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Original Article

Blood Lactate Estimation in age group after a sprint swimming test

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Abstract:
As competitive swimming performance, even in young ages, depends significantly on anaerobic conditioning, we developed equations for blood lactate concentration ([La]) estimation in age-group after sprint swimming test. Six **male and two female competitive swimmers (15.7 ± 2.2 year s old) performed a 4x**50-m maximum velocity front-crawl (10-s intervals) test four times within a training macrocycle (n = 32). Time and kinematic related variables were obtained for each 50-m repetition (with a chronometer and a digital camera), and heart rate and [La] at three, seven and 12 min of the recovery period (La_3, La_7 and La_{12}) were measured (with a portable analyser). The Pearson correlation test was carried out to select the better predictor parameter and **a linear regression estimated La_3, La_7 and La_{12}.** La_3 can be predicted by the time in the first 50-m repetition (La3=33.01-0.63Tt1), La_7 by the second 50-m repetition (La7=39.81-0.77Tt2) or using La_3 (La7=1.53+0.77La3), and La_{12} by Tt_1 or La_3 (La12=31.44-0.66Tt1 or La12=-0.36+0.84La3, respectively). [La] at three, seven and 12 min after sprint swimming test can be predicted using the times in the first and second repetitions, but at minutes seven and 12 it can be, also and better, predicted by lactate at minute three. The regression models proposed are accurate for the sample and generalizable to age-group swimmers' population.
KeywordsTraining, exercise performance, exercise physiology, assessment, exercise testing.

Introduction

Capacity and power anaerobic training has an important impact on sports performance, even among age-group swimmers, with their answers to that stimulus being very relevant for coaches (Matos & Winsley, 2007; Nasirzade, A, Ehsanbakhsh, Argavani, Sobhkhiz, & Aliakbari, 2014). In fact, and despite the importance of swimming kinematics on age-group swimmers' performance (Lätt et al., 2010; Morais, Marques, Marinho, Silva, & Barbosa, 2014; Nasirzade, Alireza, Sadeghi, et al., 2014), appropriated physiological control (and evaluation of the interaction between performance determinants) should also be sought (Anderson, Hopkins, Roberts, & Pyne, 2008; Peyrebrune, Toubekis, Lakomy, & Nevill, 2014). As an example, a direct relationship between age-group swimmers 100-m front-crawl performance and their technical quality, distance per cycle and blood lactate concentrations ([La]) has been observed (Lätt et al., 2010). In general, [La] evaluations in swimming have been performed during training sessions (Pelayo, Mujika, Sidney, & Chatard, 1996; Smith, Norris, & Hogg, 2002; Anderson, Hopkins, Roberts, & Pyne, 2006) and in competitive conditions (Greenwood, Moses, Bernardino, Gaesser, & Weltman, 2008), determining optimal intensities for aerobic-anaerobic conditioning (Costa et al., 2013; Figueiredo et al., 2014; Peyrebrune et al., 2014) and helping control training-induced adaptations (Pyne, Lee, & Swanwick, 2001; Anderson et al., 2006; Toubekis, Tsami, Smilios, Douda, & Tokmakidis, 2011). Furthermore, [La] may also be an important tool in assessing recovery after maximal stimulation in competition (Greenwood et al., 2008; Vescovi, Falenchuk, & Wells, 2011) and in controlling overtraining if assessed frequently during the macrocycle (Jeukendrup & Hesselink, 1994; Pelayo et al., 1996; Bosquet, Léger, & Legros, 2001).

However, despite the benefits of [La] evaluation in age-group swimmers, this is not a viable procedure to be used in day-to-day training sessions (Borresen & Lambert, 2009). As it is common that a single coach is responsible for conducting the training sessions, especially among age-group teams, it is important that there are practical, easily applicable and simply interpreted tests (Smith et al., 2002). These features are essential to systematically use tests that assist in controlling swimmers adaptation to training (Smith et al., 2002), because, as coaches are often overwhelmed by a number of other tasks, they are not able to be engaged in training control procedures and, even if they were, data analysis would be complex for them. In addition, the use of indirect methods has the significant advantage of being low cost and easy applicable (Smith et al., 2002). So, the purpose

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of the current study was to present regression equations for the estimation of [La] after sprint swimming conditioning control test in age-group swimmers throughout a 15-week training macrocycle.

