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Is the Critical Velocity Test a Good Tool For Aerobic Assessment of Children Swimmers?

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Abstract: Although swimmers are involved at very young ages in training and in competition, the differences in the physiological responses to exercise between them and adults are usually not respected. In fact, children swimmers are rarely involved in training control, leading to inadequate volume and prescription of training intensities. Our purpose was to verify if the critical velocity test is a good tool for aerobic assessment in children swimmers, by comparing it with the velocity corresponding to metabolic individual anaerobic threshold. Fourteen swimmers of 10.7 ± 0.73 years old voluntarily participated in the present study. Critical velocity was determined as the slope of the regression line between two competitive events (100 and 400 m freestyle), and the corresponding official times. In addition, each participant performed a 5 x 200 m front crawl intermittent incremental protocol for individual anaerobic threshold assessment, with 30 s intervals and 0.05m/s increments between steps; the velocity at 4 mmol/l of blood lactate concentrations ($[La^-]$) was also determined by extrapolation of the $[La^-]$/velocity curve. The mean values obtained were: 1.04 ± 0.07, 1.03 ± 0.05 and 1.08 ± 0.06 m/s for the critical velocity, velocity at anaerobic threshold and velocity at 4mmol/l (respectively), being the first two parameters similar but lower than the velocity at 4 mmol/l. These results confirm that the critical velocity test is of simple and practical implementation, using data from competition (or by implementing maximal tests in training context), allowing to assess in a non-invasive way the aerobic capacity of children swimmers.

Keywords: Aerobic assessment, anaerobic threshold, critical velocity, children swimmers.

INTRODUCTION

In the last decades, the participation of children in high-level sports increased significantly, and the deeper understanding of their performance influencing factors and well-being during training and competition has gained great importance [1]. Particularly in swimming, children start their participation in training, and are engaged in competitive events, in a very young age (~10 years). Following the swimming specialized literature, at these ages, it is advised to be involved in 3-5 training units per week (1-2 h per session), with a training volume of 2500 to 3000 m per session, and 7500 to 15000 m per week [2, 3]. At this moment of a swimmer's career, practitioners are in the ''basic training'' phase, developing simultaneously the proper starting, swimming, and turning techniques, as well as their basic conditional skills (namely their aerobic capacity) to prepare for future intense high-volume training [4]. Although existing several differences between the physiological responses of children and adults to exercise [5], children swimmers are rarely involved in training control, and the investigation in these ages is very low comparing to that conducted with adult swimmers [6]; this seems to be due to financial limitations, but also to ethical issues [7]. The almost inexistence of swimmers evaluation and training control at young ages could lead to inadequate volume and prescription of training intensities, essentially based on coaches' previous experience [8], not considering the swimmers specific training responses [5, 9].

Knowing that swimming is an individual and cyclic sport, in which both conditional and biomechanical factors are determinant for the swimmer's performance [10], and that a higher percentage of swimming training is dedicated to aerobic performance improvement [4, 11], the training control and evaluation of the swimmer's aerobic performance is a fundamental tool for increasing the efficiency of training processes [11, 12], and to performance prediction [13]. To evaluate the swimmer's aerobic performance one of the most valid indicators is the individual anaerobic threshold, as it gives important information regarding the level of development of the swimmer's aerobic capacity [4, 6, 14-16], being very useful to establish the aerobic training intensities in swimming. However, despite the existence of several tests to assess the velocity corresponding to the anaerobic threshold, some imply the use of invasive techniques based in expensive procedures of blood collection for lactate concentration analysis, and, frequently, are also very time consumable [10].

Trying to overcome the above referred constraints, Wakayoshi *et al.* [17] developed and adapted to swimming the concept of critical power introduced by Monod and

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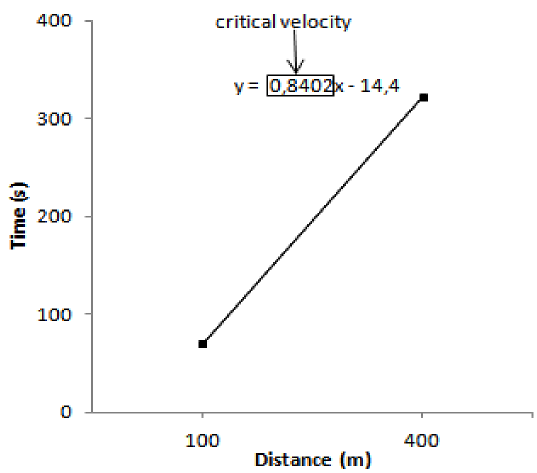

Fig. (1). Example of the critical velocity determination using two competitive events.

