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CENTRE OF MASS INTRACYCLIC VELOCITY VARIATION IN THREE VARIANTS OF THE FRONT CRAWL WATER POLO TECHNIQUE

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The purpose of this study was to analyse the intracyclic velocity variation (IVV) of the centre of mass (CM) in the x, y, z axes during the stroke cycle event in front crawl, water polo front crawl and water polo front crawl while leading the ball. Ten national level water polo players performed 3x15 m at maximum intensity in each variant of the front crawl technique, being videotaped by six cameras (two above and four underwater). One complete stroke cycle was analyzed for each 15 m test using the APASystem. The numerical treatment was conducted using MATLAB software. IVV_x and IVV_z showed less variation in the water polo front crawl, and IVV_y showed less variation for the water polo front crawl leading the ball. These suggest that water polo players have a greater proficiency in water polo specific swimming techniques rather than in front crawl.

KEY WORDS: biomechanics, kinematic, digitization, three-dimensional.

INTRODUCTION: The intracyclic velocity variation (IVV) of the centre of mass (CM) is a widely accepted criterion for the biomechanical analysis of swimming technique (Figueiredo et al. 2009). Similarly to the swimmer, the water polo player does not move at a constant velocity, existing accelerations and decelerations of the CM, even in a single stroke cycle (Barbosa et al., 2005), which results of non-constant resistive and propulsive forces acting upon the subject´s body. In fact, the different actions of the arms, legs and trunk lead to variations in the instantaneous swimming velocity within the stroke cycle.
In swimming, IVV has been assessed to characterize swimming technique (Alves et al., 1994; Holmer, 1979; Miyashita, 1971; Vilas-Boas, 1992, 1996). Vilas-Boas et al. (1992) suggested that the variations of the instantaneous velocity reflect the swimmer's ability to coordinate his/her propulsive forces, and other studies reported an inverse relationship between IVV and swimming velocity and/or performance, suggesting the possibility of high IVV values being related with lower swimming velocities (e.g. Barbosa et al., 2005; Vilas-Boas, 1996).
To assess these IVV in front crawl stroke, instantaneous velocity can be both measured from the centre of mass or the hip of the swimmer (Costill et al., 1987; Vilas-Boas et al., in press), but, to the best of our knowledge, there is no investigation, independently of the body point used, about the intra-cyclic variation for the three variants of the front crawl technique used in water polo. The purpose of this study was to analyse the IVV of the CM, in the x, y, z axes, during the stroke cycle event in front crawl, water polo front crawl and water polo front crawl while leading the ball. In addition, the displacement, velocity and acceleration of the CM (x, y, z) for the three variants of the water polo front crawl technique were also described and analyzed.

METHODS: Ten national level water polo players volunteered to participate in this study (23.2 ± 2.4 years old, 76.7 ± 8.0 kg, 176.3 ± 6.1 cm and 12.8 ± 4.5 % of fat mass). All subjects signed a written informed consent, in which the experimental protocol was described. The experimental procedures were approved by the local ethics committee.
The test session took place in a 25 m indoor pool. Each participant performed an intermittent protocol of 3x15 m at maximum intensity, performing each variant of the front crawl technique: front crawl technique, front crawl water polo (with the head above water) and front crawl water polo while leading the ball. In between bouts a rest interval of 2 min was accomplished. One complete stroke cycle was analyzed for each repetition of 15 m, being

