*Original article (short paper)*

# The response of the lactate minimum test to a 12-week swimming training

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**Abstract**—Despite the utilization of lactate minimum test (LMT) in training, its intensity response to training remains controversial. The aim of the present study was to verify alterations of LMT intensity in swimmers during a 12-week training protocol. Eight swimmers were submitted to three LMT assessments: beginning of the season, T0; after four, T4; and twelve weeks, T12. The LMT consisted of a 200m maximal effort and, after eight minutes of passive rest, five incremental stages of 200m swimming. The intensities of the incremental stages were defined subjectively ("very light," "light," "moderate," "hard," and "all-out"). The training was divided in two blocks of periodization: endurance training period (ETP, T0 – T4), and quality plus taper period (QTP, T4 – T12). The LMT intensity of T4 and T12 were significantly higher than T0. We conclude that LMT is modified due to swimming training and can be used for training prescription and detection of aerobic capacity alterations during a season.

Keywords: lactate minimum intensity, swimming, training prescription

**Resumo**—"Resposta do teste de lactato mínimo à 12 semanas de treinamento de natação." Apesar da comum utilização do teste de lactate mínimo (LMT) no treinamento, a sensibilidade da sua intensidade permanece controversa. O objetivo do presente estudo foi verificar alterações da intensidade do LMT em nadadores durante 12 semanas de treinamento. Oito nadadores foram submetidos à três avaliações LMT: começo da temporada, T0; após quatro, T4; e doze semanas, T12. O LMT consistiu em nadar 200m em esforço máximo, e após oito minutos de repouso passivo, cinco estágios incrementais de 200m. As intensidades dos estágios incrementais foram definidas subjetivamente ("muito fraco," "fraco," "moderado," "forte" e "máximo"). O treinamento foi dividido em dois blocos de periodização: período de treinamento de *endurance* (ETP, T0 – T4), e período específico mais polimento (QTP, T4 – T12). A intensidade do LMT em T4 e T12 foi significantemente maior que T0. Concluímos que o LMT é modificado com o treinamento de natação e pode ser usado na prescrição de treinamento e detecção de alterações da capacidade aeróbia durante a temporada.

Palavras-chave: intensidade de lactato mínimo, natação, prescrição de treinamento

**Resumen**—"La respuesta del test de lactato mínimo de 12 semanas de entrenamiento de natación." A pesar de la utilización de lo test de lactato mínimo (LMT) en el entrenamiento, la respuesta de su intensidad sigue siendo controvertido. El objetivo de este estudio fue investigar los cambios en la intensidad de LMT en nadadores durante 12 semanas de entrenamiento. Ocho nadadores fueron sometidos a tres evaluaciones LMT: comienzo de la temporada, T0; después de las cuatro, T4; y doce semanas T12. El LMT consistió en 200m natación de máximo esfuerzo, y después de ocho minutos de descanso pasivo, cinco etapas incrementales de 200m. Las intensidades de las fases incrementales fueron definidos subjetivamente (“muy débil,” “débil,” “moderada,” “fuerte” y “máxima”). La formación se dividió en dos bloques de periodización: período de entrenamiento de *endurance* (ETP, T0 – T4), y período específico más pulido (QTP, T4 – T12). La intensidad del LMT en T4 y T12 fue significativamente mayor que T0. Concluimos que el LMT es modificado con el entrenamiento de natación y puede ser utilizado en la prescripción de al entrenamiento y la detección de cambios en la capacidad aeróbica durante la temporada.

Palabras claves: intensidad del lactato mínimo, natación, prescripción de entrenamiento

## Introduction

Some authors have verified that the exercise intensity determined through the lactate minimum test (LMT) (Tegtbur, Busse, & Braumann, 1993) corresponds to the maximal lactate steady state (Knoepfli-Lenzin & Boutellier, 2011; Pardono *et al.*, 2008; Sotero, Pardono, Campell, & Simões, 2009), and can be considered aerobic indexes (Pardono *et al.*, 2008; Sotero *et al.*, 2009). Essentially, the LMT is composed by three phases: (i) a maximal effort to induce hyperlactatemia, (ii) an 8-min recovery period, and (iii) a graded exercise test (GET) (Tegtbur *et al.* 1993). The GET of the LMT starts when the athlete has a high blood lactate concentrations ([Lac]). During the first stages of GET, the high [Lac] drops because of the low intensity of exercise (i.e. lactate clearance is higher than production). In fact, the substrate is being used to produce energy, but then it increases again as a result of the lactate appearance being greater than its removal, once a minimum level is reached. The LMT intensity is represented by this minimum level and is objectively determined by a horizontal line tangent to a cubic spline fit to the exercise blood lactate data.

