Will you swim more efficiently by cupping your hands ?

Willem van de Water[1], Joris van den Berg[1,2], Rens Bazuin[1], Constantin Jux[2], Andrea Sciaccitano[2], Jerry Westerweel[1]

[1]Department of Mechanical Engineering, Laboratory for Aero and Hydrodynamics,

[2]Department of Aerospace Engineering,

Delft University of Technology, Delft, The Netherlands.

Humans are not created for swimming. Their hands and feet lack fins, which are a tremendous aid in propulsion. The question here is what thumb and finger posture in the front crawl stroke provides maximum drag. Increasing drag increases thrust and gives the same thrust at lower relative velocities, both resulting in enhanced swimming efficiency.

We measure the forces on real-life models of forearm with hands in a wind tunnel, flexing the thumb and fingers in various positions. It was found by others and us [1] that a slight spread of the fingers results in increased drag. The question is whether the same holds for cupping the fingers or flexing the thumb. Answering this question is challenging because the effects are so small. However, even a small effect may have a large influence in competitive swimming, namely the difference between a medal and no medal at all. A hand is a complex aerodynamic structure, and obtaining a quantitive map of the flow organisation is another challenge.

The cup anemometer is the intuitive analogy with a cupped hand. If the cup faces the incoming flow with its hollow side, the drag is 20% larger than that of a disk with the same projected area. If this would carry over to front-crawl swimming, the advantage would be tremendous. However, we find that cupping the hand is detrimental for drag. Swimming is most efficient with a flat hand.

From another accurate force balance measurement in the TUDelft low-speed wind tunnel we find that flexing the thumb has a small effect on the drag, such that the drag is largest for the opened (abducted) thumb.

Using tomographic robotic particle image velocimetry we visualize how the flow structures around the hand are influenced by thumb abduction. This technique provides the full 3D velocity field, and even enables the computation of the pressure distribution over the hand. Although the computed pressure agrees well with a direct measurement with pressure taps (figure), its accuracy is still not sufficient to reproduce the efficiency advantage of the abducted thumb.

[1] J. van Houwelingen, D. H. Willemsen, R.P.J. Kunnen, G.J.F. van Heijst, E.J. Grift, W.P. Breugem, R. Delfos, J.J. Westerweel, H.J.H. Clercx and W. van de Water, J. Biomechanics, **63**, 67-73 (2017)

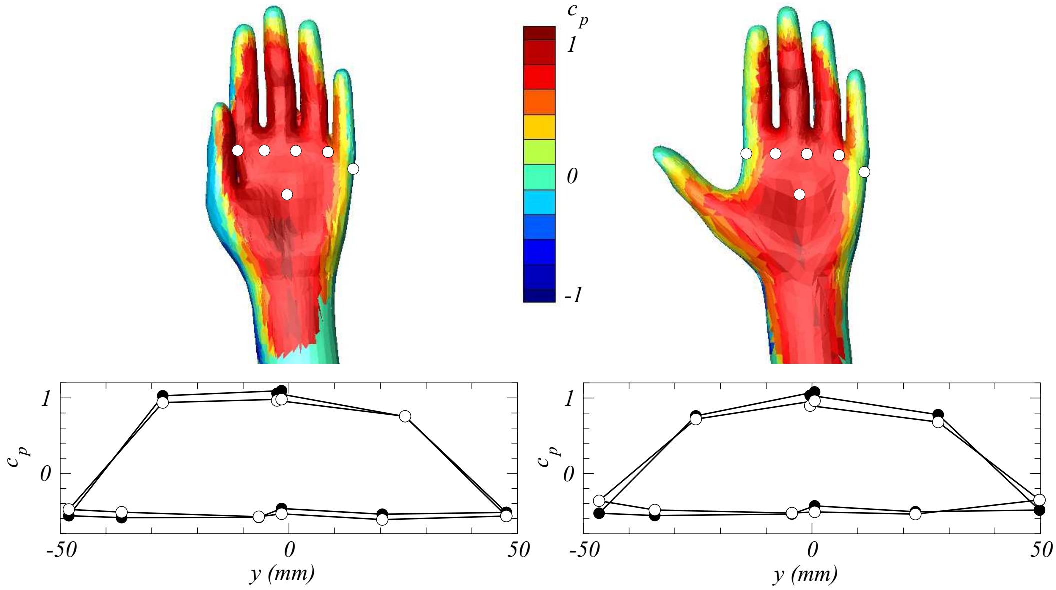

Figure 1: (a, b) Pressure distribution on the palm side of hands with adducted (a) and abducted (b) thumb. It was computed from the measured 3D flow field and Reynolds stresses. Frames (c, d) are a comparison between the pressures from PIV (open circles) and those measured with a pressure sensor (closed dots). The pressure taps on the palm side of the hand are indicated. Those at the back of the hand are approximately at the same $z-$location. The pressure at the palm center is taken as reference stagnation pressure.