DETERMINATION OF ARMS AND LEGS CONTRIBUTION TO PROPULSION AND PERCENTAGE OF COORDINATION IN BACKSTROKE SWIMMING

Morteza Shahbazi-Moghaddam

School of Physics, University of Tehran and Centre for Aquatic Research and Education, University of Edinburgh Scotland, UK

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 backstroke swimming. Contrary to MAD (Measuring of Active Drag) system, the IMAD can be used for all strokes and enabled us to study the backstroke and to estimate not only the percentage of legs' contribution to propulsion but also the arms contribution and whereas the percentage of swimmers' arms and legs co- ordinations. The method revealed that there were good correlations between arms and full strokes forces and velocities. The swimmers' mass did not much correlate with swimmers' velocities but with the forces.

Keywords: drag force, legs and arms contribution, percentage of coordination

INTRODUCTION:

It is well known that using a flutter kick in the sprint back crawl as in front crawl, enables the swimmer to achieve a greater speed than can be achieved using arm action alone (Shahbazi et al., 2006). However, it is unclear in backstroke swimming how the flutter kick causes an increase in swimming speed. So far, it is believed that there are at least three ways in which the flutter kick can positively affect swimming speed: (1) propulsion directly from the legs-a flutter kick can create propulsion directly as can be demonstrated in legs-only practice with the arms supported by a kick board. However, with regard to full stroke, there are still researchers who believe that the leg action does not aid propulsion directly (Counsilman, 1968; Onusseit, 1972), (2) streamlining the body-there are researchers who believe that the leg action in front crawl is to keep the body in a streamlined position and thereby reduce drag Counsilman (1977), (3) stabilization of the trunk-in which many believe that the kick is used as a stabilizer and neutralizer, the implication being that leg action neutralizes the reaction of the rest of the body to the arm action and as a result, keeps the position of the trunk fairly stable (Counsilman, 1968; Lawrence, 1968).
A fairly stable trunk position may reduce drag and/or produce more effective arm action.
Watkins and Gordon, (1988) reported the leg indirect contribution to propulsion in front crawl stroke by stabilizing the trunk (9% of the full stroke speed in both male and female), and streamlining the body (11% and 6% of the full stroke speed in male and female, respectively). Few researchers have reported the contribution of legs and arms in other strokes than front crawl. IMAD enables us to estimate arms and legs contributions in any strokes. The purpose of the present study was to analyze backstroke swimming and determine the contribution of legs and arms and above all the percentage of coordination of the swimmers.

METHODS:

Six male swimmers at national level (aged 16 $\pm$ 1 yr; wt 70.2 $\pm$ 6.3 kg; ht 178.83 $\pm$ 11.87 cm) volunteered in this study. The mean best time for the subjects in the 100-m backstroke, short course, was 65.4 $\pm$ 2.36 sec. The subjects swam back crawl under three conditions: (a) arms only with no bounding in legs, (b) legs only, and (c) full stroke. Contrary to MAD system (Hollander 1986), the IMAD method is capable not only to be used for all strokes but also be used for arms and legs separately. The MAD system consists of variable number of push-off pads mounted on a 23m long horizontal rod attached via a computer-linked force transducer to the wall of a swimming pool, 0.8m below the water surface. Propelling force of the arms

can only be used in front crawl swimming and is measured during each 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) 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 and again by whistling ceased swimming but gliding as far as they could. The time of 10m swim and the glided distance were used in the formulae (Shahbazi and Sanders, 2002, 2004) in order to estimate the propulsive force resulted from arms only, legs only, and the full stroke.
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:

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

X is the glided distance, V is the average velocity in 10-m swim, and

$$C_2 = \frac{X}{M} \quad (3)$$

The maximum velocity can be obtained by:

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

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 swimming speed, hydrodynamic coefficients, drag force, and the relation between these variables for all subjects were obtained. In the second, third, and forth columns of the Table 1 the full stroke, arm only (with no leg support), and leg only forces, applied by subjects are presented. In column 5 of the Table 1 the sum of the arm and leg only forces is presented as theoretical force. In fact we considered as if these two forces were applied in the same direction (direction of velocity). In column 6 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.
In column 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 column7 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 to yield the arms and legs forces separately, therefore the percentage of the contribution of arms and legs are calculated in order to compare the proposed method with the direct methods such as MAD, using oxygen consumption and the method used by Watkins and Gordon (1985) in which legs support was provided.
Our results suggest that the whole legs 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 comparing with subjects; 75.2 and 71.5 kg and therefore has a higher propulsive force and coordination.

Table1 Mean ± 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 %
85	51.77±4.02	43.36±3.31	34.56±3,17	77.92±3.91	26.15	33.06%	66.4%
80.5	58.75±4.25	40.67±5.48	34.36±3.11	75.03±4.11	16.28	21.7%	78.3%
75.2	60.55±1.37	57.22±4.43	35.09±1.28	92.31±3.55	31.76	34.4%	65.6%
71.5	54.49±4.03	40.17±2.93	22.91±1.54	63.08±3.95	9.59	15.2%	84.8%
55	41.86±1.33	32.85±4.91	21.51±4.27	54.36±3.33	12.5	23%	77%
54	40.06±1.35	29.14±2.21	20.92±1.01	50.09±2.06	10.03	20%	80%

