KINEMATIC CHARACTERISTICS OF KICK START FOR ELITE COMPETITIVE JAPANESE MALE SPRINT SWIMMERS

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

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]

This study compared the kinematic characteristics of the kick start technique at the start phase demonstrated by an elite competitive sprint swimmer and eleven male collegiate swimmers in consideration of performance enhancement. Swimmers performed maximal effort during competitive swimming for a 25 m crawl swim during experimental trials. The trials were recorded using three synchronized video cameras shooting at 60 fps. Two-dimensional video analysis was performed in the sagittal plane. Calculated variables at take-off were horizontal velocity, speed, attitude angle, angle of projection, whereas those at entry were entry angle, attitude angle, angle of attack. In addition, block time horizontal coordinates for start position and 15 m time were calculated. Based on the results of this study, the kick start technique for the elite competitive sprint swimmer was characterized as having shorter block time and higher horizontal velocity at take-off.

KEYWORDS: swimming start, Japanese male sprint swimmer, angle of attack on entry

INTRODUCTION: In 2010, the International Swimming Federation (FINA) changed its facility regulations to allow starting blocks with back plates at international tournaments, which are now used at important domestic tournaments in Japan. Swimmers use these starting blocks to perform a track start with their legs opened anteroposteriorly, by kicking their back leg off of the back plate, which can be adjusted forward and backward. A track start using a back plate has also been called a “kick start” (Honda, Sinclair, Mason & Pease. 2010). Ozeki, Sakurai & Taguchi. (2014) examined 21 collegiate swimmers (11 men, 10 women), and found that post-start block times and 15 m times were shorter with kick starts than with conventional track starts without a back plate. The mechanical factors associated with this were a high horizontal velocity at take-off and short block time.
Research comparing the new kick-start method with the track start has been published (Takeda, Takagi & Tsubakimoto. 2009; Ozeki et al., 2014), but there has been very little research on the mechanical factors needed to improve the start-phase performance and characteristics of the start motions of elite swimmers when using the kick start. Therefore, the objective of the present study was to examine the characteristics of kick-start motions by comparing start-phase kinematic variables between an elite male sprint swimmer and male collegiate swimmers.

METHODS: The participants included one elite male sprint swimmer from Japan (elite swimmer, A: 2010 Japan Open 50-m freestyle champion) and 11 male members of collegiate swimming clubs (collegiate swimmers, B-L: participants in Japanese national team trials or student national team trials). For the 11 collegiate swimmers, we reanalyzed kinematic data during swimming from a previous report (Ozeki, Sakurai & Taguchi. 2014). Table 1 shows the participants’ heights, weights, ages, specialties, best times, and competition histories. The participants received a thorough explanation of the study, including its objective, methods, and risks, and their consent was obtained in writing.
The experiment was performed at a FINA-certified indoor pool (50 m × 8 lanes, depth: 1.3-1.8 m) that had starting blocks with back plates (height 0.75 m, starting block angle 10º, back plate angle 30º, Chuo Sangio). To evaluate the participants’ start-phase performance, the time it took for the head to reach 15 m was measured while performing a crawl stroke at full

exertion for 25 m. Trials were recorded using three synchronized video cameras (DXC-990, Sony) sampling with 60 fps and 1/1000s exposure. The video data was analyzed in the 2D sagittal plane. Images from the CCD video cameras were fed into a computer and image analysis software (Frame-DIAS IV, DKH, Japan) was used to digitize the data. Two dimensional coordinate of the marked points on the swimmers body was calculated by the direct linear transformation method, and then filtered by a Butterworth digital filter. The cutoff frequency was determined by residual analysis to be 3-6 Hz (Winter, 1979). The center of gravity of the swimmer's body at each frame was estimated by the two dimensional coordinates on the body and body segment parameters (Ae et al., 1992). The block time, 15m time, horizontal and resultant velocity at take-off, angle of projection, attitude angle, angle of attack, and Horizontal coordinates for start position was calculated (Fig 1).
The kinematic variables of the elite swimmer and the colligate swimmers were compared using a 1-sample t-test, with a significance level of 5%.

Table 1: Characteristics of subjects.

