MEASUREMENT OF BUTTERFLY AVERAGE RESULTANT IMPULSE PER PHASE

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The aim of this study was to measure the average resultant impulse (ARI) per phase of the stroke cycle in butterfly and to analyse the variability of ARI according to the adopted breathing technique. The sample was composed of 6 male Portuguese swimmers at national and international level. 6 cameras were set, obtaining non coplanar images (2 "dual media" images included). The study comprised the kinematical analysis of stroke cycles of the butterfly stroke using the "Ariel Performance Analysis System" from Ariel Dynamics Inc. and a VCR at a frequency of 50 Hz. The ARI was calculated using the mean horizontal acceleration of the center of mass in each phase, the absolute duration of each phase and the body mass of the swimmer. Comparing the ARI according to the breathing technique adopted in each phase of the stroke cycle, we only observed significant differences in the outsweep. Comparing the intra-cyclic variations of the ARI in the different breathing techniques adopted, the arm's recovery when compared with the remained phases presented a significantly lower ARI.

KEY WORDS: swimming, butterfly stroke, kinematics, impulse.

INTRODUCTION: The average resultant impulse (ARI) can provide us with useful information about the technical proficiency of the swimmer (Alves, 1996). This is possible due to the ARI result from the differences between propulsion and resistance (van Tilborgh, Willems & Persyn, 1988). One method to estimate the horizontal resultant impulse is through the swimming speed profiles, knowing the time values and the swimmers body mass (Vilas-Boas, 1994). This method has the benefit of allowing the calculation of the ARI per stroke phase (van Tilborgh, Willems & Persyn, 1988). In that way, knowing the strongest and the weakest points of the stroke cycle it is possible to promote an improvement on the mechanics of the swimming technique in study. In other words, the measurement of the ARI per phase can be a useful diagnostic tool helping the optimisation of the co-ordination movement, the body position and the stroke mechanics of a swimmer. In fact, this approach has been used in several swimming techniques, such as the front crawl (Alves, 1996), the backstroke (Alves, 1996) and the breaststroke (Persyn et al., 1986; van Tilborgh, Willems & Persyn, 1988; Vilas-Boas & Fernandes, 1993; Vilas-Boas, 1994). However, there seems to be no investigation regarding the butterfly stroke. Therefore the aim of this study was to estimate the ARI per stroke phase in Butterfly and to analyse the variability of these parameter according to the breathing technique adopted by the swimmers.

METHODS: The sample was composed of 6 male Portuguese swimmers at national and international level (19.0±2.0 years old; 67.367±6.571 Kg of body mass; 173.9±4.0 cm of height). Two pairs of video cameras (JVC GR-SX1 SVHS and JVC GR-SXM 25 SVHS) were used for dual media videotape recording in non-coplanar planes. Both pairs of cameras were synchronised in real time and edited on a mixing table (Panasonic Digital Mixer WJ-AVE55 VHS and Panasonic Digital AV Mixer WJ-AVE5) creating one single image of "dual media" as it was previously described by Vilas-Boas et al. (1997). One of the two supports was set in one end walls 8.10m away from the trajectory of the swimmer. The second structure was set in one of the lateral walls at 9.30m from the forehead wall where the first structure was installed and at 10.20m from the trajectory of the swimmer. Another camera (Panasonic DP 200 SVHS) was set in an underwater window in the end wall, at 0.90m deep. One last camera (Panasonic DP 200 SVHS) was set 4.50m above the surface water. In these two last cases, the optical axis was oriented in the direction of the displacement of the swimmers. In all the situations, all cameras or pair of cameras recorded images of the swimmer in non-coplanar planes, different from all the other cameras or pair of cameras. Synchronisation of the images was obtained using LED's placed on the recording field of every camera or pair of cameras, which were turned on regularly and simultaneously to initiate the synchronisation every time the swimmer entered the performance volume. This was assumed to be delimited by the calibration volume, which was defined by a 3x3x3 meters cube. The calibration cube was marked with 32 calibration points. Each swimmer started in water and performed 3 sets of 3x25 meters in Butterfly stroke at a constant velocity as close as possible from the maximal, using exclusively frontal inspiration cycles, lateral inspiration cycles and non-inspiratory cycles in each set. The study comprised the kinematical analysis of the different stroke cycles at the Butterfly stroke using the "Ariel Performance Analysis System" from Ariel Dynamics Inc. (APAS) and a VCR (Panasonic AG 7355) at a frequency of 50 Hz. It was used the Zatsiorsky's model adapted by de Leva (1996) which is composed by 22 anatomical points of reference. The 3D reconstruction of the digitised images was performed using the "Direct Linear Transformation" procedure (Abdel-Aziz & Karara, 1971). It was used a filter with a cut-off frequency of 5Hz, as suggested by Winter (1990) for the analysis of the velocity and the acceleration of the center of mass. The ARI was calculated using the mean horizontal acceleration of the center of mass per stroke phase, the absolute duration of each phase and the swimmers body mass. The acceleration and the duration values were obtained from the APAS. The mean horizontal velocity of the center of mass did not presented significant differences between the 3 breathing styles. Differences on ARI between the breathing techniques and in each technique between phases were tested using the "ANOVA for repeated measures" ($p< 0.05$).