The main advantages of using the LMT in individual and collective sports modalities are the determination of anaerobic and aerobic parameters in a single evaluation (Pardono *et al.*, 2008, Ribeiro, Gonçalves, Kater, Lima, & Gobatto, 2009), and the fact that the LMT is not changed by neither the alteration of the hyperlactatemia induction method (Johnson & Sharpe, 2011; Smith, Balmer, Coleman, Bird, & Davison, 2002) or the nutritional condition (Voltarelli, Mello, & Gobatto, 2004). Despite these advantages, the LMT has been criticized for not showing sensitivity to aerobic training (Carter, Jones, & Doust, 1999). It is important to point out that Carter *et al.* (1999) used the same intensities in the stages of GET before and after 6 weeks of aerobic training. According to Pardono *et al.* (2008), low intensities at the beginning of GET might increase the lactate clearance promoting a left displacement of the curve between [Lac] versus intensity. Furthermore, the active recovery used in Carter’s study (Carter *et al.*, 1999) after the induction of hyperlactatemia seems to underestimate the LMT intensity (Ribeiro *et al.*, 2009). On the other hand, even when using the same intensities during the GET before and after training, passive recovery occurs in the second phase of the LMT. Silva, Bonette, Santhiago, and Gobatto (2007) verified that an 8-week soccer training program increased both the LMT intensity and the LMT [Lac].

Based on these two investigations showing contradictory results about the training effects on the LMT intensity, it is possible to consider that the LMT changes due to training remain unclear. Thus, the main aim of the present investigation was to verify the alterations of the LMT intensity during a 12-week swimming training program.

## Methods

### *Participants*

Eight swimmers (4 male and 4 female) with mean age of 15.15 years (± 1.86), height of 165.76 cm (± 8.62), and total body mass of 59.53 kg (± 11.75), volunteered to participate in this investigation. All the participants had at least two years of swimming training experience, and trained approximately 7000 $m \cdot day^{-1}$, with a frequency of 5 $day \cdot week^{-1}$. The modalities and competitive performance of the participants are presented in Table 1. All participants were athletes of state and regional level, and their personal best performance was ≈ 90% of state record. All procedures were approved by the University’s Institutional Review Board for Human Subjects (Human Research Ethics Committee) and were conducted according to the Declaration of Helsinki. Athletes and their parents, when pertinent, were informed about experimental procedures and risks, and signed an informed consent before their participation in the study.

### *Experimental design*

The swimmers were evaluated at the beginning (i.e. week 0; T0), after 4 weeks (T4) and at the end (i.e. week 12; T12) of the swimming training program on the same hour of the day. The 12-week swimming training program was set by the team coaches and was not influenced by the experimental study. Before T0 the participants were training normally, since T0 was defined as the end of a training period and beginning of a new one. Participants were instructed not to engage in strenuous activity the day before an exercise test and to maintain a consistent routine with regard to training, sleeping and diet throughout the duration of the study. The tests were performed on a 25-m swimming pool with water temperature of 25 ± 2ºC. This temperature is more comfortable than values near 30ºC (Yazigi *et al.*, 2013).

Table 1. Individual competition performance (seconds) of each athlete during the T0, T4, and T12.

| Athletes | Modality | Time (T0) | Time (T4) | Time (T12) |
|---|---|---|---|---|
| 1 | 200m medley | 148.08 | 145.75 | 150.80 |
| 2 | 400m freestyle | 327.55 | 328.34 | 313.76 |
| 3 | 400m freestyle | 273.10 | 268.50 | 245.31 |
| 4 | 400m freestyle | 282.00 | 275.64 | 283.01 |
| 5 | 200m breastroke | 198.53 | 197.33 | 202.46 |
| 6 | 50m butterfly | 29.66 | 26.11 | 25.88 |
| 7 | 200m medley | 174.29 | 172.39 | 166.53 |
| 8 | 100m freestyle | 74.25 | 73.55 | 70.48 |