Material and methods

Subjects We assessed eight regional-level competitive swimmers (two females), aged 15.7 ± 2.2 years (13 to 19 years old) and with 4.6 ± 0.5 years of experience in intermediate-level competitive swimming, who participated in a 15-week training macrocycle. Male and female swimmers were, respectively, 173.8 ± 5.3 and 159.7 ± 2.4 cm in height, had 178.3 ± 6.5 and 163.7 ± 8.8 cm of arm span and 62.8 ± 7.9 and 53.5 ± 0.4 kg of body mass. Their best performance in the 50- and 100-m front-crawl was 32.1 ± 2.9 s (male: 31,4 ± 3,0 s; female: 34,2 ± 1,5 s) and 74.2 ± 5.3 s (male: 74,2 ± 6,3 s; female: 74,13 ± 0,1 s) vs. 30.8 ± 2.3 s (male: 25,1 ± 2,4 s; female: 32,6 ± 0,5 s) and 68.8 ± 4.7 s (male: 67,1 ± 4,0 s; female: 73,8 ± 2,5 s) at the beginning and end of the macrocycle. Participants were not short-distance front-crawl specialists and devoted a significant part of their preparation to other swimming techniques and distances. However, as much of the training program comprises front-crawl, it is the fastest and the most studied swimming technique (Fernandes, Ricardo & Vilas-Boas, 2012), it was decided to use it as a performance reference. The University's Research Ethics Committee approved the study procedure, in accordance with the Declaration of Helsinki.

Design During a 15 weeks training program (August-December), swimmers performed 15.0 ± 6.2 km/week (one training session per day) and were instructed on the importance of adequate nutritional status and hydration. The training macrocycle was divided in: (i) basic preparatory period (three weeks; one to three), aiming developing aerobic capacity and power; (ii) specific preparatory period (six weeks; four to nine), trying to maintain aerobic fitness and developing anaerobic conditioning; (iii) competitive period (five weeks; 10-14), where the most important competitions occurred, looking to provide super compensation from previous training periods; and (iv) transition period (one week; 15), marking the end of a cycle and the beginning of another, the time to recover from physical and mental fatigue induced by previous training loads. The dry land training sessions, which had the purpose of increasing muscle strength, had 30-min duration three times per week during weeks one to six. After that period, muscle strengthening was carried out exclusively in-water (e.g. using paddles and fins).

In a 25-m swimming pool (27 ± 1ºC of water temperature), and always at the same time of the day, swimmers performed 4 x 50-m front-crawl at full velocity (with first block start and 10-s intervals) (Pelayo et al., 1996) at training weeks two, four, nine and 12. The time was measured for each repetition (Tr_1, Tr_2, Tr_3 and Tr_4) and overall time ($T_{overall}$) was obtained by the sum of time repetitions. A standardized warm up of 200-m medley, 100-m freestyle and 4 x 50-m front-crawl (25-m fast plus 25-m slow intensity 15-s rest) (McGowan, Pyne, Thompson, & Rattray, 2015; Neiva et al., 2015) was performed before each test. Stroke rate (SR) was obtained from the time required to perform two upper limb cycles - always on the second lap of each 50-m and based on the second upper limb cycle (Chronometer Ultrak 495). To this aim, a digital camera (Sony Handycam Dcr, HC30, Japan), operating at 30 Hz, was placed 5-m from the side of the pool and 6 m from the head of the 25-m turn. Stroke length (SL) was obtained from the ratio between velocity (ratio between 50-m distance and respective time) and SR (Poujade, Hautier, & Rouard, 2002). Stroke index (SI) was assessed by the product of swimming velocity and SL (SI = SL∗v) (Costill et al., 1985). Blood samples were collected in three different times to know behaviour of [La] in this group, from the index finger during passive recovery to determine [La] at minutes three, seven and 12 (La_3, La_7 and La_{12}, respectively) using an Accusport Lactimeter analyzer (Roche, Germany). Heart rate was measured (Polar FS1, Kempele, Finland) immediately after the test (HR_0) and at the [La] collections (HR_3, HR_7 and HR_{12}). All swimmers performed the four testes planned.