Scherrer [18] for the total work done by one muscle or one synergistic muscle group, presenting the critical velocity test. According to those authors, critical velocity corresponds to the maximal swimming velocity that can be maintained for a long period of time without exhaustion, being a parameter well related with the individual anaerobic threshold [19, 20]. This parameter has been used as an indicator of swimming aerobic capacity in adult swimmers [17, 19], being also appropriate for aerobic training in adolescent swimmers [21, 22]. The critical velocity test is a simple, non-invasive and non-expensive methodology, which can be easily implemented in the training context, being obtained through the relationship between test or competitive distances and the time necessary to perform them at maximum intensity [17]. The purpose of the present study was to verify if the critical velocity test is a good tool for aerobic assessment in children swimmers, by comparing its outputs with the velocity corresponding to metabolic individual anaerobic threshold; comparisons with velocity corresponding to 4 mmol/l of blood lactate concentration ([La$^-$]), a mean value considered as the "gold standard" for aerobic capacity assessment, were also done.

METHODS

Fourteen swimmers (10.7 ± 0.73 years old; body mass 40.6 ± 7.04 kg; height 148.9 ± 7.15 cm; arm span 149.1 ± 9.77 cm and swimming experience 5.63 ± 1.69 years) voluntarily participated in the present study. All children trained 4 times per week, covering 12000-14000 m per week, mainly at aerobic regimens. Their performance at 100 and 400 m freestyle, using the front crawl technique, were 80.40 ± 4.47 and 371.61 ± 21.05 s, respectively. The criterion for children's participation was a performance of ≤ 180 s at the 200 m front crawl event. The local ethics committee approved the procedures, and all the swimmers' parents signed a consent form in which the protocol was explained.

The critical velocity was determined as the slope of the regression line between two distances obtained in competition (100 and 400 m freestyle, performed in front crawl), and the correspondent official time. In Fig. (**1**) it is possible to observe, for one swimmer, the critical velocity result represented as the slope of the regression line ("a" value, expressed in m/s) from the distance (y) in function of the time (x) relationship; the "b" value is the y-interception value, according to the equation y = ax + b.

One week before the competition, each participant performed a 5 x 200 m front crawl intermittent incremental protocol for individual anaerobic threshold assessment, with 30 s intervals and 0.05 m/s increments between steps, as described in deeper detail by Fernandes *et al.* [6]. A standardized warm-up of 600 m, consisting primarily of aerobic swimming of low to moderate intensity, was conducted before the test protocol. All tests were conducted in a 25 m indoor swimming pool, 1.90 m deep, with a water temperature of 27ºC.

Descriptive statistics (means and standard deviations) were obtained for all variables (all data were checked for normality of distribution using the Shapiro-Wilk test). Pearson's correlation coefficient, pair wise t test, and Bland-Altman test were also used. A significance level of 5% was accepted.

RESULTS

It is possible to observe in Table **1** the individual, mean and standard deviation values of the critical velocity, the velocity corresponding to the individual anaerobic threshold, and the velocity corresponding to 4mmol/l of [La$^-$], by gender and for the total sample.

For the total sample and each gender subgroup the critical velocity values are similar to the velocity at individual anaerobic threshold. However, the critical velocity is significantly lower than velocity at 4mmol/l of [La$^-$] in the total sample and in the female group (in the male group a tendency for lower values is also observable); these differences correspond to a ~5 s gap in a 100 m front crawl effort when the total sample is considered. Nevertheless, all parameters were positively correlated (Table **2**).

The Fig. (**2**) shows the Bland-Altman diagrams comparing critical velocity and velocity at individual anaerobic threshold (A panel), critical velocity and velocity at 4 mmol/l of [La$^-$] (B panel), and velocity at individual anaerobic threshold and velocity at 4mmol/l of [La$^-$] (C panel).

The repeatability coefficient [and 95% agreement limits], as described by Bland and Altman [23] were: (i) 0.007m/s [-0.015 to 0.029] for critical velocity - velocity at individual anaerobic threshold; (ii) -0.049 [-0.075 to -0.023] for critical velocity - velocity at 4 mmol/l of [La$^-$]; and (iii) -0.056 m/s [-0.072 to 0.041] for velocity at individual anaerobic threshold - velocity at 4 mmol/l of [La$^-$], respectively.