*Lactate minimum test (LMT)*

The LMT was adapted to the procedures reported by Tegtbur *et al.* (1993). Before beginning the LMT, the swimmers performed a warm up consisting of approximately 1 000-m free style swimming of low to moderate intensity, determined subjectively by the participants. The same warm up was performed in all moments of assessment. Next, the swimmers performed a maximal front crawl swimming of 200m to elicit hyperlactatemia followed by 8-min recovery period. At the 5th and 7th min of the passive recovery period, blood samples were collected from the earlobes of the swimmers in 25-μl heparinized capillary tubes to measure their peak blood lactate concentrations ([La]peak) using a blood lactate analyzer (Yellow Springs Instruments, Yellow Springs, OH, USA). Next, the swimmers initiated the GET consisting of five progressive efforts of 200m with 1-min passive recovery between each for blood samples collection and [Lac] determinations as previously mentioned. The athletes were instructed by their coaches to perform the five efforts of the GET at intensities corresponding to "very light," "light," "moderate," "hard," and "all-out." The LMT intensity was determined for the three moments (i.e., T0, T4, and T12) through the application of a second order polynomial function. The LMT intensity was assumed as the nadir of the relationship between swimming intensity and [La] of all the five stages of GET.

*Swimming training*

The training periodization was divided in endurance training period (i.e., ETP, from T0 to T4), and quality plus taper periods (i.e., QTP, from T4 to T12). The training session intensities were based on the LMT intensity and were adjusted to the interval training according to Madsen and Lohberg (1987). As proposed by Maglischo (1999), the training sessions were performed in intensities below the LMT (End1), at the LMT (End2), and above the LMT (End3). The swimming series performed above the LMT were classified as aerobic training (End3), lactate tolerance training (V1), and speed training (V2).

A total of 51 training sessions were monitored. The quantification of training was established analyzing the training volume (i.e. meters) performed by the swimmers in each intensity zone described above (Figure 1). The total volume performed during ETP and QTP are described in Table 2 for End1, End2, End3, V1 and V2

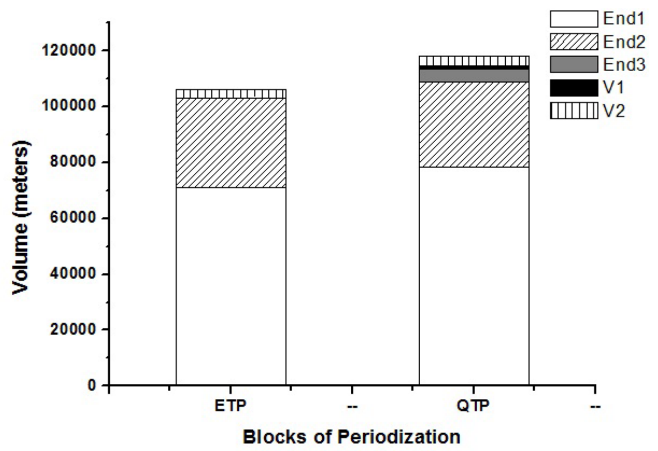


Figure 1. Training intensity distribution for each block of periodization. The bars indicate the volume swam in each zone's intensity. The white bars indicate the volume at End1; the diagonal dashed bars indicate the volume at End2; the filled gray bars indicate the volume at End3; the filled black bars indicate the volume at V1; and the vertical dashed bars indicate the volume at V2, as proposed by Santhiago *et al.* (2011).

was 71.150, 32.000, 0, 100, and 2.950m, respectively. Moreover, the total volume performed during QTP at End1, End2, End3, V1 and V2 was 78.475, 30.400, 4.500, 1400, and 3.425m, respectively.

*Statistical analysis*

The sphericity was analyzed by the Mauchly's test, and, when necessary, corrected by the Greenhouse-Geisser's test. The ANOVA one-way for repeated measures with the Bonferroni *post hoc* test were used to verify the differences between the analyzed parameters during T0, T4, ant T12. The significance level was set at 5%. For the analysis, the SPSS 13.0 for Windows was utilized.

