approach was undertaken to examine the propulsion and drag forces across the body experienced during full body freestyle swimming using CFD. The swimmer used held the 50m and 100m freestyle World Record at the time of the testing and a full 3D surface scan of the swimmer was used for the CFD simulations. Manual 3D digitising was used to provide the 3D kinematics to animate the model. A realisable K-epsilon turbulence CFD model was used in the analysis.RESULTS: The overall changes in forces throughout the stroke were characterised by six clear cycles, containing four small peaks and two large peaks. These peaks represent the six beat kick pattern that was adopted, with the two large peaks correlating with the peak propulsion of the left and right arm strokes; which occurred simultaneously with two of the kick cycles. These peaks, and in particular the peaks associated with the arm stroke propulsion, were reflected in increases in the swimmer's instantaneous velocity. An examination of the breakdown in the distribution of forces revealed that the arms and legs create a significant amount of the total propulsion, with the trunk contributing to the majority of the drag force. The hands provided a total propulsive momentum of 23.8Ns while the combined contribution of the wrist, forearm and elbow was 27.6Ns. This highlights that the forearm position during the underwater arm stroke is as critical as that of the hands. Likewise the thighs, knees and shanks also contributed a greater percentage of the propulsion than the feet. DISCUSSION: The current study provided insight into how propulsion and drag forces are generated throughout a full freestyle swimming stroke through the use of CFD analysis. The resultant outcome of the analysis is both an increased level of foundational knowledge related to the production of propulsion and drag forces, as well as the provision of practical points that may be used to improve freestyle performance.

0-076

Computational Fluid Dynamics Applied to Competitive Swimming: The Role of Finger Position

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INTRODUCTION: The best fingers' relative position during the underwater path of the stroke cycle in swimming seems to be an unclear issue. Even in elite level swimmers, different relative positions of thumb and finger spreading can be observed. The aim of the current abstract was to present the hydrodynamic characteristics of a true model of a swimmer's hand with different fingers' positions using computational CFD. METHODS: Scans of the right hand of a male elite swimmer were obtained using a computer tomography scanner. The hand was scanned with fully abducted (68º), partially abducted (30º) and adducted thumb positions (Marinho et al., 2009). Furthermore, scans were made with fingers closed together, fingers with little distance spread (0.32 cm) and fingers with large distance spread (0.64 cm) (Marinho et al., 2010). Steady-state CFD analyses were performed using the Fluent® code. The measured forces on the hand models were decomposed into drag and lift coefficients (CD and CL). Attack angles of hand models of 0º, 45º and 90º, with a sweep back angle of 0º were used. RESULTS: The position with the thumb adducted presented slightly higher CD values compared with thumb abducted positions (0º, CD=0.25; 45º, CD=0.61; 90º, CD=1.09). The position with the thumb fully abducted presented higher CL values at attack angles of 0º (CL=0.24 vs. CL=0.21, partially abducted; CL=0.18, abducted) and 45º (CL=0.65 vs. CL=0.62, between fingers (0º, CD=0.24; 45º, CD=0.68; 90º, CD=1.13); presented higher CD values than the models with fingers closed (0º, CD=0.25; 45º, CD=0.61; 90º, CD=1.09) and fingers with large distance spread (0º, CD=0.26; 45º, CD=0.57; 90º, CD=0.93). The values for the lift coefficient presented little differences between the three models, for a given attack angle (0º, CL≈0.20; 45º, CL≈0.60; 90º, CL≈0.20). DISCUSSION: For hand positions in which the lift force can play an important role (e.g. insweep phases), the abduction of the thumb may be better, whereas at higher angles of attack, in which the drag force is dominant, the adduction of the thumb may be preferable. Moreover, these thumb positions should be associated to fingers slightly spread, allowing the hand to create more propulsive force during swimming. REFERENCES: 1. Marinho DA et al. J Sports Sci and Med 2009; 8(1): 58-66. 2. Marinho DA et al. J Appl Biomech 2010; in press. Supported by FCT (PTDC/DES/098532/2008)

0-078

Hydrodynamic Characterization of the First and Second Glide Positions of the Underwater Stroke Technique in Breaststroke

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INTRODUCTION: The gliding constitutes a non-negligible part of the swimming races. The aim of this work was to experimentally study the first and second gliding positions of the breaststroke underwater stroke used after starts and turns at several gliding velocities by characterizing: gliding velocity (v); body cross sectional area (S); drag coefficient (CD); passive drag (D). METHODS: Six national level male swimmers participated in this study. A methodology similar to that described in Vilas-Boas et al. (in press) was used, namely determining S using planimetry while D and CD were assessed through inverse dynamics based upon the velocity to time curve of each glide, monitored through a swim-meter (Lima et al. 2006). RESULTS: The first glide presented higher mean values of v (1.50 ± 0.22m/s and 1.15 ± 0.24m/s) while the higher values of acceleration were verified in the second glide. D increased with v while CD decreased. Swimmers showed a smaller S in the first glide position than in the second (759.95 ± 124.12cm2 vs 814.46 ± 111.23cm2). DISCUSSION: The first glide obtained higher v values, as it follows wall impulse and has a better hydrodynamic position. For both glides, D increases with v, while CD decreases. The first one is characterised by lower D and CD values for all v, probably due to a parallel and concurrent effect of S and CD caused by the increased body length and slenderness associated with the flexed shoulders and extended arm position. Therefore, swimmers and coaches should stress the need for body position control during the glides, and the need of technical evaluation, control and advice to allow drag reductions during swimming performance, and not only emphasising propulsion increase capabilities. REFERENCES: 1. Lima, A.B.; Semblano, P.; Fernandes, D.; Gonçalves, P.; Morouço, P.; Sousa, F.; Fernandes, R.; Barbosa, T.; Correia, M.V.; Tani, G.; Vilas-Boas, J.P. (2006). A kinematical, imagiological and acoustical biofeedback system for the technical training in breaststroke swimming Portuguese Journal of Sport Sciences, 6 (Suppl.1): 22. 2. Vilas-Boas, J.P.; Costa, L.; Fernandes, R.; Ribeiro, J.; Figueiredo, P.; Marinho, D.; Silva, A; Rouboa, L.; Machado, L. (in press). Determination of the drag coefficient during the first and second gliding positions of the breaststroke underwater. Journal of Applied Biomechanics