International Journal of Sports Science 2016, 6(1A): 31-35
DOI: 10.5923/s.sports.201601.06

Anaerobic Critical Velocity and Sprint Swimming Performance in Master Swimmers

Mario André da Cunha Espada[1,2,*], Aldo Costa[3,4,5], Hugo Louro[5,6], Ana Conceição[5,6], Dalton Muller Pessôa Filho[7], Ana Pereira[1,4]

[1]Polytechnic Institute of Setubal, School of Education, Setubal, Portugal
[2]Interdisciplinary Centre for the Study of Human Performance, Lisbon, Portugal
[3]Department of Sports Science, University of Beira Interior, Covilhã, Portugal
[4]Health Sciences Research Center (CICS-UBI), Covilhã, Portugal
[5]Research Centre for Sport, Health and Human Development (CIDESD), Vila Real, Portugal
[6]Sport Sciences School of Rio Maior, Polytechnic Institute of Santarém, Rio Maior, Portugal
[7]São Paulo State University - UNESP, Bauru, Brazil

Abstract The aims of this study were to determine and analyze the relationship between anaerobic critical velocity (AnCV, $m.s^{-1}$) in master swimmers and short swimming distances performances. AnCV was determined for twenty four male master swimmers (42.0 ± 7.5 years) based on the performance in 15, 25, and 50 m swimming distances. Data was calculated for each swimmer using the slope of the distance-time relationship and compared with the individual best swimming performance in 100 and 200 m distances. $AnCV_{15-25}$ (1.25 ± 0.22 $m.s^{-1}$) was significantly lower than $AnCV_{15-25-50}$ (1.29 ± 0.23 $m.s^{-1}$) and $AnCV_{25-50}$ (1.31 ± 0.23 $m.s^{-1}$) was significantly faster compared to $AnCV_{15-25}$ and $AnCV_{15-25-50}$. All AnCV combinations were strongly correlated with swimming performance in 25, 50 and 100 m front-crawl (above 0.90, $p < 0.01$), and 25 and 200 m performances in master swimmers (below 0.90, $p < 0.01$). These findings suggest that AnCV can be used as a race-pace training reference to monitoring and prescribing anaerobic training in master swimmers, a non-invasive and inexpensive method that can estimate parameters normally obtained from blood lactate analysis.

Keywords Master swimmers, Distance-time relationship, Anaerobic critical velocity, Swimming performance

1. Introduction

The maintenance of involvement in sports with advancing age is associated with social and physical benefits, reasons associated with the increased number of regular practitioners. However, advancing age is associated to a decline in physiological functional capacity, resulting in reduced performance in various tasks and a concomitant increase in morbidity and mortality [1, 2]. Despite this fact, master competitions are no longer an extension of recreational sports as in the past. Instead, are a combination of fitness-oriented people and a lot of performance driven individuals looking for self-improvements each time they compete [3].

Swimming is a relatively low-impact, low-resistance sport, particularly suitable for the elderly [4], it is a growing movement worldwide and the 50 m event is nowadays the most participated event in official competitions. This swimming distance is aside of the 100 and 200m, the ones who present more anaerobic contribution. Even thou, according to Rubin and Rahe [5], the age-related decline in performance among swimming national champions, both men and women and in short and long swimming events, is linear, at approximately 0.6% per year up to age 70-75.

Long time ago, Monod and Scherrer [6] observed a hyperbolic relationship between the level of constant power output (P) and corresponding time to exhaustion (t) in a single muscle group. This relationship can be expressed in a linear form from total work performed (W) and "t", given the product Pt. The intercept of this line was termed the ''anaerobic work capacity'' (AWC) and its slope termed the ''critical power'' (CP) defined as the work capacity that can be keep up for a very long time without fatigue, expressed by the following equation:

$$W = AWC + CP \cdot t \quad (1)$$

The slope of the linear relationship between distance and time to cover the distance is usually termed critical velocity (CV) and was introduced in swimming by Wakayoshi et al. [7]. This modelling of the human endurance–time relationship is based on a two-component model [8].

$$d = ADC + CV \cdot t \quad (2)$$

CV represents a useful tool for evaluating performance in

* Corresponding author:
mario.espada@ese.ips.pt (Mario André da Cunha Espada)
Published online at http://journal.sapub.org/sports

several forms of locomotion [9] and seems to represent the highest velocity that can be sustained during long-term performance [10, 11]. According to Zacca et al. [12], CV is a low-cost method, easy to be applied in a mixed and sized population. As well as, it doesn't require the use of expensive equipment or invasive procedures [13] and might be analyzed during training sessions or from the results in competition either [14].