Table 2 Mean±SD of full, arm, and leg only velocities and their % 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 %
85	1.16±0.05	1.14±0.05	1.02±0.04	98.3%	87.9%	83.8%	66.8%
80.5	1.34±0.04	1.13±0.07	1.03±0.05	84.3%	76.9%	69.2%	58.5%
75.2	1.42±0.01	1.37±0.02	1.09±0.02	95.5%	79.6%	94.5%	57.9%
71.5	1.36±0.05	1.18±0.04	0.92±0.03	86.8%	67.6%	73.7%	42.1%
55	1.38±0.02	1.25±0.09	1.20±0.08	90.6%	87.1%	78.5%	42.1%
54	1.37±0.03	1.18±0.04	1.02±0.04	86.1%	86.4%	72.7%	52.2%

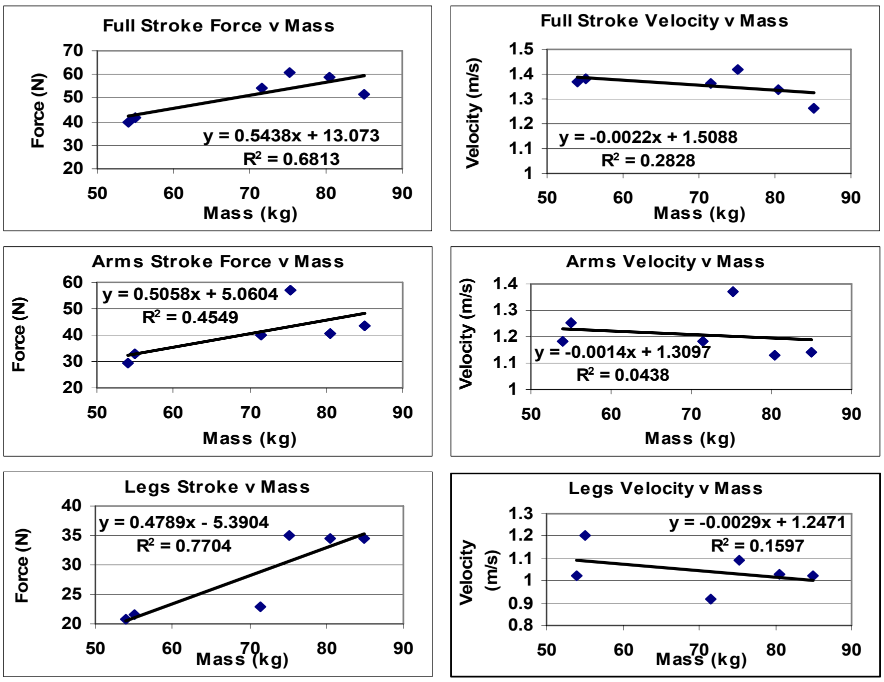

Figure 1 Left graphs present the relations between all forces and mass, while the graphs on the right show the relations between mass and velocities.

In our study the subject with 80.5 kg had highest coordination, best trunk stabilizing, and therefore applied maximum leg force directly to propulsion. But lack of global energy made him not get higher mean velocity in our study.

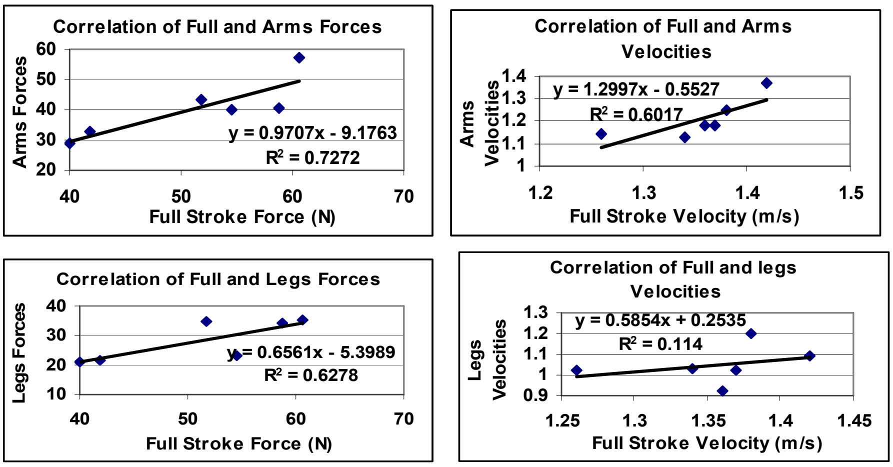

Figure 2 Left graphs show the correlations between arms and legs forces and full stroke force, while the right graphs present the correlations with velocities.

CONCLUSION:

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

REFERENCES:

Counsilman, J.E. (1968). *The Science of Swimming*. Prentice-Hall, Englewood Cliffs, NJ.

Lawrence, L. (1969). The Importance of the Freestyle Leg Kick. *Int. Swimmer*, 5:11-12

Onusseit, H.F. (1972). Two-beat versus six-beat; which kick is best. *Swim. Tech*. 9:41-43.

Shahbazi, M.M., Ravassi, A.A. & Taghavi, H. (2006). Use of a New Indirect Method in Determining the Contribution of Legs and Hands to Propulsion in Front Crawl. *Proceedings; XXIV International Symposium on Biomechanics in Sports*. Schwameder, H., Struzenberger, G., Fastenbauer, S., Lindinger, S. & Müller, E. (eds). P. 71-74. University of Salzburg- Austria.

Shahbazi, M.M., & Sanders, R.H. (2004). A Biomechanichal Approach to Drag Force and Hydrodynamic Coefficient Assessments. *Proceedings; XXII International Symposium on Biomechanics in Sports*. Lamotagne, M. Gordon, G. & Sveistrup, H. (eds). Faculty of Health Sciences, University of Ottawa, Canada. P. 225-228.

Shahbazi, M.M., & Sanders, R.H. (2002). Kinematical Approaches to Hydrodynamic Force Assessments. *Pakistan Journal of Applied Sciences.* 2(9) 895-902.