Statistical Analysis

To find out the parameter (time repetition, overall time, [La], heart rate, stroke length, stroke rate and stroke index) that could be used as good [La] predictors, and assuming a normal distribution, Pearson's Linear Product-Moment correlation test (unilateral) was used, considering all tests (n = 32). Later, to avoid multicollinearity, only higher correlation and simple collected predictor parameter were kept (Field, 2009). After choosing the predictor parameter, linear regression procedures were used to estimate La_3, La_7 and La_{12}. In all cases, the value of alpha = 0.05 was taken into account. To obtain a more accurate model, more than 5% of cases with more than 2.5 standard deviation values and no case with a Cook's distance greater than 1 were considered. Durbin-Watson statistics were used to test if the independence of errors' hypothesis was satisfied, considering values close to two as appropriate and smaller than one or larger than three as inadequate (Field, 2009). The accuracy and precision of the equations proposed were estimated, respectively, by the root mean square error ($RMS_{error} = \sqrt{predicted\ value - true\ value}$; where RMS_{error} is the accuracy, predicted value are the values obtained by the different equations proposed and true value are the one obtained using Lactimeter) and coefficient of variance ($CV = (SD_{dif})/MEAN_{dif}$); where CV is the precision indicator, SD_{dif} is the standard deviation values and $MEAN_{dif}$ is the mean values obtained from the differences between the La predicted and La true). Due to the sample size used (n = 32) and to ensure an adequate effect size, we opted to use only one predictor parameter.

Results

The average values (mean ± standard deviation) of time repetition, stroke length, stroke rate and stroke index in repetitions can be seen in Figure 1(a) to (d), respectively. The average heart rate and [La] variables measured in tests are shown, likewise, in Figure 1(e) and (f). As expected, time decreased along repetitions, with the best time in repetition one and a large variation between swimmers performance (Figure 1(a)). This is a consequence of the SL and SR´s behaviours during repetitions (Figure 1(b) and (c)) and seems that SL values were more constant than SR between repetitions 1-4. Best SI occurred in repetition one and decreased as consequence the worsening in SL and velocity. The highest heart rate value occurred immediately after test (HR_0), decreased during rest but keeping close in HR_3, HR_7 and HR_{12} (Figure 1(e)) and presented high variations among the swimmers. The highest value of [La] was seen in La_3 but it is still relatively high in La_7 and La_{12}. Higher [La] values were in test one and four, and again, with a large variation among the swimmers in all tests (Figure 1(f)).