The CV may be used as an index of swimming endurance capacity [7, 15]) and may be appropriate for endurance training in adult swimmers [16, 17]. Although, recent studies indicate that CV overestimate indexes associated to the transition from the heavy to the severe domain of exercise [18, 19]. Based on the concept of CV, a new trend has been suggested with the aim to determine anaerobic performances. Using short distances trials (below 50-m) and the respective time-limited, the concept of anaerobic critical velocity (AnCV) seems to represent the functional anaerobic capacity of swimmers [20-22] and be useful to anaerobic training and predicting swimming performance in short-distance swimming races.

Nevertheless, AnCV related studies are very scarce [14] and to the best of our knowledge master swimmers were not previously involved in research with the objective of better understand the real meaning and application of AnCV. Therefore, this study aimed to assess AnCV in master swimmers based upon different sprint swimming distances combinations (15, 25 and 50-m) and to analyze its relationships with 100-m and 200-m front-crawl swimming performance. It was hypothesized that AnCV is associated with swimming performance in short-distance races in master swimmers.

2. Methods and Procedures

2.1. Subjects

Twenty four male master swimmers (42.0 ± 7.5 years, 1.74 ± 0.10 m, 74.8 ± 14.1 kg and 24.7 ± 3.5 kg·m^2) participated in this study. Volunteered subjects participated in a regular basis in regional and national level competitions and signed a consent form in which the present protocol was explained. All procedures were in accordance to the Declaration of Helsinki in respect to Human research. The Ethics Committee of the hosting Higher Education Institution approved the study design.

2.2. Procedures

Time performance for 100-m and 200-m races was obtained during front-crawl started from dive. AnCV was determined through three short-distance swimming performance in front-crawl swimming (15, 25 and 50-m) with in-water start for the elimination of the dive influence. A standard warm-up was performed before teach trial (600 m and 10 min rest). The tests were performed in a 25-m indoor swimming pool, with 28℃ water temperature and less than 75% of humidity). Performance was determined by two expert researchers with a chronometer (Seiko S140, Japan), and the mean value assumed (never above 0.20 seconds). Each individual swimming bout was separated by a 10-minute rest interval.

AnCV was calculated for each swimmer using the slope of the distance-time (Dd-t) relationship, plotting the following swimming time performance over time: 15, 25 and 50- m. The equation of the regression line obtained was of $y = ax + b$ type, where here y is distance swam, x is time and a = Anaerobic critical velocity (i.e., strait-line slope), b is y-interception value [20, 22]. The coefficient of determination (R^2) was calculated to determine the strength of the regression line equation.

2.3. Statistical Treatment

The normality and homoscedasticity assumptions of all distributions were verified using a Shapiro-Wilk and Levene tests. Standard descriptive statistical methods were used for the calculation of means and standard deviations. The Pearson product moment correlation coefficient (r) was used to verify the associations between AnCV and swimming performance. In order to compare mean values of each swimming velocity (SV), a repeated–measures analysis of variance with Bonferroni adjustment was used. Statistical significance for all analyses was as accepted at $p \leq 0.05$.

3. Results

Mean swimming performance and the respective SV in the covered swimming distances are present in Table 1 and an example for AnCV modelling approach is showed in Figure 1. Both SV_{25} on SV_{50} were strongly associated ($R^2 = 0.94$; SEE = 0.05, Figure 2). Figure 2 also show Bland-Altman plot with the bias and limits of agreement between SV_{25} on SV_{50} evidenced that the random scatter of points between the upper and lower confidence limits is indicative of relatively a good fit, although, the range between these two limits is too broad.

Table 1. Performance and swimming velocity associated to 15, 25, 50, 100 and 200 meters

Parameters	Time (s)	Swimming velocity (m·s^{-1})
15-m	10.7 ± 1.3	1.42 ± 0.18*
25-m	12.9 ± 1.7	1.34 ± 0.19
50-m	38.8 ± 6.4	1.32 ± 0.20
100-m	83.3 ± 18.9	1.25 ± 0.24*
200-m	189.1 ± 46.0	1.11 ± 0.23*

* Significantly different ($p \leq 0.05$).

