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Maximal Swimming Distance At Anaerobic Critical Velocity

Hugo Gonçalo Duarte Louro[1,3], Pedro Gomes Silva[1], Ana Teresa Silveira Conceição[1,3], Henrique Pereira Neiva[2,3] , Daniel Almeida Marinho[2,3], and Aldo Filipe Matos M. C. Costa[2,3,4]

Affiliations:

[1] Sport Sciences School of Rio Maior, Polytechnic Institute of Santarém, Rio Maior, Portugal

[2] University of Beira Interior, Department of Sport Sciences, Covilhã, Portugal

[3] Research Center in Sports Science, Health and Human Development, Vila Real, Portugal

[4] Health Sciences Research Center (CISC- UBI), University of Beira Interior, Covilhã, Portugal

Abstract

International Journal of Swimming Kinetics 2(1) : 71-86, 2013. The aim of this study was to assess anaerobic critical velocity in swimming, its relationships with short distance performance and determine the maximal distance that can be performed at this assessed velocity. Nine male swimmers performed 15, 25 and 50 m maximal front-crawl swimming (30 min rest intervals) to calculate anaerobic critical velocity. Each swimmer also performed 100 m front-crawl at maximal velocity. Additionally, it was aimed to assess the maximal distance that could be performed at the previously assessed individual anaerobic critical velocity (up to 150 m). Capillary blood lactate concentrations and biomechanical variables were assessed on both swimming tests. Results show that anaerobic critical velocity and maximal 100 m front-crawl were highly correlated (r=0.88, P<0.01) and no differences were noted between them (1.61 ± 0.07 m.s-1 and 1.60 ± 0.08 m.s^{-1}, respectively; P=0.34). The swimmers were able to perform 97.22 ± 20.51 m at anaerobic critical velocity. However, no relationship was found between the total distance achieved and anaerobic critical velocity (r=0.27, P=0.49) and 100m performance (r=0.49, P=0.19). Blood lactate concentration values were also different in the 3rd and 5th minutes of recovery between the two tests (P<0.05). Likewise, variations of the biomechanical variables were noted between the tests. Our results suggest that anaerobic critical velocity is a relevant tool related to the swimmer's overall performance in short distances events. However, higher assessed velocities are not necessarily correspondent to more swimming distances without fatigue.

KEY WORDS: Swimming, anaerobic, testing, front-crawl.

Corresponding author

Daniel A. Marinho ✉

University of Beira Interior, Department of Sport Sciences

Address: Rua Marquês d'Ávila e Bolama 6201-001 Covilhã Portugal

E-mail: marinho.d@gmail.com Phone: +00351 275329153 Fax: 00351 275320695

INTRODUCTION

The overload of training hours and the incapacity to continually increase the swimming volume to improve performance highlights the importance of the training control as a fundamental tool to optimize swimmers results (Wright & Smith, 1994). Critical velocity has been investigated over time as a reliable parameter of evaluation and control of swimmer's aerobic capacity, being increasingly the subject of interest from researchers and coaches. This is a simple, non-invasive and low cost parameter, suitable for a large number of swimmers and that can be applied either in laboratory tests or in field test (Dekerle et al., 2002; di Prampero et al., 2008; Costa et al., 2009).

Critical velocity in swimming (Wakayoshi et al., 1992) was defined as the highest intensity of exercise that can be maintained for a long period of time without exhaustion. According to that definition, it corresponds to the swimming velocity of the maximum steady state lactate and it is calculated as the slope of the regression line between the swimming distance (m) and the respective duration (s), at maximal intensity (Wakayoshi et al., 1992).

Recently, the critical velocity was presented as a parameter of anaerobic evaluation of the swimmer (Fernandes et al., 2008; Marinho et al., 2011; Neiva, Fernandes & Vilas-Boas, 2011). The different methodologies used to assess critical swimming velocity led to different relationships with performance, and it was verified that the shorter the distances used for critical velocity assessment, the higher its relationship with anaerobic powerful efforts (Fernandes et al., 2008). Considering that anaerobic metabolism assessments are difficult to achieve, usually involving invasive measures and requiring knowledgeable technicians and sophisticated equipment (Rohrs et al., 1990), Fernandes et al. (2008) introduced the concept of anaerobic critical velocity as a possible parameter of anaerobic evaluation of the swimmer.

