

DETERMINATION OF ARMS AND LEGS CONTRIBUTION TO PROPULSION AND PERCENTAGE OF COORDINATION IN BREASTSTROKE SWIM

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In the present study, the Indirect Measurement of Active Drag (IMAD) was used to study the contribution of the legs and arms to propulsion in breaststroke swim. Contrary to the Measuring of Active Drag (MAD) system, the IMAD can be used for all strokes and therefore enabled us to study the breaststroke swim to estimate not only the percentage of legs and arms contribution to propulsion but also the percentage of swimmers' arms and legs co-ordinations. The method revealed that the best coordination was 87.8% and that the contributions of arms and legs in propulsive force were 67% and 65% and in velocities were 97.7% and 98.2%, respectively, showing that the swimmers received equal contributions from the arms and legs in propulsion and velocity during breaststroke swim.

KEY WORDS: legs and arms contribution, percentage of coordination, breaststroke swim

INTRODUCTION:

There is little research on the determination of arms and legs contribution to propulsion and percentage of coordination in breaststroke swim. It is well known that in breaststroke swim the legs play the main role in propulsion however; it is unclear what percentage the arms contribute to increase swimming speed. By using the indirect measurement of active drag (IMAD), Shahbazi, (2007) and Shahbazi et al., (2006) showed these percentages in front and back crawl swims. Contrary to MAD which is a sophisticated, but very expensive, and complex system which can only be used for front crawl, indirect measurement of active drag method is mainly based on a mechanical modeling in which swimmer is considered as a lump mass and moves along X axis. Solving the general equation of motion and considering appropriate approximations ended to the equations (1) to (4) to estimate swimmers' propulsive force. Breaststroke is the most popular recreational swimming style due to its stability and the ability to keep the head out of the water at all times. In most swimming classes, beginners learn either the breaststroke or the front crawl first. In competitive swim, however it is regarded as one of the most difficult strokes requiring comparable endurance to other strokes.

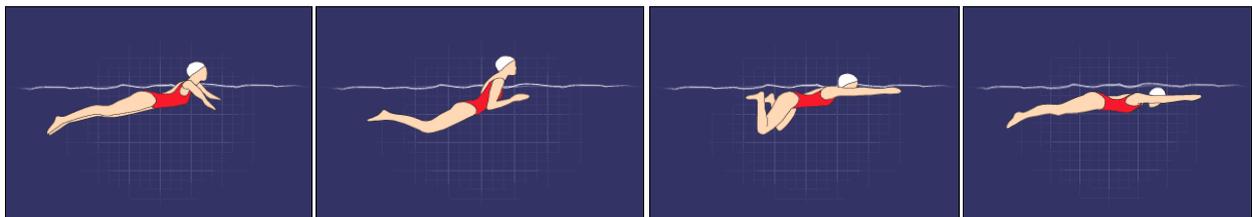


Figure 1- The four main phases in breaststroke swim; initial position, pre-thrust, thrust and gliding phases in which the maximum drag is produced in second phase.

The movement starts in the initial position with the body completely straight, the body movement is coordinated such that the legs are ready for the thrust phase, while the arms are halfway through the in-sweep, and the head is out of the water for breathing. In this position, the body has also the largest angle to the horizontal. The arms are recovered during the thrust phase of the legs. After the stroke, the body is kept in the initial position for some time to utilize the gliding phase. Depending on the distance and fitness, the duration of this gliding phase varies. Usually the gliding phase is shorter during sprints than during long distance swim. The gliding phase is also longer during the underwater stroke after the start and each turn. The three main styles of breaststroke seen today are the conventional (flat),

undulating, and wave-style. The wave-style breaststroke starts in a streamlined position, with shoulders shrugged to decrease drag in the water. While the conventional style is strongest at out-sweep, the wave-style puts much emphasis on the in-sweep, thus making the head rise later than in the conventional style, Fig. 1.

The purpose of the present study was to analyze breaststroke swim and determine the contribution of legs and arms and the percentage of coordination of swimmers.

METHODS:

Six male swimmers at national level (aged 18 ± 1 yr; mass 66.68 ± 10.89 kg; height 175.59 ± 14.35 cm) volunteered in this study. The mean best time for the subjects in the 100-m breaststroke, short course, was 67.3 ± 2.87 s. The subjects swam breaststroke under three conditions: (a) arms only with no bounding in legs, (b) legs only, and (c) full stroke. At a constant speed and using the arms only, the mean propelling force equals total drag at any given speed. In IMAD method Shahbazi and Sanders (2002, 2004); Shahbazi et al., (2006); Shahbazi, (2007), there is no special system but a tape-meter, a start-stop watch and appropriate formulae extracted from a theoretical mathematical modeling.