$AnCV_{15\text{-}25}$ (1.25 ± 0.22 m·s^{-1}) was significantly lower (p = 0.001) than $AnCV_{15\text{-}25\text{-}50}$ (1.29 ± 0.23 m·s^{-1}). On the other hand, $AnCV_{25\text{-}50}$ (1.31 ± 0.23 m·s^{-1}) was significantly faster (p = 0.001) compared to $AnCV_{15\text{-}25}$ and $AnCV_{15\text{-}25\text{-}50}$.

$CV_{100-200}$ (1.00 ± 0.23 m·s^{-1}, SEE 0.05) was correlated to $AnCV_{15-25}$, $AnCV_{15-25-50}$ and $AnCV_{25-50}$ (respectively, r = 0.69, r = 0.79, r = 0.77; p < 0.01). W (19.1 ±10.5 m, SEE 2.1) presented no correlations to anaerobic variables (Table 3 and Figure 3).

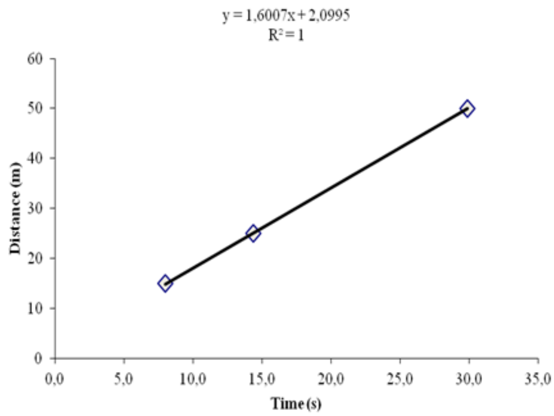

Figure 1. An example of the assessment of anaerobic critical velocity for one swimmer ($AnCV_{15,25,50}$ = 1.60 m·s^{-1})

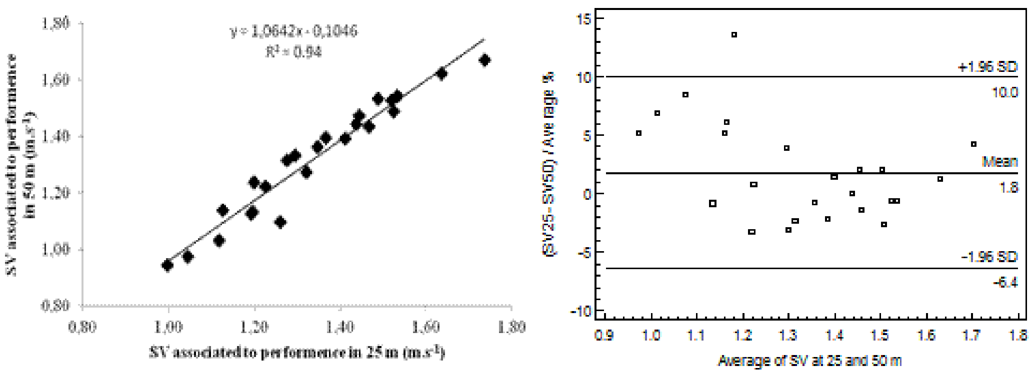

Figure 2. Linear regression of SV_{25} on SV_{50} (SSE = 0.04 m·s^{-1}) and Bland-Altman plot showing the agreement between SV_{25} and SV_{50}

Table 3. Correlation between time (T) performance and anaerobic critical velocity (AnCV) from combining swimming distances

	T_{15} (s)	T_{25} (s)	T_{50} (s)	100-m (s)	200-m (s)
$AnCV_{15-25}$ (ms^{-1})	-0.72	-0.94	-0.94	-0.91	-0.73
$AnCV_{25-50}$ (m.s^{-1})	-0.76	-0.92	-0.98	-0.97	-0.84
$AnCV_{15-25-50}$ (m.s^{-1})	-0.75	-0.94	-0.98	-0.97	-0.80

All correlations are significant at 0.01 level.

