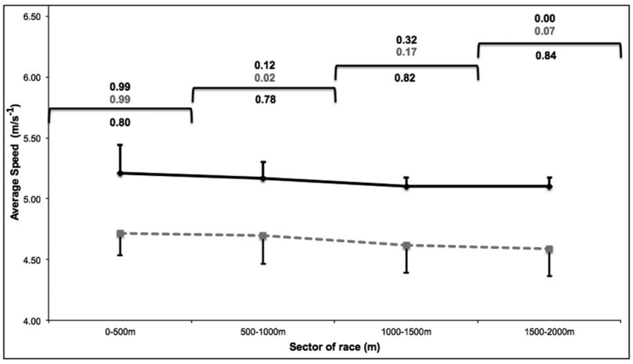

Figure 7. Average speed taken from the last 60s of each sector of the race.
The **Grey Dashed Line** represents novice rowers and the **Black Line** represents experienced rowers.

The average speed shows the outline of the pacing strategy adopted by novice and experienced rowers. A medium to large effect was found between the groups (Cohen's d=0.80, 0.78, 0.82, 0.84). A large to insignificant effect was found within the experienced group (Cohen's d = 0.99, 0.12, 0.32, 0.00) and a large to small effect within the novice group (Cohen's d = 0.99, 0.02, 0.17, 0.07).

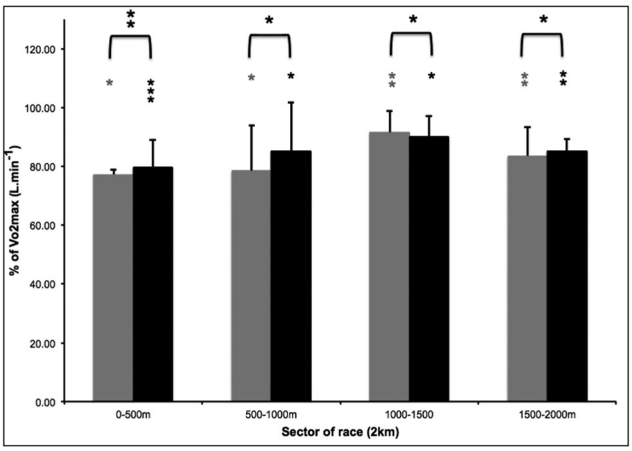

Figure 8. Percentage of VO_{2max} that is carried out at each interval.
The **Grey Blocks** represent novice rowers and the **Black Blocks** represent experienced rowers.

The percentage of VO_{2max} across the 2000m showed medium to small effect between the groups (Cohen's d = 0.50, 0.21, 0.10, 0.12). Within the experienced group, a large to small effect was found (Cohen's d = 0.98, 0.19, 0.18, 0.38) and the novice group had an insignificant to medium effect (Cohen's d = 0.00, 0.05, 0.47, 0.42).

Discussion

This study aimed to evaluate the physiological responses to a 2000m time-trial performed by novice and experienced rowers, which to the authors' knowledge has not been addressed previously.

Pacing strategies adopted

Previous literature has determined that rowers of a national standard or above follow a "J-shaped" strategy (Brown, 2010; Garland, 2005; Muehlbauer, 2011). However the pacing profiles of club level rowers or absolute novices are not well established. It is suggested that the pacing is based on previous experiences (St Clair, 2001), therefore, it would be hypothesised that recreational or novice athletes would be less capable of following a J-shaped strategy, due to insufficiently developed perceptually orientated template (Gordon et al 2017, Stone et al 2012). The findings of this study do in fact show that novice rowers adopt an 'all-out' pacing strategy as expected. However, the experienced rowers outlined in the current study adopt a 'negative' or 'even' strategy, which was unexpected as experienced rowers

Despite these findings, there are still differences between the groups used in the current study, which suggests that experience is still meaningful (Green et al 2010). Novice rowers had a total time of 7:17 ± 0:22 (min:s) where experienced rowers performed the 2000m time trial in 06:32 ± 00:05 (min:s), a difference of45 seconds associated with a large effect size (Cohen's d = 0.81). In terms of rowing this is considered to be a meaningful difference as 1% difference could be the difference between success and failure (deKoning, 2011).

For the first 500m, novice rowers were 10.7 ± 7.56 s^{-1} slower. In the second 500m the novice rowers were again 10.2 ± 7.21 s^{-1} slower. For the third 500m they were 11.8 ± 8.34 s^{-1} slower, with the greatest difference in the final quarter of 20.5 ± 14.49 s^{-1} slower. Given these split times, it is evident that the overall pacing strategy adopted by novice and experienced rowers to differ. The novice group shows an expected 'all-out' pacing strategy where the average speed drops following each quarter. Whereas, the experienced group unexpectedly adopt a negative pace strategy whereby in the first 2 quarters speed drops and then is maintained across the second half. These data arein contrast to Garland (2005), Brown (2010), and Muehlbaurer (2012) who found a "J-shaped" or "parabolic" strategy in elite athletes. Additionally, there was shown to be a medium to large effect size between the groups across the entire 2000m time trial (Cohen's d = 0.78-0.84).