## Results

The mean speed values of the 200m maximal effort at T0, T4, and T12 were 1.3 ± 0.1 $m \cdot s^{-1}$, 1.4 ± 0.1 $m \cdot s^{-1}$, and 1.4 ± 0.1 $m \cdot s^{-1}$, respectively. The [La]peak measured after the maximal front crawl swimming of 200m used to elicit hyperlactatemia during the LMT did not present significant alterations during T0 (i.e., 9.79 ± 3.01mM), T4 (i.e., 9.90 ± 3.46mM) and T12 (i.e., 11.47 ± 3.39mM) ($p$ = .07). Table 3 shows the absolute values and relative values - expressed as percentage of the maximal effort of 200m - of the intensities of each stage of the GET during T0, T4, and T12. Although the absolute intensities of the 1st, 2nd, 3rd, 4th, and 5th stages of the GET measured in T0 were 9, 11, 5, 5, and 6% higher compared to T12, no differences were observed for the relative values.

Table 2. Total volume (meters) performed during endurance training period (ETP), and quality training period (QTP).

| | End 1 | End 2 | End 3 | V1 | V2 |
|---|---|---|---|---|---|
| ETP | 71150 | 32000 | 0 | 100 | 2950 |
| QTP | 78474 | 30400 | 4500 | 1400 | 3425 |

Table 3. Mean ± standard deviation of the absolute values and relative values—expressed as percentage of the maximal effort of 200m—of the intensities of each stage of the GET during T0, T4, and T12.

| | 1st Stage | 2nd Stage | 3rd Stage | 4th Stage | 5th Stage |
|---|---|---|---|---|---|
| Absolute Values ($m.s^{-1}$) | | | | | |
| T0 | 1.0 ± 0.1 | 1.1 ± 0.1 | 1.1 ± 0.1 | 1.2 ± 0.1 | 1.2 ± 0.1 |
| T4 | 1.0 ± 0.1 | 1.1 ± 0.1 | 1.2 ± 0.1 | 1.2 ± 0.1 | 1.3 ± 0.1 |
| T12 | 1.1 ± 0.1* | 1.2 ± 0.1* | 1.2 ± 0.1* | 1.2 ± 0.1* | 1.3 ± 0.1* |
| Relative Values (%) | | | | | |
| T0 | 75.5 ± 5.1 | 80.1 ± 5.7 | 85.7 ± 6.8 | 87.8 ± 5.6 | 91.5 ± 6.6 |
| T4 | 76.0 ± 4.5 | 80.3 ± 4.2 | 85.7 ± 4.8 | 89.4 ± 4.1 | 96.2 ± 5.2 |
| T12 | 77.9 ± 8.7 | 85.3 ± 5.4 | 87.7 ± 4.6 | 90.0 ± 6.4 | 94.8 ± 6.5 |

Table 4. Mean ± standard deviation of the lactate minimum test (LMT) intensity, LMT intensity expressed as percentage of the maximal effort of 200m (LMT%), and blood lactate concentration corresponding to the LMT intensity ([La]-LMT) during T0, T4, and T12.

| | T0 | T4 | T12 | *p* value |
|---|---|---|---|---|
| LMT ($m \cdot s^{-1}$) | 1.1 ± 0.1 | 1.1 ± 0.1* | 1.22 ± 0.1* | .003 |
| LMT % | 82.8 ± 4.5 | 84.7 ± 3.8 | 87.07 ± 6.3 | .008 |
| [La]-LMT (mM) | 5.1 ± 2.5 | 4.6 ± 1.6 | 5.02 ± 2.8 | .060 |

* Significantly different from T0 ($p < .05$)

The LMT intensity measured in T4 ($p = .01$) and T12 ($p \leq .001$) increased significantly (i.e., 3.91 ± 3.48% and 6.69 ± 3.18%, respectively) compared to that measured in T0. No change was observed between T4 and T12 ($p = .41$) On the other hand, no differences were observed for the other analyzed parameters (Table 4).

## Discussion

The main finding of the present investigation was that the LMT intensity was partially changed during the 12-week swimming training program, since no alteration was found between T4 and T12. However, we did not find significant alteration in [La]-LMT during the same period. No significant differences were observed between the absolute intensities of stages during the GET between T0 and T4. This result highlights two important results of study. The first is related to the athlete's capacity in performing progressive efforts subjectively, which reduces the need of a previously incremental exercise to determine intensities of GET (Sotero *et al.*, 2009). Together with the improvement of LMT intensity measured in T4, other important finding is the response of LMT to training becoming a useful tool to training prescription and evaluation.

