Abstract

Relationship Between Energy Cost and the Index Of Coordination in Front Crawl - A Pilot Study

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References

[1] Chollet D, Chalies S, Chatard JC. A New Index of Coordination for the Crawl: Description and Usefulness. International Journal of Sports Medicine. 2000(21):54-9.

[2] Fernandes R, Cardoso C, Soares S, Ascensão A, Colaço P, Vilas-Boas JP. Time limit and VO2 slow component at intensities correspondent to aerobic power in swimmers. International Journal of Sports Medicine. 2003;24(8):576-81.

Swimming is individual, closed and cyclic sport where both bioenergetic and biomechanical factors seem to have great relevance. The method of technical analysis recently introduced by Chollet et al. [1] proposed to measure swimmer's arm stroke adaptations during increases of velocity: this methodology was denominated Index of Coordination (InC). However, no studies have been made in order to relate the InC with the Energy Cost (C) in order to understand how these two variables are related. The C of swimming is well reported in the literature since 1970's, and is considered as the amount of energy spent by unit of distance swam. The purpose of the present study was to relate the InC with the C at sub-maximal front crawl intensities.

For the present study, a female high level swimmer (height: 168.5 cm, weight: 58.2 kg and 62.6 $ml.kg^{-1}.min^{-1}$w of maximal oxygen consumption) was tested. The subject performed an intermittent incremental protocol, with increments of 0.05 $m.s^{-1}$ each 200m stage (and 30s intervals), until exhaustion [2]. Velocity was controlled using a visual pacer. VO_2 was measured through direct breath-by-breath oximetry ($K4b^2$, COSMED). Blood lactate concentrations were assessed at rest, during the 30s intervals, and immediately after each step (YSI1500LSport auto-analyser), and video analysis was used in order to obtain the InC value to all stages.

Table 1. Mean values of InC and C obtained in each 200 m step for the swimmer analysed.

Stage	%VO2max	InC (%)	C (J.Kg-1. min-1)
1	53.4	-8.48	7.14
2	57.3	-7.89	7.41
3	63.2	-6.38	8.36
4	76.8	-6.06	10.07
5	85.5	-5.09	11.51
6	93.9	-4.04	12.74
7	99.9	-2.25	13.85
8	99.9	-1.50	13.96

In Table 1 it is possible to observe that the InC and C, at sub-maximal intensities (under the VO_2max intensity), seems to increase with swimming intensity. Moreover, InC and C presented a very highly correlation value ($r = 0.97$, $p < 0.01$). Complementarily, it is also possible to observe that, as the swimming intensity increases, the swimmer seems to change her inter-arm coordination: switching from a "catch-up" pattern, to an "opposition" mode when reaching a swimming intensity near of the VO_2max intensity.

These results seem to indicate that the swimmer changed her inter-arm stroke coordination at sub-maximal intensities in order to reach a higher swimming velocity, even if that implicates a higher C. These results corroborate the fact that an increase in the swimming velocity implies an increase of the InC. This fact seems to be highly associated to the C increase.

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Introduction

Performance in swimming is measured by the time that the swimmer needs to cover a distance, in which the capacity to reach and maintain a given velocity (v) during the race depends, among others, on biomechanical and bioenergetics factors. Among the biomechanical factors, the influence of the stroke rate, stroke length and stroke index on the swimming performance is well reported in the literature [1]. Furthermore, it was showed that the temporal organization of the stroke is also important to characterise highly skilled performance swimmers [2].