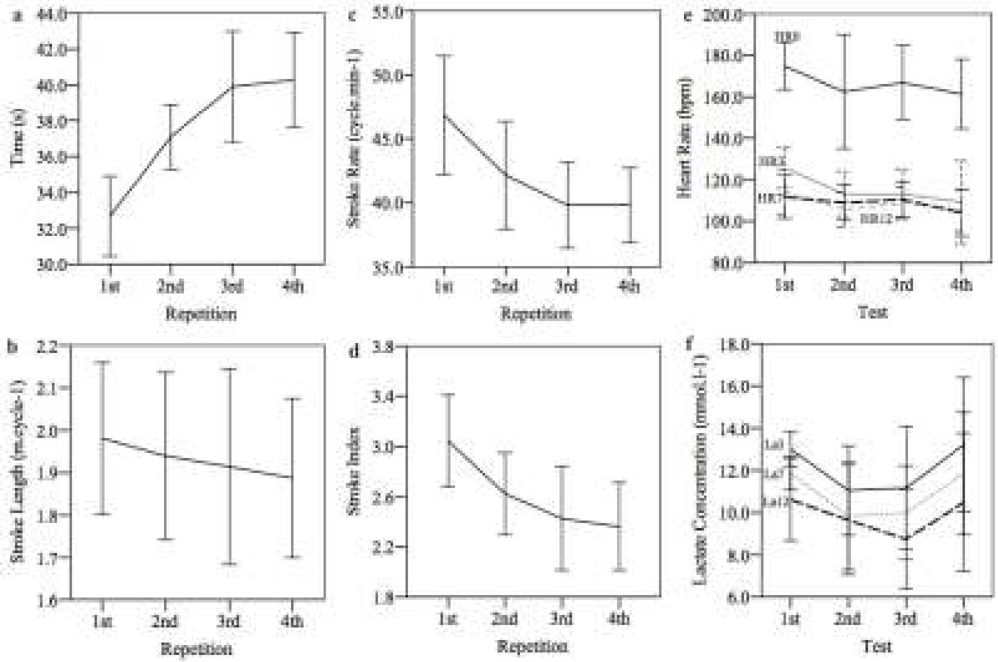

Figure 1. Average behaviour (mean ± standard deviation) of time (a), stroke length (b), stroke rate (c) and stroke index (d) for repetitions and average heart rate (e) and lactate concentration in minutes 3 (La_3), 7 (La_7) and 12 (La_{12}) (f) in testing throughout the training program.

The correlation analyses to evaluate which parameter (time repetition, overall time, [La], HR, SL, SR and SI) best correlate with lactate concentration values in minutes three, seven and 12 (La_3, La_7 and La_{12}) are displayed in Table 1. Moderate correlation of La_3 with the first time repetition (r = -0.55 and $P < 0.01$) and high correlation with La_7 (r = 0.87 and $P < 0.01$) and La_{12} (r = 0.84 and $P < 0.01$) were evidenced. The regression model for La_3 is shown in Table 2 and had an accuracy of 4,4 ± 2,1 $mmol^{-1}$ and a precision of 0,4. We found moderate correlation of La_7 with the first time repetition (r = -0.58 and $P < 0.01$) and second time repetition (r = -0.61 and $P < 0.01$), and high correlation with La_3 and La_{12} (r = 0.81 and $P < 0.01$). The regression model for La_7 from the second time repetition (accuracy of 3,5 ± 1,9 $mmol^{-1}$ and precision of 0,5) and La_3 (accuracy of 1,33 ± 1,17 $mmol^{-1}$ and precision of 0,8) are shown in Table 2. We found moderate correlation of La_{12} with the first time repetition (r = -0.56 and $P < 0.01$) and second time repetition (r = -0.48 and $P < 0.01$), and high correlation with La_3 and La_7. The regression models for La_{12} is shown in Table 2, and had, respectively for Tr_1 and La_3, an accuracy of 4,3 ± 2,1 $mmol^{-1}$ and 1,8 ± 1,3 $mmol^{-1}$, and a precision of 0,4 and 0,7. Results indicated that the sample was adjusted to what is considered an accurate model since there is no more than 5% of cases with values above 2.5 deviations. No case presented Cook's distance greater than one, indicating that none of them will unduly influence the model (Field, 2009).

Table 1. Correlation analyses to evaluate which parameter best correlate with lactate concentration values in minutes 3, 7 and 12 (La_3, La_7 and La_{12}).

Variables	La_3 (mmol·l^{-1})	La_7 (mmol·l^{-1})	La_{12} (mmol·l^{-1})
Tr_1 (s)	-0.55[b]	-0.58[b]	-0.56[b]
Tr_2 (s)	-0.45[b]	-0.61[b]	-0.48[b]
Tr_3 (s)	-0.05	-0.16	0.04
Tr_4 (s)	0.06	-0.01	0.09
Ot (s)	-0.27	-0.39[a]	-0.23

HR_0 (bpm)	0.28	0.37[a]	0.30[a]
HR_3 (bpm)	0.31[a]	0.53[b]	0.35[a]
HR_7 (bpm)	0.10	0.27	0.16
HR_{12} (bpm)	0.13	0.29	0.08
SL_1 (m·cycle^{-1})	0.01	0	0
SL_2 (m·cycle^{-1})	0.08	0.13	0.02
SL_3 (m·cycle^{-1})	0	0.04	-0.06
SL_4 (m·cycle^{-1})	0.02	0.03	-0.06
SR_1 (cycles·min^{-1})	0.29[a]	0.31[a]	0.31[a]
SR_2 (cycles·min^{-1})	0.13	0.16	0.22
SR_3 (cycles·min^{-1})	0.09	0.11	0.10
SR_4 (cycles·min^{-1})	-0.03	0.01	0.07
SI_1	0.34[a]	0.34[a]	0.34[a]
SI_2	0.23	0.34[a]	0.18
SI_3	0.04	0.12	-0.03
SI_4	0	0.05	-0.07
La_3 (mmol·l^{-1})	-	0.87[b]	0.84[b]
La_7 (mmol·l^{-1})	0.87[b]	-	0.81[b]
La_{12} (mmol·l^{-1})	0.84[b]	0.81[b]	-

