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Swimming Propulsion Forces Are Enhanced by a Small Finger Spread

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The main aim of this study was to investigate the effect of finger spread on the propulsive force production in swimming using computational fluid dynamics. Computer tomography scans of an Olympic swimmer hand were conducted. This procedure involved three models of the hand with differing finger spreads: fingers closed together (no spread), fingers with a small (0.32 cm) spread, and fingers with large (0.64 cm) spread. Steady-state computational fluid dynamics analyses were performed using the Fluent code. The measured forces on the hand models were decomposed into drag and lift coefficients. For hand models, angles of attack of 0°, 15°, 30°, 45°, 60°, 75°, and 90°, with a sweep back angle of 0°, were used for the calculations. The results showed that the model with a small spread between fingers presented higher values of drag coefficient than did the models with fingers closed and fingers with a large spread. One can note that the drag coefficient presented the highest values for an attack angle of 90° in the three hand models. The lift coefficient resembled a sinusoidal curve across the attack angle. The values for the lift coefficient presented few differences among the three models, for a given attack angle. These results suggested that fingers slightly spread could allow the hand to create more propulsive force during swimming.

Keywords: hand shape, numerical simulations, computational fluid dynamics, forces, competitive swimming

The study of human swimming propulsion is one of the most complex areas of interest in sport biomechanics (Payton et al., 2002). Over the past decades, research in swimming biomechanics has evolved from the observation of a subject's kinematics to a basic flow dynamics approach, following the line of the scientists working on this subject in experimental biology (Dickinson, 2000; Arellano et al., 2006).

Computational fluid dynamics (CFD) is one of the recent methodologies used to achieve this goal. This methodology allows us to analyze the water flow around the human body, to understand the magnitude of drag forces resisting forward motion (Silva et al., 2008; Marinho et al., 2009), and to compute the propulsive forces produced by the propelling segments (Bixler & Riewald, 2002; Lecrivain et al., 2008).

Computational fluid dynamics could help coaches, in the short term, with technique prescription. Moreover, this methodology could provide answers to some practical issues that remain controversial. The finger's relative position during the underwater path of the stroke cycle is one of these cases. A large intersubject variety of relative finger positioning can be observed during training and competition. Some swimmers (i) maintain the fingers closed together (not spread apart), (ii) others have a small distance between fingers, and (iii) still others have a large distance between fingers. Indeed, the propulsive repercussions of those three possibilities remain unclear for swimming coaches and scientists. There is a lack of research on this issue, and some ideas are passed among members of the swimming community with little empirical (experimental or numerical data) support. Experimental data are controversial: for example, Schleihauf (1979) showed that the fingers closed together and the

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