Recently, attention has been given to these modifications on temporal organisation of arm stroke phases and inter-arm coordination, assessed by the Index of Coordination (IdC), initially proposed by Chollet et al. [3]. The IdC is based on the four arm-stroke phases (entry/catch, pull, push and recovery) and allows the measure of the inter-arm coordination. According to Seifert et al. [4], this inter-arm coordination is influenced by some constraints: (i) environmental constraints (e.g. active drag and v); (ii) task constraints (pace imposed, goal, instructions or rule of the task); and iii) organismic constraints (the swimmer speciality, anthropometric characteristics and gender). In addiction to these constraints, it was also hypothesized that physiological parameters could influence the inter-arm coordination [5], being observed that the IdC is sensitive to the fatigue. So, an increase on the IdC seems not to be exclusively linked to an increase in v or to the above-referred factors, seeming that other parameters could explain the increase of IdC values concomitant with the increase of swimming intensity (such as some physiological parameters). The idea that physiological parameters could influence coordinative and biomechanical parameters had already been defended before, namely when observed that swimming economy is highly correlated with biomechanical parameters [2,6]. More recently, it was also seen that the stroke mechanics is highly correlated with the Energy Cost (C) [7]. Additionally, it was showed that swimming technique and the C are highly related [8].

The C of swimming is well reported in the literature since the 1970's, being considered as the total energy expenditure required for displacing the body over a given unit of distance [9], and seen as an important bioenergetical determinant of swimming performance [10]. However, to our knowledge, no studies have been made in order to relate the IdC with the C and to understand how these two variables are connected. In this sense, the purpose of the present study was to relate the IdC with the C at sub-maximal front crawl intensities.

Material and Methods

A female high level swimmer (height: 168.5 cm, weight: 58.2 kg and 62.6 $ml.kg^{-1}.min^{1}$ of maximal oxygen consumption) was tested. In a 25m pool, the swimmer performed an intermittent incremental protocol, with increments of 0.05 $m.s^{-1}$ each 200 m stage (and 30 s intervals), until exhaustion [11]. Initial v was established according to the individual level of fitness and was set at the swimmer's individual performance on the 400 m freestyle minus seven increments of v. V was controlled using a visual pacer (TAR 1.1, GBK-electronics, Aveiro, Portugal) with successive flashing lights, 2.5m apart, on the bottom of the pool.
Oxygen consumption was measured through direct breath-by-breath oximetry (K4 b^2, COSMED, Rome, Italy) and capillary blood lactate concentrations, from samples collected from the ear lobe, were assessed at rest, during the 30s intervals, immediately after each step and 1, 3, 5 and 7 min after the last swim (YSI1500LSport Auto-analyser, Yellow Springs Inc., USA). The C was calculated by dividing total energy expenditure ($\dot{E}_{tot}$) by v [9,10] and converted to SI units, were 1 mlO_2 is equivalent to 20.1 J:

$$C = \dot{E}_{tot} / v \qquad (1)$$

The $\dot{E}_{tot}$ corrected for body mass was calculated using the VO_2 net (difference between the value measured in the end of the stage and the rest value), and the blood lactate net (difference between the value measured in two consecutive stages) transformed into VO_2 equivalents using a 2.7mlO_2 Kg^{-1} $mmol^{-1}$ constant and by Eq. (2)

$$\dot{E}_{to} = VO_2net + [La^-]net \quad (2)$$

Two synchronized video cameras (JVC GR-SX1 SVHS and JVC GR-SXM 25 SVHS) fixed on the lateral wall of the pool at 10 m of the swimmer and perpendiculars to his displacement were used. The cameras were connected to a double entry audiovisual mixer (Panasonic AG 7355) and edited on a mixed table (Panasonic Digital Mixer WJ-AVE55 VHS), giving a double projection, up and above the water surface [12].

For each stage, 2 arm strokes were analysed in every 50 m of the 200 m step. Arm stroke coordination was obtained through IdC [3]. Each arm stroke was broken down into four phases: (i) Entry and Catch (corresponding to the time between the entry of the hand into the water and the beginning of its backward movement); (ii) Pull (corresponding to the time between the beginning of the hand's backward movement and its arrival in a vertical plane to the shoulder); (iii) Push (corresponding to the time from the position of the hand below the shoulder to its release from the water) and (iv) Recovery (corresponding to the point of water release to water re-entry of the arm, i.e., the above water phase). The duration of each phase was measured for each arm-stroke cycle with a precision of 0.02 s. The duration of the propulsive phases was the adittion of the pull and the push phases, and the duration of the non-propulsive phases was obtained by the sum of the catch and the recovery phases (the duration of a complete arm-stroke was the sum of the propulsive and non-propulsive phases). The IdC calculated the time gap between the propulsion of the two arms as a percentage of the duration of the complete arm stroke cycle.

