High intensity interval training series as indices of acidosis tolerance determination in swimming anaerobic performance prediction

Rafael Deminice[1], Lucas Gabarra[1], Arthur Rizzi[2] and Vilmar Baldissera[1]

ABSTRACT

The aim of the present study was to determine the acidosis tolerance through one high intensity interval swim serie and to relate with anaerobic threshold speed (ATS), blood lactate peak concentration ($[Lac]_{peak}$), anaerobic work capacity (AWC), stroke rate (SR), stroke length (SL) and stroke index (SI) in swimming 100 m performance prediction. Ten swimmers performed six maximal swims along 100 m by crawl style with 6 minutes for a rest. Blood samples were taken 5 minutes before each swim for lactate analyses ([Lac)]. Through the division of the [Lac] for the time to complete the 6 swims, was determined acidosis tolerance (AT). The numbers of strokes in the six efforts were taken for SR, SL and SI determination. A maximal 100 m swim was considered as performance parameter (P100) and blood samples were taken for blood lactate peak concentration determination ($[Lac]_{peak}$). Three progressive efforts along 400 m were accomplished for ATS determination corresponding to 3.5 mM lactate fixed concentration; 200 and 400 m maximal efforts were accomplished for AWC determination by linear regression (linear coefficient). The results showed significant correlations ($p < 0.05$) of AT with ATS ($r = 0.77$), $[Lac]_{peak}$ ($r = 0.81$), SL ($r = 0.85$) and SI ($r = 0.84$). Moreover, P100 was correlated with ATS ($r = 0.88$), AT ($r = 0.95$), $[Lac]_{peak}$ ($r = 0.77$), SL ($r = 0.97$) and SI ($r = 0.96$). It was concluded that AT determined through a high intensity training series appears to be useful to anaerobic fitness determination and 100 m swim performance prediction, besides suffer SL and SI influence.

Keywords: Swimming. Interval training. Acidosis tolerance. Stroking parameters. Performance.

INTRODUCTION

Contrary to what occurs with the intensities determination methods for aerobic training, the methodologies for measuring anaerobic variables are not well-developed[1-2]. Such fact exposes a problem, since the majority of swimming events requires a significant contribution both of aerobic and anaerobic ways (50 to 400 m events with 25 s to 4 min of duration). Maglischo[3] suggested as an evaluation method to the anaerobic capacity the determination of the blood lactate concentration after maximal efforts, where low values of lactate, joined with unsatisfactory results, could indicate the deterioration of such capacity. These peak blood lactate ($[Lac]_{peak}$) levels can also be an excellent indicator of the energy derived from the anaerobic glycolysis during effort and an important tool for identifying the contribution of anaerobic mechanisms in specific swimming events[4-5]. Nevertheless, during competitive performance, not only the ability to produce but also keep high levels of blood lactate during the last meters of the event is associated with its success. Holroyd and Swanwick[6] proposed that the tolerance rate to lactate, defined as the velocity difference between the blood lactate concentration of 5 to 10 mM in the progressive test, can be used to monitor the changes derived from the anaerobic training. Pyne *et al.*[7] making use of this methodology, concluded that the relationship between lactate tolerance and performance reflects in specific alterations in high intensity training.

For training the tolerance to acidosis, Maglischo[3] suggests interval sets with distances between 75 and 200 m in maximal velocities or very close to the maximal ones, since they should be sufficiently long and intense so that severe acidosis occurs. According to Seiler and Hetlelid[8], the main aim of the high intensity interval training is to accumulate a good training rhythm in high intensities, which could not be kept in a constant effort. Studies have shown that 4 to 6 weeks of this kind of training are sufficient to improve the buffering capacity, increase the neural activation and blood lactate concentration[9], improve performance of cyclists[10], and increase pain tolerance caused by acidosis[3]. Deminice *et al.*[11] in a recent study, found significant correlations between performance time versus blood lactate concentration obtained through an interval training set and 100, 200 and 400 m performances in swimming.