Interestingly, the stroke rates between novice and experienced rowers had a difference of around 3 strokes a minute. The novice rowers held stroke rates of 27 ± 3, 26± 4 and 25 ± 4 s/min^{-1} for each quarter respectively. Whereas, experienced rowers held stroke rates of 30 ± 1, 30 ± 0, 29 ± 1 and, 29 ± 1 s/min^{-1} for each quarter. Volianitis (2009) stated that keeping a high stroke rate, a higher momentum is kept and therefore more efficient on the boat drag. Volianitis (2009) stated that stroke rates of 25·min^{-1} and bellow can increase momentum by 18% but for stroke rates greater than 35·min^{-1}, momentum can rise to 23%. Therefore, in this case it would suggest that novice rowers are not optimising the momentum of the boat drag.

Physiological responses:

Given that rowing is a strength endurance sport and the aim is to get the best time of a 2000m course, it is important for athletes to maintain large power outputs for an entire 6-7 minutes. In order to maintain this power output, the power outputs and metabolic responses need to work together. In other words, as the muscles are working to create as much force as they can, the metabolites need to be well adapted to maintain homeostasis throughout.

Previous findings have suggested that rowers accumulate the largest concentrations of blood lactate than any other sport (Astrand, 2000). For example, values of 15 and 17 mmol.L^{-1} were recorded at the national regatta and FISA championship respectively (Volianitis, 2009). In addition, Gee (2013) found experienced club levels rowers to obtain blood lactate concentrations of 18.6±3.8, 16.3±3.5, and 17.2±3.1 mmol.L^{-1} over three 2000m ergometer trials. Desgorces (2008) found college and national rowers had average concentrations of 10.45±0.45 mmol.L^{-1} after just 1000m. In the current study it is shown that both groups accumulate large concentrations of blood lactate by the end of the time trial (Novice=16.5 mmol.L^{-1}. Experienced=17.24mmol.L^{-1}). Therefore, the findings in this study support the findings in previous literature. Additionally, not only does it show that rowers have given a maximal effort but that rowing demands a very high lactate tolerance level.

Previous literature has suggested that rowing is associated with a large $\dot{V}O_2$response in order to meet the demands. For example, Volianitis's (1983) found elite rowers to have maximal oxygen uptakes of 65-70 ml·kg^{-1}·min^{-1}. Whereas, the college rowers in Schabort's study (1999) and the club rowers in Vogler's study (2007) found maximal oxygen uptakes of 60-63 ml·kg^{-1}·min^{-1}. Furthermore, the groups in this study would appear to exhibit proportional differences between elite and national level rowers

Moreover, rowers are found to work at intensities of around 90% $\dot{V}O_{2max}$ over the entire 2000m race (Mahler, 1984). In the current study, the experienced group appear to work on average around 85%±0.18 of $\dot{V}O_{2max}$ and the novice group have an average of 82.7%1.38 $\dot{V}O_{2max}$across the 2000m course. These findings, would suggest that there is a barrier or fear for not working at higher intensity throughout the 2000m bouts.

The results in this study show that as speed declines, so does the $\dot{V}O_2$response, however, the decrease in $\dot{V}CO_2$evidenced in the results, suggests CO_2 cannot leave the cell because either the $HCO3^-$cannot bind to the haemoglobin because the pH of the blood is too acidic or that the $HCO3^-$ is depleted rendering the manifestation of CO_2 concentration gradient between the intra and extra-cellular spaces inert..

Both groups began each test with similar haematocrit percentages, between 43.8%±2.3 and 46.5±3.8% suggesting comparable red cell packed volumes for both groups, which when compared to nationally recognized limits of 42% - 54% are in agreement. The current study found that both groups began each test with similar Hemoglobin levels at 14.6 -15.5 $g.dL^{-1}$. Again, this suggests that all individuals despite rowing status had similar O_2 carrying capacities when compared to national limits for individuals of a similar age (14-18 $g.dL^{-1}$). However, in comparison to haemoglobin levels in other rowers of an elite standard, rowers in the current study exhibited markedly reduced values. Indeed, elite Chinese rowers, who had 3 years of professional experience reported haemoglobin levels of 16.1±0.5 $g·dL^{-1}$ study (Yan, 2008). These haematological data from the current study may well have impacted on the manifestation of the VO_2 slow component under heavy exercise conditions (Burnley and Jones 2007) and the ability to sustain workloads in excess of the critical power (Burnley & Jones 2016) thus impacting on the finite anaerobic capacity, coupled with the reduced VO_{2max} scores in comparison to elite rowers.

Conclusion

This study is unique in the field of pacing research in that it has attempted to identify the physiological and biochemical responses at set times points under time-trial conditions. The data suggests that a key facet of the pacing paradigm is athlete experience and the previous exposure to the associated sensations of pain and fatigue and that limited exposure is associated with a less controlled 'all-out' effort. This coupled with the depressed physical fitness of these rowers compared to elite counterparts helps to clarify the interplay between the change in pace and the physiological responses. Therefore optimal pacing, based on these data is a function of both physiological status and the prior exposure to the exercise challenge.

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