DISCUSSION

It is accepted for some time that the improvement of swimmer's performance can no longer be obtained only by increasing the training volume and using nonspecific methodologies, but by carefully designing the training process and systematically monitoring it [4, 8]. Given that a high percentage of the training volume is dedicated to the improvement of the swimmer's aerobic capacity [11], particularly at young ages [3-5], coaches need objective data that allow them to, complementarily to the improvement of the swimmer's technical skills, better prescribe the adequate intensities to develop the aerobic performance [10]. This is particularly true for infant swim training programs once it is

Table 1. Individual Mean and SD Values for Critical Velocity (CV), Velocity at Individual Anaerobic Threshold (IndAnTv) and Velocity at 4mmol/l of $[La^-]$ (v4), in Male and Female Groups, and in the Total Sample

	CV (m/s)	IndAnTv (m/s)	v4 (m/s)
1	1.19	1.12	1.15
2	1.15	1.09	1.17
3	1.08	1.08	1.19
4	1.04	1.01	1.06
5	1.06	1.06	1.12
6	1.01	1.00	1.03
7	0.98	1.03	1.07
Mean ± SD ♂	1.07 ± 0.07	1.05 ± 0.05[a]	1.10 ± 0.06[b]
9	1.06	1.08	1.11
10	1.06	1.02	1.06
11	1.04	1.05	1.08
12	0.97	0.97	1.03
13	0.96	1.01	1.06
14	0.95	0.98	1.07
15	0.98	0.93	1.02
Mean ± SD ♀	1.00 ± 0.05[a]	1.00 ± 0.05[a]	1.06 ± 0.03[b,c]
Mean Total	1.04 ± 0.07[a]	1.03 ± 0.05[a]	1.08 ± 0.06[b,c]

Significant differences between variables are represented by [a] v4, [b] IndAnTv, [c] CV f or $p \leq 0.05$.

Table 2. Correlation Matrix Obtained Between the Critical Velocity (CV), Velocity at Individual Anaerobic Threshold (IndAnTv) and Velocity at 4 mmol/l of $[La^-]$ (v4). All Parameters were Significantly Correlated ($p < 0.01$)

	CV	IndAnTv	v4
CV	1		
IndAnT	.84**	1	
v4	.77**	.88**	1

Significant correlations are represented by **($p \leq 0.01$)

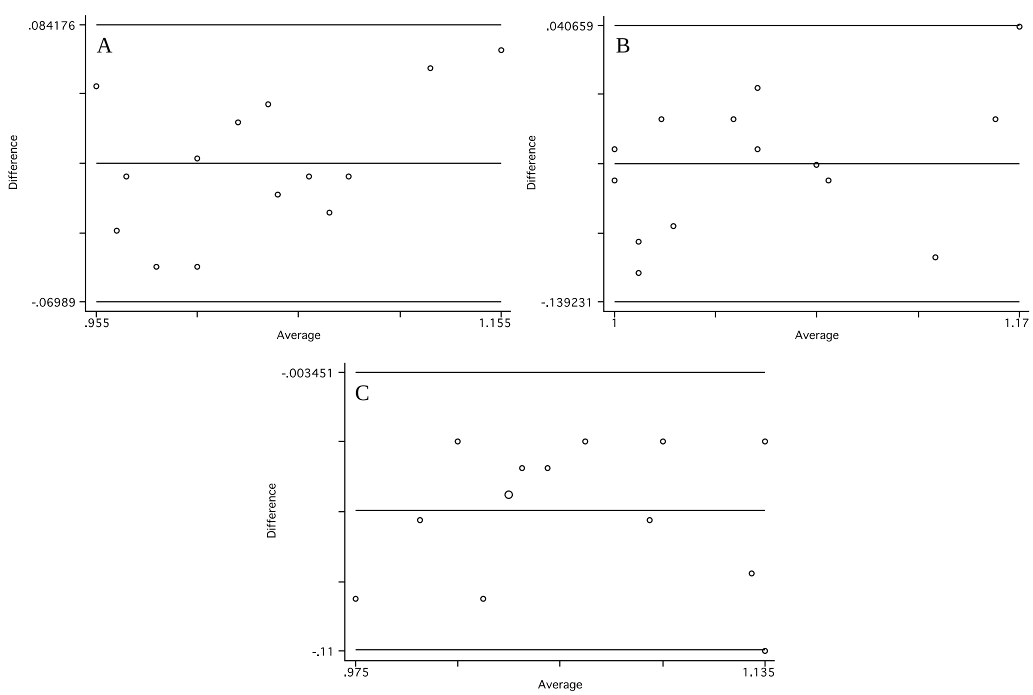

Fig. (2). Bland-Altman diagram comparing critical velocity and velocity at individual anaerobic threshold (panel **A**), critical velocity and velocity at 4 mmol/l of $[La^-]$ (panel **B**), and velocity at individual anaerobic threshold and velocity at 4 mmol/l of $[La^-]$ (panel **C**).

common to see children in early elementary school engaged in several hours of practice each week throughout the year. Therefore, more objective and specific training programs are required to develop the training process quality (aiming to improve performance), which is possible through the training control process [10]. However, physiologic assessment in children should not be expensive, invasive, complex and time consuming comparing to the battery of tests carried-out in adult swimmers [7, 24].