Anaerobic work capacity (AWC) theoretically corresponds to the anaerobic variable of the critical velocity model, being represented by the linear coefficient (intercept-y) and considered a non-invasive and of easy application method for the evaluation of anaerobic capacity. This variable has been studied as a predictor of anaerobic skill[2], sensibility to the high intensity interval training[12], intense training[13], resisted training[14], and also as predictor of success in swimming[1,15]. Nonetheless, these authors evidenced the need of new research dedicated to investigate the use of the AWC as a prediction index of performance and anaerobic skill in swimming due to the high incidence of controversial results in the literature.

Swimming mechanics also plays a crucial role in the myriad of factors which determine performance. For this reason, these technical variables have been the target of many studies on swimming[16-20]. These authors report that performance in swimming is shown by a good variability of stroke length (SL) and stroke rate (SR), giving a good indication of the mechanical efficiency, and being very useful for the evaluation of the energy savings and especially the swimming technical individual progress during trainings or events. Alberty *et al.*[20] when studying the changes in stroke of front crawl under exhaustion conditions, concluded that such alterations have straight relationship with the athlete's muscular resistance, being one of the factors which influences stroke parameters the most and limits swimming high velocity maintenance during the event.

Thus, few authors have studied the use of lactacidemia in high intensity interval training sets as a way to determine acidosis-tolerance, its capacity to reflect anaerobic skill and its possible associations with technical skill in athletes' performance prediction in swimming.

1. Laboratório de Fisiologia do Exercício/UFSCAR.
2. Laboratório de Fisiologia e Nutrição Experimental/UNAERP.

Approved in 22/11/06.

Correspondence to: Rafael Deminice, Rua Arnaldo Victaliano, 971, Iguatemi – 14091-220 – Ribeirão Preto, SP, Brazil. E-mail: deminice@ig.com.br

The aim of the present study was to determine acidosis tolerance (AT) in competitive swimmers through a set of high intensity interval swims and to relate them with the anaerobic threshold velocity (VLan), peak blood lactate concentration ($[Lac]_{peak}$), anaerobic work capacity (AWC), stroke rate (SR), stroke length (SL) and stroke index (SI) in the prediction of 100 m swimming performance.

MATERIAL AND METHODS

Participants

The sample consisted of 10 swimmers who voluntarily participated in the present study (eight males and two females), age range of 16.2 ± 1.8 years, 65.3 ± 10.1 Kg of body mass, 1.70 ± 8.6 m of height and 1.74.5 ± 9 m of wingspan. They were members of the swimming team of the Portuguese Sports Society of Ribeirão Preto-SP. After the research project had been approved by the Ethics in Research Committee of the University of Ribeirão Preto, the volunteers were informed about the aims and possible risks involved in the study, and signed a consent form. The athletes performed regular training, have participated in state competitions for more than three years and were familiarized with the high intensity interval training sets within the training routine.

Procedures

The study was performed in a semi-Olympic swimming pool (25 x 12 meters), of the Portuguese Sports Association (Ribeirão Preto-SP), with water temperature of 27°C ± 1°C.

Three days of tests in front crawl style were performed with interval of at least 48 hours between them. Prior to each test, the swimmers performed a standardized warm-up period of approximately 1000 m in crawl.

Determination of the anaerobic threshold velocity (VLan)

In order to determine the VLan, the swimmers were submitted to three progressive efforts of 400 meters in the corresponding intensities to 85, 90, and 100% of maximal velocity for the distance. A three-minute interval was performed between each swim. The three trials were initiated with exits from the water. The participants were verbally motivated during the entire test and received gesture information in order to control their swimming intensity. Blood samples were collected (25 µl from the earlobe) one minute after the end of each swim and one, three and five minutes after the end of the test for lactacidemia analysis. Mean velocity and blood lactate concentration were calculated for each swim. The anaerobic threshold velocity (VLan) was assumed as the swimming velocity corresponding to the steady concentration of 3.5 mM of lactate in the ratio lactate versus velocity by adjustment of exponential growth curve[21].

