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Original paper

Changes in physiological and stroking parameters during interval swims at the slope of the d–t relationship

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Abstract

The slope of the distance–time relationship from maximal 200 and 400 m bouts ($S_{200–400}$) has been increasingly employed for setting training intensities in swimming. However, physiological and mechanical responses at this speed are poorly understood. Thus, this study investigated blood lactate, heart rate (HR), stroke rate (SR), stroke length (SL) and RPE responses to an interval swimming set at $S_{200–400}$ in trained swimmers. In a 50-m pool, twelve athletes (16.5 ± 1.2 yr, 176 ± 7 cm, 68.4 ± 5.4 kg, and 7.8 ± 2.5% body fat) performed maximal 200 and 400 m crawl trials for $S_{200–400}$ determination (1.28 ± 0.05 m/s). Thereafter, swimmers were instructed to perform 5 × 400 m at this speed with 1.5 min rest between repetitions. Three athletes could not complete the set (exhaustion at 21.0 ± 3.1 min). For the remaining swimmers (total set duration = 32.0 ± 1.3 min) significant increases ($p < 0.05$) in blood lactate (5.7 ± 0.8–7.9 ± 2.4 mmol/l), SR (29.6 ± 3.2–32.1 ± 4.1 cycles/min), HR (169 ± 11–181 ± 8 bpm) and RPE (13.3 ± 1.6–16.3 ± 2.6) were observed through the IS. Conversely, SL decreased significantly ($p < 0.05$) from the first to the fifth repetition (2.48 ± 0.22–2.31 ± 0.24 m/cycle). These results suggest that interval swimming at $S_{200–400}$ represents an intense physiological, mechanical and perceptual stimulus that can be sustained for a prolonged period by most athletes.

Keywords: Swimming; Critical speed; Interval training; Blood lactate; Stroking parameters; Perceived exertion

1. Introduction

As an extension of the critical power concept introduced by Monod and Scherrer,[1] critical speed (CS) was firstly considered an exercise intensity that could be theoretically maintained continuously without exhaustion.[2,3] Early studies in swimming suggested that this parameter could be easily estimated by the slope of distance–time relationship (Sd–t) from maximal time trials over different distances,[3,4] which seemed to provide valid non-invasive estimates of aerobic endurance markers like the onset of blood lactate accumulation[2,3] and maximal lactate steady state.[4] However, despite high correlations between Sd–t and lactate related speeds in trained swimmers,[4–6] several authors have questioned its physiological meaning.[6–8]

Contemporary research suggests that CS indicates the upper limit of the heavy intensity exercise domain, i.e., the highest intensity that does not allow VO_2 max to be attained during a constant load exercise,[9] below which progressive drifts in physiological demand are observed but maximal values are not reached.[10] According to Dekerle et al.[10,11] CS is a useful reference to set training intensities in swimming, being Sd–t derived from 200 and 400 m bouts ($S_{200–400}$) considered the most pertinent approach for its estimation.[4,10,12] Although it has been argued that only two performances would decrease the reliability of Sd–t[10] and that this method overestimates the "true" CS in swimming,[8] $S_{200–400}$ has been increasingly adopted in swimmer's evaluation, mainly because it is well accepted by coaches and athletes, that tend to refute too long and/or several maximal trials in their testing routine.

Dekerle et al.[12] pointed that in the same way as for CS, a stroke rate would exist which could be, in theory, maintained

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without exhaustion for a long period, i.e., the critical stroke rate (CSR). According to these authors, swimming at CSR yields speeds close to CS, and vice-versa, suggesting that these could be useful parameters for simultaneous control of mechanical and physiological responses in training. However, in the above cited study swimmers' pace for continuous 30 min swims were set by reducing $S_{200–400}$ and its stroke rate analogue by 3.2% and 3.9%, respectively, which in turn may have attenuated both metabolic and SR responses observed and limit the external validity of their findings. Interestingly, no additional papers were found dealing with CSR concept in the international literature and questions about it remain to be answered.