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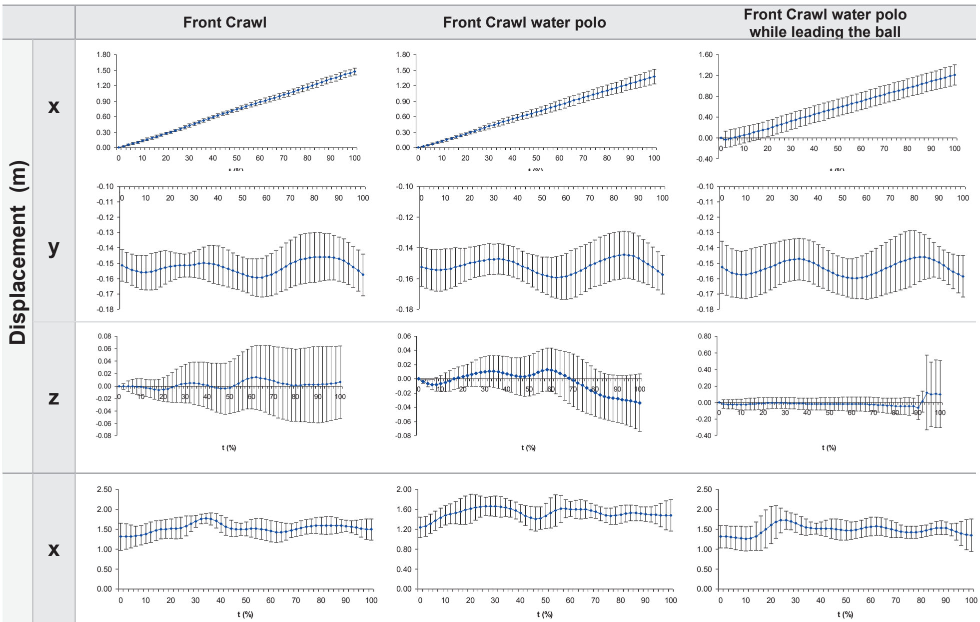
monitored while the swimmer passed through a specific calibrated space. A cubic calibration of 27 m^3 for the x, y and z was used. Twelve calibration points were used, and the synchronisation of the images was obtained using a pair of lights visible in the field of each video camera. Six stationary video cameras (Sony® DCR-HC42E) were used: two located on the surface and four underwater. The video images were digitized with Arial Performance Analysis System (Ariel Dynamics, USA) at a frequency of a 50 Hz, manually and frame by frame, coupled with Zatsyiorky anthropometric biomechanical model, adapted by De Leva (1996). The 3D reconstruction used Direct Linear Transformation (Abdel-Aziz & Karara, 1971) procedure and a low-pass filter of 5 Hz, for the analysis of the horizontal, vertical and lateral displacement, velocity and acceleration of the CM. The IVV were assessed through the calculation of the variation coefficient, and were also expressed as a percentage of the average horizontal velocity of the CM. The numerical treatment was conducted using MATLAB software.

Initially, the data were processed through a descriptive approach, using measures of central tendency (mean) and dispersion (standard deviation). The normal distribution was assessed using Shapiro-Wilk and homogeneity of variances was assessed using Levene Test. Given the lack of data normality and the sample size, for inferential analysis we used Friedman test to test the equality of averages between groups and when differences where found we used the Wilcoxon test to identify which groups presented differences. The level of statistical significance was set at α=0.05.

RESULTS: Figure 1 shows the average curves displacement (d), velocity (v) and acceleration (a) of the CM during the stroke cycle (x, y, z) in the front crawl, in water polo front crawl and in water polo front crawl while leading the ball. Significant differences were observed in d_x between the water polo front crawl leading the ball and front crawl (p=0.007) and d_z between the water polo front crawl leading the ball and front crawl (p=0.018) and with water polo front crawl (p=0.009). It was possible to observe significant differences in v_z between the water polo front crawl and front crawl (p=0.015). The other variables d (y), v (x, y) and a (x, y, z) do not display significant differences between the three conditions studied.