Determination of the acidosis tolerance (AT)

For the AT determination, 6 maximal swims of 100 m with a 6-minute interval between them were performed. Blood samples were collected five minutes after each swim and in the third and fifth minutes after the end of the set for lactacidemia analysis. The athletes were verbally motivated during the entire test in order to guarantee the performance of the maximal effort (adapted from Maglischo[3] and Santiago *et al.*[22]). The AT corresponded to the ratio between the mean value of blood lactate ([Lac]) and the time for 100 m (t) of the six swims performed (equation 1).

$$AT = \Sigma([Lac]/t)/6 \qquad \text{(equation 1)}$$

Determination of the 100 m performance (P100) and peak lactate concentration in 100 m ($[Lac]_{peak}$)

A 100 m maximal effort was performed 48 h prior to the tests mentioned above. The mean velocity to complete 100 m was adopted as performance parameter (P100). Blood samples were collected one, three and five minutes after swimming. The highest value found among the three samples was considered as the peak blood lactate concentration ($[Lac]_{peak}$).

Blood samples

25 µl of blood from the earlobe were collected for measurement of lactate concentration [Lac]. The samples were stored in 1.5 ml Eppendorf tubes containing 50 µl of sodium fluoride at 1% (NaF). The compound was analyzed in an electro-chemical laximeter, YSI model 1500 Sport (YSI, Ohio, EUA). Lactate concentrations were expressed in mM.

Determination of the anaerobic work capacity (AWC)

In order to determine the AWC, 200 and 400 m maximal efforts were performed. The distance and time values to complete the efforts were submitted to linear regression procedure (distance-time model). The linear coefficient (intercept-y) represented the anaerobic work capacity as proposed by Wakayoshi *et al.*[23].

Determination of the stroke parameters (SR, SL and SI)

In order to determine the stroke rate (SR), stroke length (SL) and stroke index (SI), in the AST test, the number of strokes (ns) performed at each 25 m was registered for the total of 100 m of each swim. The stroke length (SL) was determined by the ratio between the distance (d) and the number of strokes (equation 2). The swimming velocity (V) was calculated from the ratio between the 100 m distance (d) by the time to complete it (t) (equation 3). The stroke rate (SR) corresponded to the V ratio by the SL (equation 4). The stroke index (SI) was calculated according to Costill *et al.*[24], by the V product by the SL (equation 5). The SR, SL and SI were determined in the six 100 m swims for all athletes.

$$SL = d/ns \qquad \text{(equation 2)}$$

$$V = d/t \text{ in } 100 \text{ m} \qquad \text{(equation 3)}$$

$$SR = V/SL \qquad \text{(equation 4)}$$

$$SI = V \times SL \qquad \text{(equation 5)}$$

Statistical analysis

The values are expressed in mean ± standard deviation. A *Pearson* correlation test was used in order to verify possible associations between AT and P100. Such test was also used to verify associations of the TA and P100 parameters with VLan, AWC, $[Lac]_{peak,}$ *SR*, SL and SI. ANOVA for repeated measurements with *Tukey* post-hoc test was used in order to evaluate possible differences in the performance time, SR, SL and SI in the swims of the acidosis tolerance set. In all cases the significance level was preset for $p \leq 0.05$.

RESULTS

Figure 1 demonstrates the lactacidemia behavior during the AT test. The mean of blood lactate concentration reached by the athletes in the six swims was of 13.5 ± 1.6 mM. The high concentrations of blood lactate reached as well as the velocities above to VLan in the six performed swims demonstrate the anaerobic profile of the proposed set. The blood lactate concentration of the first swim (9.6 ± 2.5 mM) was significantly lower than the ones found from the second to the sixth swim (13 ± 2.4; 14.5 ± 4.6; 14.3 ± 3; 14.4 ± 2.8 and 14.3 ± 2.6 mM, respectively) and in the third and fifth minutes of rest (14.1 ± 3.9 and 13.6 ± 2.7 mM, respectively). Lactacidemia stabilization was observed from the second swim until the rest values (figure 1).