The swimmers were requested to start swimming a 10m long distance from still position by whistling as fast as they could and then at the end of the 10m distance, again by whistling, they ceased swimming but gliding as far as possible. The time of 10m swim and the glided distance were used in the formulae Shahbazi and Sanders, (2002, 2004) in order to estimate the mean propulsive force (F_P) resulted from arms only, legs only, and the full stroke. In each step, swimmers swam three times with enough time of rest in between.

The mean propulsive force is given as:

$$F_P = (C_1 V_L + C_2 V_L^2) \quad (1)$$

V_L is the maximum velocity that the swimmer can reach in 10m swim; C_1 and C_2 are the hydrodynamic coefficients to be obtained by:

$$C_1 = 2MV/(X+Vt) \quad (2)$$

X is the glided distance, V is the average velocity in 10-m swim, t is time of 10m swim, M is swimmer's mass, and

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

The maximum velocity (limit velocity) can be obtained by:

$$V_L = 0.5\{C_1/C_2 + \sqrt{(C_1/C_2)^2 + (4MV/C_2t)}\} \quad (4)$$

RESULTS AND DISCUSSION:

By measuring time of 10m swim with a precision of 10^{-2} sec. and the glided distance with a precision of 10^{-2} m and using above formulae, the individual values for maximum swim speed, hydrodynamic coefficients, drag force, and the relation between these variables for all subjects were obtained. In the second, third, and fourth columns of Table 1 the full stroke, arms only (with no leg support), and legs only forces, applied by subjects are presented. In column 5 of Table 1 the sum of the arm and leg only forces is presented as theoretical force. Theoretical force, considered as if these two forces were applied in the same direction (direction of velocity). In column 6 of Table 1 the difference between theoretical and real forces are presented. In column 7 of Table 1 the percentage of force which has not been used for increasing the swimmer velocity is presented. From these data the percentage of the arms and legs coordination can easily be achieved and is presented in column 8 of table 1.

In columns 2, 3, and 4 of Table 2 the mean velocities of full stroke, arms and legs only are presented. In columns 5 and 6 the percentage of arms and legs are presented using their velocities and in column 7 and 8 the percentage of arms and legs contributions are presented by using IMAD method. As is indicated in Table 1, IMAD method is capable of yielding the arms and legs forces separately, therefore the percentage of the contribution of arms and legs were calculated. Our results suggest that the legs only force does not aid propulsion directly and therefore it follows from the present results that partly; an amount of ΔF (in Table 1) is used in stabilizing the trunk in the full stroke. In the first two data of column

6 we notice that the subject with 80.5 kg mass has a better trunk stabilizing and higher coordination compared to other subjects (75.2 and 71.5 kg) and therefore has a higher propulsive force and coordination.

Table1. Mean \pm SD of full, arm, and leg forces and the percentage of coordination

Mass Kg	Full Stroke F_F (N)	Arms only F_A (N)	Legs only F_L (N)	Theoretical (F_A+F_L) (N)	Difference ΔF (N)	Loss $\Delta F/(F_A+F_L)$	Coordination %
80.5	40.23 \pm 1.15	25.72 \pm 2.75	20.1 \pm 1.53	45.82 \pm 3.91	5.59	12.2	87.8
75.2	42.47 \pm 2.0	36.85 \pm 2.37	24.8 \pm 0.71	60.65 \pm 4.11	18.18	29.98	70.0
71.5	40.43 \pm 2.42	28.32 \pm 2.09	23.51 \pm 1.02	51.83 \pm 3.55	11.40	22	78.0
63.9	28.44 \pm 1.6	21.17 \pm 1.44	19.82 \pm 0.12	40.99 \pm 3.95	12.55	30.6	69.4
55	33.64 \pm 2.28	30.61 \pm 1.61	20.96 \pm 2.15	51.57 \pm 3.33	14.93	28.95	71.05
54	35.4 \pm 0.5	24.09 \pm 2.77	23.02 \pm 1.4	47.86 \pm 2.06	12.46	26.03	73.97

Table 2. Mean \pm SD of full, arms, and legs only velocities and their percentage of contributions

Mass Kg	Full Stroke V_F (m/s)	Arms only V_A (m/s)	Legs only V_L (m/s)	V_A/V_F %	V_L/V_F %	F_A/F_F %	F_L/F_F %
80.5	1.12 \pm 0.03	0.97 \pm 0.03	0.8 \pm 0.03	86.6%	71.4%	63.9%	50.0%
75.2	1.18 \pm 0.04	1.1 \pm 0.04	0.93 \pm 0.04	93.2%	78.8%	86.8%	58.4%
71.5	1.17 \pm 0.01	1.03 \pm 0.06	0.92 \pm 0.02	88.0%	78.6%	70.1%	58.2%
63.9	1.06 \pm 0.05	0.95 \pm 0.05	0.89 \pm 0.03	89.6%	67.6%	74.4%	69.7%
55	1.25 \pm 0.02	1.20 \pm 0.07	0.98 \pm 0.08	96.0%	84.0%	91.0%	62.3%
54	1.27 \pm 0.03	1.2 \pm 0.04	1.02 \pm 0.04	94.5%	80.3%	68.1%	65.1%

The lightest subject, 54kg, had highest mean velocities in full, arms and legs but failed in having very good coordination. Most of his arms and legs contributions were used for stabilizing himself.

