DIFFERENCES IN STROKE TECHNIQUE TO EXERT HAND PROPULSION BETWEEN ADVANCED AND INTERMEDIATE SWIMMERS

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The aim of this study was to investigate differences in hand propulsion exerted by advanced and intermediate swimmers during insweep and upsweep phases in the front crawl stroke. Swimmers wore pressure sensors on their hands while performing the front crawl stroke in the swimming pool where a motion capture system was set up. The hand propulsive drag (PD) and lift (PL) were estimated during the two phases. The advanced swimmers exerted more PD than PL (70% vs 30%) during the insweep phase and used a similar amount of PD to PL in the upsweep phase. The intermediate swimmers used a similar amount of PD to PL in the insweep phase and exerted more PD than PL in the upsweep phase (65% vs 35%). The advanced swimmers used the different technique to exert hand propulsion in the two phases as compared to the intermediate ones.

KEY WORDS: propulsive drag and lift, front crawl stroke.

INTRODUCTION: One of the important stroke techniques in the front crawl stroke is associated with the hand movement during the insweep and upsweep phases because a swimmer exerts most of hand propulsion in the two phases (Maglischo, 1993). The two types of stroke technique namely S-shaped hand path (stroke *S*) and I-shaped hand path (stroke *I*) during the insweep and upsweep phases have been discussed to maximise hand propulsion (Takagi et al., 2014). The movement of stroke *S* involves backward and lateral hand motions on the plane parallel to the water surface while the movement of stroke *I* involves a backward hand motion. With stroke *S*, a swimmer can propel forward using drag and lift force acting on the hand because a backward hand motion results in the hand propulsive drag and a lateral hand motion induces the hand propulsive lift. With stoke *I*, a swimmer can propel forward using mainly drag force acting on the hand due to a backward hand motion.

When a swimmer improves the stroke technique in the front crawl stroke, the swimming speed becomes faster. Differences in the stroke technique can be identified by comparing swimmers with different ability levels where the different stroke techniques may be related to the improvement of the stroke technique. The magnitude and ratio of propulsive drag and lift exerted by the hand may change due to the improvement of the stroke technique. Therefore, the aim of this study was to investigate the difference in the hand propulsive forces exerted by advanced and intermediate swimmers during the insweep and upsweep phases.

METHODS: Ten swimmers (5 advanced and 5 intermediate swimmers) participated in this study after they have provided their signed informed consent. The mean personal best record in the 100 m frontal crawl, height, mass and age of the advanced swimmers were 49.1 ± 0.8 s, 1.81 ± 6 m, 76 ± 8 kg, and 23 ± 3 years, respectively. The mean personal best record in the 100 m frontal crawl, height, mass and age of the intermediate swimmers were 60.0 ± 0.6 s, 1.68 ± 6 m, 62 ± 5 kg, and 24 ± 5 years, respectively.

A motion capture system (Qualisys, Sweden) with eighteen cameras was set up at a 25 m swimming pool. The reflective markers were attached on the right hand, the third fingertip, trapezium and pisiform, to determine hand motion. Twelve pressure sensors with a portable data logger (MMT, Japan) were attached on the swimmer's hand to estimate the magnitude of hydrodynamic forces exerted by the swimmers (Kudo et al. 2008). The portable data logger, synchronized with the motion capture system, was attached on the back of the swimmer. All signals were recorded at 100 Hz. A right-handed Cartesian coordinate system was embedded at the bottom of the pool; the x-direction defined the direction of swimming, the y-direction defined the side-to-side direction, and the z-direction defined the vertical direction. The swimmers were asked to swim the front crawl stroke at their maximal sprinting pace without breathing at the 25 m swimming pool.

The marker and pressure data were smoothed using a low-pass Butterworth filter with a cut-off frequency of 12 ± 6 Hz. Combining the resultant hydrodynamic forces on the hand predicted by the dynamic pressure approach and the hand movement based on the markers, hand propulsion (P) as well as propulsive drag and lift forces (PD and PL) exerted by the swimmers were computed. The one stroke used for the quantification of the hand propulsion was decomposed into two phases; insweep and upsweep. The insweep phase was from the frame for the catch where the hand started moving backwards to the frame before the hand started moving outwards, and the upsweep phase was the frame where the hand started moving outwards to the exit of the hand out of the water. Mean of P, PD and PL among the 5 swimmers for each group was calculated for the two stroke phases. Additionally, the mean magnitude of hand velocity in the x-component ($|V_x|$) and in the yz-component ($|V_{yz}|$) as well as acceleration ($|A|$) and the angle of attack (α) of the 5 swimmers in each group were calculated for the two stroke phases.

