

DRAG FORCE RELATED TO BODY DIMENSIONS IN FRONT CRAWL SWIMMING

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So far, a great deal of attention has been given to find out relationship between body dimensions (anthropometrical variables) and hydrodynamic resistance for actively swimming subjects. The development of a new indirect method for determining active drag (IMAD) warranted a reevaluation of this relationship, which was the aim of present study. Twenty one novice male swimmers with different body shape and experience ranging from 11 to 14 years and in mass from 35 to 70 kg have volunteered in this study. The variables were mass, height, upper limb length, arm, forearm, hand lengths, and torso, arm, and head circumferences. Very high and significant correlations were found between active drag and anthropometric variables. The drag force was ranging from 14.5 to 52.5 N. The results achieved from this study agreed well with the results obtained by other researchers using direct measurement systems.

KEY WORDS: anthropometric variables, drag force, front crawl swimming

INTRODUCTION:

During four last decades, a great deal attention has been given to the presupposed relationship between body shape and dimensions and hydrodynamic resistance (Clarys, 1976, 1979; Clarys et al., 1974; Councilman, 1971; Gadd, 1963; Jaeger, 1937; Jurina, 1972; Karpovich, 1933; Miyashita and Tsuoda, 1978; Tilborg et al., 1983; Zaciorski and Safarian, 1972. Clarys, (1976, 1979) was the first who related drag for actively swimming subjects (active drag) to anthropometric variables. Contrary to expectations, Clarys (1976, 1979) found only few correlations between active drag and anthropometric variables, which forced him to conclude that the shape of human body has hardly any influence on active drag and that other factors are therefore more important.

Many researchers have been encouraged to use MAD system (Measurement of Active Drag), which is only suitable for front crawl (Hollander et al., 1986). MAD system consists of a variable number of push-off pads mounted on a 23-m long horizontal rod attached via a computer-linked force transducer to the wall of a swimming pool, 0.8m below the water surface. Propelling forces of the arms in only front crawl swimming can be measured during each stroke. The other limitation of the system is that the subject should swim at a constant speed and using the arms only, the mean propelling force equals total drag at any given speed.

The development of the indirect method for determining active drag (IMAD), (Shahbazi and Sanders, 2002, 2004) has already allowed Shahbazi and Sabbaghian (2005) to use this method for butterfly swim and then warranted a reevaluation of this relationship in front crawl, which was the aim of present work.

METHODS:

The subjects in this study were 21 male front crawl novice swimmers for whom the mean propulsive forces were obtained by using indirect measurement method (IMAD) developed by Shahbazi and Sanders, (2002, 2004). This indirect method has the advantage of being used for all four strokes.

The swimmers performed three 10-m trials with enough rest in between and with zero initial velocity over which average velocity was calculated. In each trial they were requested to start swimming, by whistling, a 10 meter distance as fast as they could and have also been instructed to stop swimming, again by whistling at the end of 10-m swim and glide until still position, Shahbazi and Sanders (2002). The time of 10-m swim and the glided distance were

measured with reasonable precision (10^{-2} Sec. and 10^{-2} m respectively) and then used in the established formulae for determining the drag force.

Formalism: The equation of motion of the swimmer in water was proposed by Shahbazi and Sanders (2002, 2004) as followings:

$$F_p - (C_1 V + C_2 V^2) = Mdv/dt \quad (1)$$

V_L is the maximum speed the swimmer can reach in 10-m swim, C_1 and C_2 are the hydrodynamic coefficients, which are given as:

$$C_1 = \frac{2MV}{X + 10} \quad (2)$$

V is the mean velocity in 10-m swim, X is the glided distance, M is the swimmer mass, and

$$C_2 = M/X \quad (3)$$

The limit speed V_L is given as:

$$V_L = 0.5[C_1 / C_2 + \sqrt{(C_1 / C_2)^2 + 4MV / C_2 t}] \quad (4)$$

By inserting these values in the following relationship, the propulsive force, which at limit speed equals the drag force; can be obtained:

$$F_p = C_1 V_L + C_2 V_L^2 \quad (5)$$

RESULTS AND DISCUSSION:

By measuring the anthropometric variables directly on the body such as: body height and weight, biacromial distance, arm length (i.e., distance between acromion and most distal part of the hand), upper and lower arm length (i.e., distance between acromion and caput radii, distance from caput radii to processus styloideus radii, hand length (i.e., distance from processus styloideus radii to most distal part of the hand), torso, arm circumferences and wrist thickness. Very high and significant coefficients of correlation were found between active drag and anthropometric variables.

It should be kept in mind that the methods employed in the present study (i.e., considering swimming speed and drag data with linear and quadratic functions and using proportionality coefficients C_1 and C_2 for active drag) are sensitive for skin friction as well as viscous pressure drag. No conclusions can be drawn regarding wave drag using the methods employed, even though the wave drag is included in the measurements performed in this study. In contrast with Clarys (1976, 1979) significant correlations were shown to exist between selected anthropometric variables and a variable characterizing drag of the actively propelling swimmer.