Considering prior statements about the physiological meaning of CS[9,10] and the questionable validity of its estimation using Sd–t in swimming,[8] the later should represent a severe intensity exercise. Nevertheless, rather different metabolic responses have been found during swimming at Sd–t in trained athletes, with both stable (∼3.2 mmol/l)[4] and increasing blood lactate levels (∼5.5–8.0 mmol/l)[13] reported during 4 × 400 m blocks separated by short rest intervals (30–45 s) for blood sampling. Yet, these brief pauses are not precisely described and may be shorter than those employed for such intense and long interval training. Alternatively, using greater rest intervals (i.e., 1.5 min) between repetitions may attenuate physiological responses and enable the pace to be sustained for a longer period with good technique. Besides, the magnitude of physiological and mechanical responses in this condition remains to be investigated to provide coaches and athletes with more precise information about the stress induced. Thus, the aims of this study were to analyse blood lactate, heart rate, stroke mechanics and perceived exertion responses to interval swimming at $S_{200–400}$ in trained swimmers.

2. Methods

Twelve male trained swimmers of regional and national levels volunteered to take part in this study, which was approved by the University of West São Paulo Ethics Committee and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Athletes and their parents were informed about the nature and risks involved in the experiment and signed a statement of informed consent. Athlete's age, height, body mass, body fat and training experience were respectively 16.5 ± 1.2 yr, 176 ± 7 cm, 68.4 ± 5.4 kg, 7.8 ± 2.5% and 5.3 ± 1.1 yr. Their best performance over 400 m in the season was 84.7 ± 2.9% of that for the FINA Youth World Championships Record.

Within the first week after their main competition in the season, swimmers underwent 3 exercise sessions separated by 48 h. Two time trials (TT) and a constant speed interval set (IS) were performed in an outdoor 50-m swimming pool (28–29 °C water temperature) 2–3 h after a light meal. Each athlete was tested at approximately the same time of the day (±1 h) within their routinely training schedule, with ambient temperature between 28 and 30 °C. Individual warm up regimens were employed before each test and nutritional ergogenic aids and extra sessions of hard physical activity were avoided during the experimental period. Crawl stroke was the only used swimming style.

Initially, swimmers randomly underwent maximal 200 (TT200) and 400 (TT400) m time trials from a push off for $S_{200–400}$ determination. Times to cover these distances were taken by a trained assistant by means of a digital stopwatch and $S_{200–400}$ was individually calculated as the slope of the regression line between distance and time, according to Wakayoshi et al.[4] During both TT, time to complete four stroke cycles was taken each 50-m length while athletes progressed through a 20-m marked length between 15 and 35 m in the pool. The number of stroke cycles was then extrapolated for each race for $SR_{200–400}$ to be calculated as the slope of regression line between stroke count and time.[12] Within 5 s after the end of TT, athletes had assessed their heart rate (HR) (Polar S810, Polar Electro Oy, Finland), and were asked about their overall rating of perceived exertion (RPE) using the Portuguese language version of the Borg's 6–20 scale.[14]

Following TT, athletes were instructed to perform an IS consisting of 5 × 400 m at $S_{200–400}$ with 1.5 min passive rest between repetitions. Immediately after each repetition, HR and RPE were assessed as described above. In addition, 25 μl blood samples were taken in calibrated capillaries from athlete's earlobes and immediately placed and iced in 1.5 ml Eppendorfs tubes containing 50 μl NaF 1% solution for posterior electrochemical blood lactate analysis (YSI 1500 Sport, Yellow Springs Co., USA). As in TT, time to complete four stroke cycles was taken to get SR values in each 20 m mid-pool length. Time to cover this distance was also taken to get the real swimming speed, being stroke length (SL) determined by dividing this speed by SR. Mean SR and SL were then calculated for each 400 m repetition. During IS swimming speeds were controlled through constant visual feedback to guide the athletes to perform minor adjustments.[15] Criteria for IS interruption included volitional exhaustion or the inability to keep the pre-determined speed (mean speed decrease >0.02 m/s) in two consecutive 50-m length splits.

Results are presented as means ± standard deviation. Statistical analysis was carried out using a statistical software package (Statistic 6.0, Statsoft, Tulsa, USA). Before using parametric analysis, normal distribution and homogeneity of the data were verified by the Shapiro–Wilk's and Levene's test, respectively. Comparisons were carried out using Student's *t*-test for paired samples or one-way ANOVA for repeated measures followed by Tukey HSD post hoc test when appropriate. Pearson product moment correlation coefficients were calculated for relationship analysis. Significance was set at $p < 0.05$ in all cases.