Validity of 30 minutes test (T-30) in aerobic capacity, stroke parameters and aerobic performance determination of trained swimmers

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ABSTRACT

The aim of the present study was to verify the use of the 30 minutes velocity (VT-30), stroke rate (SR), stroke length (SL) and stroke index (SI), obtained in T-30 test, as non-invasive methods for trained swimmer's aerobic performance and technical determination. Fourteen swimmers accomplished three efforts along 400 m (85, 90 and 100% of the maximum effort) for anaerobic threshold speed determination (ATS) corresponding to 3.5 mM lactate fixed concentration, as well as a 30 minutes maximal effort (VT-30). SR, SL, and SI were calculated within the 10 m midsection of the swimming pool (clean swim) for T-30 test (SRT-30, SLT-30 and SIT-30) and progressive test. Through the relation between ATS and stroke parameters in progressive test, stroke rate threshold (SRT), stroke length threshold (SLT) and stroke index threshold (SIT) were determined. The time to complete 400 m at maximal effort was considered as performance parameter (P400). No significant difference was found between the ATS (1.29 ± 0.07 $m.s^{-1}$) and VT-30 (1.29 ± 0.08 $m.s^{-1}$), along with a correlation ($r = 0.90$). The values of SRT (33.6 ± 4.14 cycles/min) and SRT-30 (34.9 ± 3.53 cycles/min) and of SLT (2.09 ± 0.20 m/cycle) and SLT-30 (2.09 ± 0.20 m/cycle) also had no significant differences. Significant correlations ($p < 0.05$) were also found between VT-30 and P400 ($r = 0.95$); SRT and SRT-30 ($r = 0.73$); SLT and SLT-30 ($r = 0.89$) and SIL and SIT-30 ($r = 0.94$). It was concluded that the VT-30 shows reliability for training monitoring, performance prediction and technical parameters determination in swimmers.

Keywords: Swimming. Anaerobic threshold. Stroking parameters. 30 minutes test. Performance.

INTRODUCTION

The monitoring and assessment of physiological variables and performance in sports training may be factors which determine success of elite swimmers. It is known nowadays that the lactacidemia technique has been a trustworthy and sensitive assessment, prescription and alterations instrument derived from the training state of this modality[1-3]. An analysis of the relationship between blood lactate concentration ([LAC]) versus swimming velocity (V), represented by curves obtained through incremental tests, show improvement, stability or degradation of the aerobic capacity of the swimmer[3].

The determination of the anaerobic threshold (Lan) through the use of the blood lactate concentration identifies the highest exercise intensity in which the ATP resynthesis is performed by the aerobic metabolism[4], which is represented by a parameter of aerobic capacity. Lan has been used for training monitoring[3], prescription of the aerobic training intensity[5-6] and performance prediction of long distance events[2]. However, the determination of the anaerobic threshold using the blood lactate concentration needs specific equipment and has a financial acquisition and operational cost, which is not possible for most swimming teams in Brazil. Moreover, it consists of an invasive test which requires care with hygiene and safety[2], limiting thus, its use in most clubs and fitness centers. Therefore, many researchers try to make less costly and of easy application assessment protocols available, which also precisely and reliably evaluate and monitor training[1-2,6-7].

Olbrecht *et al.*[6] have developed the T-30 test, which consists in moving the longest distance in 30 minutes at regular rhythm from beginning to end of the test. The mean velocity of the T-30 test (VT-30) has been highly correlated with the anaerobic velocity threshold[6,8-11] and with swimming performance[12], which is non-invasive and of easy application.

Nevertheless, the swimming mechanics also plays a crucial role in the myriad of determinant factors of swimming performance and should be considered in the assessments. It has been demonstrated that the dislocation velocity in swimming is the product of the stroke rate (SR) by the stroke length (SL) and variations in the swimming velocity by training and lack of training mainly occur by modifications in SR and SL[13-14]. For this reason, these variables have been the aim of studies on elite swimming[13,15], educational status[16], disabled subjects[17] and for technical analysis between swimmers and triathletes[18].