In present study, active drag was actually measured using IMAD method, while Clarys (1979) obtained estimates of the same order of magnitude as those calculated by Schleihauf et al., (1983) and Kolmogorov et al., (1998). In addition, a high degree of correlations were also found between several other anthropometric variables and drag force. In Table 1 the swimmers kinematic and kinetic parameters values are presented for each swimmer. We can notice how much the drag force is correlated to swimmer's mass but it is not certain that all the exerted force is used for higher speed. In fact, this depends on the swimmer's technique and movement coordination (Shahbazi et al., 2006; and Shahbazi, 2007). A swimmer with a good technique may swim at higher speed than another with higher force. In Table 2 the anthropometric variables values in (cm) and

It is interesting to notice that remarkable correlations are achieved with arm length, hand length, lower limit, acromions distance and mass. There was no correlation between head circumference at all and the correlations between foot length, arm span, and wrist thickness with propulsive force were not significant. Unfortunately we had not access to swimmers at national team level but these swimmers are permanently trained to prepare them for national competition and are available at any time for further tests to see their progress and examine the new correlations.

Table 1- Average values of different swimmers' data in 10 meters swim

Subj.	F _p	V _L	C ₁	C ₂	X (m)	T (s)	M (kg)
1	37.86±2.32	1.51±0.22	9.43±1.68	10.32±1.13	5.62±0.65	7.78±1.21	58
2	36.74±2.12	1.45±0.13	9.49±1.45	10.88±1.15	5.24±0.93	7.88±1.23	57
3	35.43±2.45	1.26±0.17	10.38±1.55	13.95±0.65	4.30±0.85	8.08±1.03	60
4	22.69±1.52	1.15±0.19	7.33±1.67	10.89±1.61	4.22±0.52	8.84±1.33	46
5	28.79±2.05	1.29±0.18	8.30±0.32	10.85±1.55	4.61±0.74	8.24±1.08	50
6	23.72±1.65	1.08±0.21	8.01±1.15	12.82±0.65	3.67±0.64	8.59±1.14	47
7	27.37±2.12	1.19±0.12	8.01±0.95	12.82±0.35	3.60±0.63	7.72±1.25	44
8	27.17±1.92	1.15±0.18	8.69±0.65	13.04±0.25	3.83±0.57	8.32±1.34	50
9	15.26±1.39	0.92±0.15	6.06±0.25	11.54±1.14	3.47±0.63	9.81±1.16	40
10	42.88±3.12	1.34±0.09	11.76±1.05	14.82±0.35	4.25±0.36	7.52±1.23	63
11	52.44±2.92	1.50±0.14	13.02±0.62	14.61±0.25	4.65±0.68	7.13±1.46	68
12	30.82±2.02	1.24±0.18	9.08±1.15	12.51±1.15	3.92±0.74	7.75±1.35	49
13	42.06±2.52	1.28±0.19	12.16±0.65	16.09±0.65	4.35±0.65	8.02±1.45	70
14	23.16±2.15	0.98±0.14	8.59±1.15	15.05±0.65	3.72±0.83	9.50±1.44	56
15	26.63±1.32	1.15±0.23	8.42±1.22	12.74±1.15	3.53±0.74	7.89±1.46	45
16	22.30±1.22	0.90±0.18	8.94±1.12	17.80±0.35	3.03±0.54	9.27±1.67	54
17	14.38±0.85	0.94±0.19	5.55±0.55	10.35±1.35	3.38±0.67	9.43±1.17	35
18	19.79±1.32	0.86±0.16	8.24±1.11	17.11±0.85	2.98±0.25	9.54±1.76	51
19	23.89±1.51	0.95±0.17	8.96±1.25	16.90±0.75	2.90±0.17	8.48±1.43	49
20	14.42±0.66	0.84±0.22	6.06±0.64	13.13±1.33	2.67±0.28	9.12±1.24	35
21	17.32±1.02	1.00±0.11	6.26±0.25	10.86±1.35	3.50±0.23	8.98±1.63	38

Table 2- Mean ± SD of anthropometric variables values in (cm) and their correlations with propulsion

Variables	Mass	Height	F.Ar m leng.	Acro- mions	Trunk Leng	Legs leng.	Hand leng.	Foot Leng	Torso Circu	Head Circu	Arm Span	Wrist Thick	Arms Leng
Measures SD	50.7 ±9.8	156. 4 ±11. 37	26.9 ±1.2	34.4 5 ±3.5	66.1 ±4.9	91.7 ±6.1 2	17.2 ±1.2	28.3 ±1.3	81.9 ±6.9 2	54.6 ±2.4	24.3 ±2.3	4.7 ±0.3 5	28.4 ±2.4
Corr. P<	0.88 0.01	0.58 0.01	0.85 0.01	0.82 0.01	0.78 0.01	0.81 0.01	0.85 0.01	0.57 0.01	0.74 0.01	0.24 0.24	0.69 0.01	0.58 0.01	0.85 0.01

CONCLUSION:

With simple indirect measurement of drag force IMAD, we were able to find correlations between body variables and propulsive force. Significant correlations between mass, arm length, upper and lower limits, acromions and drag force have been found. The present study showed how easily the IMAD method enabled us to find the correlations between different anthropometrical parameters and propulsive force which at constant speed is the drag force.

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