Portuguese Journal of Sport Sciences
11 (Suppl. 3), 2011

MEASUREMENT OF DRAG TO ASSESS THE EFFECT OF SWIM SUITS

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The purpose of this study was to demonstrate the effect of different suits on drag for Olympic level swimmers. The effect on drag for some suits were with 5-7% rather large given the small differences observed in competitive time during Olympic finals. It is also found that the same suit may have a drag reducing effect for one swimmer while for the other no or a detrimental effect on drag is observed. Apparently, the simple reasoning to create a level playing field for all swimmers that one suit must be available for all is not as simple as the present FINA rules suggest.

KEY WORDS: active drag, passive drag, performance effect.

INTRODUCTION: Swimming is a highly competitive sport where the difference between success and failure can be very small. For example, the time difference between 'gold' and 'silver' for the 100 m freestyle finals for men at the last Olympic games is roughly 0.5%, and between the winner and the slowest finalist less than 3%. Small changes to factors determining performance will have significant effects. One of the factors determining the outcome in a 100 m freestyle race is drag. Drag is the force resisting movement through water. The total drag (F_d) swimming at a constant speed consists of frictional (F_f), pressure (F_p), and wave drag (F_w) components, namely (Toussaint & Beek, 1992):

$$F_d = F_f + F_p + F_w \qquad (1)$$

In different phases of the race the components of drag that dominate total drag may vary as they depend on speed and swimming depth. After the start, the swimmer dives into the water and below a certain depth, wave drag may be negligible [insert animal boil] leaving pressure and friction drag as relevant components. Frictional or viscous drag originates from fluid viscosity, and produces shear stresses in the boundary layer (a layer of water extending out from the body to the point at which it is moving at 99% of free stream speed; (Prandtl & Tietjens, 1957)). The magnitude of frictional drag will depend on the wetted surface area of the body and flow conditions within the boundary layer (Webb, 1975). The basic causes of pressure drag are vortices and this type of drag depends on the difference between the dynamic pressures at the front and rear of a moving body and the exposed area to flow (Aleyev, 1977). When swimming near the surface, the pressure field around the swimmer sets up a wave system. At race speeds exceeding about 1.6 $m \cdot s^{-1}$ wave drag will be important (Vennel, Pease, & Wilson, 2006). It was estimated that wave drag amounts to 50% of total drag (Toussaint & Truijens, 2005).

Active drag versus passive drag: Drag can be measured in a passive and active condition. Passive drag is the resistance on the body of the passive swimmer, when towed through the water. The relevance of measuring passive drag is to evaluate drag as occurs during the gliding phase of swimming after start and turns. This is relevant since about 15% of the distance covered in a race occurs in a passive state (Bixler, Pease, & Fairhurst, 2007). Active drag is the resistance on the body of the swimmer when propulsion is generated. This form of drag would be more closely related to changes in body position and may thus be influenced by swimming technique (Chatard, Bourgoin, & Lacour, 1990).
Another factor that may influence the magnitude of both active and passive drag is the swimming suit as was first demonstrated by Toussaint et al in 1989. In the present study the effect of different suits on both passive and active drag is studied.

METHODS: The measurement of drag while swimming front crawl (i.e. 'active' drag) is a challenge. Unlike activities on land (like running) the swimmer is not using a fixed point to generate propulsion. If there would be a fixed point, it would be the ideal spot to put a force transducer to measure the forces involved in swimming. The Measuring Active Drag-system (MAD-system). The MAD-system provides the swimmer with a series of fixed push-off points mounted below the water surface, such that a front-crawl like 'swimming' movement can be made (Figure 1). The push-off forces from the hands are measured with a force transducer. If the swimmer 'swims' at constant speed the average drag will equal the average propulsion. Thus the MAD-system approach relies on a balance of resistive and propulsive forces. Propulsive forces of the leg action can not be measured using this approach, so the legs are tied together with a rubber strap and supported by a pull buoy to keep the body in a horizontal position similar to that during actual swimming. The swimmer swims a series of laps on the system whereby each lap is swum at a constant speed. Each lap results in one speed-drag data point. For a range of lap-speeds, drag is measured and the relation between speed and drag is calculated using a least squares fitting approach (see also: Toussaint, et al., 1988; Toussaint, de Looze, van Rossem, Leijdekkers, & Dignum, 1990; Toussaint, Knops, de Groot, & Hollander, 1990). Measurement of drag of a swimmer in a passive, stretched position (i.e. 'passive' drag) is relatively easy. An example of such a contraption to do so is given in Figure 1 (right panel).