Anaerobic critical velocity (AnCV) is calculated as previous mentioned, but it is based upon sprint swimming distances (below 50 m) and its respective time durations. Recent studies showed strong relationships between AnCV (calculated based on swimming short distances) and distances with high anaerobic demands (Abe et al., 2006; Fernandes et al., 2008). Neiva et al. (2011) showed high correlations between this parameter and 100 m performance ($r \geq 0.60$, $P \leq 0.05$) and each 50 m lap ($r \geq 0.61$, $P \leq 0.05$), for the four swimming strokes. Further, anaerobic critical velocity converted to time evidenced to be similar to 100 m front-crawl time (67.5 ± 2.0 s, 68.3 ± 2.6 s, $P > 0.05$) and correlated with 200 m front-crawl performances (Marinho et al., 2011) ($r = 0.90$, $P < 0.01$). As the anaerobic metabolism is preponderant in efforts less than or equal to 200 m (Troup & Trappe, 1994), AnCV could represent the functional anaerobic capacity of the swimmers, and it is suggested as a possible parameter of anaerobic evaluation.

The practical application of anaerobic training and its evaluation and control is necessary mean to enhance the performance of swimmers in short races (Olbrecht, 2000). Thus, this study aimed to assess AnCV, to analyze its relationships with 100 m front-crawl performance and to determine the maximal distance that can be performed at this swimming velocity, contributing to the better understanding of the physical meaning of this new trend of critical velocity as a parameter to evaluate and monitor anaerobic training.

METHODS

Approach to the problem

This study assesses the utility of the Anaerobic Critical Velocity in terms of its relationship to 100-m swimming. Biomechanical and energetic parameters were assessed. All measurements were assessed in the end of the preparatory period of training to ensure that all athletes would be in a state of good overall performance. The swimmers were involved in three testing protocols on three different days: (i) the anaerobic critical velocity assessment – three swimming distances performed at maximum velocity were performed (15, 25 and 25m); (ii) 100 m front-crawl at maximal intensity and; (iii) the maximal distance performed at anaerobic critical velocity. To ensure the stability and reliability of the performance variables, all subjects were evaluated in the same location and time and supervised by the same researchers.

Subjects

Nine male swimmers (18.4 ± 3.2 years old; 1.80 ± 0.10 m; 70.89 ± 10.32 kg) participated in the study. All of them trained in the same swimming club for the last 2 years and competed in national level competitions, recording a personal 100 m best time corresponding to 495 ± 104.4 FINA ranking points. All subjects and their parents (in the under 18 years old subjects) provided written informed consent to participate in this study, and the procedures were approved by the institutional review board and conducted according to current Portuguese law and regulations.

Procedures

The experiments were performed in a 50 m indoor swimming pool at a water temperature of 27.5 ° C and 75% of humidity. The swimmers were involved in three testing protocols, falling on different days of the week, with a previous 1000 m warm-up and 10 min rest.

Anaerobic Critical Velocity assessment

In the first protocol, each swimmer performed three swimming distances (15, 25 and 50 m with in-water starts) in front-crawl at maximum velocity, with 30 min rest intervals (active rest). Two stopwatches were used to record times (Seiko stopwatches, Japan) and the average result was chosen for analysis. AnCV was calculated as being the slope of the distance-time relationship obtained from the following equation of the regression line where y is the distance swam, x is the time and a is the AnCV and b is the y-interception value:

$$y = ax + b \qquad \text{(equation 1)}$$

The standard error of AnCV was calculated to determine the strength of the regression line equation.

