INTRACYCLIC SPEED FLUCTUATIONS OF THE CENTER OF MASS AND ITS RELATIONSHIP WITH THE INDEX OF COORDINATION - A PILOT STUDY

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The purpose of this study was to analyse the relationship between the intracyclic speed fluctuations (*dv*) of the center of mass (*CM*), in the *x*,*y*,*z* axes, and the Index of Coordination (*IdC*), as well as to assess the general stroking parameters during the 200 m front crawl event. A good level male swimmer performed the 200 m front crawl at maximum intensity, being video taped by six cameras (2 above and 4 under the water). One complete stroke cycle was analysed in each 50 m of the 200 m test, using the APASystem (Ariel Dynamics Inc). *IdC* appeared to be well related to *dv*, both in the horizontal and vertical axes. It was also observed, during the 200 m effort, that the *IdC*, *dv*, stroke rate and stroke length changed during the exercise.

KEY WORDS: swimming, centre of mass, intracyclic speed fluctuations, index of coordination

INTRODUCTION:

Swimming velocity (*v*) depends both on stroke rate (*SR*) and stroke length (*SL*) according to the relationship: *v* = *SL* x *SR*. In order to achieve higher performances, swimmers adapt their *v*, *SL*, and *SR* to the swimming event distance. However, the swimmer does not move at a constant velocity, existing accelerations and decelerations of the centre of mass (*CM*), even in a single stroke cycle (Barbosa et al., 2005), which are a effect of non-constant resistive and propulsive forces acting upon the swimmer's body. This velocity variations within a stroke cycle are known as intracyclic speed fluctuations (*dv*) (Holmér, 1979), being *dv* considered as an indicator of the inverse of swimming efficiency (Kolmogorov and Duplisheva, 1992). More recently, Chollet et al. (2000) proposed the concept of Index of Coordination (*IdC*), a swimming technique evaluation tool based upon the recognition of lag times between propulsive and non-propulsive phases that may, theoretically, influence the *dv*. The purpose of the present study was to observe the *dv* and *IdC* modifications during a 200 m front crawl effort performed at maximum *v*, and to assess their relationship. We aimed also to relate *dv* and *IdC* with *SR* and *SL*.

METHODS:

A good level male front crawl swimmer (19 years old, 74.1 kg, 184.5 cm, 189.0 cm of arm span and 10.6% of fat mass) was tested. The subject performed a 200 m front crawl effort at maximum intensity, being monitored while passing through a specific calibrated space: a cube of 27m^3 volume, with 12 calibration points (Figure 1, left panel). One complete stroke cycle was analyzed for each 50 m of the 200 m front crawl test. The protocol was videotaped by 2 surface and 4 underwater fixed cameras *(Sony® DCR-HC42E)* as described in Figure 1. The video images were digitized with APASystem *(Ariel Dynamics, USA)* at a frequency of 50 Hz, manually and frame by frame, in order to analyse *dv* of the *CM*, as well as to assess the *SR* and *SL*. Zatsiorsky's model, adapted by de Leva (1996), was used with 22 anatomical reference points. Synchronisation of the images was obtained using a pair of lights fixed to the calibration volume. The 3D reconstruction of the digitised images was performed using the Direct Linear Transformation procedure (Abel-Aziz and Karara, 1971). Data were filtered with a cut-off frequency of 5Hz as proposed by Winter (2005), for the analysis of the horizontal, vertical and lateral velocity of the *CM* (Figure 1, right panel). *dv* was assessed through the calculation of the variation coefficient, and was also expressed as a percentage of the average horizontal *v* of the *CM*. Video images were also used to determinate the *IdC*.