Figure 2 represents the stroke parameters behavior during the AT test. Concerning the SR, a significant decrease from the first (35.8 ± 1.1 cycles/min) to the second swim (33.4 ± 1.7 cycles/min), and later stability from the third to the sixth swim (32.7 ± 1.9;

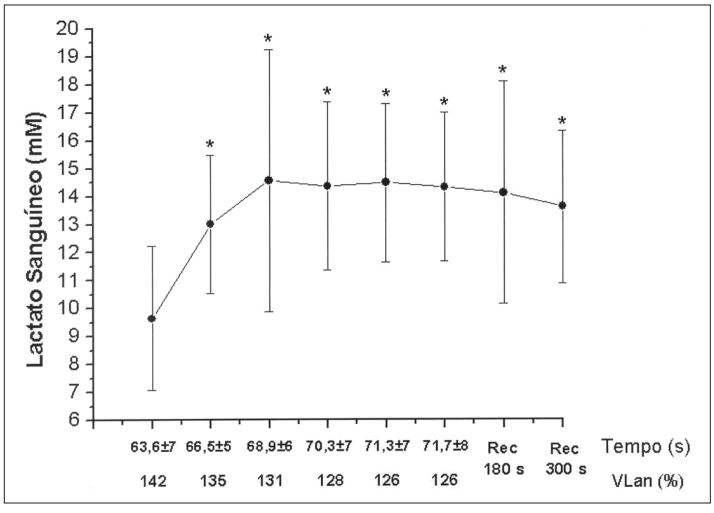

Figure 1 *– Lactacidemia behavior concerning time of execution of each 100 m swimming (mean ± SD) and intensity concerning VLan (%) during the acidosis tolerance test and in 3 and 5 minutes of recovery (Rec) (*: significant difference (p < 0.05) concerning the first 100-meter swim).*

32.6 ± 1.4; 32.6 ± 2.2 and 32.9 ± 2 cycles/min, respectively) were observed. The contrary was observed for the SL, which increased from the first (2.66 ± 0.2 m/cycle) to the second swim (2.72 ± 0.3 m/cycle) and later significantly decreased in the end of the test concerning the first swim (2.69 ± 0.2; 2.65 ± 0.3; 2.62 ± 0.3 and 2.58 ± 0.3, m/cycle, respectively from the third to the sixth swim). From the third swim on, the SI significantly decreased concerning the two first swims and this decrease successively continued until the least swim (4.27 ± 0.7; 4.15 ± 0.7; 3.96 ± 0.7; 3.83 ± 0.7; 3.74 ± 0.7 and 3.66 ± 0.7, respectively from the first to the sixth swim) (figure 2).

Positive significant correlation of the AT with VLan, $[Lac]_{peak,}$ SL and SI was found. The P100 was strongly correlated with the AT, besides the positive significant correlations concerning VLan, $[Lac]_{peak}$, SL and SI (table 1).

TABLE 1
Pearson correlation values (r) among the acidosis tolerance (AT), performance in 100 m (P100), anaerobic threshold (VLan), peak blood lactate concentration ($[Lac]_{peak}$), anaerobic work capacity (AWC), stroke rate (SR), stroke length (SL) and stroke index (SI) variables

	AT	VLan	$[Lac]_{peak}$	AWC	*SR*	SL	SI
TA		0.77*	0.81*	0.15	–0.49	0.85*	0.84*
P100	0.95*	0.88*	0.77*	0.03	0.02	0.97*	0.96*

* p < 0.05

DISCUSSION

High intensity interval training sets have two main aims: to increase the swimming velocity, which will allow swimmers start and finish the events faster and to improve the buffering capacity, so that the swimmers are able to keep their velocities during the competition despite the accumulation of lactic acid[3]. These two aims united refer to the anaerobic capacity[25]. Thus, the importance of the anaerobic metabolism for speeders becomes evident, since high swimming velocities cannot be reached without high rates of anaerobic glycolysis. However, the period in which the athletes can sustain such high anaerobic metabolism rates may limit their performance. The high intensity interval training exercises increase the activity of monocarboxylate proteins transporters of lactate (MCT1 and MCT4) through the muscular membrane, which enables a faster appearance of lactate in the blood[26]. This kind of training also works by increase of the buffering capacity in the muscles and blood as well as by the increase of pain tolerance caused by the acidosis[3]. When the buffering capacity improves, the swimmers are able to keep the fast velocity of lactate production for longer, delaying the decrease in the swimming velocity, one of the possible adaptations produced by the tolerance to these exercises known as lactate tolerance.

