ROLES OF THE EXTREMITIES DURING KICK START IN COMPETITIVE SWIMMING

Kazumasa Ozeki[1], Hiroshi Suito[2], Shinji Sakurai[3], and Tatuya Urata[4]

School of Health and Sport Sciences, Osaka University of Health and Sport Sciences, Sennan, Japan[1]
Faculty of Psychological and Physical Science, Aichi Gakuin University, Nisshin, Japan[2]
School of Health and Sport Sciences, Chukyo University, Toyota, Japan[3]
Department of Social Work, Kobe University of Health and Welfare, Kanzaki, Japan[4]

This study was aimed at examining the role of the hands and feet at takeoff by measuring the forces applied to the starting block by the right/left hands and feet. A small, waterproof force plate and a three-axis force sensor (operating at 500 Hz) were placed at the front and back of a custom-made starting block with an inclination angle of 10° and on the right and left sides of the front of the starting block, respectively, to measure the force exerted on the starting block. Five male collegiate competitive swimmers were requested to perform kick starts from the starting block. The rear and front feet had the greatest contribution to the horizontal and vertical velocities, respectively, at kick start. In addition, the hand and foot exerted downward and upward forces, respectively, to the vertical velocity at kick start, revealing bilateral differences in the horizontal and vertical velocities of the hand.

KEY WORDS: block phase, measuring force.

INTRODUCTION: Starting skill is one of the most important factors for race performance in competitive swimming. The International Swimming Federation has recently approved a starting block equipped with a back plate for use in swimming competitions. Swimmers who utilize the track start technique have thus developed a new technique called the kick start (Honda, Sinclair, Mason & Pease, 2010). The key mechanical factors that influence the start performance in competitive swimming are the horizontal velocity of the center of gravity (COG) at takeoff (Guimaras & Hay, 1985; Takeda & Nomura, 2006; Ozeki, Sakurai, Takahashi & Taguchi, 2010) and deceleration control upon entering the water (Ozeki et al., 2010). A study on the start phase in competitive swimming reported a significant positive correlation between leg extension force and start performance (Miyashita et al., 1992). Thus, leg extension force has been shown to be especially important for the attainment of high horizontal velocity of the COG at takeoff.
Recently, several studies that used a force platform rigidly fixed to the starting block have been conducted to measure the force exertion of swimmers on the starting block. However, no study has examined the force exertion of the hands and feet acting on the starting block during competitive swimming start. Therefore, this study aimed to examine the roles of the hands and feet during kick start in competitive swimming.

METHODS: Five male collegiate competitive swimmers were requested to perform kick starts from the starting block for one trial (Table 1). Prior to the tests, the swimmers were given 3 year to practice their starts using starting blocks equipped with back plates. Two small, waterproof force plates (TF-2050-W; Tec Gihan, Kyoto, Japan) were placed at the front and back of a custom-made starting block inclined at 10° to record separately the force exerted by right and left feet, respectively. Two waterproof three-axis force sensors (TLB05-500N; Tec Gihan) were placed on the right and left sides of the front of the starting block to record separately the force exerted by the right and left hands, respectively. The force plates and sensors were operated at 500 Hz. The momentum of

the force acting from the hands and feet was determined by time integration of the force. The momentum was divided by the body mass to estimate the change in the velocity of the COG of the subject. The subject was stationary before the start signal, and the estimated change in velocity corresponds to the takeoff velocity.

Table 1
Characteristics of Subjects

Subject	Specialty	Best record (m:s.ms)	Age (years)	Height (cm)	Weight (kg)
A	Freestyle 100 m	00:51.8	20	164	61
B	Buteafly 50 m	00:24.9	18	172	67
C	Freestyle 100 m	00:49.4	22	185	72
D	Freestyle 100 m	00:49.8	21	183	78
E	Freestyle 100 m	00:51.5	20	180	80
Average			19.8	174	69.4
Standard deviation (SD)			1.3	4.6	6.1

RESULTS: The force and velocity measurement results are given in Table 2. The greatest contribution to the horizontal velocity was from the rear foot. The greatest contribution to the vertical velocity was from the front foot. The hand exerted a downward force, whereas the foot exerted an upward force in the kick start. Additionally, a bilateral difference in the force exertion of the hands in the vertical and horizontal directions was observed.