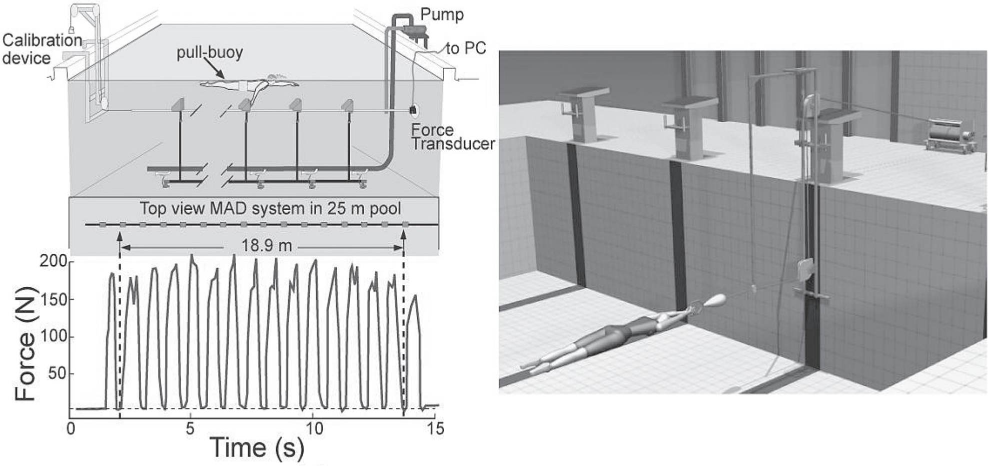

Figure 1: Schematic drawing of the MAD-system (left panel) mounted in a 25 m pool. The MAD-system allows the swimmer to push off from fixed pads with each stroke. These push-off pads are attached to a 22 m long rod. The distance between the push-off pads can be adjusted (normally 1.35 m). The rod is mounted ± 0.8 m below the water surface. The rod is connected to a force transducer enabling direct measurement of push-off forces for each stroke (see lower panel). Swimming one lap on the system yields one data-point for the speed-drag-curve. (note: the cord leading to the calibration device is detached during drag-measurement). Towing device for passive drag measurement (right panel). A force transducer is mounted in the yellow buoy.

RESULTS: Tests were conducted at the end of May 2008. For each swimmer 2 suits were evaluated to decide what to wear during the finals in the Olympic Games. It should be noted that for subject 'Maarten' the 'LZR racer legskin' was tested and that this suit only covered the legs. All other suits were 'full' suits covering both legs and torso. 'Old' indicates the Fastskin FS-Pro that was launched by Speedo in 2007. Blue indicates the blue-70 swimsuit. During passive drag measurements swimmers kept the head between the outstretched arms (see Figure 1 right panel). The towing depth was set at 1 m below the water surface to evade the effect of wave drag.