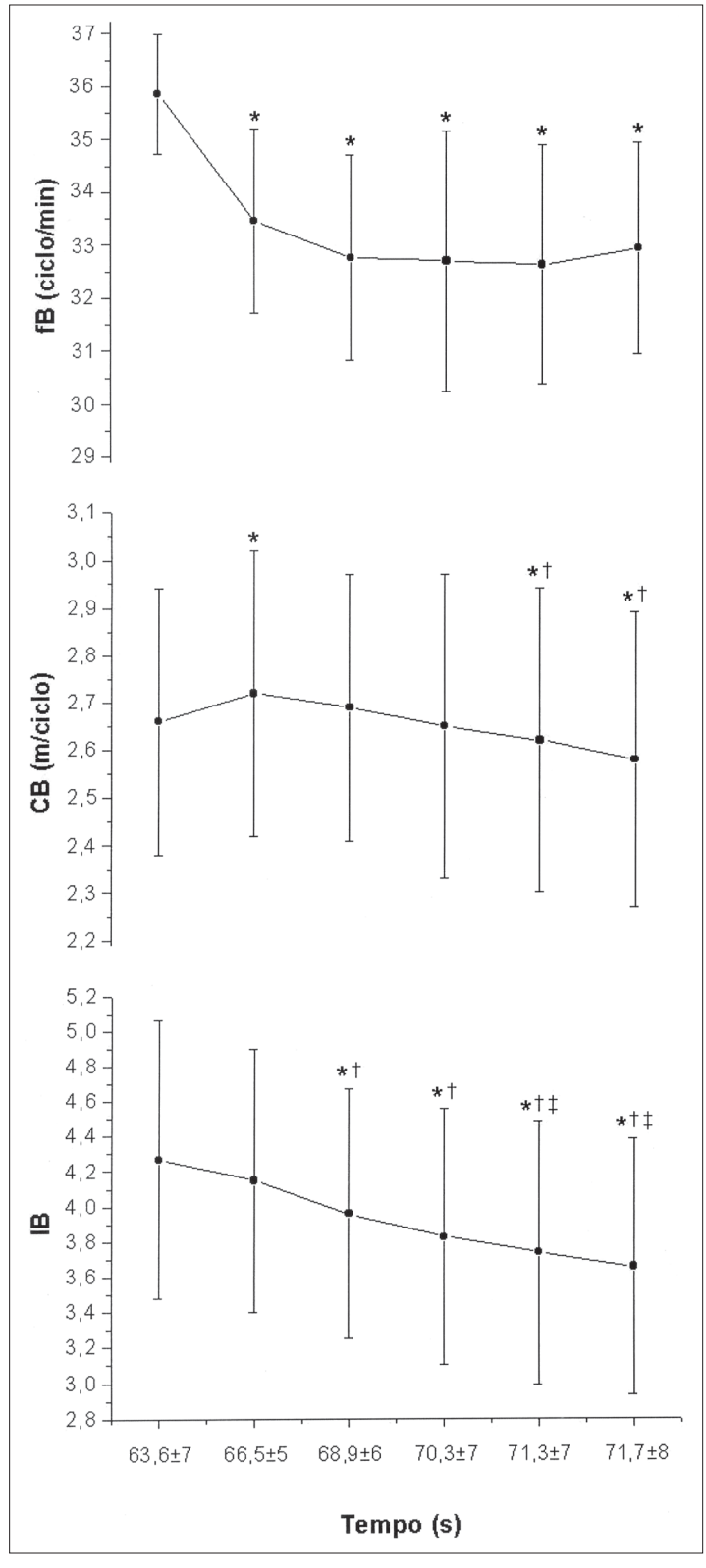

Figure 2 *– Stroke length (SL), stroke rate (SR) and stroke index (SI) behavior concerning the execution time of each 100-m swimming (mean ± SD) in the acidosis tolerance test (*: significant difference (p < 0.05) concerning the first 100 m swim; †: significant difference concerning the second 100 m swim; ‡: significant difference concerning the third 100 m swim).*

