Study of sculling actions during hovering and displacement, applying cinematic analysis, flow visualization and velocimetry.

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New techniques of flow visualization applied to swimming strokes are changing the point of view to study, analyse and the interpretation of propulsive mechanisms. The concept of induced-momentum propulsion based on the reciprocal interaction between the body motion and motion of water momentum tried to explain the propulsive phenomenon using an unsteady flow approach. Sculling is a propulsive technique applied isolated in synchronized swimming and water-polo and combined with the movements of the pull in the swimming strokes. This movement can be performed while "hovering" or tethered sculling (or supporting sculling) and sculling producing displacement. The sculling movement is composed by four kinematic portions: two translational phases (in-sweep and out-sweep), when the hands move through the water with efficient angle of attack (about 40º) and two rotational phases (pronation and supination), when the hands rapidly rotate and reverse direction. The purpose of this pilot study is to analyze the sculling action in two conditions: hovering and displacement. Kinematic analysis and velocimetry will be combined with flow visualization.

Two subjects participated in the study. They performed several trials alternating hovering and sculling with and without flow visualization. The trials were developed using one underwater video camera perpendicular to the plane of the swimmer's actions or displacements. Three cycles were digitalized and studied for each swimmer and condition.

Two different trajectories were found, an infinite symbol shape while hovering and a zigzag shape during displacement scull. In displacement the outward phase is perpendicular to the swimmers displacement and the inward movement is about 45º diagonal moving the hand forward 0.35 m and producing a similar distance body displacement. A near constant body velocity is observed (0.66 m/s), including both sculls and stroke reversal phases where an unsteady propulsive phenomenon seems to be applied. The scull frequency is changed (1.82 displ - 1.21 hov. Hz) while the amplitude is kept similar. Peak velocities are observed in the middle of both scull displacements with similar values (more than 2 m/s) during the in and out phases. During the reversal phase no hand displacement is observed. This velocity behaviour is almost the same during the hovering actions.

The flow visualization method applied (injected bubbles in the hand palm) allowed us to see how vortices are generated after each stroke reversal. A wake composed by a vortex trail shed is produced, similar than the generated by an oscillating foil that produces thrust. The vortices maintained their rotation for several seconds while its size is expanding. While hovering the vortices are generated after each stroke reversal, but moving backwards while the hands are kept in the same plane, moving in and out.