Performance data collection

Each swimmer performed 100 m front-crawl at maximal intensity to obtain the personal best in this period of the season (start from dive). Lap and final times were recorded by two experienced coaches (Seiko stopwatches, Japan) and the average result was chosen for statistical analysis. Additionally, it was aimed to assess the maximal distance that could be performed at the previously assessed individual AnCV. All the swimmers were informed about the target time on each 25 m and sonorous and visual feedbacks were agreed to help maintaining the velocity through the distance and motivating them to perform the maximal distance. Each subject underwent one familiarization session (at a lower swimming speed) to validate particularly the precision of pacing. Times were taken by experienced coaches (stopwatch Seiko, Japan). The distance performed at AnCV was considered to be the first of two consecutive 12.5 m swimming distances (marks were set in the pool) without performing the expected time. Even below the expected velocity, all the swimmers were encouraged to swim up to 150 m.

Energetic and Biomechanical data collection

Energetic and biomechanical variables were assessed on the 100 m maximal and on the 150 m at AnCV. Swimming velocity was determined in 10 m of the swimming pool (between the 15 m and 25 m) as the result of the division between the distance covered by the swimmer and the time spent to cover such distance. Stroke frequency (SF) was measured with a chrono-frequency meter (Golfinho Sports MC 815, Aveiro, Portugal) from three consecutive stroke cycles in those 10m and afterwards being converted to International System Units (Hz). The velocity and SF were assessed by two different and experienced researchers and the mean value was used for analysis. Distance per stroke (DPS) was estimated as the division between the velocity obtained during the 10 m and the SF (Craig & Pendergast, 1979). The stroke index (SI) was computed as the product between the velocity of the swimmer during the 15 m recorded and the corresponding DPS (Costill et al., 1985). Additionally, the Froude efficiency (np) was also estimated as being (Zamparo et al., 2005):

$$np = \left(\frac{v.0,9}{2\pi.SF.l}\right).\frac{2}{\pi} \qquad \text{(equation 2)}$$

where v is the swimming velocity ($m.s^{-1}$), the SF is the stroke frequency (Hz) and l is the arm's length (m). The l is computed trigonometrically measuring the arm's length and considering the average elbow angles during the insweep of the arm pull (Zamparo, 2006).

Complementarily, capillary blood samples were collected from the ear lobe at the 3rd and 5th min of recovery, to assess the highest vales of blood lactate concentration ([La-]) (Accutrend Lactate®Roche, Germany)

Statistical Analysis

Statistical procedures were performed using SPSS 19.0 for Windows® (Chicago, IL, USA). Standard statistical methods were used for calculation of means and standard deviations (SD) for all variables. The normality of all distributions was verified using Shapiro-Wilk test and nonparametric procedures were adopted. Spearman's rank correlation coefficient was used to verify the relationships between the anaerobic critical velocity in 100 m and between the anaerobic critical velocity and distances performed. To compare the mean values of the different variables assessed, Friedman test was used as well as the Wilcoxon signed rank test to assess the differences between them. The level of statistical significance was set at $P \leq 0.05$.

RESULTS

Linear relationships between distances swum at maximal intensity and corresponding times were found when assessing individual AnCV ($r^2 \geq 0.99$). In Table 1 the mean ± s, minimum and maximum values of AnCV and maximal 100 m swimming velocity are presented, as well as the distance performed at AnCV. As signed, anaerobic critical velocity and maximal 100 m front crawl were quite similar ($P = 0.34$) and highly correlated ($r = 0.88$, $P < 0.01$). However, no relationship was found between the anaerobic distance at AnCV versus AnCV ($r = 0.27$, $P = 0.49$) and anaerobic distance at AnCV versus 100 m performance ($r = 0.49$, $P = 0.19$).

	Mean ± s	Min	Max
VCAn ($m.s^{-1}$)	1.61 ± 0.07	1.48	1.74
100m ($m.s^{-1}$)	1.60 ± 0.08	1.50	1.71
Distance@ VCAn (m)	97.22 ± 20.51	87.5	150

Table 1. Mean ± s, minimum (min) and maximum values of anaerobic critical velocity (VCAn), 100m front crawl swimming performance in front crawl.

Figure 1 shows the variation of the biomechanical variables during each 50 m lap of the 150 m at anaerobic critical velocity and the 100 m maximal front-crawl. As noted, each one of the variables assessed assumed different values in all 50 m laps on both tests, with the exception of the Froude efficiency that showed to be similar within the same swimming protocol, but different from the other one.

