USE OF A NEW INDIRECT METHOD IN DETERMINING THE CONTRIBUTION OF LEGS AND HANDS TO PROPULSION IN FRONT CRAWL

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The aim of the present study was to determine the contributions of arms and legs action in front crawl. So far many researchers using different methods, such as oxygen consumption, filming and measurement of active drag, measured and reported the percentage of arms and legs contributions to propulsive force. A newly indirect measurement of active drag IMAD, which has recently been introduced, enabled us to estimate not only the percentage of arms and legs contributions but also the percentage of swimmers´ arms and legs coordination. Our results have been well comparable with other researchers' results.

KEY WORDS: arms and legs contributions, coordination, front crawl

INTRODUCTION: Swimming is performed with both arms and legs and so far many researchers tried to find out, to what extent the arms or legs contribute to swimming speed and propulsion force. It has generally been accepted that in front crawl swimming a greater part of the propulsion results from the arm stroke (Adrian et al., 1966, Holmer, 1972, 1986, Holmer et al., 1988). Nevertheless, many instructors still spend a lot of time in drilling the leg kick of the crawl stroke indicating leg kicking's relative importance at least during sprint swimming.
Evidence for the contribution of leg action to swimming speed was derived from indirect methods using oxygen consumption (Holmer, 1974) or the speed that can be achieved by swimming with arms or legs only (Bucher, 1975; Watkins and Gordon, 1985; Carpovich, 1935). It is evident that from these kinds of experiments the power delivered by the arms while swimming arm stroke only cannot be assumed to be the same as when the legs are additionally involved in propelling the body. After the development of a direct method measurement of active drag system, MAD (Hollander, 1986), the researchers (Hollander et al., 1988) have used this system to find the contribution of hands to propulsion in front crawl swimming.
In the present study, an indirect method to measure active drag (IMAD) (Shahbazi and Sanders, 2002, 2004; Shahbazi and Sabbaghian, 2005) was used to study the contribution of legs and arms to propulsion in front crawl swimming and to find out the percentage contribution of arms and legs and discover whether the force applied by the arms is the same in swimming with and without leg kicking.

METHODS: Eight male swimmers of national level (aged 17.3 ± 2.8 yr; wt 72.7 ± 9.8 kg; ht 178.6 ± 7.6 cm) volunteered in this study. The mean best time for the subjects in the 100-m front crawl, short course, was 58.3 ± 2.14 sec. The subjects swam front 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 can 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 only in front crawl swimming can be 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) 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 10m distance, again by whistling they 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; Shahbazi and Sabaghian, 2005)) in order to estimate the propulsive force resulted from arms only, legs only, and the full stroke.
The mean propulsive force is given as:

$$F_P = (C_1 V_L + C_2 {V_L}^2) \tag{1}$$

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:

$$C_1 = \frac{2MV}{X + Vt} \tag{2}$$

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

$$C_2 = \frac{X}{M} \tag{3}$$

The maximum velocity can be obtained by:

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

RESULTS AND DISCUSSION: By measuring the 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 was indicated in Table 1, IMAD method is capable to yield the arms and legs forces separately, therefore the percentage of 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 Δ F (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 85 kg mass has a better trunk stabilizing and higher coordination comparing subject with 86.8 kg and therefore has a higher mean velocity and propulsive force. In our study the subject with 63.9 kg had highest coordination, best trunk stabilizing, and therefore applied maximum leg force directly to propulsion. But the lack of global energy made him not get higher mean velocity in our study. On Figure 1, a comparison of IMAD results, which support well a good correlation between propulsive forces in full, arms, and legs only strokes and the subjects mass, is depicted. In contrast with MAD (Hollander, 1985), the IMAD method not only can give propulsive force in legs only but also can be used in three other strokes.