RESULTS AND DISCUSSION: Figure 1 presents the comparison of the ARI in each swim phase between the three breathing techniques. Comparing the ARI according to the adopted breathing technique in each phase of the stroke cycle, we only observed significant differences in the outsweep. In this phase, the ARI was significantly higher using the frontal inspiration cycles rather than the lateral inspiration cycles [$F(1;5)= 82.688$, $p=0.0003$] or the non-inspiratory cycles [$F(1;5)= 12.944$, $p=0.0156$]. There was no significant differences between the three breathing techniques in the hands path or in the relative duration of the outsweep, factors that could explain this results. However, the absolute duration of the outsweep was higher using the frontal inspiration technique than the others two, but without statistical significance. However, this is probably one explanation for the higher values of the ARI during the outsweep adopting the frontal breathing. In other way, the inspiration act might also have a little influence in the ARI. Doing the inspiration through a cervical extension, it will promote an increase of the maximal body cross-section area; and therefore, an increase of the Drag Force (Clarys, 1979). Therefore, the swimmer needs a higher horizontal impulse in the subsequent phases, specially the outsweep, to achieve mean horizontal velocities in the most propulsive phases of the stroke cycle, similar to the ones observed in the other breathing techniques.

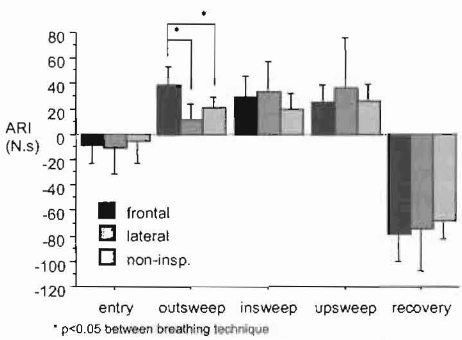

Figure 1. Comparison of the average resultant impulse (ARI) in each swim phase between the breathing techniques.

Figure 2 presents the intra-cyclic variations of the ARI using the different breathing techniques. Comparing the intra-cyclic variations of the ARI in the different breathing techniques, they were quite similar. In all models, the recovery phase when compared with the remained phases presented a significantly lower ARI. In fact, this is in agreement with the findings of Schleihauf (1979), Schleihauf et al. (1988) and Mason, Tong & Richards (1992).

This might be explained due to the body position in that phase, which is characterised by an increase of the maximal body cross-section area and consequently a decrease of the mean horizontal acceleration of the center of mass of the swimmer. In the non-inspiratory cycles the ARI during the entry was significantly lower than in the outsweep [F(1;5)=18.095, p=0.0081] and in the upsweep [F(1;5)= 8.370, p=0.0341]. And in the frontal inspiration cycles the ARI was significantly lower in the entry than in the outsweep [F(1;5)= 22.458, p= 0.0052], in the insweep [F(1;5)= 33.349, p=0.0029] and in the upsweep [F(1;5)=14.706, p=0.0129]. In other word, the entry was the second less propulsive phase of the stroke cycle as it was reported previously by Schleihauf (1979), Schleihauf et al. (1988) and Mason, Tong & Richards (1992). This might be a result of the entry of the hands in the water as well as of the previously entry from part of the body, increasing the wave drag and, therefore, promoting a decrease of the mean horizontal acceleration of the center of mass. The ARI in the frontal inspiration cycles in the outsweep was higher than in the insweep [F(1;5)= 0.568, p=0.4853] and the upsweep [F(1;5)=1.547, p=0.2687]. Although this values did not present significant differences, the higher ARI in the outsweep might be due to a higher absolute duration of this phase in the frontal technique.