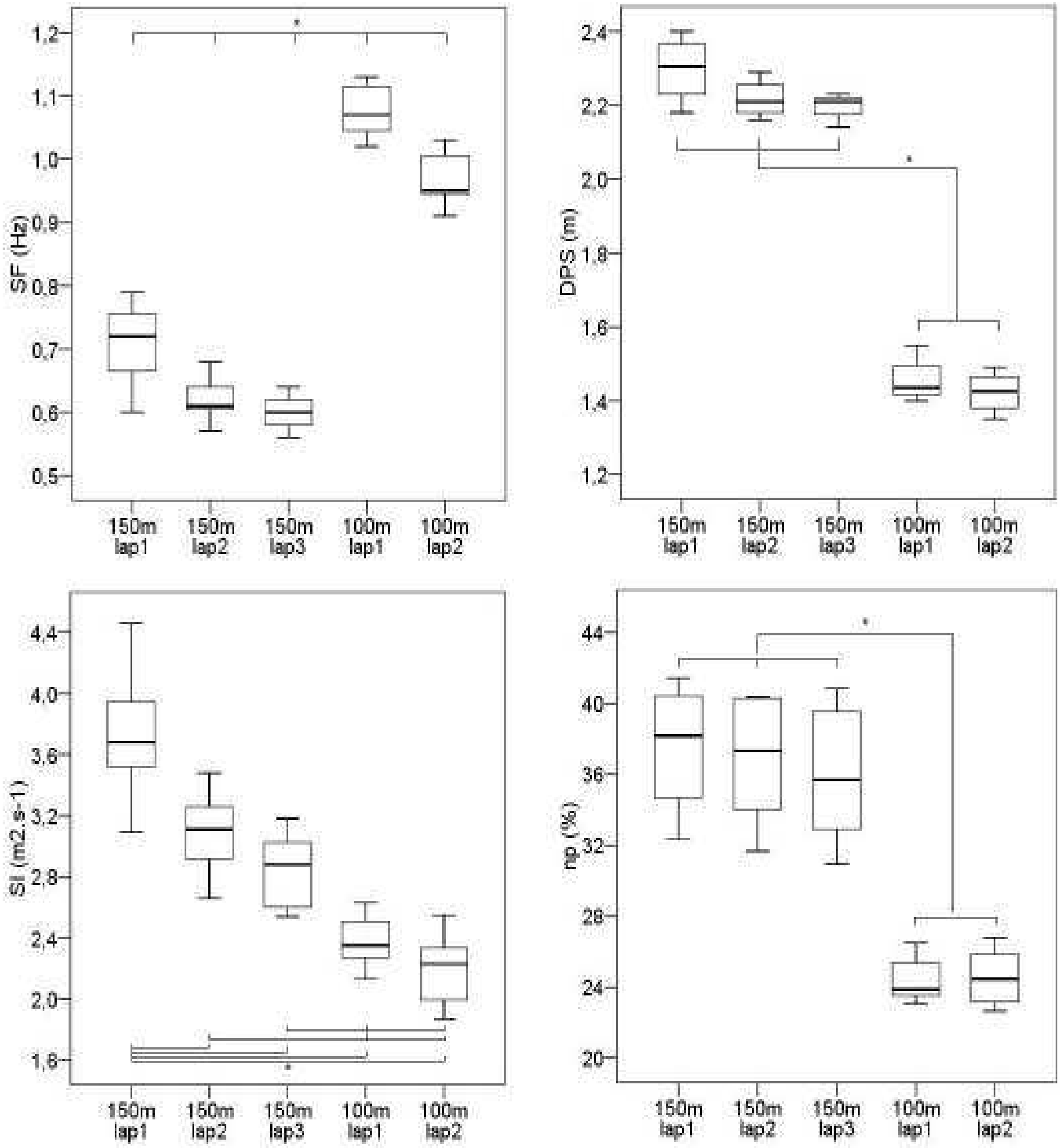

Figure 1. Variation of the biomechanical variables (SF – stroke frequency, DPS - distance per stroke, SI – stroke index, *np* – propulsive efficiency) in each 50 m lap during the 150 m swum at VCAn (150 m lap1, 150m lap2, 150 m lap3) and the maximal 100 m (100 m lap1, 100 m lap2).

