ACTIVE DRAG AND PHYSICAL CHARACTERISTICS IN AGE GROUP SWIMMERS

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The purpose of this study was to identify the influence of body size and morphology in active drag (D_a) in front crawl swimming. Seventeen male national level swimmers (age: 15.42 ± 0.53 years, height: 178.52 ± 7.42 cm, body mass: 66.82 ± 7.45 kg) were selected from a large pool (350) of swimmers evaluated using the velocity perturbation method. Inclusion criterion was having achieved the same maximal velocity in the test (1.78 $m.s^{-1}$). Hydrodynamic variables showed large variation and were correlated to body mass and height. Height corrected for the squared body mass showed a strong negative association with D_a (-0.810). Swimmers of equivalent performance level have different active hydrodynamic profiles, according to body size and morphological characteristics.

KEY-WORDS: Active drag, front crawl, velocity perturbation method, wave drag

INTRODUCTION:

Maximal performance in swimming depends on the maximal metabolic power and on the economy of locomotion, measured by the energy cost per unit of distance (Capelli et al., 1995). Swimming economy has been shown to depend on propelling efficiency and the technical skill of the swimmers but also on body drag and buoyancy which are associated with individual anthopometric features (Kjendlie et al., 2004). Contrarily to passive drag, which is mainly influenced by body dimensions (Clarys, 1979), especially body cross section area, a determinant factor of pressure drag, active drag (D_a) is thought to depend mainly on swimming technique (Kolmogorov & Duplishcheva, 1992). As a matter of fact, most of the studies on passive drag used towing settings with the body completely submerged (Havriluk, 2005). In free swimming, however, the body is displaced crossing the surface of the water, inducing pressure drag and wave drag as main components of total body drag, since is considered that, at the Reynolds number characterising human body, frictional drag seems to be negligible (Vorontsov & Rumyantsev, 2000). Nevertheless, several studies reported an association of D_a with body geometrical characteristics other than cross section area (Huijing et al., 1988), as is the case of height or total body length, a determinant factor of wave drag.
The purpose of this study was to identify the main body characteristics associated to D_a in front crawl swimming.

METHOD:

Subjects: 17 male national level swimmers (age: 15.42 ± 0.53 years, height (H): 178.52 ± 7.42 cm, body mass (B_m): 66.82 ± 7.45 kg, best time at 100m front crawl (BT_{100mF}): 57,26 ± 1,67s) were selected for this study.

Data Collection: Subjects were tested for D_a in front crawl swimming using the velocity perturbation method (VPM) (Kolmogorov & Duplishcheva, 1992). Acording to this method, manual timing of a 13 m (11 to 24 m) maximal sprint freestyle swim permitted the calculation of maximal velocity (V_{max}). A second timed maximal 13 m freestyle swim, in rested conditions, towing a hydrodynamic body of known characteristics, allows to use the observed difference in velocity for the calculation of the added drag, and then of D_a, of the drag

coefficient (C_D) and of the power output (P_o) of each swimmer (Active Drag, V1.06, Magus, 1992-94,97: http://www.arh.ru/constanta/SwimDrag), assuming equal power output for both trials. The hydrodynamic body was attached to a harness wore by the swimmer with a low friction and non elastic 8,35 m cable. Swimmers were evaluated in an indoor 25 m pool. The sample for this study was selected out of a total of 350 swimmers tested with the VPM, and the inclusion criterion was having achieved the same V_{max} in the test (V_{max} = 1.78 m.s^{-1}).
Anthropometric measurements were made following standard procedures. A slenderness coefficient as the ratio between height and the squared body surface area (H/B_s^2) was calculated to account for the influence of height independent of frontal cross area. Competitive performance was assessed considering the swimmer's best time in the 100 m freestyle (BT_{100mF}) at the moment of the VPM evaluations.

Data Analysis: All data are expressed as mean ± SD. Level of association between variables was tested using the Pearson product moment coefficient of correlation (r). Significance was set at $p<0.05$.

RESULTS:

In spite of the rather homogeneous physical characteristics observed within this group of swimmers, hydrodynamic variables showed large variation.
D_a was significantly correlated ($p\leq0.001$) to B_m (r= 0.859), height (r= 0.721) and B_s (r= 0.852), as well as with H/B ratio. H corrected for the squared B_s showed a negative association with D_a (-0.810). Main results of this study are showed in Table 1.

Table 1: Age, physical characteristics, hydrodynamic profile and performance of the swimmers evaluated.