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 %
86.8	86.87±4.31	77.97±3.83	29.64±2.93	107.61±4.05	20.74	19.3%	80.7%
85	90.50±4.52	73.29±3.42	31.82±3,12	105.11±3.91	14.62	13.9%	86.1%
80.5	73.85±3.95	57.65±3.75	32.92±2.76	90.57±4.11	16.72	18.5%	81.5%
75.2	80.43±2.97	72.48±3.12	29.93±2.77	102.41±3.55	21.98	21.5%	78.5%
71.5	68.68±3.12	64.35±3.32	21.58±3.21	85.93±3.95	17.25	20.1%	79.9%
63.9	59.61±2.78	41.81±3.62	26.72±2.95	68.53±2.58	8.92	13.0%	87.0%
55	53.81±3.55	44.18±2.95	24.41±3.32	68.59±3.33	14.78	21.6%	78.4%
54	51.11±2.75	44.25±3.22	20.84±2.98	65.09±2.97	13.98	21.5%	78.5%

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 %
86.8	1.55±0.15	1.46±0.14	0.92±0.04	94.2%	59.4%	89.8%	35%
85	1.65±0.13	1.48±0.12	0.99±0.03	89.7%	60.0%	81.0%	34%
80.5	1.50±0.14	1.31±0.11	1.02±0.05	87.7%	68.0%	78.0%	45%
75.2	1.62±0.16	1.54±0.15	0.92±0.04	95.1%	56.8%	89.0%	45%
71.5	1.53±0.14	1.48±0.17	0.87±0.05	96.7%	56.9%	93.7%	45%
63.9	1.52±0.13	1.29±0.14	1.02±0.06	84.9%	67.0%	70.0%	37%
55	1.55±0.14	1.41±0.13	1.06±0.05	91.0%	68.4%	82.0%	45%
54	1.54±0.15	1.43±0.14	0.99±0.04	92.9%	64.3%	86.5%	31%