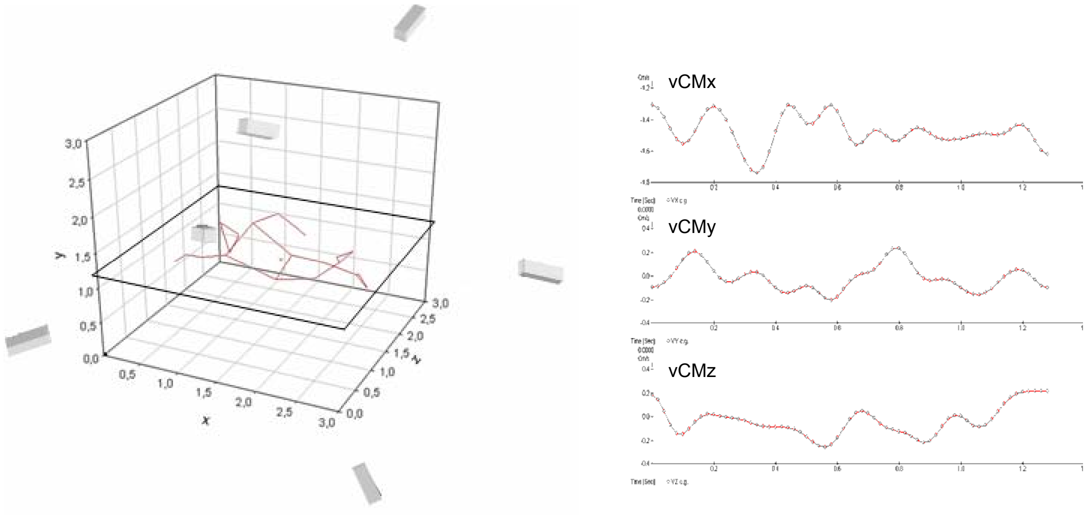


Figure 1. Position of the video cameras in relation to the calibration volume, and one stick figure resulting from the digitalization (left panel). Velocity to time curves (*x*, *y*, *z*) of *CM* during the stroke cycle are also presented (right panel).

The average horizontal swimming *v* was calculated by dividing the displacement of *CM* in one stroke cycle for its total duration. Additionally, *SR* was assessed through the inverse of its time duration, and *SL* was assessed through the horizontal displacement of the *CM* during a stroke cycle. Capillary blood samples (5µl) were collected from the ear lobe, at rest, as well as at 1, 3, 5, and 7 min of recovery, to assess rest and post exercise peak blood lactate concentrations ([La^-]) (Lactate Pro, Arkray, Inc.).
Individual regression equations describing the relation between *dv* (*x*, *y*, *z*) and *IdC*, as well as its coefficients of determination and Spearman correlation coefficients, were computed. The r values were assessed also for the other above-referred parameters. The level of statistical significance was set at $p<0.05$.

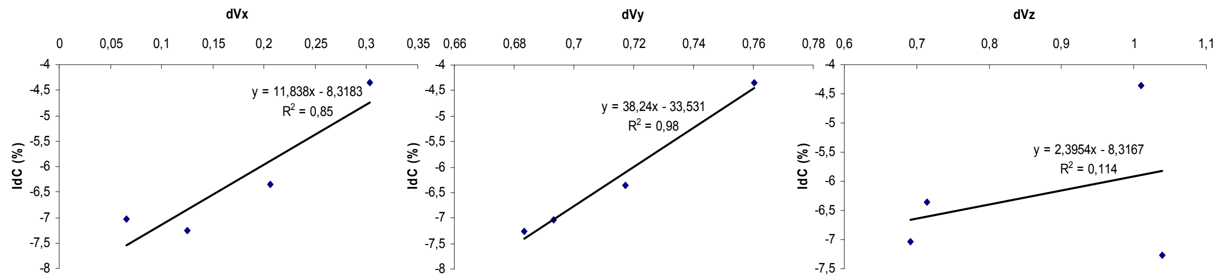
RESULTS AND DISCUSSION:
The values of *v*, *SR*, *SL*, *IdC*, *dv* (*x*,*y*,*z*) and %*dv* (*x*,*y*,*z*) are presented in Table 1.

Table 1. Values of *v, SR*, *SL*, *IdC*, *dv* (*x*,*y*,*z*) and *%dv* (*x*,*y*,*z*) in each evaluated stoke cycle of the 200 m front crawl event.

	Stroke cycle$_1{}^{st}{}_{50}$	Stroke cycle$_2{}^{nd}{}_{50}$	Stroke cycle$_3{}^{rd}{}_{50}$	Stroke cycle$_4{}^{th}{}_{50}$
v (m.s^{-1})	1.72	1.57	1.53	1.48
SR (cycles.min^{-1})	52.63	47.62	48.39	46.88
SL (m/cycle)	1.96	1.98	1.90	1.90
IdC (%)	-4.35	-6.35	-7.26	-7.03
dvx	0.30	0.21	0.12	0.07
dvy	0.76	0.72	0.68	0.69
dvz	1.01	0.71	1.04	0.69
%dvx	17.48	13.06	8.18	4.45
%*dvy*	43.90	45.44	44.78	46.77
%*dvz*	58.33	45.24	68.11	46.68