N = 17 V_{max} (m.s^{-1}) = 1.78 m.s^{-1}	Mean ± SD	Coef. Var. (%)	Correlation to D_a
H (cm)	178.51 ± 7.45	4.16	r = 0.72 p = 0.001
B_m (kg)	66.82 ± 7.45	11.15	r = 0.86 p ≤ 0.001
B_s (m^2)	1.84 ± 0.14	7.35	r = 0.85 p ≤ 0.001
H/B_s^2	53.42 ± 5.94	11.12	r = -0.81 p ≤ 0.001
D_a (N)	96.50 ± 42.50	44.04	_______
C_{Da}	0.36 ± 0.13	36.24	_______
P_o (W)	171.55 ± 75.27	43.88	_______
BT_{100mF} (s)	57.26 ± 1.67	2.92	r = 0.17 p = 0.50

Further analysis of the relationship between B_m and D_a, indicated that the best fit between these two variables was of polynomial nature (Figure 1).

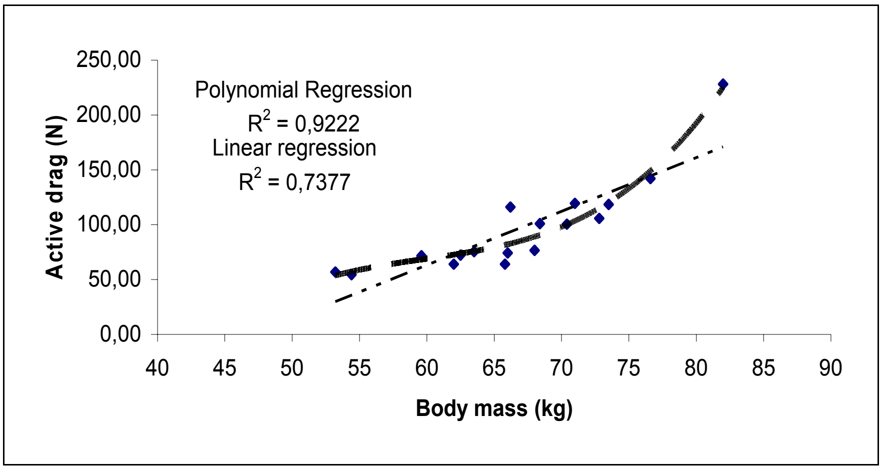

Figure 1 Active drag and body mass relationships. Best fit is of polynomial nature.

DISCUSSION:

Drag measurements with VPM have been questioned (Toussaint et al., 2004) but this procedure seems to be valid as long as the assumption of equal power output between free and towed swimming is respected. Due to this limitation, care was taken not to have velocity differences between free and towed swims higher than 10%, as indicated by Kolmogorov & Duplisheva (1992).

However, the particular constraints related to the equal power assumption prevent its utilization in a broader way, to analyse inter-individual variability of hydrodynamic profile. In fact, it is not possible to normalize for fixed velocities or pre-determined fractions of maximal velocity when using the VPM. In this study, we were able to select a sample of evaluations where swimmers performed the free swimming trial with the same mean velocity. This way, contrarily to what is reported in studies where active body drag measurement was effectuated with VPM (Kolmogorov et al., 1997), we could confirm a high dependency of D_a on body characteristics, previously put forward using the MAD-system (Huijing et al., 1988). D_a revealed a strong nonlinear dependence on B_m in the group of swimmers evaluated, due probably to larger cross sectional area and higher hydrostatic torque in heavier swimmers.

Pressure drag prevails in total drag encountered by a completely submersed swimmer, depending mainly on cross surface area and the squared velocity (Vorontsov & Rumyantsev, 2000). Ungerechts & Niklas (1994) presented evidence that D_a on bodies with the same area decreased with an increase in body length since longer bodies allow for a more laminar flow. Furthermore, moving at the surface causes extra drag by generating waves. The relative amount of energy lost by wave generation is expressed by the dimensionless Froud number, which varies inversely to body length (Lighthill, 1993). Using a slenderness coefficient as the ratio between height and the squared body surface area, we confirmed a strong negative correlation between body length and D_a, previously only verified indirectly in young swimmers (Toussaint et al., 1990, Alves et al., 2005).

Performance variability, as measured by best times in the 100 m front crawl, accompanied the large variability shown by the hydrodynamic profile but both were unrelated. The two best swimmers of this group (54.72 s and 55.09 s) had some of the highest D_a values (119.37 N and 142 N, respectively) but the swimmer ranked third (55.31 s) had a rather low D_a (64 N). Interestingly, this athlete had also much lower values in body dimensions than the other two. On the other side, the slowest performance time (59.90 s) belonged to the swimmer who obtained the peak D_a value of this group (228.16 N). Circumstantial technical observation during testing allowed us to identify in this swimmer basic problems of body streamlining at maximal velocity.

CONCLUSION:

Swimmers of equivalent maximal velocity have a different active hydrodynamic profile, according to body size and morphological characteristics.
Heavier swimmers were able to compensate for active drag yielding a higher power output enhanced by larger propulsive surfaces, longer limbs and larger active muscle mass.
Taller swimmers seem to have a hydrodynamic advantage when height is corrected for body surface area.

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