Values in each stage were calculated for all variables. Pearson correlation coefficient was applied. Level of significance was established at 5%.

Results and Discussion

The values of means for $\%VO_2max$, IdC and C, which were obtained in each step during the incremental test, are presented in Table 1. It is possible to observe that an increase of the swimming intensity seems to imply an increase of the IdC. This is consistent with studies previously conducted [3,4], which showed that the IdC values increased with swimming intensity. This increase seems to be a strategy that the swimmer uses to overcome the higher active drag, which is related with a higher swimming v [13]. It also reveals that the swimmer changed her inter-arm stroke coordination at sub-maximal intensities in order to reach a higher swimming v. Complementarily, it is also possible to observe that, as the swimming intensity increases, the swimmer seems to change her inter-arm coordination, from a "catch-up" pattern to a pattern more close to the "opposition" pattern, when reaching the VO_2max swimming intensity. However, this specific transition only seems to occur at 93.3% of maximal v, which corresponds to the 100 m maximal v [13]. Relatively to the values of IdC obtained in the present study, they also were similar to those obtained on the previously mentioned studies.

Table 1. Mean values of IdC and C obtained in each 200 m step for the swimmer analysed.

Stage	$\%VO_2max$	IdC (%)	C ($J.Kg^{-1}. min^{-1}$)
1	53.4	-8.48	7.14
2	57.3	-7.89	7.41
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7	99.9	-2.25	13.85
8	100	-1.50	13.96

Such as the IdC, the C also seems to increase with swimming intensity. This fact has been described before [7,14] and seems to be related to the increase of drag forces. Relatively to the values of C obtained in the present study they seem similar to those presented in the specialized literature [7,14].

The relationship between IdC and C is shown in Figure 1, being possible to observe a high correlation value between variables. Although no studies had been conducted in order to relate the IdC and C, other studies have been carried out in order to relate the C with other biomechanical parameters. One of these studies [7] showed that the C is highly related to stroke biomechanical parameters, namely with the stroke rate and stroke length. In the same way it was observed that C is highly related with swimming technique [8]. In this sense, after observing that the IdC, a coordinative parameter, is highly related with the C, a physiological parameter, our results seems to be consistent with literature [5], seeming to indicate that the mode of coordination might be an individual response to physiological constraints associate to the task.

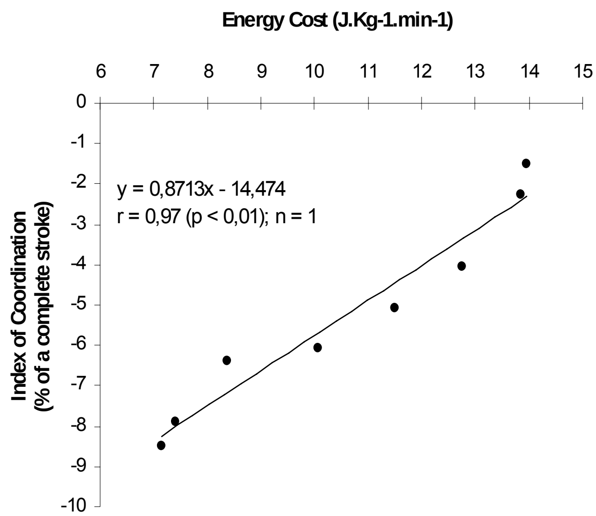

Figure 1. Relationship between IdC and C for the swimmer analysed.

