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 4x50-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 (La3, La7 and La12) were measured (with a
portable analyser). The Pearson correlation test was carried out to select the better predictor parameter and a
linear regression estimated La3, La7 and La12. La3 can be predicted by the time in the first 50-m repetition
(La3=33.01-0.63Tt1), La7 by the second 50-m repetition (La7=39.81-0.77Tt2) or using La3, La7=1.53+0.77La3, and La12 by Tt1 or La3 (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.

Keywords: Training, 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, Elsanhuksh, Argavani, Sobkhiz, & 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;

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 \([\text{La}]\) 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 ± 1°C 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) (Payelo et al., 1996) at training weeks two, four, nine and 12. The time was measured for each repetition (Tr1, Tr2, Tr3 and Tr4) and overall time (Toverall) 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 (La3, La7, and La12, respectively) using an Accusport Lactimeter analyzer (Roche, Germany). Heart rate was measured (Polar FS1, Kempele, Finland) immediately after the test (HR0) and at the [La] collections (HR3, HR7, and HR12). 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 La3, La7 and La12. 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 (RMSE\text{error} = \sqrt{\frac{\text{predicted value} - \text{true value}}{\text{predicted value} - \text{true value}}}), where RMSE\text{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\text{dif}/MEAN\text{dif}); where CV is the precision indicator, SD\text{dif} is the standard deviation values and MEAN\text{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 (HR0), decreased during rest but keeping close in HR3, HR7 and HR12 (Figure 1(e)) and presented high variations among the swimmers. The highest value of [La] was seen in La3 but it is still relatively high in La7 and La12. 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 (La3), 7 (La7) and 12 (La12) (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 (La3, La7 and La12) are displayed in Table 1. Moderate correlation of La3 with the first time repetition ($r = -0.55$ and $P < 0.01$) and high correlation with La7 ($r = 0.87$ and $P < 0.01$) and La12 ($r = 0.84$ and $P < 0.01$) were evidenced. The regression model for La3 is shown in Table 2 and had an accuracy of $4.4 ± 2.1$ mmol·l$^{-1}$ and a precision of 0.4. We found moderate correlation of La7 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 La3 and La12 ($r = 0.81$ and $P < 0.01$). The regression model for La3 from the second time repetition (accuracy of $3.5 ± 1.9$ mmol·l$^{-1}$ and precision of 0.5) and La7 (accuracy of $1.33 ± 1.17$ mmol·l$^{-1}$ and precision of 0.8) are shown in Table 2. We found moderate correlation of La12 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 La3 and La7. The regression models for La12 is shown in Table 2, and had, respectively for Tr1 and La3, an accuracy of $4.3 ± 2.1$ mmol·l$^{-1}$ and $1.8 ± 1.3$ mmol·l$^{-1}$, 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 (La3, La7 and La12).

<table>
<thead>
<tr>
<th>Variables</th>
<th>La3 (mmol·l$^{-1}$)</th>
<th>La7 (mmol·l$^{-1}$)</th>
<th>La12 (mmol·l$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tr1 (s)</td>
<td>-0.55$^b$</td>
<td>-0.58$^b$</td>
<td>-0.56$^b$</td>
</tr>
<tr>
<td>Tr2 (s)</td>
<td>-0.45$^b$</td>
<td>-0.61$^b$</td>
<td>-0.48$^b$</td>
</tr>
<tr>
<td>Tr3 (s)</td>
<td>-0.05</td>
<td>-0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>Tr4 (s)</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.09</td>
</tr>
<tr>
<td>Ot (s)</td>
<td>-0.27</td>
<td>-0.39$^b$</td>
<td>-0.23</td>
</tr>
</tbody>
</table>
Table 2. Prediction equations for lactate concentration in minutes three, seven and 12 (La$_{3,7,12}$) from predictor parameter in the first and second time repetitions (Tr$_1, 2$), and La$_3$ with the corresponding $R^2$ values, $P$ and Durbin-Watson (DW).

<table>
<thead>
<tr>
<th>Predictor [La]</th>
<th>Equation</th>
<th>$R^2$</th>
<th>$P$</th>
<th>DW</th>
</tr>
</thead>
<tbody>
<tr>
<td>La$_3$ (mmol·l$^{-1}$)</td>
<td>Tr$_1$ (s)</td>
<td>0.30</td>
<td>0.001</td>
<td>1.97</td>
</tr>
<tr>
<td>La$_5$ (mmol·l$^{-1}$)</td>
<td>Tr$_2$ (s)</td>
<td>0.37</td>
<td>0.011</td>
<td>1.67</td>
</tr>
<tr>
<td>La$_{3,12}$ (mmol·l$^{-1}$)</td>
<td>La$_3$ (mmol·l$^{-1}$)</td>
<td>0.75</td>
<td>0.001</td>
<td>2.34</td>
</tr>
<tr>
<td>La$_{12}$ (mmol·l$^{-1}$)</td>
<td>Tr$_1$ (s)</td>
<td>0.32</td>
<td>0.001</td>
<td>2.55</td>
</tr>
<tr>
<td>La$_{12}$ (mmol·l$^{-1}$)</td>
<td>La$_3$ (mmol·l$^{-1}$)</td>
<td>0.70</td>
<td>0.001</td>
<td>2.39</td>
</tr>
</tbody>
</table>

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$_{3,7,12}$, lactate concentration in minutes 3, 7 and 12 after the test.

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*Significant at the 0.05. **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$_{1,4}$: 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.
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 La₃ values of 6.40 ± 2.81 mmol·l⁻¹ and La₅ 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 VO₂ uptake. Estimated aerobic contribution in 4 x 30-s was 25 ± 4% and 52 ± 9% in repetitions one and four, respectively, and O₂ uptake was 84 ± 6% of VO₂max 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 VO₂max (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 does 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 VO₂ 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 VO₂ (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 La₃). Opting for La₃, 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; Hofelder 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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References