Subject	Specialty	Best record (m:s.ms)		Age (yrs)	Height (cm)	Weight (kg)	Athletic career (yrs)
A	Freestyle	50m	0:22.50	24	171	71	19
B	Freestyle	100m	0:52.12	22	179	80	15
C	Freestyle	100m	0:52.74	20	177	75	8
D	Freestyle	100m	0:52.92	19	175	73	11
E	Freestyle	50m	0:24.42	19	173	65	9
F	Freestyle	50m	0:26.27	20	180	72	5
G	Butterfly stroke	100m	0:54.16	22	171	71	16
H	Butterfly stroke	100m	0:54.41	20	171	63	12
I	Butterfly stroke	100m	0:56.00	19	180	71	14
J	Butterfly stroke	100m	0:56.59	18	169	61	9
K	Backstroke	100m	0:57.11	20	173	71	17
L	Breaststroke	200m	2:18.12	19	166	61	8
Average				20.2	173.8	69.5	11.9
±SD				1.7	4.5	5.8	4.3

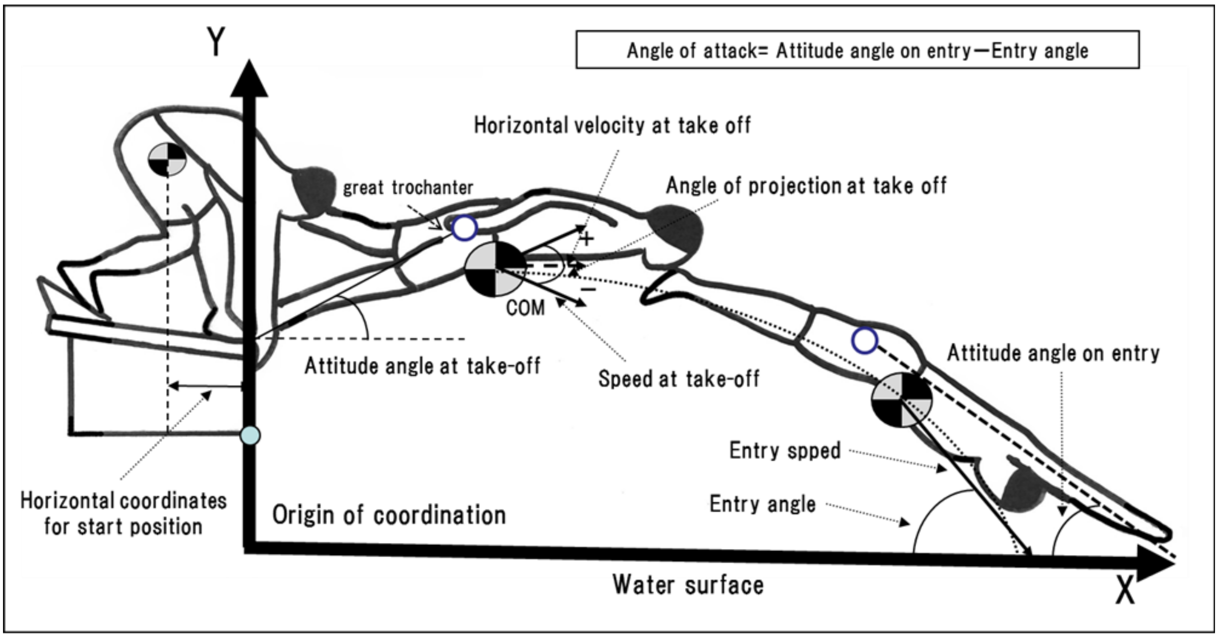

Figure 1: Definitions of kinematic variables in the block and flight phase of a swimming start.

RESULTS: Table 2 shows the kinematic variables for the elite swimmer and collegiate swimmers. Significant differences were observed for horizontal velocity at take-off ($p<0.01$), speed at take-off ($p<0.01$), angle of projection at take-off ($p<0.05$), horizontal coordinates for start position ($p<0.01$), block time ($p<0.01$), and 15-m time ($p<0.01$).