[a] Significant at the 0.05. [b]Significant at the 0.01 levels. Tr_{1-4}: time in repetitions 1 to 4; $T_{overall}$: overall time (sum of Tr_{1-4}); HR_{0-12}: heart rate immediately after the test and in minutes 3, 7 and 12 in rest; SL_{1-4}: stroke length in repetitions 1 to 4; SR_{1-4}: stroke rate in repetitions 1 to 4; SI_{1-4}: stroke index in repetitions 1 to 4; La_{3-12}: lactate concentration in minutes 3, 7 and 12 after the test.

Table 2. Prediction equations for lactate concentration in minutes three, seven and 12 (La_3, La_7 and La_{12}) from predictor parameter in the first and second time repetitions (Tr_1, Tr_2), and La_3 with the corresponding R^2 values, *P* and Durbin-Watson (DW).

Foreseen [La]	**Predictor**	**Equation**	R^2	***P***	**DW**
La_3 (mmol·l^{-1})	Tr_1 (s)		0.30	0.001	1.97
La_7 (mmol·l^{-1})	Tr_2 (s)		0.37	0.001	1.67
La_7 (mmol·l^{-1})	La_3 (mmol·l^{-1})		0.75	0.001	2.34
La_{12} (mmol·l^{-1})	Tr_1 (s)		0.32	0.001	2.55
La_{12} (mmol·l^{-1})	La_3 (mmol·l^{-1})		0.70	0.001	2.39

Tr_1 and Tr_2: first and second time repetitions; La_{3-12}: lactate concentration in minutes 3, 7 and 12 after the test.

Discussion

In the current study, age-group swimmers were assessed during a training macrocycle through a sprint-swimming test. The obtained time repetitions, overall time, [La], heart rate, and stroke length, rate and index were used as reference for forecasting La_{3-12}. The first and second time repetitions (Tr_1 and Tr_2) and La_{3-12} were better correlated with La_{3-12} values and, therefore, estimation equations [La] taking into account these parameters were proposed. The first and second time repetitions showed moderate correlation with La_{3-12} and explain only about 30-37% of [La], but their use is simple and requires no invasive procedure. Moreover, when obtaining La_3, it is possible to estimate and know the behavior of La_7 and La_{12} values, explaining about 70-75% of [La] - making it a simpler, faster and more inexpensive procedure. However, as indicated in literature, [La] showed low or no correlation with kinematic parameters of upper limbs (Psycharakis, Cooke, Paradisis, O'Hara, & Phillips, 2008; Holfelder, Brown, & Bubeck, 2013) and is dependent on the actual training status of the swimmer (Pyne et al., 2001; Toubekis et al., 2011).

The heart rate in our study was close to that found after sprint swimming (4 x 30-s with 30-s intervals with 95% intensity) with older and experienced athletes (Peyrebrune et al., 2014), but while in our study the stroke rate decreased along repetitions, during the 4 x 30-s test, the swimmers could maintain this parameter. It could be possible in consequence of the better performance athletes, lower intensity and greater rest period. A high [La] after a maximum stimulus, coupled with adequate performance, is a positive indicator of the swimmer’s anaerobic condition (Bonifazi, Sardella, & Lupo, 2000), and peak [La] depends on the swimming intensity, while the length of achieved values (magnitude) is determined by the event’s duration (Smith et al., 2002). [La] peak for this study seems to have occurred at La_3 and no increase was found for La_7 and La_{12}, while other study observed [La] peak around 6-7 min (Bonifazi et al., 2000). In any case, given the relative maintenance of [La] at La_{12}, the test performed seems to last and to be intense enough for [La] to be elevated for a longer period. La_3 and La_{12} values obtained in older, more experienced and with better performance level swimmers performing the same test (Pelayo et al., 1996) were higher than those found in this study, but towards the end of the basic preparatory period, La_{12} values were similar to those found. In 4x30-s swim test, [La] value obtained immediately after the test (12.1 ± 3.6 mmol·l^{-1}) was like to that obtained in tests one and four. However, another study with age-group swimmers found La_3 values of 6.40 ± 2.81 mmol·l^{-1} and La_5 6.58 ± 3.03 mmol·l^{-1} after a 100-m stimulation (Lätt et al., 2010).