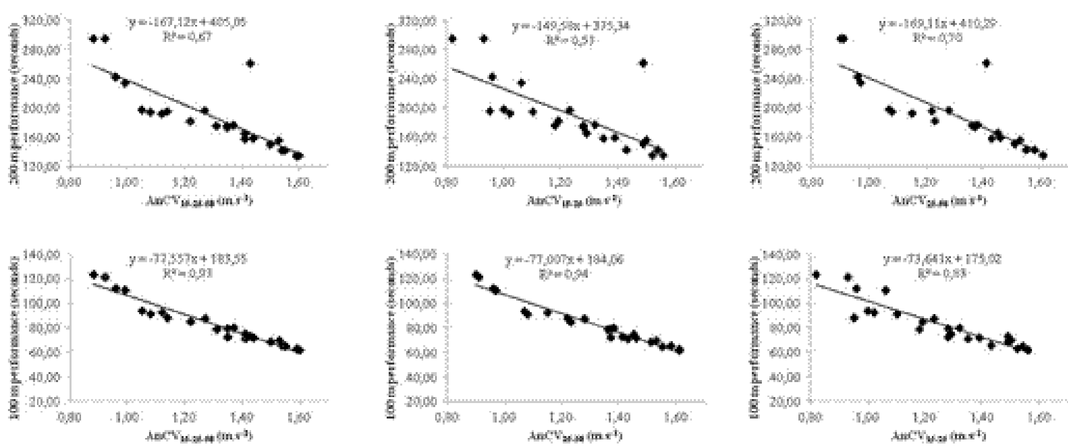

Figure 3. Linear regression between AnCV from combining swimming distances and velocity performance during 100 a 200-m

4. Discussion

The aims of the present study were to determine AnCV in master swimmers and to comparing it with short swimming distances performances. To our best knowledge, the present study is the first to analyse the relevance of this functional parameter of training control in master swimmers. The results showed that both $AnCV_{15,25}$, $AnCV_{25\text{-}50}$ and $AnCV_{15\text{-}25\text{-}50}$ combinations were strongly correlated with swimming performance in 25, 50 and 100 meters front-crawl (above 0.90, $p < 0.01$), and 25 and 200 m performances in master swimmers (below 0.90, $p < 0.01$). The lack of previous studies in master swimmers makes it difficult to compare our data. Nevertheless the results seem to be in accordance with previous studies conducted by other authors [20-23], predominantly in young swimmers.

For example, it was previously reported a high linearity between distance covered and the corresponding time in the individual AnCV assessment [21-24]. Our results also support these findings, which mean that it is possible to assess AnCV through working with linear relationships within specific short swimming distances tests and the corresponding times. Even, we would like to highlight the strong correlation coefficient between AnCV and T_{50}, the most popular swimming event in master competitions, which is in strong agreement with the data reported by Marinho et al. [22] for age-group swimmers. Our correlation coefficient values were slight higher than those presented by the existing literature, which may be explained by differences in age and experience. The T_{15} should only reflect breakdown of PCr (ATP-PCr shuttle), not anaerobic glycolysis since the time to cover the 15 m swimming distance is too brief to exploit the glycolytic ATP production system completely. This fact resulted in lower correlations values when compared to 25 and 50 meters swimming distances.

Other works found correlations between the AnCV and maximal performance for 100-m [24] and 200-m [22] races. Louro et al. [24] reported values of $r = 0.88$ ($p < 0.01$), as well as, no significant differences between swimming velocity at AnCV and 100-m freestyle in adult swimmers ($1.61 \pm 0.07\ m \cdot s^{-1}$ and $1.60 \pm 0.08\ m \cdot s^{-1}$). Convergent results were found by several authors regarding AnCV and the performance during 50-m. Abe et al. [20] reported a strong association between the AnCV and the 50-m breaststroke performance ($r = 0.85$, $p \leq 0.05$). Neiva et al. [23] obtained values of $r = 0.81$ ($p \leq 0.01$) for backstroke, $r = 0.83$ ($p \leq 0.05$) for breaststroke, and $r = 0.78$ ($p \leq 0.01$) for front-crawl. Fernandes et al. [21] also indicated values of $r = 0.84$ ($p < 0.01$) for front-crawl performance. Complementarily, the present study added that the coefficient of correlation between the AnCV and swimming performance decrease as the distance increases (between 100-m and 200-m). This is an expected result, justified by the fact that the preponderance of the anaerobic metabolism in maximal efforts decrease over time. Therefore, the performance while swimming distances over 200-m has an increasing influence of aerobic metabolism [25-27].