Table 2. The result of variables during start phase

Kinematic variables	Elite swimmer (n=1)	College swimmers (n=11) (mean±SD)	**p**
Horizontal velocity at take-off (m/s)	5.21	4.41±0.18	$p<0.01$
Speed at take-off (m/s)	5.39	4.58±0.26	$p<0.01$
Angle of projection at take-off (degree)	-17.7	-14.4±4.4	$p<0.05$
Attitude angle at take-off (degree)	29.0	32.1±5.5	n.s
Entry angle (degree)	38.8	39.9±5.7	n.s
Attitude angle on entry (degree)	37.0	38.5±2.4	n.s
Angle of attack on entry (degree)	-1.8	1.4±6.4	n.s
Horizontal coordinates for start position (cm)	14.4	25.4±5.3	$p<0.01$
Block Time (s)	0.62	0.70±0.04	$p<0.01$
15m Time (s)	5.55	6.78±0.33	$p<0.01$

※"p" indicates p value of one sample t-test (Elite swimmer vs College swimmers)

DISCUSSION: The elite swimmer's 15-m time, an indicator of start-phase performance, was significantly shorter than that of the collegiate swimmers. Factors thought to be associated with a shorter 15-m time were a short block time, greater horizontal velocity at take-off, and anterior positioning of the physical center of gravity in the start position.
In our results, the elite swimmer's 15-m time, an indicator of start-phase performance, was significantly shorter than that of collegiate swimmers. This shows that elite swimmers have better start-phase performance, and that differences in start-phase performance can affect the results of competition. The factors cited as determining start performance in competitive swimming are a high horizontal velocity of center of gravity at take-off (Guimarase & Hay 1985) and deceleration control on entering the water (Ozeki, Sakurai, Takahashi & Taguchi. 2010). Thus, past research supports the result of the present study.
Block time was one of the factors found in the present study that may contribute to differences in start-phase performance. A study by Ozeki et al. (2010) found that swimmers with higher horizontal velocity at take-off had shorter block times, which is consistent with the results of the present study. As for other factors, Robert, Richard & Thomas. (2008) found that positioning the physical center of gravity anteriorly when preparing for a track start reduced block time, while positioning the physical center of gravity posteriorly when preparing to start increased speed at take-off. In the present study, the elite swimmer's physical center of gravity was significantly more anterior in the start position than that of the collegiate swimmers. That is, a start position in which the physical center of gravity is positioned anteriorly appears to shorten the block time.

Moreover, the angle of projection at take-off of the elite swimmer in the present study was significantly smaller than that of the collegiate swimmers. Angle of projection at take-off has been reported to correlate negatively with horizontal velocity at take-off and speed at take-off (Takeda, T., Ichikawa, H., Sugimoto, S. & Nomura. 2006; Ozeki et al., 2010), which suggests that elite swimmers do not seek to increase their horizontal velocity and speed at take-off when they start, but to leave the starting block as quickly as possible after the start signal.
Only one elite swimmer was examined in this study; therefore, the results may only represent the characteristics of the start motions of this swimmer. Because other elite swimmers may have different characteristics than those observed in the present study, data on other elite swimmers should be gathered in the future.

CONCLUSION: We found a higher horizontal velocity at take-off in the elite male Japanese sprint swimmer than the collegiate swimmers. In order to shorten 15-m time, a forward start position should be adopted with a large horizontal velocity at take-off.

REFERENCES

Ae, M., Tang, H., Yokoi, T. (1992). Estimation of inertia properties of the body segments in Japanese athletes. Biomechanisms 11(0), 23-33.

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.

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.

Ozeki, K., Sakurai, S., Takahashi, S. & Taguchi, M. (2014).Comparison between Kick start and Track start in the competitive swimming: Analysis of sex differences. Japanese journal of sciences in swimming and water exercise, 17(1), 4-11.

Robert, L.W., Richard, N.H. & Thomas, R.G. (2008) Front- or rear-weighted track start or grab start: Which is the best for female swimmers? *Sports Biomechanics*, 7(1): 100-113.

Takeda, T., Takagi, H. & Tubakimoto, S. (2009) Effect of back plate on starting block in competitive swimming. *Conference for Japanese journal of Sciences in Swimming and Water Exercise 2009 Book of Abstracts*.24-27.

Takeda, T., Ichikawa, H., Sugimoto, S. & Nomura, T. (2006) Effects of take-off angle on take-off velocity, flight distance and block time during swim-start. *Japan Society of Physical Education, Health and Sport Sciences*, 51.515-524

Winter, D. A. (1979). *Biomechanics of Human Movement.* NY, John Wiley & Sons.

ACKNOWLEDGEMENTS: This work was supported by JSPS KAKENHI Grant Numbers JP22700639, JP16K01681.