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Characterization of speed fluctuation and drag force in young swimmers: A gender comparison

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ABSTRACT

The aim of this study was to compare the speed fluctuation and the drag force in young swimmers between genders. Twenty-three young pubertal swimmers (12 boys and 11 girls) volunteered as subjects. Speed fluctuation was measured using a kinematical mechanical method (i.e., speedo-meter) during a maximal 25-m front crawl bout. Active drag, active drag coefficient and power needed to overcome drag were measured with the velocity perturbation method for another two maximal 25 m front crawl bouts with and without the perturbation device. Passive drag and the passive drag coefficient were estimated using the gliding decay velocity method after a maximal push-off from the wall while being fully immersed. The technique drag index was also assessed as a ratio between active and passive drag. Boys presented meaningfully higher speed fluctuation, active drag, power needed to overcome drag and technique drag index than the girls. There were no significant gender differences for active drag coefficient, passive drag and passive drag coefficient. There were positive and moderate-strong associations between active drag and speed fluctuation when controlling the effects of swim velocity. So, increasing speed fluctuation leads to higher drag force values and those are even higher for boys than for girls.

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1. Introduction

Swimming is an aquatic locomotion technique based on periodic limb actions to overcome drag force and propel the body forward in the water. The subject's arms, legs and trunk actions within a swimming stroke cycle lead to changes in the velocity described as:

$$v = v_0 + \Delta v(t) \tag{1}$$

where v is the swimmer's mean velocity, v_0 is the swimmer's velocity at the beginning of the stroke cycle, Δv is the variation of the swimming velocity throughout the stroke cycle and t is the time (Barbosa, Bragada et al., 2010). In this sense, the swimmer is not able to sustain a uniform movement (i.e., $\Delta v = 0$ m/s). Instead, he/she is submitted to an intra-cyclic variation of the horizontal velocity of his/her body, also known as 'speed fluctuation' (i.e., $\Delta v \neq 0$ m/s).

The speed fluctuation, considering a given period of time, defines the swimmer's acceleration and is dependent on the applied resultant force, as well as the inertial term of Newton's equation of motion:

$$F = m \cdot a \tag{2}$$

where F is the resultant force, m is the body mass and a is the acceleration. In competitive swimming (i) the resultant force is the balance between propulsion and drag; (ii) the inertial term includes the swimmer's body mass plus the added water mass, and (iii) the body's acceleration (Seifert, Toussaint, Alberty, Schnitzler, & Chollet, 2010; Vilas-Boas et al., 2010):

$$Pr + D = (BM + m_a) \cdot a \tag{3}$$

where Pr is the total of all propulsive forces, D is the drag force, BM is the swimmer's body mass, m_a is the added water mass and a is the swimmer's acceleration.

Theoretically there seems to exist a relationship between the swimmer's hydrodynamic profile and his or her swimming kinematics. Indeed, few research attempts have been made to uncover the relationship, or co-variance, between speed fluctuation and drag force (e.g., Schnitzler, Seifert, Ernwein, & Chollet, 2008; Seifert et al., 2008). Drag force can be assessed (i) with the swimmer being towed or gliding in the hydrodynamic position, without any further limb action – passive drag, or (ii) with the swimmer performing limb action to propel him/herself forward in the water – active drag. Both passive and active drag can be measured using numerical simulations as well as experimental methods (Marinho et al., 2009). Several experimental methods have been reported in literature to measure passive and active drag. Passive drag can be measured with the gliding decay velocity method (Klauck & Daniel, 1976). In this method, it is assumed that the ratio of velocity decay gliding in the hydrodynamic position, after a push-off from the wall, can estimate the drag force to which the swimmer is submitted. For the measurement of active drag, the velocity perturbation method might be used (Kolmogorov & Duplischeva, 1992). This method assumes that the power output to overcome drag is maximal and constant while swimming with and without a perturbation device attached to the swimmer. Active drag can be calculated since power to drag equals drag force times speed.

The ratio of active drag to passive drag is one of the main concerns for swimming researchers. It seems that there is no consistent evidence about the exact difference between passive and active drag intensities. Some authors suggested that active drag is: (i) almost twice the value of passive drag measured with the VO_2 back-extrapolation method (di Prampero, Pendergast, Wilson, & Rennie, 1974; Zamparo, Gatta, Pendergast, & Capelli, 2009); (ii) ranging between 0.5 and 1.5 times the passive drag using the velocity perturbation method in adult swimmers (Kjendlie & Stallman, 2008; Kolmogorov & Duplischeva, 1992); (iii) being almost the same value of the passive drag using the measuring active drag method in adult swimmers (Toussaint et al., 1988; van der Vaart et al., 1987) and young swimmers with the velocity perturbation method (Kjendlie & Stallman, 2008). Data variations among studies might be related to differences in the methods applied to assess both passive and active drag, as well as, the competitive level, age and gender of the subjects evaluated. This ratio of active to passive drag was widely broadcasted in literature after having been reported by Kolmogorov and Duplischeva (1992). Thereafter, Kjendlie and Stallman (2008) designated the active–passive drag ratio as 'tech-