Also, CV was correlated to AnCV, highlighting the pertinence of this parameter not only to anaerobic training, but also aerobic/anaerobic demanding races, as the 100-m and 200-m. The anaerobic metabolism has a significant role to overall energy [25, 27, 28]) and a substantial contribution for the 50-m swimming races, approaching 80% or more of total energy demand [29]. This fact supports the notion that the 50-m should be involved in AnCV determination, but should not be used for the estimation of CV. For that reason, higher linear relationships were obtained between the combination $AnCV_{25\text{-}50}$ and $AnCV_{15\text{-}25\text{-}50}$ and 100-m swimming performance. Otherwise, even during a single 30-s swimming bout, the aerobic energy contribution approaches almost 33% [29], which is similar to that previously reported using a swimming flume [27]. Louro et al. [24] also found that adult swimmers were not able to sustain the velocity at AnCV longer than 97.22 ± 20.51 meters. However, no relationship was found in Louro et al [24] study between the total distance swam and AnCV ($r = 0.27$, $p = 0.49$), which probably means that a high anaerobic performance is not directly associated to better swimming performances for distances higher than 100-m [30].

5. Conclusions

The results suggest that AnCV can be an important indicator of performance for the 100-m swimming races, and could be used as training parameter for short-distances events (25-m and 50-m). As such, coaches can use AnCV as a race-pace training reference to monitoring and prescribing anaerobic training in master swimmers, thus be applied as a non-invasive an inexpensive method that can estimate parameters normally obtained from blood lactate analysis. This concept might be relevant to the maximal swimming velocity, as an inexpensive and non-invasive method it seems relevant to conduct further studies to validate the use of this recent functional parameters of the swimmer's anaerobic fitness. Further studies should be conducted involving different swimming techniques and distances, kinematic parameters and gender differences.

REFERENCES

[1] Martin, J.C., Farrar, R.P., Wagner, B.M., Spirduso, W.W. (2000). Maximal power across the lifespan. J Gerontol A Biol Sci Med Sci; 55(6): M311-M316.

[2] Tanaka, H. & Seals, D.R. (2003). Dynamic exercise performance in Masters athletes: insight into the effects of primary human aging on physiological functional capacity. J Appl Physiol; 95(5): 2152-62.

[3] Espada, M.C., Costa, M.J., Costa, A.M., Silva, A.J., Barbosa, T.M., Pereira, A.F. (2015). Relationship between Performance, Dry-land Power and Kinematics in Master Swimmers. Acta Bioeng Biomech. [Epub ahead of print]. Doi:

10.5277/ABB-00223-2014-02.

[4] Rubin, R.T., Lin, S., Curtis, A., Auerbach, D., Win, C. (2013). Declines in swimming performance with age: a longitudinal study of Masters swimming champions. Open Access J Sports Med; 12: (4) 63-70.

[5] Rubin, R.T.; Rahe, R.H. (2010). Effects of aging in Masters swimmers: 40-year review and suggestions for optimal health benefits. Open Access J Sports Med; 1: 39-44.

[6] Monod, H. & Scherrer, J. The work capacity of a synergic muscular group. Ergonomics, London, vol. 8, n. 3, p. 329 – 338, 1965.

[7] Wakayoshi, K., Ikuta, K., Yoshida, T., Udo, M., Moritani, T., Mutoh, Y., Miyashita, M. (1992). Determining and validity of critical velocity as an index of swimming performance in the competitive swimmer. Eur J Appl Physiol; 64: 153-57.

[8] Billat, V.L.; Blondel, N.; Berthoin, S. Determination of the velocity associated with the longest time to exhaustion at maximal oxygen uptake. European Journal of Applied Physiology, Berlin, vol. 80, p. 159 – 161, 1999.

[9] di Prampero, P.E., Dekerle, J., Capella, C., Zamparo, P. (2008). The critical velocity in swimming. Eur J Appl Physiol; 102, 165-71.

[10] Hill, D.W. (1993). The critical power concept: a review. Sports Med; 16: 237-254.

[11] Vandewalle, H., Vautier, J.F., Kachouri, M., Lechevalier, J.M., Monod, H. (1997). Work exhaustion time relationships and the critical power concept. J Sports Med Phys Fitness; 37: 89-102.

[12] Zacca, R., Wenzel, B.M., Piccin, J.S., Marcilio, N.R., Lopes, A.L., de Souza Castro, F.A. (2010). Critical velocity, anaerobic distance capacity, maximal instantaneous velocity and aerobic inertia in sprint and endurance young swimmers. Eur J Appl Physiol; 110(1): 121-31.