Costill *et al.*[7] presented the stroke index (SI) as the product of the swimming velocity by the distance completed per stroke cycle, and found significant correlations among oxygen uptake ($\dot{V}O_2$), swimming velocity and this variable. These authors demonstrate that the swimmer's energy cost in crawl depends on the technique of his/her stroke. Keskinen and Komi[19] demonstrated that the relationship between SR and SL is influenced by the increase of the effort intensity. When the swimming velocity is lower than the anaerobic threshold intensity, the swimmers are able to control the velocity and simultaneously keep the stroke length steady. However, when the effort is performed at intensities above the anaerobic threshold, a progressive reduction in SL is observed, this fact being relied on the development of local muscle fatigue. Dekerle *et al.*[8] highlighted that the swimmer should be able to choose the SR corresponding to the lowest energy cost during his event, suggesting hence a relationship between physiological and technical parameters in swimming. Langeani *et al.*[20] demonstrated the occurrence of increase and sudden decrease of SR and SL, respectively, following the lactacidemia behavior in progressive exercise.

Thus, it was shown that dynamic lactate balance may be observed during extensive exercise at intensities corresponding to the Lan[6,21]; hence, this metabolic balance must reflect in the behavior of technical parameters in swimming. However, studies

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which investigated the T-30 in order to relate the mechanical and physiological parameters with the aerobic capacity test and performance of swimmers are still insufficient in the literature. Therefore, the aim of the present study was to verify the use of the VT-30 and stroke parameters (SR, SL and SI) obtained with the T-30 performance as non-invasive instruments in the aerobic capacity assessment, swimming technique and performance prediction of swimmers.

MATERIAL AND METHODS

Participants

Fourteen swimmers (9 males and 5 females), aged range of 15.9 ± 1.9 years, members of the swimming team of Bauru-SP, voluntarily participated in the present study. Prior to the study, the volunteers signed a written consent form approved by the Ethics Committee of the UNESP, Rio Claro.

The athletes performed regular training and have participated in state and national competitions for over three years. General characteristics of the participants are present in table 1.

TABLE 1
General characteristics of the studied athletes (n = 14)

	Weight (kg)	Height (cm)	Wingspan (cm)	Performance 400 m ($m.s^{-1}$)
Mean	62.5	171.1	175.2	1.38
SD	9.1	7.7	9.5	0.09

Procedures

The study was performed in a semi-Olympic swimming pool (25 x 12 meters), of SESI, Bauru-SP (Brazil), with water temperature at 27°C ± 1°C.

Two tests in crawl with 48-hour interval between them were performed. The swimmers previously performed a standardized warm-up period of approximately 1000 m in crawl and at intensity subjectively determined by the athletes and coaches as 'easy'.

Determination of the anaerobic threshold velocity (VLan) and maximal performance in 400 m crawl (P400)

In order to determine the VLan, the protocol validated by Pereira *et al.*[22] was used. In this protocol the swimmers were submitted to three progressive efforts of 400 meters at intensities corresponding 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 encouraged during the whole test and received visual information for swimming intensity control. 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. For each swim, the mean velocity and blood lactate concentration were calculated. The anaerobic threshold velocity (VLan) was assumed as the swimming velocity corresponding to the lactate steady concentration of 3.5 mM in the lactate versus velocity ratio by exponential growth curve adjustment[22].

The 400 m effort performed at 100% was assumed as the 400 m maximal performance parameter (P400).

Determination of the mean velocity in 30 minutes (VT-30)

In the T-30 test, the athletes were told to swim the longest distance possible in 30 minutes. The VT-30 was determined by the ratio between the distance swum (m) and the swimming time (1800 s). Blood collections were performed at one, three and five minutes after the end of the test for lactacidemia analysis.

Blood samples

25 µl of blood were collected from the earlobe for lactate concentration measurement [LAC]. The samples were stored in 1.5 ml Eppendorf tubes containing 50 µl of sodium fluoride at 1% (NaF). The homogeneity was analyzed in an electrochemical YSI lactate meter; model 1500 Sport (YSI, Ohio, USA). Lactate concentrations were expressed in mM.

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 VLan and T-30 tests, an S-VHS Panasonic M9000 camera was used. The camera was placed parallel to the swimming pool lanes, registering only the swimming in the ten central meters of the pool (figure 1). In order to have only the 10 meters of clean swim registered (with no influence of the impulse of the laps and exits), colored balloons were set in the lanes in which the participants performed the swims 7.5 meters away from the exit boarder, as shown in figure 1.