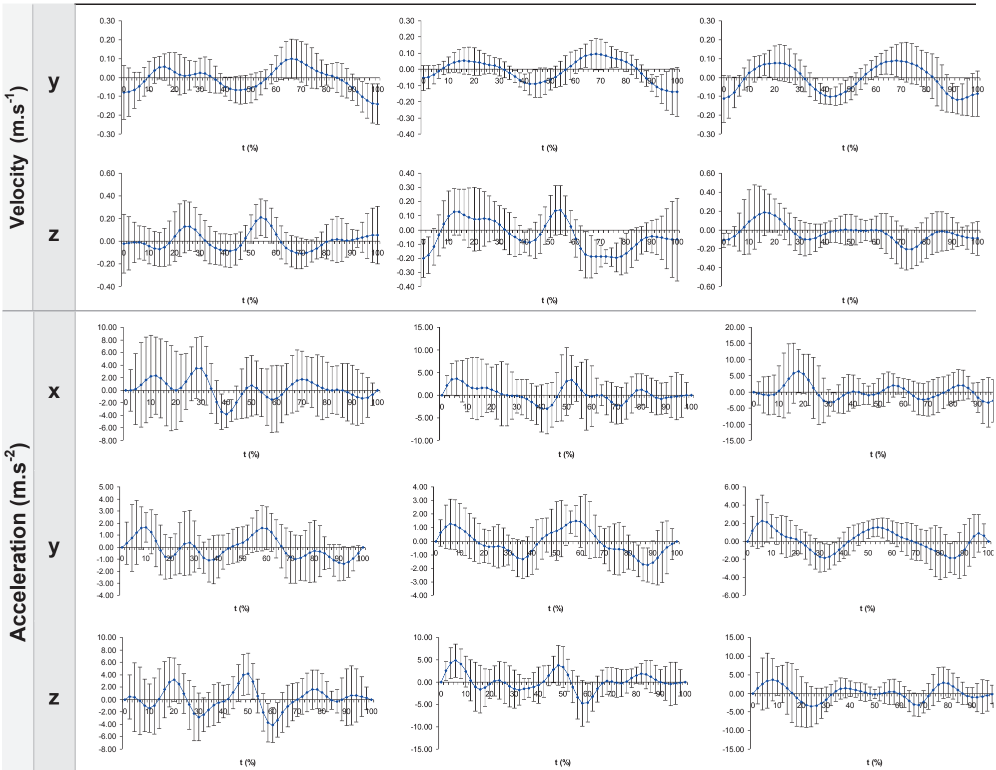


Figure 1: Average curves for the displacement, velocity and acceleration of the CM during the stroke cycle (x, y, z) in the three variants of the water polo front crawl technique.

Table 1 shows the values of IVV (x, y, z) and %IVV (x, y, z) during the stroke cycle analysed in front crawl, in water polo front crawl and water polo front crawl while leading the ball. The mean values found for the v_x were as follows: 1.52 $m.s^{-1}$ for the front crawl and water polo front crawl and 1.48 $m.s^{-1}$ for the water polo front crawl while leading the ball.

Table 1
Values of IVV (x, y, z) and %IVV (x, y, z) during the stroke cycle analyzed in three variants of water polo front crawl technique.

	Front crawl	Front crawl water polo	Front crawl water polo while leading the ball
IVVx	14.98	13.57	15.78
IVVy	74.81	72.91	67.31
IVVz	73.72	71.69	80.49
%IVVx	9.86	8.93	10.38
%IVVy	49.22	47.97	44.28
%IVVz	48.50	47.16	52.95

DISCUSSION: Given the lack of literature regarding the general kinematical variables and the IVV assessment in water polo, it is difficult to discuss the obtained results. However, it can be hypothesized that the different front crawl techniques studied imposed different d_x patterns; in fact, when performing front crawl while leading the ball players need to control the ball position, raising the elbows higher and shorting the amplitude of the hand entering the water, which are typical in the other two studied techniques. The similarity observed between the front crawl and the water polo front crawl could be explained by the players' specialization in the water polo techniques, since they present a lower front crawl stroke

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length compared with elite swimmers (2.16 m/cycle observed by Seifert et al., 2004). For differences found for d_z and v_z we can assume that they are due to the fact that the three conditions vary in the swimming position and the amplitude of the beating of the lower limbs. The similarity found between the three test conditions in d_y may be due to the water polo front crawl and water polo front crawl leading the ball techniques being derived from the front crawl. The acceleration variations in all the motion axes presented great similarity between the three test conditions, since the techniques are very similar for water polo players. The relative %IVV in the three axes for the three techniques studied present coherent results with previously published literature for the front crawl technique (Figueiredo et al., 2008). The IVV_x was higher in the water polo front crawl leading the ball, probably due to the constrains caused by the ball. The IVV_y was higher in the front crawl probably due to water polo players having better proficiency in techniques of water polo. The IVV_y was lower in front crawl leading the ball, possibly by the players seeking to maintain a more stable position helping to control the ball. The IVV_z was higher in the water polo front crawl leading the ball, probably because of the movement of the ball that determines the direction of player movement in order to achieve a better and more efficient driving of the ball.