In Figure 2 [La-] values obtained before (resting values) and after the maximal 100 m swimming and the anaerobic distance at AnCV are presented. Although the pre-values demonstrated to be similar between the procedures, the values showed differences after the test in the 3rd and 5th minutes of recovery.

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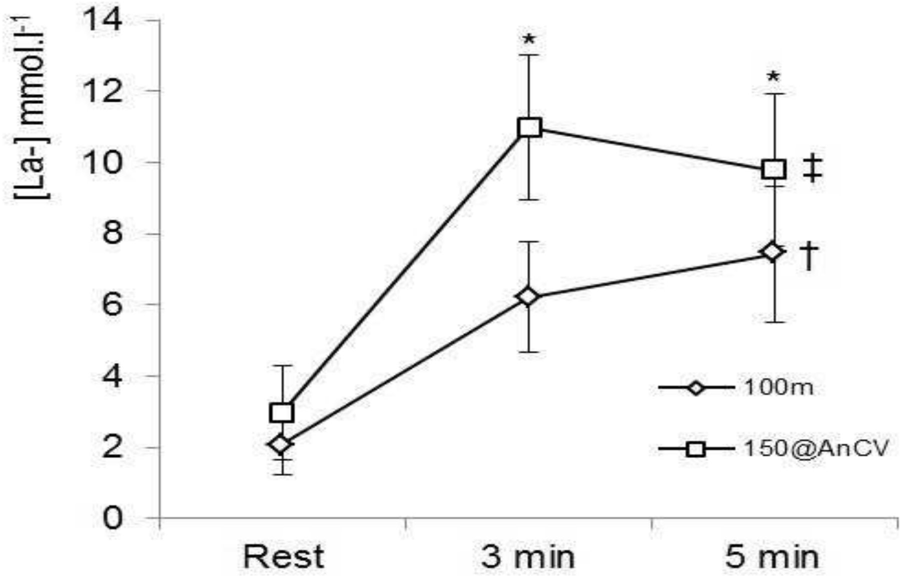

Figure 2. Values of blood lactate concentration [La-] before (rest) and after 100 m maximal (100 m) and 150 m swum at anaerobic critical velocity (150 m@ VCAn). * Significant difference (*P*<0.05) between 100 m and 150 m@ VCAn. Significant differences (*P*<0.05) between rest and both 3 and 5 min. Significant differences (*P*<0.05) between the three moments

DISCUSSION

The purpose of the current study was to assess AnCV, comparing this anaerobic indicator with the 100 m front-crawl swimming performance and additionally to verify the maximal distance performed at this velocity. The results showed strong relationship between the AnCV and 100 m front-crawl as well as no differences were found between these velocities. There was no relationship between AnCV and the distance performed at this swimming velocity, which values were close to 100 m. These findings suggest that AnCV could be used as a specific tool to evaluate and control the anaerobic fitness of male adult swimmers.

The high linearity observed between distance and corresponding time verified in the individual AnCV assessment was previously reported (Fernandes et al., 2008; Marinho et al., 2011; Neiva, Fernandes & Vilas-Boas, 2011). Indeed, our results confirm that it is possible to assess AnCV through working with linear relationships within specific short test distances swimming tests (lower than 50 m) and the corresponding times.

The lack of previous research assessing AnCV in swimming makes it difficult to compare our results. Nevertheless lower values were reported by Neiva et al. (2011) (1.75 ± 0.05 $m.s^{-1}$) and higher values by Marinho et al. (2011) (1.27 ± 0.16 $m.s^{-1}$). These disparities can be mainly attributed to age, experience and sport level differences. .