It seems that additionally to the factors that others studies found out that influence the IdC (e.g. v, gender, anthropometric characteristics, rules of the task), other parameters such as the physiological parameters, like the C, could help to explain the increase of IdC value with the increase of swimming intensities. It is possible to conclude that, in spite of being a coordinative parameter, the IdC seems to be highly influenced by physiological parameters. In this sense, the manipulation of IdC might be one of the factors through which C can be altered in competitive swimming for a given v, and should be taken into consideration on the training process of swimmers.

References

[1] Costill, D.; Kovaleski, J.; Porter, D.; Kirwan, J.; Fielding, R.; King, D. (1985). Energy expenditure during front crawl swimming: predicting success in middle-distance events. Int. J. Sports Med., 6 (5), 266-270.

[2] Chatard, J. C., Collomp, C., Maglischo, E., Maglischo, C. (1990). Swimming skill and stroking characteristics of front crawl swimmers. Int J Sports Med, 11(2):156-61.

[3] Chollet, D., Chalies, S., Chatard, J. C. (2000). A new index of coordination for the crawl: description and usefulness. Int J Sports Med, 21(1), 54-59.

[4] Seifert, L., Chollet, D., Rouard, A. (2007). Swimming constraints and arm coordination. Hum Mov Sci, Feb;26(1):68-86.

[5] Alberty, M., Sidney, M., Huot-Marchand, F., Hespel, J. M., Pelayo, P. (2005) Intracyclic velocity variations and arm coordination during exhaustive exercise in front crawl stroke. Int J Sports Med 26(6):471-5.

[6] Vilas-Boas, J.P. (1996). Speed fluctuations and energy cost with different breaststroke techniques, In: J. Troup, A.P. Hollander e D. Strass (eds.), Biomechanics and Medicine in Swimming VII, pp.167-171. E&FN SPON. Chapman & Hall, London.

[7] Barbosa, T. M., Fernandes, R. J., Keskinen, K. L., Vilas-Boas, J. P. (2008). The influence of stroke mechanics into energy cost of elite swimmers. Eur J Appl Physiol, DOI 10.1007/s00421-008-0676-z

[8] Chatard, J.C., Lavoie, J. M., Lacour, J.R. (1991). Energy cost of front-crawl swimming in women. Eur J Appl Physiol, 63(1):12-6.

[9] Pendargast D., Zamparo, P., di Prampero, D., Capelli, C., Cerretelli, P., Termin, A., Craig, A., Bushnell D., Paschke D., Mollendorf, J., (2003). Energy Balance of Human Locomotion in Water. Eur J Appl Physiol, 90: 377-386

[10] Zamparo, P., Pendargast, D.; Mollendorf, j.; Termin, A.; Minetti, A. (2005). An Energy Balance of Front Crawl. Eur J Appl Physiol, 94:134-144.

[11] Fernandes, R. J., Cardoso, C. S., Susana, S. M., Ascensão, A. A., Colaço, P. J., Vilas-Boas, J. P. (2003). Time limit and VO_2 slow component at intensities corresponding to VO_2max in swimmers. Int J Sports Med, 24:576-581.

[12] Vilas-Boas, J.P.; Cunha, P.; Figueiras, T.; Ferreira, M. e Duarte, J.A. (1996). Movement analysis in simultaneous swimming techniques, In: K. Wilke, K. Daniel; U. Hoffmann e J. Klauck (eds.), Symposiumsbericht Kolner Schwimmsportage, pp. 95-103. Sport Fahnemann Verlag. Bockenem.

[13] Seifert, L., Chollet, D., Bardy, B. G. (2004). Effect of swimming velocity on arm coordination in the front crawl: a dynamic analysis. J Sports Sci, 22(7):651-660.

[14] Fernandes, R.J.; Billat, V.L.; Cruz, A.C.; Colaço, P.J.; Cardoso, C.S.; Vilas-Boas, J.P. (2006). Does net energy cost of swimming affect time to exhaustion at the individual's maximal oxygen consumption velocity? J Sports Med Phys Fitness 46 (3): 373-80