In the present study, we proposed a high intensity training routine with six-minute intervals, long enough to allow a high swimming velocity and consequent high levels of lactic acid and at the same time, short enough to guarantee that the muscles will continue in acidosis. The sets of acidosis tolerance, therefore, need to be designated concerning the time swum in high levels of lactate[3]. The high blood lactate concentrations after the swims and the stabilization of the lactate curve found during the acidosis tolerance test (figure 1), demonstrate the anaerobic profile of the proposed set. These outcomes confirm that the specific training set proposed directly corresponds to the postulated biomotor component. The significant correlations found of AT with the $[Lac]_{peak}$ and P100, (table 1) demonstrate the applicability of the used set as a determinant of the anaerobic fitness and performance predictor of 100 m swimming. The correlations found between $[Lac]_{peak}$ and P100 confirm the use of this parameter as a performance predictor in swimming[4-5].

Nevertheless, some caution should be taken with the use of these sets of acidosis tolerance during the training season. This kind of training is both physically and psychologically very stressful to the athlete. The athletes' motivation was one of the great difficulties found in the performance of the proposed set in this study. Maglischo[3] highlights that a lot of psychological resistance is needed in order to regularly stand the pain caused by acidosis. Moreover, the intensity of muscular strength required, joined with the intense acidosis produced, may lead to a temporary injury of the muscular tissue. For these reasons, the excessive use of acidosis tolerance training sets may lead to an athlete's supertraining state damaging his performance in the training season.

In order to determine the VLan in the present study, we used a protocol validated by Pereira *et al.*[21], who used the steady concentration of 3,5 mM with the purpose to optimize the tests' time. The use of this concentration is contrary to Heck *et al.*[27] who suggest the steady concentration of 3.5 mM only for protocols with stages with duration of up to 3 min, lower than the ones used in this study (4 to 5 min). The use of the steady concentration of 4 mM, suggested by these authors when the duration of the stages was of 5 minutes, seems to overestimate the VLan in swimming, if the pause between incremental efforts was small, probably due to the existence of residual effects of the metabolism and fatigue specific to the previous stages[21]. The significant correlations of the VLan with the P100 (r = 0,88) and with the AT (r = 0.77) found in this study confirm the use of this methodology as a performance predictor in swimming[28], and demonstrate the importance of the aerobic capacity as grounding for the development of the anaerobic capacity[7]. Improvement in aerobic and anaerobic capacities will reduce the velocity of acidosis installation, delaying fatigue during competition[3].

The great advantage in using indirect methods for evaluating swimmers is mainly concerned with low cost and easy applicability. As mentioned by Papoti *et al.*[1] who did not find associations of anaerobic work capacity with anaerobic fitness and performance in our study, the AWC did not present significant correlation with any of the correlated parameters (table 1). Guglielmo and Denadai[15] did not find correlations between the AWC of swimmers with mean power determined during maximal efforts of 30 seconds in ergometer of isokinetic arm. Dekerle *et al.*[29] did not find significant correlation between AWC and the maximal anaerobic distance in swimmers and suggested the non-use of this parameter to control anaerobic variables. The use of only two maximal efforts (200 and 400 m), as the one used in the present study, may limit the use of the AWC, since small variations in swimming velocity may result in significant alterations in the intercept-y[29]. Toussaint *et al.*[30] highlight that the AWC suffers influence derived both from the aerobic and anaerobic systems, not providing a real estimate of the anaerobic capacity.

Partly confirming the validity of the technical indices for performance prediction, high correlations among the SL, SI and P100 were verified in this study (table 1). The significant correlations among SL, SI and AT demonstrate the importance of the swimmer's technical skill and confirm the relationship between physiological and technical parameters in swimming[16-18,20,24]. These correlations may be explained by the swimmers' difference of skill in performing a higher number of strokes with a better strength application, which is important in the minimization of drag and fatigue decrease, being able to develop strength for a longer time even in high intensity exercises where the accumulation of lactic acid may cause great discomfort and swimmer's efficiency and coordination loss[20]. Thus, the cause for decrease of SL and SI during the set (figure 1) may be attributed to the swimmer's technical skill joined with the his anaerobic skill[19].