High direct relationships were found between the AnCV and the maximal 100m swimming velocity, as expected since AnCV was assessed based on short distances tests and in accordance with previous studies (Abe et al., 2006; Fernandes et al., 2008; Marinho et al., 2011; Neiva, Fernandes &Vilas-Boas, 2011). Together with the high correlation coefficient values found in the literature, particularly by Fernandes et al.(2008), Neiva et al.(2011) and Marinho et al. (2011) (0.85, 0.78 and 0.91, respectively; $P \leq 0.01$), it is strengthened the anaerobic preponderance of this parameter.

No differences were found between the AnCV and the 100 m swimming performance, which confirms the results obtained by Fernandes et al. (2008) in younger swimmers of both genders. However, divergent results were found by Neiva et al. (2011) that showed differences between the assessed anaerobic critical velocity and 100 m swimming velocity, in the four swimming strokes, suggesting the exclusion of the starting action in the AnCV assessment. In the present study it should be noted that the swimmers were in the preparatory period of the season and therefore anaerobic mechanisms were not fully adapted as evidenced by the low maximal values of [La-] after maximal 100 m compared with previous studies (Bonifazi, Sardella & Lupo, 2000). Knowing that performance of swimming events is closely related to the condition of the swimmer (Mujika et al., 1995), this could partly explain some diverse findings in the literature related to the comparison between the assessed AnCV and the 100 m swimming velocity (Marinho et al., 2011; Neiva, Fernandes &Vilas-Boas, 2011).

The similarity between the 100m swimming velocity and the assessed AnCV was complementary reinforced by the distances performed at this velocity. To our knowledge the present study was the first to attempt to evaluate the maximal distance at AnCV, as it was already done with other training control parameters (i.e. time limit at maximal oxygen consumption). However, no consistent relationships were found between this distance and AnCV, which highlights that higher assessed velocities are not necessarily correspondent to more swimming distances.

The results suggested the AnCV as an indicator of performance on 100m front-crawl, but the biomechanical variables assessed showed different swimming patterns. The swimmers propelling efficiency of the 150 m laps swum at AnCV were different from the lap 1 and 2 of the maximal 100 m. The initial controlled pace of the 150 m allowed using higher DPS and ηp and combining differently the SL and SF to achieve similar correspondent velocities on the 100 m in the tests. Considering that higher distance per stroke is important to increase swimming economy at a given velocity (Barbosa et al., 2010), the first meters of the 150 m swimming test were completed more economical and efficiently. SF was dropping throughout the 150 m test and eventually being resulted of the development of local fatigue and reduction in mechanical power output (Toussaint et al., 2006). Therefore, swimmers were not capable to maintain the velocity correspondent to AnCV for more than 97.22 ± 20.51 m as possible changes in technique due to fatigue could led to an increase in body drag or even a loss of feel for the water (Wakayoshi et al., 1995) and conditioned the test. The [La-] values were different in the 3rd and 5th minutes of recovery between the two tests, confirming that swimmers required the anaerobic metabolism differently between efforts.

An increase of anaerobic power reflects a greater swimming velocity, i.e., higher work per unit time. In turn, anaerobic capacity is a measure of ATP turnover via cytosolic processes, reflecting total work done. Training tasks for increasing swimming distances with increasing velocities are unusual. This kind of workout would develop the glycoltic capacity allowing the swimmer to perform higher distances with less effort and not necessarily more anaerobic work (Wilmore & Costill, 2001). More research is needed to understand the effects of training on anaerobic power and on anaerobic capacity and the relationship between these two components of swimmer's anaerobic fitness level. Measuring the rate of decrease in power output over a period of time or distance would be quite relevant.

PRACTICAL APPLICATIONS

To the best of our knowledge, this was the first study that has been conducted regarding the assessment of maximal distance performed at AnCV. Linear relationships and no differences were found between anaerobic critical velocity and 100 m swimming velocity, and thus suggesting this to be an important indicator of performance in the 100 m swimming events, and could be used as training reference for short events. The distance performed at anaerobic critical velocity was not different from maximal 100 m, confirming the similarity between these velocities and suggesting being a parameter to monitoring and prescribe anaerobic swimming performances. As an inexpensive and non-invasive method it seems relevant to conduct further studies to validate the use of this recent functional parameters of the swimmer's anaerobic fitness.

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