The LMT proposed by Tegtbur *et al.* (1993) is used in different modalities for aerobic capacity evaluation (Knoepfli -Lenzin & Boutellier, 2011; MacIntosh, Esau & Svedahl, 2002; Pardono *et al.*, 2008; Silva *et al.*, 2007; Simões *et al.*, 2009; Sotero *et al.*, 2009). On the other hand, the response of the test to training has been questioned (Carter *et al.* 1999). Carter *et al.* (1999) verified improvements in maximal lactate steady state, without alteration in LMT after six weeks of mixed continuous (at anaerobic threshold intensity) and interval (above anaerobic threshold intensity) aerobic training and concluded that the LMT is not sensitive to training effects. However, Silva *et al.* (2007) verified that an 8-week soccer training program increased both the LMT intensity and the LMT [Lac]. In the current investigation, the mean increases in LMT intensity of 3.91 ± 3.48% and 6.69 ± 3.18% between T0 and T4, and T0 e T12, respectively are in contrast to Carter's study (Carter *et al.*, 1999), but in accordance with Silva's data (Silva *et al.*, 2007).

It is possible to consider that the type of recovery used after the hyperlactatemia by Carter *et al.* (1999) may have influenced their results, since Ribeiro *et al.* (2009) have found that recovery exercises at 30% and 50% of maximal oxygen consumption ($VO_2max$) after the maximal effort underestimated the LMT intensity compared with passive recovery. According to these authors (Ribeiro *et al.*, 2009), the active recovery would lead the [La] at the first stage close to rest values, becoming the U-shaped curve similar to single graded exercise test (Ribeiro *et al.*, 2009). In addition, as shown by Carter *et al.* (1999), six weeks of training decrease the [La]peak after the induction of hyperlactatemia with exercise performed at the same intensity (≈120% $VO_2max$, 6.8 ± 1.8 vs. 5.3 ± 1.2 $mmol \cdot l^{-1}$; $p < .05$). This modification would also influence the maintenance of LMT intensity after training, since Donovan and Brooks (1983) verified that physical training reduce the [La] at a maximal effort due to higher lactate clearance and oxidation, as well gluconeogenesis. In addition, the lactate removal during the hyperlactatemia and GET could increase after training, since Carter *et al.* (1999) have also found a significantly decrease in [La]-LMT (2.4 ± 1.5 vs. 1.5 ± 0.8 $mmol \cdot l^{-1}$; $p < .05$) after training, while the present study did not present any difference between [La]-LMT.

Although the LMT intensity increased from T0 to T4, we did not verify significant alterations between T4 and T12. In accordance, Tubekis, Tsami, Similios, Douda, & Tokmakidis (2011) did not find any alteration in the anaerobic threshold in the last 7 weeks of training during a 14-week swimming training program. However, these authors considered that the anaerobic threshold increase during the quality phase of training is more dependent on intensity than volume of training (Tubekis *et al.*, 2011). In the present study, during the last eight weeks of training, the total volume was reduced, but the distance performed in elevated intensities was increased; however, the LMT intensity in T4 was not different compared to T12. According to Soultanakis, Mandaloufas, and Platanou (2012), the high intensity training is not associated with anaerobic threshold increase, but is associated with swimming performance increase. However, anaerobic threshold is usually well related with performance, including in swimming (Altimari, Altimari, Gulak, & Chacon-Mikahil, 2007), evidencing that LMT intensity improvement might be related with training type.

We consider that the main limitation of the present investigation was not evaluating the effects of quality and taper periods in isolation. It is possible that the lack of evaluation at the end of the quality period may have influenced the lack of significant alteration in LMT intensity between T4 and T12. Moreover, although the LMT protocol responded to swimming training, the subjective increment during the GET must be more investigated.

According to the present data, it is possible to conclude that the LMT is partially responsive to swimming training, since it is dependent of training characteristic. Moreover, it can be used to evaluate the aerobic capacity, and to prescribe aerobic and anaerobic training during swimming training programs. The LMT intensity may be used as a boundaries between the moderate (below LMT intensity), heavy (at LMT intensity), and severe (above LMT intensity) intensity, and thus, enable the use of this speed to aerobic (i.e., moderate and heavy domain) and anaerobic (i.e., severe domain) training on swimming. Future studies from our research group will evaluate the effects of swimming training phases in isolation and their possible relations with free swimming performance alterations.

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