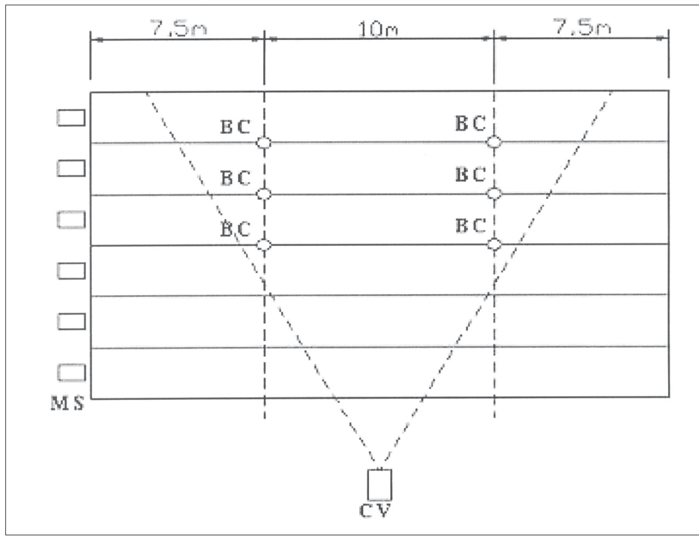

Figura 1 *– Modelo representativo dos procedimentos de determinação dos parâmetros de braçada nos 10m de nado limpo: balões coloridos (BC); posicionamento da câmera de vídeo (CV); perspectiva de registro (—); margem de saída (MS).*

The images analysis was performed with the aid of the Studio DC10 Plus software. The images recorded by the camera at 30 Hz were digitalized and analyzed shot by shot at 0.03 s for accurate determination of the time spent in order to perform the 10 m clean swimming as well as four complete stroke cycles.

The stroke rate (SR) was determined by the adapted four-cycle method by Kennedy *et al.*[23]. The SR was corresponding to the four stroke cycle (sc) by the time spent ratio in order to complete it in the ten meters of clean swimming (equation 1). The swimming velocity (V) was determined by the ratio between ten meters of clean swimming by the time spent in order to complete it (equation 2). The stroke length in 10 m was determined by the ratio between V and SR (equation 3). The stroke index (SI) was calculated according to Costill *et al.*[7], through the product of the swimming velocity of clean swimming by the stroke length (equation 4). All stroke parameters were calculated in 400 m during the progressive test and at each four hundred meters in the T-30 test.

$$SR = 4 \text{ sc/time for 4 sc} \times 60 \text{ s} \quad \text{(equation 1)}$$

$$V = 10 \text{ m/time for 10 m} \quad \text{(equation 2)}$$

$$SL = V/SR \quad \text{(equation 3)}$$

$$SI = V \times SL \quad \text{(equation 4)}$$

The stroke rate in 30 minutes (SRT-30), stroke length in 30 minutes (SLT-30) and stroke index in 30 minutes (SIT-30) were determined through the mean of the SR, SL and SI in 30 minutes values.

The values corresponding to the stroke rate threshold (SRLan), stroke length threshold (SLLan) and stroke index threshold (SILan) were determined by linear interpolation from the ratio between anaerobic threshold velocity and stroke parameters obtained in the progressive test, as seen in figure 2.

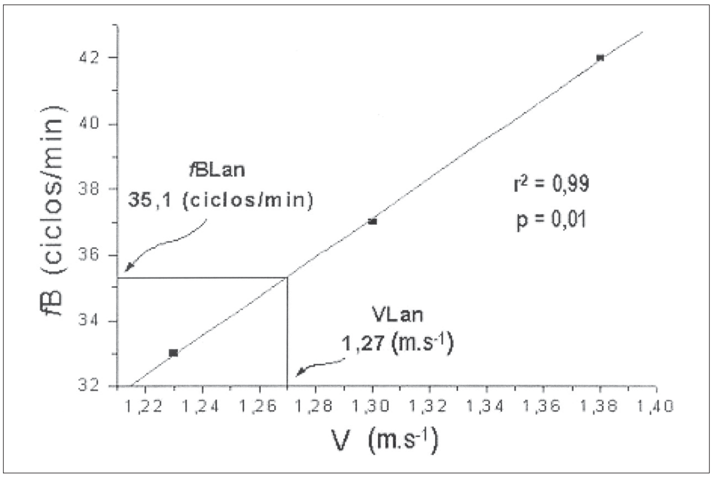

Figura 2 *– Exemplo de regressão linear para determinação da freqüência de braçada de limiar (fBLan), comprimento de braçada de limiar (CBLan) e índice de braçada de limiar (IBLan) no teste progressivo*