It was possible to observe that *v* decreased along each stroke cycle studied (corresponding to each 50 m lap of the 200 m test), which is explained by different *SR* and *SL* combinations, as previously reported (Huot-Marchand et al., 2005). As Pelayo et al. (1996) stated, swimmers make different combinations of *SR* and *SL* even when achieving similar *v*. Table 1

shows that when *SR* decreases, *SL* increases (although in the last 50 m lap the swimmer had to decrease *SR* in order to maintain the *SL*, as observed by Alberty et al., 2005), which could reflect an inability to maintain adequate neural activation (Keskinen and Komi, 1993). This fact may explain the inexistence of significant correlations between SR and SL, which is not in accordance with the majority of the specialized literature (e.g. Seifert et al., 2004). However, these studies used the mean values of *SR* and *SL* obtained in different swimming distances, which is a different methodological approach to this problem.
Regarding the *IdC*, which has been used to assess the inter-arm coordination in front crawl, it was observed a significant decrease from the 1st to the 2nd laps, and a stability in the 3rd and 4th 50 m of the event. These findings are in accordance with Seifert et al. (2005), although using the 100 m front crawl testing distance. However, in the 200 m effort, Alberty et al. (2005) reported an improvement from the 1st until the 4th 50 m lap. In opposition to the majority of the literature, the *IdC* has improved with the decrease of *SR*, corroborating the data obtained by Alberty et al. (2005) during exhaustive exercise. Thus, it seems that metabolic conditions also influence *IdC* (cf. Morais et al., 2008), which occurs, probably, in the final stages of the 200 m effort, where the swimmer achieved higher blood lactate concentrations ($[La^-]$). At the end of the protocol, the swimmer achieved 11.9 mmol.L^{-1} of $[La^-]$ peak,,indicating a high muscle acidosis corresponding to a strenuous effort.
In Figure 2 the regression lines and the correlation coefficients obtained for the relationships between the *IdC* and *dv*x, *dv*y, *dv*z are shown. Significant correlations were obtained between the *IdC* and *dv*y (r = 0.99, p = 0.018) and *dv*x (r = 0.92, although only for p = 0.072).



a b c

Figure 2. Illustration of the regression equations and correlation coefficients obtained between *IdC* and *dvx*, *dvy* and *dvz* (a, b, and c panels, respectively).

Studies that relate *IdC* and *dv* are scarce and very recent (Alberty et al., 2005; Schnitzler et al., 2007) and focused only in the *dv*x. Complementarily, those studies were conducted always in 25 m repetitions protocols, using a speedometer. So, this new observed relationship between *IdC* and the *dv*y and *dv*z, and the possible influence of implementing a continuous protocol of a competitive distance, may provide a better knowledge of the phenomena. Alberty et al. (2005) found, during exhaustive exercise, a maintenance of *dv*x and an improvement in the *IdC*, and Schnitzler et al. (2007) reported that the *IdC* changed during different swimming intensities but *dv*x stayed stable. However, in the present study, the results showed a high correlation between *IdC* and vertical intracyclic speed fluctuations (*dv*y). Additionally, different *dv*s occurs during each 50 m of the 200 m event. When the *dv* was expressed in percentage values, the dynamic of *dv* throughout each 50 m lap of the 200 m test, changed from the obtained for the *dv* absolute values. %*dv*x showed high correlation values when related to performance (r = 0.95, p = 0.05), as when expressed as absolute values (r = 0.96, p = 0.039). %*dv*y and performance does not present significant correlation value, whereas *dv*y and performance are highly related although only for a p = 0.065 (r = 0.94).

CONCLUSION:

It was possible to conclude that *IdC* and *dv* (*x*,*y*) were strongly related, and that both parameters seem to have a great influence on swimming performance. These facts indicate a new finding: that the *IdC* could be used as a method to assess the adequacy of coordination adaptations at an individual level. It is suggested that if a subject could swim at a specific *v*, or maintain it's inter arm coordination decreasing its *dv*x and *dv*y, this could mean that a technical improvement has occurred. Additionally, this study seems to reveal that the velocity dynamics through a swimming distance is rather a much more complex phenomenon than the use of a mean velocity for that same distance. So, each 50 m lap of the 200 m event has different characteristics, which should be taken into account to better understand the specific swimming effort.

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