The greatest limitation of the present study was the use of a 100 m maximal effort, performed as a competitive simulation in a training environment, as performance parameter (P100). Pyne *et al.*[7] used the International Punctuation System, acknowledged by the FINA (International Amateur Swimming Federation), to evaluate performance in its study with Australian elite swimmers. This system allows the comparison of any performance, regardless of gender or event performed by the athlete. It also reflects the real data of the competition environment, besides the possibility of evaluating and comparing athletes in their specific events.

It seems important to determine both physiological and technical parameters as well as consider its interactions and interrelations in order to establish a good training period according to the swimmer's capacities. However, little scientific data concerning the criteria and possible applications of parameters for determination of the anaerobic skill, joined with technical parameters and their possible relationships with performance in swimming is published.

Through the obtained results, we can conclude that the AT determined from the high intensity interval training set behaved as a useful parameter for determination of anaerobic fitness and predict performance of 100 swimming meters. Moreover, the great influence of the stroke parameters as SL and SI over the AT demonstrate the importance of the swimmer's technical skill regardless his anaerobic fitness.

ACKNOWLEDGMENTS

The authors thank the technician of the Physiology of the Exercise Laboratory of UFSCar, José Carlos Lopes for his help with the samples analysis.

All the authors declared there is not any potential conflict of interests regarding this article.

REFERENCES

1. Papoti M, Zagatto AM, Freitas Jr PB, Cunha AS, Martins LEB, Gobatto CA. Utilização do intercepto-y na avaliação da aptidão anaeróbia e predição da performance de nadadores treinados. Rev Bras Med Esporte. 2005;11(2):126-30.
2. Dekerle J, Brickley G, Hammond AJ, Pringle JS, Carter H. Validity of the two-parameter model in estimating the anaerobic work capacity. Eur J Appl Physiol. 2005;1:1-8.
3. Maglischo EW. Nadando ainda mais rápido. São Paulo: Ed. Manole; 1999.
4. Bonifazi M, Martinelli G, Marugo L, Sardella F, Carli G. Blood lactate accumulation in top level swimmers following competition. J Sports Med Phys Fitness. 1993;33:13-8.
5. Avlonitou E. Maximal lactate values following competitive performance varying according to age, sex and swimming style. J Sports Med Phys Fitness. 1996; 36:24-30.
6. Holroyd AM, Swanwick KM. A mathematical model for lactate profiles and a swimming power expenditure for use in conjunction with it. J Swimming Research. 1993;9:25-31.