[13] Marinho, D., Barbosa, T., Silva, A., Neiva, H. (2012). Applying anaerobic critical velocity in non-elite swimmers. International Journal of Swimming Kinetics; 1(1): 33-50.

[14] Costa, A.M., Silva, A.J., Louro, H., Reis, V.M., Garrido, N.D., Marques, M.C., Marinho, D.A. (2009). Can the curriculum be used to estimate critical velocity in young competitive swimmers. J Sports Sci Med; 8: 17-23.

[15] Toussaint, H.B., Wakayoshi, K., Hollander, H.P., Ogita, F. (1998). Simulated front crawl swimming performance related to critical speed and critical power. Med Sci Sports Exerc; 24: 144-51.

[16] Wakayoshi, K., Yoshida, T., Udo, M., Harada, T., Moritani, T., Mutoh, Y., Miyashita, M. (1993). Does critical swimming velocity represent exercise intensity at maximal lactate steady state? Eur J Appl Physiol; 66: 90-95.

[17] Rodríguez, F.A., Moreno, D., Keskinen, K.L. (2003). Validity of a two-distance simplified method for determining critical swimming velocity. In: Chatard, J.C. (Eds) Biomechanics and Medicine in Swimming IX. University of Saint-Etienne, Saint-Etienne, France: pp. 385-390.

[18] Dekerle, J., Pelayo, P., Clipet, B., Depretz, S., Lefevre, T., Sidney, M. (2005). Critical swimming speed does not represent the speed at maximal lactate steady state. Int J Sports Med; 26: 524-30.

[19] Espada, M.A. & Alves, F.B. (2010). Critical velocity and the velocity at maximal lactate steady state in swimming. In: Per-Ludvik Kjendlie, Robert Keig Stallman and Jan Cabri (Eds.). Biomechanics and Medicine in Swimming XI (pp. 194-196). Oslo: Norwegian School of Sport Science.

[20] Abe, D., Tokumaru, H., Nihata S., Muraki, S., Fukuoka, Y., Usui, S., Yoshida, T. (2006). Assessment of short-distance breaststroke swimming performance with critical velocity. J Sports Sci Med; 5:340-48.

[21] Fernandes, R., Aleixo, I., Soares, S., Vilas-Boas, J.P. (2008). Anaerobic Critical Velocity: a new tool for young swimmers training advice. In: P Noemie, Beaulieu (Eds). Physical activity and children: new research. Nova Science Publishers: New York: 211-223.

[22] Marinho, D.A., Amorim, R.A., Costa, A.M., Marques, M.C., Pérez-Turpin, J.A., Neiva, H.P. (2011). Anaerobic critical velocity and swimming performance in young swimmers. J Human Sport Exerc; 6: 80-86.

[23] Neiva, H.P., Fernandes, R., Vilas-Boas, J.P. (2011). Anaerobic critical velocity in four swimming techniques. Int J Sports Med; 32(3): 195-98.

[24] Louro, H., Silva, P., Conceição, A., Neiva, H., Marinho, D., Costa, A. (2013). Maximal swimming distance at anaerobic velocity. International Journal of Swimming Kinetics; 2(1): 71-86.

[25] Ogita, F. (2006). Energetics in competitive Swimming and Its Application for Training. Rev Port Cien Desp; 6: 117-82.

[26] Gastin, P.B. (2001). Energy system interaction and relative contribution during maximal exercise. Sports Med; 31: 725-41.

[27] Barbosa, T.M., Bragada, J.A., Reis, V.M., Marinho, D.A., Carvalho, C., Silva, A.J. (2010). Energetics and biomechanics as determining factors of swimming performance: updating the state of the art. J Sci Med Sport; 13: 262-69.

[28] Holmer, I. (1983) Energetics and mechanical work in swimming. In: Hollander, A.P., Huijing, P.A., Groot, G.D. (Eds.). Biomechanics and Medicine in Swimming. Champaign III: Human Kinetics Publishers. 154-164.

[29] Peyrebrune, M.C., Toubekis, A.G., Lakomy, H.K., Nevill, M.E. (2014). Estimating the energy contribution during single and repeated sprint swimming. Scand J Med Sci Sports; 24(2): 369-76.

[30] Costa, A.M., Costa, M., Marinho, D.A. (2015). Velocidade crítica em natação: uma revisão da literatura. Motricidade [Epub ahead of print]. Doi: 10.6063/motricidade.2903.