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Hydrodynamics in Swimming: practical implications to enhance swimming performance

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Abstract

This presentation covers topics in swimming simulation from a computational fluid dynamics (CFD) perspective. This perspective means emphasis on the fluid mechanics and CFD methodology applied in swimming research. We concentrated on numerical simulation results, considering the scientific simulation point-of-view and especially the practical implications with swimmers.

Regarding aquatic locomotion, CFD has been applied in swimming attempting to understand deeply the biomechanical basis underlying swimming locomotion. Several studies have been conducted willing to analyze the propulsive forces produced by the propelling segments (e.g. Bixler and Riewald 2002; Rouboa et al. 2006) and the drag force resisting forward motion (e.g. Bixler et al. 2007; Marinho et al. 2010). However, it would be interesting to apply this methodology in other fields such sailing, windsurfing, surfing, canoeing and rowing, not only in the analysis of equipment design (Pallis et al. 2000) but also to relate different displacing strategies with performance. In the same way, CFD can also provide new highlights about aquatic activities related to health (e.g. head-out aquatic exercises or water-aerobics) and muscle-skeletal injuries rehabilitation in water (e.g., hydrotherapy) (Lauer et al., 2017).

CFD analysis in swimming has addressed to understand two main topics of interest: (i) the propulsive force generated by the propelling segments and; (ii) the drag forces resisting forward motion, since the interaction between both forces will influence the swimmer's speed.

Concerning the analysis of the propulsive force, CFD methodology can be used for instance to study the contribution of arm's action to propulsion (Lecrivain et al., 2008; Gardano and Dabnichki, 2006), the contribution of leg's action and kicking to propulsion (Lyttle and Keys, 2006), the effect of finger's positions in the propelling force (Marinho et al., 2009a; Marinho et al, 2010; Vilas-Boas et al, 2015).

In addition to the analysis of the propulsive forces generation, CFD methodology can be used to understand the intensity of drag forces resisting forward motion and its effects over swimming performance, namely analysing the kicking performance after start and turn (Lyttle and Keys, 2006), the different gliding positions (Marinho et al., 2009b; Zaidi et al., 2008), the drafting effects (Silva et al., 2008), and the effects of swimsuits and training equipments in swimming performance (Marinho et al., 2012).

CFD can be a good approach to study swimming hydrodynamics and can contribute to the development of swimming science. However, despite the important steps forward in the application of CFD in swimming, there are several aspects that can be improved. Therefore, we can state some ideas and some purposes for other studies following and complementing the ones we have presented:

1. Propulsive forces studies:

(i) The computation of the ideal shape for a swimmers hand, arm, foot, or other body segment;
(ii) The computation of the effects of acceleration (positive and negative), and multi-axis rotations on lift and drag;
(iii) The computation of the added mass of water as an inertial effect to the body displacement during the stroke cycle;
(iv) The computation of the effect of different stroke patterns on propulsion in front crawl, backstroke, butterfly and breaststroke.

2. Drag forces studies:

(i) The computation of total drag force on a swimmer moving through the water, and the relative contribution of pressure drag, skin-friction drag and wave production drag for the total drag;
(ii) The effect of different forms of streamlining on the hydrodynamic drag;
(iii) The computation of the effect of underwater turbulence and waves on a swimmers motion;
(iv) The effect on hydrodynamic drag of "dragging" off a swimmer, either in an adjacent lane and/or behind;
(v) The evaluation of the effects of different swimming suits and other equipments on hydrodynamic drag;
(vi) The computations of the ideal body shape and size to minimise drag;
(vii) Eventually, to calculate active drag, using moving meshes would be an important task.

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