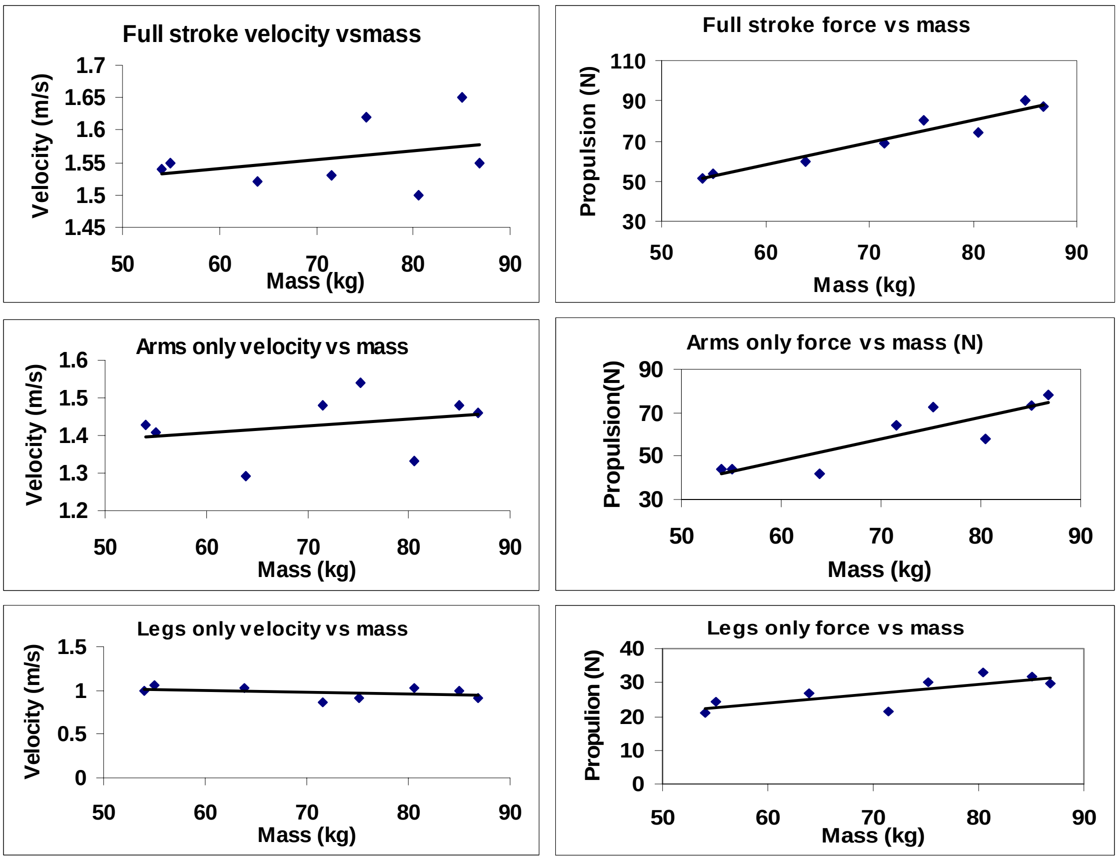

Figure 1. On left graphs the relation between arms and legs velocities with mass is depicted while for comparison, the relation of arms and legs forces with mass achieved from our method is depicted.

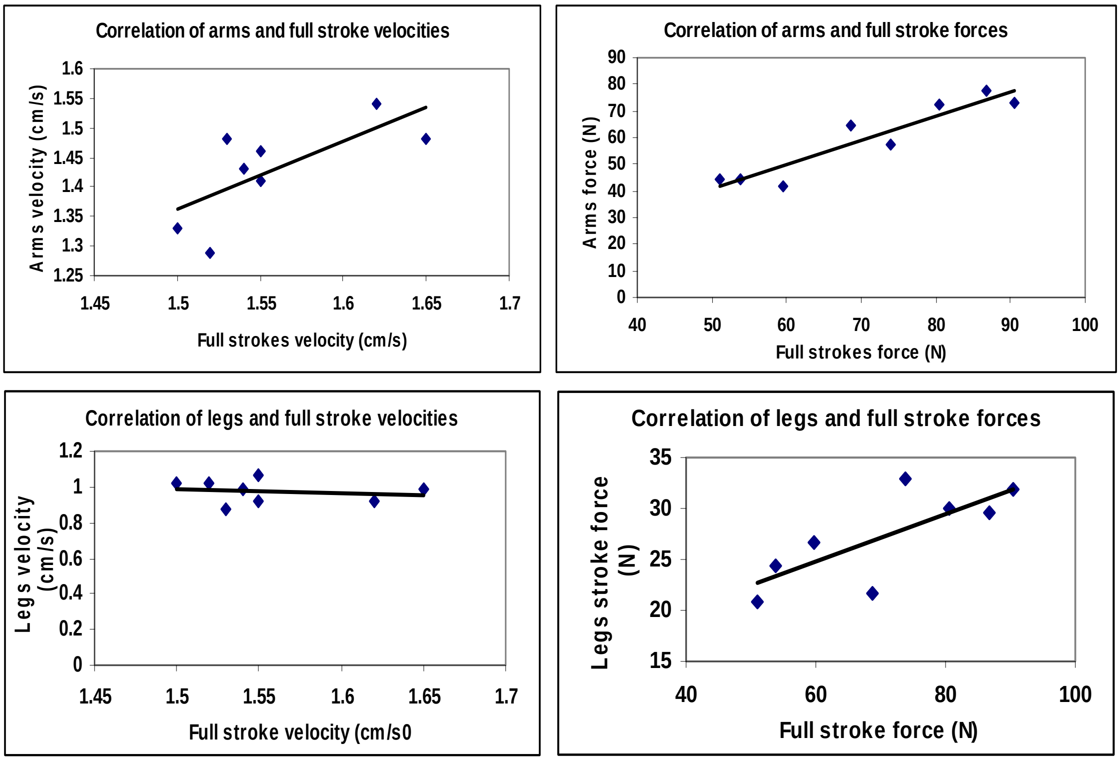

Figure 2. Left side graphs depict velocities correlations and on the right graphs depict the forces correlation. The graphs can support the reliability of the method.

CONCLUSION:

In order to determine the contributions of arms and legs action in front crawl swimming, an indirect method has been involved. The method aided in finding the forces applied in full, arms and legs only strokes. From these data, the percentage of contribution of arms and legs were remarkably determined. The results supported well the correlation between propulsive force and mass of swimmer. The method also presented the swimmers who had highest coordination and best trunk stabilizing.

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The China Institute of Sport Science, Volume 2