RESULTS: Overall, the advanced-swimmers exerted a greater amount of P than the intermediate swimmers in both phases as shown in Table 1. During the insweep phase, the contribution of PD to P in the advanced swimmers was greater than that for PL (70% vs 30%) whereas the contribution of PD to P in the intermediate swimmers is relatively similar to that for PL (54% vs 46%). During the upsweep phase, the contribution of PD to P was similar to that for PL in the advanced swimmers (54% vs 46%), whereas the contribution of PD to P was greater than that for PL in the intermediate swimmers (65% vs 35%). The magnitude of hand velocities and acceleration in the advanced swimmers was greater than those in the intermediate swimmers except for $|V_x|$ in the upsweep phase (Table 2). The value of α in the advanced swimmers was smaller than that in the intermediate swimmers, and vice versa for the upsweep phase.

Table 1

Hand propulsion (P), propulsive drag and lift (PD and PL) in the insweep and upsweep phases

	Insweep		Upsweep	
	Advanced	Intermediate	Advanced	Intermediate
P (N)	53 9	37 7	43 8	36 14
PD (N)	37 5	20 9	24 7	23 9
PL (N)	16 5	17 2	20 8	13 6
PD/P	0.70	0.54	0.54	0.65
PL/P	0.30	0.46	0.46	0.35

Table 2

Magnitudes of hand velocity in the x-axis (V_x), in the yz-plane (V_{yz}) and acceleration (|A|) and the angle of attack (α) in the insweep and upsweep phases

	Insweep		Upsweep	
	Advanced	Intermediate	Advanced	Intermediate
V_x (m/s)	1.48 0.17	1.16 0.27	0.95 0.34	1.10 0.47
V_{yz} (m/s)	1.52 0.17	1.34 0.16	2.41 0.40	2.10 0.19
|A| (m/s^2)	28.11 2.16	24.07 5.13	26.18 2.54	21.66 2.17
α ( )	52 7	57 10	43 7	39 5

DISCUSSION: P, PD and PL exerted by the swimmers during the insweep and upsweep phases were compared between the advanced and the intermediate ones. The advanced swimmers exerted greater amount of P than the intermediate ones in both phases, which would relate to the difference in their morphological differences, potentially facilitating the advanced swimmers to swim faster. The advanced swimmers exerted greater amount of P during the insweep phase than the upsweep phase while the intermediate swimmers exerted the similar amount of P in both phases. During the insweep phase, the advanced swimmers used more PD than the intermediate swimmers to propel themselves as the contribution of PD to P of the advanced and intermediate swimmers was 70% and 54%, respectively. This could be because the advanced swimmers swept their hand faster in the backward direction (V_x) with the large amount of hand acceleration (|A|) (Schleihauf, Gray & DeRose, 1983; Kudo, Vennell & Wilson, 2014). The advanced swimmers used a slightly smaller angle of attack (α)

than the intermediate swimmers, which might help in increasing V_x and $|A|$. During the upsweep phase, the advanced swimmers increased the contribution of PL to P up to 46% from 30% to propel themselves whereas there was a decrease in the contribution from 46% to 35% observed in the intermediate swimmers. Due to these variations during the upsweep phase, the magnitude of PD exerted by the advanced swimmers was similar to the one of the intermediate swimmers (24 N vs 23 N); and PL of the advanced swimmers was greater than that of the intermediate swimmers (20 N vs 13 N). The advanced swimmers swept their hand faster in the lateral and vertical directions ($|V_{yz}|$) with the larger magnitude of hand acceleration ($|A|$), which could result in the increased contribution of PL to P.

An estimated active drag based on the fitted curves of active drag against swimming speed using MAD-system (Toussaint et al., 2004) for swimmers whose profiles were similar to the advanced swimmers in the present study was about 82 N at 1.82 m/s of swimming speed. At the constant swimming speed, the swimmers in the present study would exert about 59% of propulsion by the hand during the insweep and upsweep phases while the rest might be exerted by the other limbs such as the forearm and legs. This might indicate that the hand propulsion predicted in this study was reasonable.

CONCLUSION: The advanced swimmers used a different technique to exert P, PD and PL from the intermediate swimmers when performing the front crawl stroke at their maximal sprinting pace. The advanced swimmer used more propulsive drag in the insweep phase using the faster backward motion of the hand with large magnitude of hand acceleration as compared to the intermediate ones and used propulsive drag as well as lift more equally in the upsweep phase as compared to the intermediate swimmers.

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