Despite the greater value of [La] after sprint swimming tests in short distance or time (Pelayo et al., 1996; Peyrebrune et al., 2014), recent study demonstrated that aerobic metabolism contributes progressively during repeated sprints and there are elevated VO_2 uptake. Estimated aerobic contribution in 4 x 30-s was 25 ± 4% and 52 ± 9% in repetitions one and four, respectively, and O_2 uptake was 84 ± 6% of VO_2max in repetition four (Peyrebrune et al., 2014). Then, due to smaller rest period between repetitions used in our study, we speculate a greater aerobic contribution and high percentage of VO_{2max} (Fernandes, RJ et al., 2012). Any way, different methodology, sprint duration, competitive level and swimming specialization may influence the results (Peyrebrune et al., 2014). Important notice that the determination of [La] after exercise doe not provide information that can be directly applied and it does not exactly reflect the real physiological process involved (Pelayo et al., 1996). In the same way, [La] after maximal effort should be interpreted with caution and many factors should be taken into account to explain the observed difference in blood lactate accumulation (Bonifazi et al., 2000).

The use of indirect methods for evaluating swimmers is relatively common because the aquatic environment limits the performance of some procedures (Lätt et al., 2010) and, as an example, the use of heart rate obtained at particular swimming speeds in consequence of measurement limitations of VO_2 in swimming training situations (Smith et al., 2002). The device used to measure [La] in the present study is commonly used by swim teams due to its low price and easy use. However, even if [La] assessment methods are simpler than for VO_2 (Peyrebrune et al., 2014), it is still not an affordable procedure for all beginning teams. Thus, due to the high ratio between swimming velocity and [La] (Psycharakis et al., 2008), the proposed equations can be used by coaches who do not have a [La] measurement device (through first and second time repetitions) or can make the procedure faster and more economical when there is possibility of their collection (using only La_3). Opting for La_3, there is greater accuracy in the model than with time repetitions, but in both cases mathematical procedures were satisfactory and indicate a possibility of use by coaches.

As periodic performance testing is important in swimmers training programs (Anderson et al., 2008), information resulting from the current study may be useful to coaches who are interested in using this test as a way of controlling aerobic-anaerobic conditioning and performance along the training process. Age-group swimmers are also affected by excessive training (Matos & Winsley, 2007) and the use of [La] can be a tool to help control training (Jeukendrup & Hesselink, 1994; Pelayo et al., 1996; Bosquet et al., 2001). Moreover, coaches can have one simple estimation of [La] in minutes three, seven and 12 of recovery after the test. Therefore, it is important that coaches choose the moments of the training program for testing and that they take into account the level of the swimmers' performance assessed for result interpretation (Smith et al., 2002). This knowledge will allow them to make individual adjustments and respect swimmers' characteristics (Anderson et al., 2008), as individual and male and female swimmers (Anderson et al., 2008; Psycharakis et al., 2008; Holfelder et al., 2013) adapt differently to training stimuli (Borresen & Lambert, 2009). Moreover, variables related to growth, development and maturation have great influence on age-group swimmers' performance (Moreira et al., 2014). Thus, the process of adaptation is an individual phenomenon, which may influence test results and consequently [La] (Borresen & Lambert, 2009), this is a factor to be considered during evaluation.

Conclusion

[La] in minutes three, seven and 12 after sprint swimming test can be predicted using the first and second time repetitions in a 50-m front-crawl (explain only about 30-37% of [La]), and in minutes seven and 12 using [La] in minute three (explaining about 70-75% of [La]). Statistical parameters showed that regression models for the prediction of [La] in minutes three, seven and 12 were accurate for the sample and generalizable to population of regional-level competitive swimmers.

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