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Patterns of flow pressure due to hand-water-interaction of skilled breaststroke swimmers – a preliminary study

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Abstract

Self-induced aquatic propulsion is an effect of interaction of the limbs and water mass (LWI) which change the energy-density per volume and the momentum of water mass, simultaneously. The change of volumetric energy-density of water can be measured via pressure tap probes detecting static pressure of unsteady flow via pressure sensors. The data of elite breaststroke swimmers wearing gloves with pressure taps on both sides of the hands were presented as pressure difference per hand (p-diff) in real-time in a split screen video together with the hand action. The purpose of this preliminary study was to check a) the stability of the setup including the data collection under pool condition with various swimmers and b) to answer coaches' questions concerning the relation of peak pdiff-data and hand action. Among others it is shown that p-diff(max) coincides with a) deepest hand penetration at the end of the inward sweep of the hands and b) max body acceleration during hand action, shortly before max body velocity occurs.

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Keywords: pressure measurement; hand action; breaststroke swimming

1. Introduction

Breaststroke swimming is a common self-induced activity in aquatic space. Limb-water-interaction (LWI) is a means to transfer energy to the surrounding water affecting its volumetric energy-density and momentum causing a momentum-couple (conservation of momentum) known as action & reaction. In Fig. 1 various aspects of aquatic locomotion - from origin of motion to the acceleration of the swimmer - are presented, highlighting a level with intermediate effects, which lacks attention in most swimming books. Intermediate effects are related to displaced water mass e.g. by hand action. The intermediate level is essential to understand the interaction and its unsteady flow effects which are the basis to accelerate the swimmer as an end effect.

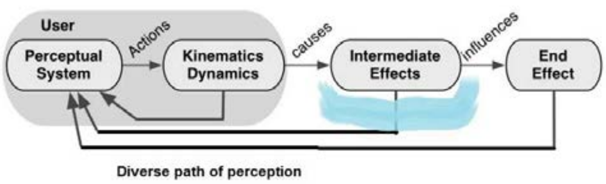

Fig. 1. Various aspects from brain to the acceleration of the swimmer and feedback routes of invisible effects (Herman et al, 2012).

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Aquatic Space Activities (ASA) can be defined as cognitively controlled, goal-oriented self-induced cyclic actions in water with body-water-mass interaction under the conditions of limited energy reservoir with relatively low efficiency. Cognition is defined as the cerebral information processing. Knowledge of cognitive matter in relation to ASA is potentially important for a better communication about specific stroke aspects, like straight path of the hand versus turning of hand orientation in terms of supination / pronation. Provided the rate of energy liberation via the aerobic/anaerobic metabolism are sufficiently trained fast swimming breaststroke demands highly skilled cyclic limb interactions following unsteady flow physics and cover 100m in less than 60 s. Unsteady flow physics considers acceleration and velocity terms without spending too much energy. Concentration on the effects due to the changes of volumetric energy-density in the water is necessary to overcome the myth, that a push off from the water is possible, which is not, even though this is a common saying, since water is giving way to firm bodies (drag does not explain the interaction effects sufficiently even if repeatedly stated).

2. Liquid pressure represent volumetric energy density

The research of the efficient locomotion of aquatic vertebrates with periodical change of their outer form direct the attention to appropriate aspects, like importance of flow pressure. Water mass set in motion by animals or man is invisible but can be sensed (fishes need flow sensing to survive). Elite swimmers are masters of displacing water mass at low energy costs resulting in high swimming speeds. To increase the mastery of self-induced locomotion it is advantageous to possess a specialized cognitive control transmission tool, which is named the “feel for water”. Experts, when asked about their opinion concerning the representative agent of the feel for water emphasize the pressure difference of the flow around the hands as a decisive parameter. However, communication between coach and swimmer about the intermediate effects in terms of perceivable parameters is hardly possible due to lack of comparative scales of this particular agent. In the history of swimming research, e.g. documented by the congress series of Biomechanics and Medicine in Swimming (https://www.iat.uni-leipzig.de/datenbanken/iks/bms/) some works related to pressure recordings in conjunction with body actions were published.

Some of these former works, mentioning the term (hand)pressure in their title or obviously recorded pressure components, however, presented the data as normalized hand force terms ([3] Havriluk, 2006, [9] Takagi & Wilson, 1999), an approach which is not followed in this paper. The works which focus on the nature of flow pressure change due to interaction of body parts and deformable water mass which provide information about the pressure data ([1] Dubois et al, 1979, [6] Loetz et al , 1984, [10] Toussaint et al. 2002, [11] Ungerechts, 1983) is followed here because it is still a matter of discussion how changes of flow pressure contributes to reaction in and against swimming direction, simultaneously.

Using the term flow pressure one should keep in mind that it is not equivalent to the pressure term used in daily life (e.g. physios exert pressure) since water gives way to solid objects. [5] Klauck & Ungerechts (1997) showed that the mere kinematics of limb actions is no indicator of flow effects since the effect of interaction with water mass is not considered. From studies considering the unsteady flow in human swimming ([7] Matsuuchi et al., 2009, [10] Toussaint et al. 2002, [12] Ungerechts & Klauck, 2008) it can be concluded that the focus on changes in static (also named hydrodynamic) pressure component is justified because it represents the origin of the work done on the water ([13] Webber et al, 2001). Unsteady flow means that time-average methods cannot be applied since static pressure varies locally and with time (see body undulation) while so-called engineering turbulence can be treated by time-average equation ([8] Naka & Obi, 2009). As mentioned, self-induced interaction in aquatic space simply transfer metabolic energy via limb action to the energy field of a unit of water volume. For pressure terms the same unit, named Pascal (Pa) is correct; this applies also to the change of energy density per unit volume or volumetric energy-density as well as the static pressure, respectively. Placing emphasis on the flow pressure, instead on pressure values, normalized to a unit area, called hand force, has to do with the claim of elite swimmers that pressure is the essential parameter feeding their elaborated perception of water flow. The purpose of this preliminary study was to check a) the stability of the setup including the data collection under pool condition with various swimmers and b) to answer coaches’ questions concerning the relation of peak pdiff-data and hand action relative to the water.

3. Methods

Related to the purpose of this preliminary study of a setup enabling to measure, calculate, register and show the results in real-time need to be explained as well as the description of the hand actions relative to the water. Defining key points of the hand action instead listing of propulsive phases result from a study following the strategy of functional attribution of actions modes. As explained by [12] Ungerechts & Klauck (2006) the functional attribution of swimming strokes activities is closely related to the idea about flow conditions induced by hand-water-interaction and leads to more conceptual description of hand positions facilitating communication about stroking and overcome the gross distinction into – pull and push - per stroke (which hardly applies to hand-water-interaction in breast)stroke. Key points (Act) relative to the water were defined per cycle and shown along the hand path in Fig 2: (act 1) hands outwards action begin, (act 2) hands turning action begin, (act 3) hands moved inwards halfway, (act 4) hands inwards action end, (act 5) hands forwards action begin - the feet (heels) near the body coincides more or less with the act 5 -, (act 6) hands remain stretched out. Numbering the key points is logical and can be used as an ordinal like scale, including