CONCLUSION: The findings obtained in this study emphasize the importance of kinematical parameters in the analysis of variants of a swimming technique, in this case, those used in water-polo front crawl. It was possible to confirm that, despite the general similarities of the variants, the water polo front crawl while leading the ball imposes higher intra-cycle velocity changes, being possibly a less economic and efficient technique. Furthermore, in the same perspective, the front crawl seem to be the more mechanically sound technique for the water polo player, but it doesn't allow the same tactical advantages as the others, so it only can be used for fast and recovering swims.

REFERENCES:

Abdel-Aziz, Y. I. & Karara, H. M. (1971). Direct linear transformation from comparator coordinates into object space coordinates in close range photogrammetry. *American Photogrammetry Symposium on Close Range Photogrammetry* (pp 1-18). Falls Church: American Society of Photogrammetry.

Alves F, Santos PM, Veloso A, Pinto Correia I, Gomes-Pereira J (1994). Measurementof intracycle power variation in swimming. Motricidad Humana; 10: 69–75.

Barbosa, T. M., Keskinen, K. L., Fernandes, R., Colaco, P., Lima, A. B., and Vilas-Boas, J. P. (2005). Energy cost and intracyclic variation of the velocity of the centre of mass in butterfly stroke. *European Journal of Applied Physiology, 93*, 519-523.

Costill D, D'Aquisto L. (1987). Video-computer analysis of swimming technique. *J Swim Res*, 3: 5–9.

De Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*, 1223-1230.

Figueiredo, P., Vilas Boas, J.P., Maia, J., Gonçalves, P., Fernandes, R.J. (2009). Does the hip reflect the centre of mass swimming kinematics? Int J Sports Med; 30: 779-781.

Figueiredo, P., Contreras, G., Morales, E., Pereira, S., Gonçalves, P., Arellano, R., Seifet, L., Chollet, D., Vilas-Boas, J.P., Fernandes, R. (2008). Intracyclic speed fluctuations of the center of mass and its relationship with the index of coordination. In Y. Kwon, J. Shim, J. Kum Shim, I. Shim (eds.), Proceedings of XXVI International Conference on Biomechanics in Sports, pp.412-415. Seoul, Korea.

Holmer I. (1979). Analysis of acceleration as a measure of swimming proficiency. In: Terauds J, Bedingfield EW (eds). Swimming Science III. Champaign, IL: Human Kinetics Publishers; 119–125.

Miller D. (1975). Biomechanics of swimming. Exerc Sport Sci Rev; 3: 219–248.

Miyashita M.(1971). An analysis of fluctuations of swimming speed. In: Lewillie L, Clarys JP (eds). Proceeding of the First International Symposium on "Biomechanics in Swimming, Waterpolo and Diving". Bruxelles: Université Libre de Bruxelles, 53-58.

Seifert, L., Chollet, D., and Bardy, B. G. (2004). Effect of swimming velocity on arm coordination in the front crawl: a dynamic analysis. *Journal of Sports Sciences, 22*, 651-660.

Vilas-Boas JP. (1992). A photo-optical method for the acquisition of biomechanical data in swimmers. In: Ronado R, Ferringo G, Santambrogio G (eds). X Symposium of the International Society of Biomechanics in Sports. Milan: Edi. Ermes, 142–146.

Vilas-Boas JP. (1996). Speed fluctuations and energy cost of different breaststroke techniques. In: Troup JP, Hollander AP, Strass D, Trappe SW, Cappaert JM, Trappe TA (eds). Biomechanics and Medicine in Swimming: Swimming Science VII. London: E. & F. N. Spon, 167–171.