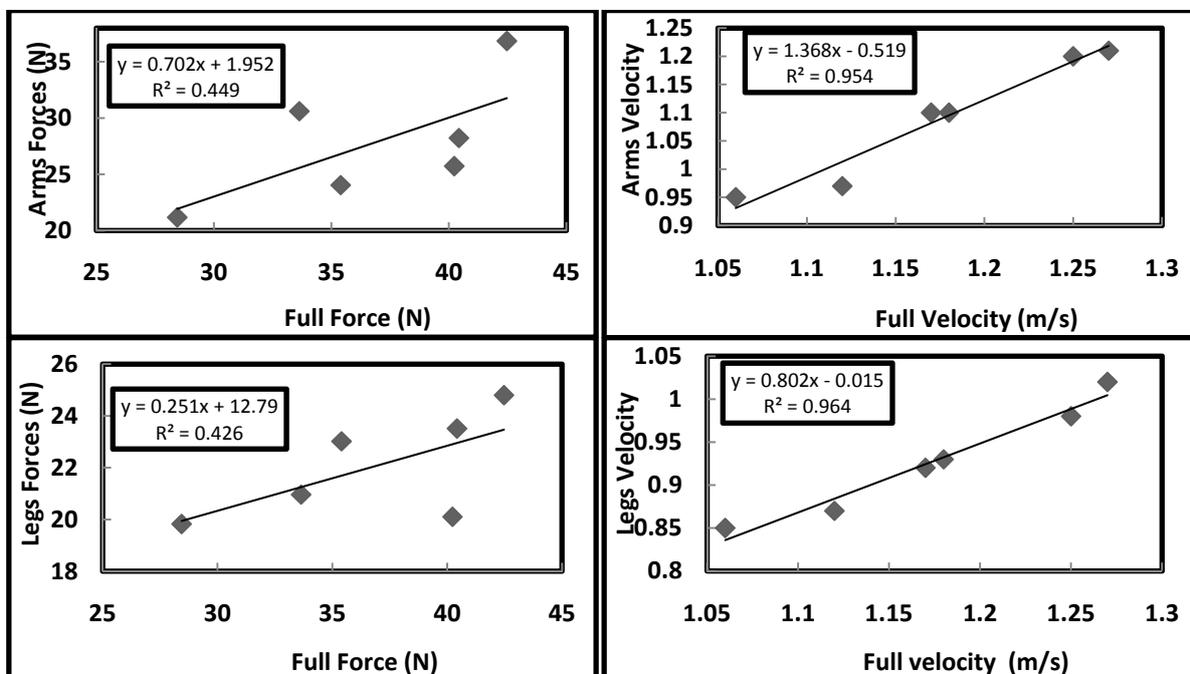


Figure 2- The correlations between arm, leg forces and total force exerted by swimmers are 0.67 and 0.65 respectively, while these correlations for velocities are 0.977 and 0.982.

Figure 2 reveals that the swimmers received equal contributions from arms and legs in full propulsive force; 0.67 and 0.65 and 0.977 and 0.982 in velocity. In our study the subject with 80.5 kg had highest coordination, best trunk stabilizing in gliding, and therefore applied

maximum leg force directly to propulsion. But lack of enough power made him not get higher mean velocity in our study. Unfortunately, our subjects were not breaststroke swimmers but still the results are satisfactorily acceptable. The method is reliable and simple to use, therefore other researchers can use this with good breaststroke swimmers and get remarkable results.

CONCLUSION:

The IMAD method has been used to determine the contribution of arms and legs in propulsion and velocity in breaststroke swim. The method is simple and very easy to use and can be used for all strokes. The study revealed that there were remarkable correlations between swimmers' masses and legs forces and, while it was not the case for arms forces this meant that the swimmers' kicking is mostly used for body stabilizing. Swimmers' masses were not much correlated with propulsive force. Arms forces and velocities were remarkably related with full stroke force and velocity. The IMAD method reliably and easily revealed the swimmers parameters which could not be achieved with the MAD system.

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