Journal of Ergonomics

Takagi, J Ergonomics 2015, 5:2
DOI: 10.4172/2165-7556.1000e138

Research Article

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Competitive Swimming and Ergonomics

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Received date: June 08, 2015, **Accepted date:** June 12, 2015, **Published date:** June 19, 2015

Editorial

During the course of evolution, hominid ancestor had become human being by mastering upright and bipedal walking. Due to the bipedal walking, our ancestors became possible to use their upper limb freely and such a behavioural change caused their brain development. That is to say, an adaptation to walk on two legs on land is what makes us human. If so, human beings do not need to swim in the water.

In fact, human beings are not physically well suited to swimming. If you examine the physical environment that a human swims in from the perspective of Reynolds number, surface flow undergoes a transition from laminar flow to turbulent flow and friction drag dramatically increases. Furthermore, from the perspective of Froude number wave drag is also maximized. Therefore, a human swimming is a battle against drag, and only those who can beat the drag factor will become the champions who receive the accolades [1]. The drag opposes the motion of anybody that travels though fluids, such as water and air. As water is around 800 times-1000 times denser than air, the drag is a much greater limitation in swimming than it is in land-based sports [2].

In swimming, speed depends on the interaction of propulsive and resistive forces. A swimmer can improve by increasing the propulsive forces that he or she can produce, or by reducing the resistive forces that act on the body at a given speed. But coaches and swimmers tended to focus most of their attention on increasing the propulsive forces by improving their strength, endurance or stroking technique. In the case where all the competitors have reached the same degree of physiological fitness, success at the top level depends on small refinements in technique. Knowledge of hydrodynamics could therefore help elite competitive swimmers improve their technique by reducing resistive drag and by increasing propulsion. Although reducing drag and increasing propulsion are both important, I refer only to an increase of propulsion because of space limitations.

For mechanisms in generating of propulsion during swimming, a distinct paradigm shift has been seen recently. In the past, a quasi-static approach was the mainstream to predict fluid forces on the hand during swimming. When the force is produced by a swimmer's hand with a given cross-sectional area (S), depends on its orientation and its speed (U) relative to the water. Lift force (L) and drag force (D) acting on the hand are estimated as

$$L = \frac{1}{2}\rho S C_L U^2,$$

$$D = \frac{1}{2}\rho S C_D U^2,$$

where ρ is the density of water and C_L and C_D are the coefficients of lift and drag. However, an unsteadiness in the flow field during swimming must be considered because the quasi-static approach might underestimate the fluid forces up to four times when ignoring the effect of acceleration and vortices [3,4]. Therefore Takagi, Nakashima, Ozaki, and Matsuuchi [5,6] attempted to directly measure the hydrodynamic forces, the pressure distribution, and the flow field around a hand by using a robotic arm and particle image velocimetry (PIV).

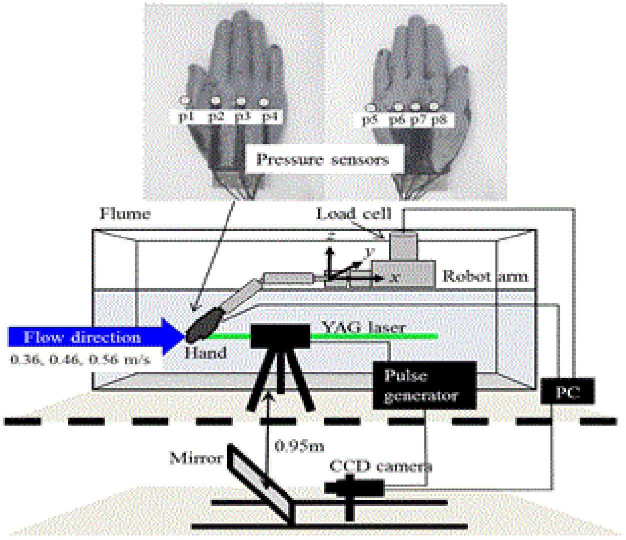

Figure 1: Schematic of experimental devices.

As results, two new mechanisms were found in their studies. One is the unsteady lift force generated when hand movement changes direction during the stroke, leading to vortex shedding and creation of a bound vortex around it. This bound vortex circulation results in a lift that contributes to the thrust. The other occurs when the hand moves linearly with a large angle of attack, creating a Kármán vortex street. This street alternatively sheds, resulting in a quasi-steady drag contributing to the thrust [6]. To understand these mechanisms for generating hydrodynamic forces must bring significant benefits to coaches and swimmers and might lead to the development of a new stroking technique.

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