7. Pyne DB, Lee H, Swanwick KM. Monitoring the lactate threshold in world-ranked swimmers. Med Sci Sports Exerc. 2001;33:291-7.
8. Seiler S, Hetlelid KJ. The impact of rest duration on work intensity and RPE during interval training. Med Sci Sports Exerc. 2005;37(9):1601-7.
9. Creer AR, Ricard MD, Conlee RK, Hoyt GL, Parcell AC. Neural, metabolic, and performance adaptations to four weeks of high intensity sprint-interval training in trained cyclists. Int J Sports Med. 2004;25(2):92-8.
10. Westgarth-Taylor C, Hawley JA, Rickard S, Myburgh KH, Noakes TD, Dennis SC. Metabolic and performance adaptations to interval training in endurance-trained cyclists. Eur J Appl Physiol Occup Physiol. 1997;75(4):298-304.
11. Deminice R, Gabarra L, Rizzi A, Baldissera V. Série de treinamento intervalado de alta intensidade como índice determinante das performances de 50, 100, 200 e 400m em natação. Rev Bras Ciên e Mov. (suplemento) 2005;13(4):61.
12. Hill DW, Jimmy C, Smith C. A method to ensure the accuracy of estimates of anaerobic capacity derived using the critical power concept. J Sports Med Phys Fitness. 1994;34:23-37.
13. Jenkins DG, Quigley BM. The influence of high-intensity exercise training on the Wlim-Tlim relationship. Med Sci Sports Exerc. 1993;25(2):275-82.
14. Bishop D, Jenkins DG. The influence of resistance training on the critical power function & time to fatigue at critical power. Aust J Sci Med Sport. 1996;28:101-5.
15. Guglielmo LGA, Denadai BS. Correlação do teste de Wingate de braço com a capacidade de trabalho anaeróbio determinada através do conceito de velocidade critica na natação. Motriz (Supl) 1999;5:92.
16. Dekerle J, Nesi X, Lefevre T, Depretz S, Sidney M, Marchand FH, et al. Stroking parameters in front crawl swimming and maximal lactate steady state speed. Int J Sports Med. 2005;26:53-8.
17. Deminice R, Papoti M, Zagatto AM, Prado Júnior MV. Validade do teste de 30 minutos (T-30) na determinação da capacidade aeróbia, parâmetros de braçada e *performance* aeróbia de nadadores treinados. Rev Bras Med Esporte. 2007;13(3): 195-9.
18. Wakayoshi K, Acquisto LJD, Cappaert JM, Troup JP. Relationship between oxygen uptake, stroke rate and swimming velocity in competitive swimming. Int J Sports Med. 1995;16:19-23.
19. Laffite LP, Vilas-Boas JP, Demarle A, Silva J, Fernandes R, Billat VL. Changes in physiological and stroke parameters during a maximal 400 m free swimming test in elite swimmers. Can J Appl Physiol. 2004;29(Suppl):S17-S31.
20. Alberty M, Sidney M, Huot-Marchand F, Hespel JM, Pelayo P. Intracyclic velocity variations and arm coordination during exhaustive exercise in front crawl stroke. Int J Sports Med. 2005:26(6):471-5.
21. Pereira RR, Papoti M, Zagatto AM, Gobatto CA. Validação de dois protocolos para determinação do limiar anaeróbio em natação. Motriz. 2002;8:63-8.
22. Santiago V, Ramos da Silva AS, dos Santos FC, Gobatto CA. Avaliação da tolerância à acidose em nadadoras em três momentos distintos de um ciclo periodizado de treinamento. Rev Bras Ciên Mov. 2004;(edição especial):S192.
23. Wakayoshi K, Yoshida T, Udo M, Harada T, Moritani T, Mutoh Y, et al. Does critical swimming velocity represent exercise intensity at maximal lactate steady state? Eur J Appl Physiol Occup Physiol. 1993;66(1):90-5.
24. Costill D, Kovaleski J, Porter D, Kirwan J, Fielding R, King D. Energy expenditure during front crawl swimming: predicting success in middle-distance events. Int J Sports Med. 1985;6:266-70.
25. Issurin VB, Kaufman LE, Tenenbaum G. Modeling of velocity regimens for anaerobic and aerobic power exercises in high-performance swimmers. J Sports Med Phys Fitness. 2001;41:433-40.
26. Juel C, Klarskov C, Nielsen JJ, Krustrup P, Mohr M, Bangsbo J. Effect of high-intensity intermittent training on lactate and H^+ release from human skeletal muscle. Am J Physiol Endocrinol Metab. 2004;286:E245-51.
27. Heck H, Mader A, Hess G, Mucke S, Muller R, Hollman W. Justification of 4-mmol/l lactate threshold. Int J Sports Med. 1985;6:117-30.
28. Denadai BS. Avaliação aeróbia: determinação indireta do lactato sanguíneo. Rio Claro: Motrix; 2000.
29. Dekerle J, Sidney M, Hespel JM, Pelayo P. Validity and reliability of critical speed, critical stroke rate, and anaerobic capacity in relation to front crawl swimming performances. Int J Sports Med. 2002;23:93-8.
30. Toussaint HM, Wakayoshi K, Hollander AP, Ogita F. Simulated front crawl swimming performance related to critical speed and critical power. Med Sci Sports Exer. 1998;30:144-51.