Statistical analysis

The t-Student test for dependent samples and the Pearson correlation test were used to compare and verify possible associations of V, SR, SL and SI derived from the VLan and T-30 tests, respectively. The Pearson correlation test was also used to verify associations among the parameters obtained from the VLan and T-30 tests with the maximal performance of 400 m crawl. In all cases the significance level was pre-set for $p \leq 0.05$.

RESULTS

The results are expressed in mean and standard deviation. The VLan (1.29 ± 0.07 $m.s^{-1}$) was not significantly different from the VT-30 (1.29 ± 0.08 $m.s^{-1}$) and they were highly correlated (0.90). Moreover, 3.76 ± 1.65 mM of blood lactate were verified after the T-30.

Significant differences between SRLan and SRT-30 and between SLLan and SRT-30 were not found, contrary to what occurred between SILan and SIT-30 (table 2). Additionally, correlations of 0.73, 0.89 and 0.94 for SR, SL and SI values respectively, derived from the VLan and T-30 tests were verified.

The P400 (1.38 ± 0.09 $m.s^{-1}$) presented significant correlations with the VLan (0.94) and VT-30 (0.95).

TABLE 2
Mean values and SD of stroke rate threshold (SRLan), stroke rate in 30 minutes (SRT-30), stroke length threshold (SLLan), stroke length in 30 minutes (SLT-30), stroke index threshold (SIBLan) and stroke index in 30 minutes (IBT-30)

	SR (cycles/min)		SL (m/cycle)		SI	
	SRLan	*SR*T-30	SLLan	SLT-30	SILan	SIT-30
Mean	33.9	34.9	2.09	2.09	2.44	2.53*
SD	4.14	3.53	0.20	0.20	0.29	0.32

* $p < 0.05$ concerning SILan.

DISCUSSION

The greatest advantage of using indirect methods in the training routine of swimmers is mainly concerned with low cost and easy application. Although the T-30 is a widely used methodology in the determination of VLan in swimming, it presents some limitations, since the swimmers should be instructed to swim the longest distance within the pre-set time (30 minutes), which many times is influenced by the degree of motivation. Moreover, this methodology does not consider the participation of the anaerobic metabolism involved. Thus, it is possible that a given swimmer presents improvement in the mean velocity obtained in the T-30 (V-T30) as a result of application of training sessions with the aim to develop lactate tolerance. However, the anaerobic training effects over the V-T30 seem to be modest concerning aerobic training effects[10].

In the present study, the V-T30 was not significantly different from the VLan. This finding corroborates the results by Olbrecht *et al.*[6] who in their study used the two-velocities test (2x400 m) to determine the aerobic capacity, where the VLan was assumed as the swimming velocity corresponding to the 4 mM steady concentration. In order to verify the VLan in the present investigation, we used pauses of only 3 minutes between efforts, with the purpose to optimize the time in the tests. Therefore, the lactate steady concentration of 3.5 mM was adopted[22,24], not the 4.0 mM as it is usually used[4,25]. The utilization of this concentration clashes with Heck *et al.*[4], who suggest the steady concentration of 3.5 mM only for protocols with stages with duration up to 3 min, which is lower than the ones used in this study (4 to 5 min). The use of the 4 mM steady concentration suggested by these authors when the stages duration is of 5 minutes seems to overestimate the VLan in swimming, if the pause between incremental efforts is small. This fact is probably due to the existence of residual effects of metabolism and fatigue specific to the previous stages, once the incremental tests for determination of the VLan, may be considered dependent protocols[24].