Table 2
Force and velocity measurement results

Subject	Force (N s/BM)									Velocity (m/s)		
	Right hand		Left hand		Front foot		Rear foot		Gravity	Horizontal	Vertical	Resultant
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Vertical			
A	0.09	−1.37	0.19	−1.10	1.06	6.20	2.83	3.00	−6.57	4.18	0.16	4.18
B	0.13	−1.07	0.21	−0.96	1.17	5.68	2.73	2.97	−7.06	4.24	−0.45	4.26
C	0.20	−1.03	0.17	−1.00	0.81	5.47	3.06	3.83	−6.77	4.24	0.51	4.27
D	0.16	−1.61	0.21	−1.02	1.11	5.37	3.12	3.81	−6.97	4.61	−0.42	4.63
E	0.13	−1.08	0.06	−1.13	1.47	5.81	3.14	2.91	−6.87	4.80	−0.35	4.81
Mean	0.14	−1.23	0.17	−1.04	1.13	5.71	2.98	3.30	−6.85	4.41	−0.11	4.43
SD	0.04	0.25	0.07	0.07	0.24	0.33	0.19	0.47	0.19	0.27	0.42	0.27

DISCUSSION: The results of this study showed differences in the contribution to the horizontal and vertical velocities between the feet, bilateral differences in the

contribution of the hands, and bilateral symmetry of the motion of the upper extremity.
Takeda et al. (2017) reported that the contribution of the rear foot to takeoff horizontal velocity at kick start was greater than that of the front foot, and similar results were obtained in this study. Most of the takeoff velocity resulted from the rear foot. Therefore, the role of the rear foot is the exertion of the driving force that accelerates the swimmer's body in the horizontal direction.
The downward force generated by the hands suppresses the upward force generated by feet, enabling takeoff in the anterior direction. The contribution of the front foot to the vertical velocity was greater than that of the horizontal velocity. The result indicates that the force exertion of the front foot plays a role in supporting the body rather than in attaining horizontal velocity. Ozeki et al. (2012) reported that the body accelerated in the horizontal direction during the single-support phase of the front foot in top swimming sprinters. The front foot should contribute in supporting the swimmer's body when the body dramatically accelerates in the horizontal direction, suggesting that the role of the front foot is support and does not generate a driving force to the horizontal direction. We expected bilateral symmetry on the role of the hands; however, bilateral differences in the contribution of the hands were observed. This might be associated with the asymmetry in the anteroposterior position of the front and rear feet.
A limitation of this study was its inability to reveal any correlation between the contribution of the extremities and takeoff velocity. A cross-sectional study across swimmers and a longitudinal study within swimmers are required to determine the force acting on the starting block that contributes to the improvement in performance outcome of kick start in competitive swimming.

CONCLUSION: This study shows that the hands play a role in pulling the body to the starting block to avoid the body from taking off in an upward direction through the vertical component force generated at takeoff. The rear foot helps in gaining horizontal velocity during the start, whereas the front foot supports the body during the performance on the block.

REFERENCES:

Guimarase, A.C.S. & Hay, J.G. (1985). A mechanical analysis of the grab starting technique in swimming. *International Journal of Sport Biomechanics,* 1, 25-35.

Honda, K.E., Sinclair, P.J., Mason, B.R. & Pease, D.L. (2010). A biomechanical comparison of elite swimmers start performance using the traditional track start and the new kick start. *The XIth International symposium for biomechanics and medicine in swimming program & book of abstracts*, 75.

Miyashita, M., Takahashi, S., Troup, J.P. & Wakayoshi, K. (1992).Leg extensions power of elite swimmers. *Biomechanics and Medicine in Swimming, Swimming Science Ⅵ*, 295-299.

Ozeki, K., Sakurai, S. & Taguchi, M. (2012).Characteristics of top competitive swimmers movement for start phase. *Japanese Society of Sciences in Swimming and Water Exercise Program & Proceedings,* 90-91.

Ozeki, K., Sakurai, S., Takahashi, S. & Taguchi, M. (2010).The effect of the different technique of entry in competitive swimming start. *Japanese Journal of Biomechanics in Sports & Exercise,* 14 (1), 12-19.

Takeda, T., Sakai, S., Takagi, H., Okuno, K. & Tsubakimoto, S. (2017).Contribution of hand and foot force to take-off velocity for the kick-start in competitive swimming. *Journal of Sports Sciences,* 35(6), 565-571.

Takeda, T. & Nomura, H. (2006). What are the differences between grab start and track start? *International Symposium for Biomechanics and Medicine in Swimming X,* 6, 102-105.