Although the "gold standard" for the evaluation of the aerobic capacity, by assessing the balance between lactate production and its removal, is the Maximal Lactate Steady State test [33], its implementation is rather difficult once: (i) it is required several samples of blood (at least four in each bout, repeating it each trial); (ii) swimmers need to perform, in general, three 30 min trials at different velocities, which demands high levels of motivation. In addition, to avoid the blood collection required for the assessment of the metabolic anaerobic threshold (an invasive and expensive method), age-group coaches usually implement simple non-invasive distance tests, particularly the 30 min continuous swim test - T30 [4] - and the 2000 m [25] swim test. However, the referred tests contain significant limitations preventing coaches to use them mainly when testing high number of children swimmers: (i) as the tests are performed in training conditions (with swimmers performing very close from each other), the final result of the swimmers that followed the line leader could be adulterated due to the drafting phenomenon and (ii) the continuous long distance tests are boring, not motivating the children to give an effective effort during the testing.

The critical velocity methodology seems to be a good alternative for aerobic monitoring in young ages, once it is simple, non-invasive and non-expensive, being easily implemented using competition distances, as previous conducted by our group [21]. The critical velocity test could also be implemented in a training context by performing maximal tests [10], once two bouts are perfectly conducted in a training unit carrying out the shorter distance after the warm up, and the longer distance after a regenerative training series of, at least, 45 min duration. As Wright and Smith [13] advised to do not suppress a long test distance when carrying out a critical velocity test, once it may lead to an overestimation of the final result, and as Dekerle et al. [26] proposed its duration to be within 2 to 30 min, the use of 100 and 400 m distances (with a mean duration of 79 ± 4 s and 373 ± 22 s, respectively) seem to be well justified.

The critical velocity mean value obtained in the current study was very similar, and strongly related, with the velocity at the individual anaerobic threshold, corroborating the studies of Wakayoshi *et al.* [17] and Wakayoshi *et al.* [27] conducted in adult swimmers. This fact evidences that the critical velocity test allows assessing the maximal velocity of a swimmer in a physiological aerobic balanced regimen [20, 28], and that it is useful for prescribing specific training intensities to the aerobic capacity development [21, 22] in these children swimmers. Based on the critical velocity values obtained in this study, and as it is accepted that for developing aerobic capacity efforts lasting ~30 min are required, it is purposed a training series of 2 x (7 x 100 m, each 2 min) m front crawl, with 400 m recovery between sets. As a group, these swimmers should complete every 100 m repetition in 95 s, resting 25 s, to effectively develop aerobic capacity. As expected, the obtained critical values are lower than those described for older swimmers [13, 17, 21, 22, 29, 30].

The significantly higher values of the velocity at 4 mmol/l of [La$^-$] compared to critical velocity values confirm that these parameters are not coincident and interchangeable, as noticed before in young and post pubertal [22] and juvenile swimmers [21]; in fact, the significant difference obtained between them - close to 5 s for a 100 m effort - seems to show that, in these swimmers, the velocity at 4 mmol/l of [La$^-$] is not representative of the velocity at the individual anaerobic threshold. As previous described [15, 30-33], the velocity at 4 mmol/l of [La$^-$] overestimates the velocity corresponding to individual anaerobic threshold, and limits the use of the reference velocity at 4 mmol/l of [La$^-$] value to assess the proper intensities to develop swimming aerobic capacity. The velocity at 4 mmol/l of [La$^-$] was closer to the velocity obtained in the 400 m distance, reinforcing that this parameter is a non-specific and inappropriate intensity to be used in the aerobic training.

CONCLUSION

It was confirmed that the critical velocity test is a good tool for aerobic assessment in children swimmers once its outputs are similar and well related with the velocity corresponding to metabolic individual anaerobic threshold. The critical velocity test is of simple and practical implementation, allowing obtaining objective data in real time to use for evaluating swimmers and to control and prescribe aerobic conditioning.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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