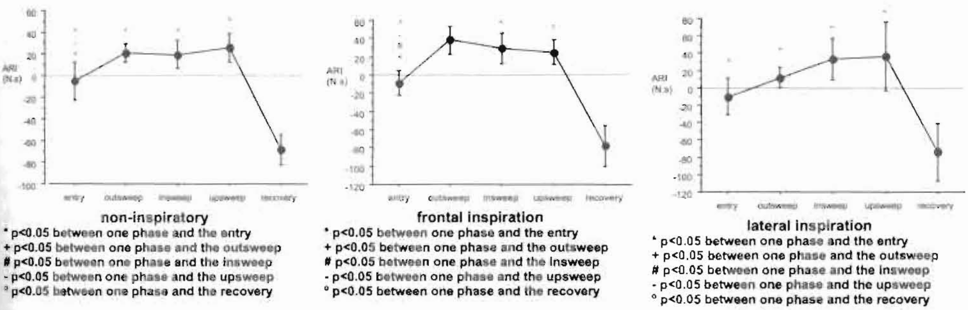

Figure 2. Comparison of the intra-cyclic variations of the average resultant impulse (ARI) using the different breathing techniques.

CONCLUSIONS: The butterfly stroke is a swimming technique where it is possible to observe some specific intra-cyclic variations of the ARI due to greater reductions of this parameter during the arm's recovery. So swimmers must learn to reduce the drop of the ARI during the arm's recovery by increasing the propulsive force produced by the legs actions and adopting a more streamline position of the body during this phase. It seems that there is no significant differences in the ARI during almost every phases of the stroke cycle, except for the outsweep, according to the breathing technique. So, the breathing style used it is not decisive for the adoption of a more fluent swimming in butterfly.

REFERENCES:

Abdel-Aziz, Y. & Karara, H. (1971). Direct linear transformation: from comparator coordinates into object coordinates in close range photogrammetry. *Proceedings of the Symposium on close-range photogrammetry,* 1-18. Church Falls.

Alves, F. (1996). Average resultant impulse per phase in swimming: a tool for technical analysis. In J. Abrantes (Ed.), *Proceedings of the XIV Symposium on Biomechanics in sports,* 281-284. Lisbon: Faculty of Human Movement of the Technical University of Lisbon.

Clarys, J.P. (1979). Human morphology and hydrodynamics. In J. Teradus & W. Bensingfiel (Eds.), *Swimming III,* 3-41. Baltimore: University Park Press.

De Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *J. Biomechanics,* **29**(9), 1223-1230.

Mason, B.; Tong, Z. & Richards, R. (1992). Propulsion in the Butterfly stroke. In: D. MacLaren, T. Reilly & A. Lees (eds.). *Biomechanics and Medicine in Swimming VI,* 81-86. London: E & FN SPON.

Persyn, U.; Van Tilborgh, L.; Daly, D., Colman, V.; Vijfvinkel, D. & Verhetsel, D. (1986). *Computuraized evaluation and advice in swimming.* 1° Congreso Mundial de entrenadores. Madrid.

Schleihauf, R. (1979). A hydrodynamic analysis of Swimming propulsion. In: J. Teraus & W. Bendingfied (eds.). *Swimming III*, 70-117. Baltimore: University Park Press.
Schleihauf, R.; Higgins, J.; Hinrichs, R.; Luertked, D.; Maglischo, L.; Maglischo, E. & Thayer, A. (1988). Propulsive techniques: Front Crawl Stroke, Butterfly, Backstroke and Breaststroke. In: B. Ungerechts, K. Wilke & K. Retsche (eds.). *Swimming V*, 53-59. Champaign : Human Kinetics Books.
Van Tilborgh, L.; Willems, E. & Persyn, U. (1988). Estimation of breaststroke propulsion and resistance-resultant impulse from film analysies. In P. Hollander, P. Huijing & G. de Groot (Eds.), *Biomechanics and medicine in swimming*, 207-214. Champaign: Human Kinetics.
Vilas-Boas, J.P. & Fernandes, P. (1993). Avaliação foto-óptica da técnica em nadadores. In J. Bento & A. Marques (Eds.), As ciências do desporto e a prática desportiva 337-360, Oporto: Faculty of Sport Sciences of the University of Oporto.
Vilas-Boas, J.P. (1994). Maximum propulsive force and maximum propulsive impulse in breaststroke swimming technique. In A. Barbarás & G. Fábian (Eds.), *Biomechanics in sports XII*, 307-310. Budapeste: Hungarian University of Physical Education.
Vilas-Boas, J.P.; Cunha, P.; Figueiras, T.; Ferreira, M. & Duarte, J. (1997). Movement analysis in simultaneous swimming techniques. In K. Daniel, U. Huffmann & J. Klauck (Eds.), *Cologne Swimming Symposium*, 95-103. Verlag, Bocknem: Sport Fahnemann.
Winter, D. (1990). *Biomechanic and motor control of human movement.* Chichester: John Wiley and sons.