In the present study, the correlation tests outcomes show that the best VLan predictor was the VT-30 (r = 0.90), which did not present differences between the two variables. This result confirms the findings in the literature, reinforcing the possibility to use the T-30 test as a determinant index of aerobic capacity in swimming[2,6,8-11]. Besides that, the mean concentration of peak lactate found at the end of the T-30 test was of 3.76 ± 1.65 mM, a value very close to the lactate concentration used in the test for VLan determination. Dekerle *et al.*[8] observed peak lactate concentration of 3.65 ± 1.58 in the T-30 test, a value also close to 3.5 mM. Olbrecht *et al.*[6] while using the steady concentration of 4 mM did not find significant difference either, besides finding a high correlation between the VLan and mean velocity in 30 minutes, with peak lactate concentration of 4.01 ± 0.75 mM. The VT-30 also acted as a good 400 meters performance predictor, showing a high correlation (r = 0.95).

Pioneering studies have used the swimming final time or velocity based on the total final time by the swimming distance ratio for stroke parameters determination (SR and SL)[13-14], a procedure which considers the influence of the exits and laps impulse at each swimming segment. In order to calculate the SR, SL and SI in the present study, we used the clean swimming velocity (with no influence of the exits and laps impulse). The use of this method allows the real calculation of the swimmer's technical skill, since it decreases the interference by particularities in the exits and laps of the athletes. Craig *et al.*[14] demonstrated that when calculating the stroke length for uniform laps, the values decrease in 5%.

In our study, the determination of the stroke thresholds were performed from the plotting of the linear ratio between anaerobic threshold velocity and stroke parameters (figure 2). Keskinen and Komi[19] while studying different ratios between the stroke parameters in different exercise intensities, reported that the swimming velocity and the stroke rate were kept practically steady until the anaerobic threshold intensity was reached. However, a significant decrease in the stroke length curve was observed when this threshold intensity was surpassed. In a recent study, Langeani *et al.*[20] found an increase and a dramatic decrease in the stroke rate and length respectively, in progressive exercise of 6 increments which corresponded with the blood lactate curve behavior, with high correlations between lactate threshold velocities and stroke parameters threshold (V-LT vs V-SRT, r = 0.98; V-LT vs V-ST, r = 0.96), suggesting the use of these parameters as alternatives to the invasive lactacidemia tests for the VLan determination.

The relationship between swimming velocity and stroke parameters observed in this study presented a linear behavior ($r^2 = 0.99$), clashing with the findings by Keskinen and Komi[19]. A possible explanation for these differences may be the use of only 3 points in the determination of the stroke parameters concerned with the VLan, and may not reliably reflect the behavior of the swimming mechanical characteristics due to the increase of the exercise intensity.

The non-difference found from the SRLan and SLLan values with SRT-30 and SLT-30, respectively, besides the significant correlations found between these parameters, corroborate the hypothesis that the SR and the SL are directly related with fatigue in swimming[7,15]. These findings show that stroke length is spontaneously kept at steady intensities. They also suggest the existence of a reflex technical balance of the lactate dynamic balance observed during prolonged exercise at intensities corresponding to the VLan. Thus, SR and SL corresponding to the VLan and/or the V-T30 may be useful parameters for the control and training prescription intensities and evaluation of the swimming mechanics. Improvement in the swimming mechanics, especially in aerobic bouts, will be probably reflected in changes in these parameters, being able to influence the increase of the swimming velocity during the competition[8].

The majority of studies which try to relate swimming mechanical parameters and physiological aspects have been using the anaerobic threshold determined through the ratio between blood lactate concentration versus swimming velocity from incremental swims[11,19-20], a methodology also used in the present study. Pereira *et al.*[22] highlighted that incremental protocols may fail or indicate an unsuitable training intensity. Therefore, the maximal swimming velocity which can be kept with the maximal balance of lactate production and removal, determined from the maximal lactate steady state protocol[4] (MLSS), may represent the most suitable intensity to control and improve the swimming technique during the aerobic training. Thus, further studies are necessary in order to relate the MLSS and swimming technical parameters.

The results of the present study suggest the use of the T-30 as a non-invasive and low cost instrument in aerobic capacity assessment, determination of parameters concerned with the swimming technique as well as prediction of 400 m performance in trained swimmers.

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