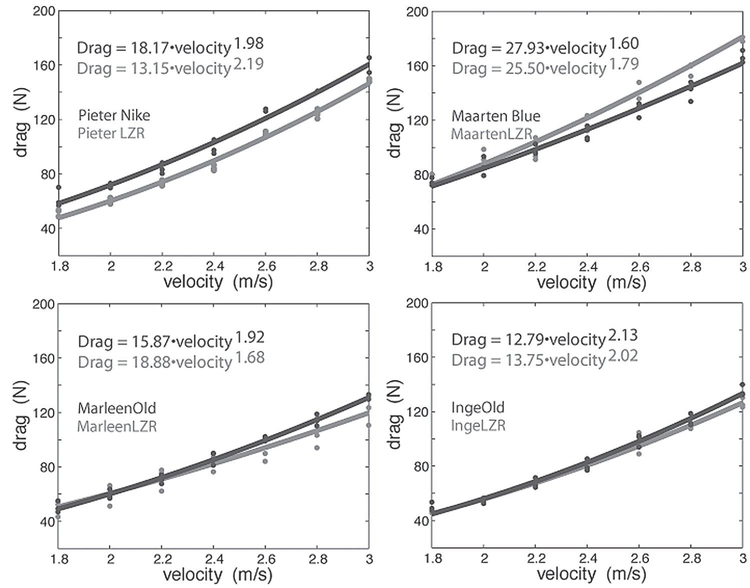

Figure 2: Results of passive drag testing using towing device (see Figure 1 right panel). Each swimmer was towed three times at each speed and the average recorded drag value for each lap is plotted. The relation ship between speed and drag was least square fitted to give Drag = A•velocity^n. The testing speed was between 1.8 and 3 m•s^{-1}. The high speeds were set to evaluate the effect of the suit after start and turns were the swimmer is gliding through the water.

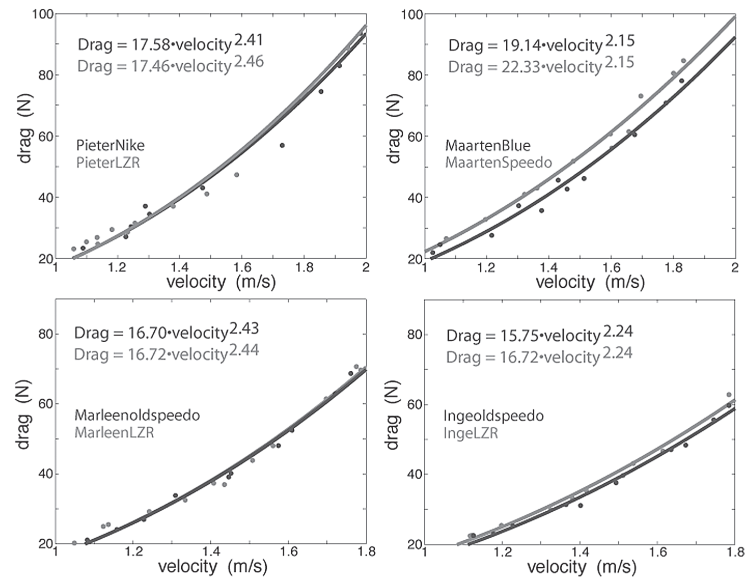

Figure 3: Results for active drag using the MAD-system (see Figure 1 left panel). Each swimmer was swimming 10-11 laps in a range of speeds, but each lap was swum at a constant speed. The average recorded drag per lap is plotted dependent on the recorded swimming speed. The relation ship between speed and drag was least square fitted to give Drag = A•velocity^n. The testing speeds were between 1.0 and 2 m•s^{-1}.

For the passive tests (Figure 2), the LZR gives lower drag values for one male swimmer in comparison to the Nike suit, but the LZR legskin is not as good as a full blue 70 suit for the other male swimmer (upper 2 panels). For the two female swimmers the LZR gives a drag reduction especially at higher speeds.

DISCUSSION: The difference in results of the two swimmers in the 2 lower panels of Figure 3 suggests that a drag reducing effect of a suit may be subject-specific. Although both swimmers were testing similar suits (both fitting each swimmer well), for one of them the older Fastskin provided a drag reduction while swimming, while for the other no drag differences were found.

CONCLUSION: Testing of the suits in both active and passive condition helped choosing the swim suit that appeared most advantageous to swim races in Olympic finals. It also demonstrates that the idea that a good fitting suit of a certain fabric will have an equal effect on all swimmers may be not correct. This reasoning seems the underpinning of the present FINA regulations that may therefore be in need for revision.

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