Original Article

Changes in the front and rear knee angles depending on the body and kick plate positions during the kick start

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Published online: November 30, 2020

(Accepted for publication: November 22, 2020)

DOI:10.7752/jpes.2020.s6450

Abstract

The OBS12 is a new starting platform, which can be used by swimmers at all swimming facilities, because the platform can be mounted to every starting block. The rear knee angle of 90° promotes acceleration during the swim start, which results in shorter block time. The study aims to assess differences in the front and rear knee angles relative to the kick plate position during the kick start. The sample consisted of 10 competitive swimmers (17.5 ± 1.9 years) who were studied in three body positions with all kick plate positions. The video data were collected using a SwimPro camera system. Then, we used the Dartfish© software to evaluate the kinematic parameters for the on-block, flight, and underwater phases. To determine differences in the kinematic data with regard to the kick plate and starting positions, we used the analysis of variance (ANOVA). The statistical software used was Statistica 12. We found that swimmers produced shorter times to 5 meters when the front knee angle and rear knee angles in the starting position ranged from 130° - 132° and 76° - 82°, respectively. The rear-weighted position produced higher takeoff and entry angles, shorter glide distance than the front-weighted or neutral-weighted position. According to the results of the study, the swimmers should choose the rear-weighted position and adjust the kick plate on the OSB12 starting block to positions 3 (1.749 s) to 4 (1.758 s). We observed changes in all studied swim start parameters between the front-weighted position and rear-weighted position for all kick plate positions ($p < .05$) (Table 2).

Keywords: swimming, kinematic parameters, biomechanics, body position

Introduction

Swim start considerably determines the structure of sports performance, especially in sprint races, affecting the final standings. This applies in particular to international swim events where swimmers' performances differ in hundredths of second. Swim start refers to the time between the sound of the start signal and the time when the swimmer's head breaks the surface of water over the course of 15 m (Tor et al., 2014; Ružbarský & Matuš, 2017). The kick start is one of the commonly used block start techniques in competitive swimming (Tanaka et al., 2020), which consists of the block phase, flight phase, water phase, and swim phase (Blanco et al., 2017). Out of all phases, swimmers produce the highest velocity in the block phase. In this phase, the average horizontal takeoff velocity is significantly correlated with times to 5 and 15 m (Garcia-Ramos et al., 2015). Before 2009, swimmers started from traditional starting blocks equipped with handles on both sides. Since 2009, swimmers in Slovakia and all over the world have been using a new starting block (manufactured by Omega) at world-class swim events. The new block has a rear footrest that is adjustable in the front and rear directions (5 positions in the range of 200 mm) at an angle of 30° (90° rear knee angle) (Swiss Timing, 2014). This technical innovation resulted in the modification of the basic position during the track start. When using the new OSB starting platform, swimmers place the rear foot against the so-called kick plate.

The advantages of using this starting block include shorter block time (Fischer 2017; Takeda et al., 2017), higher take-off horizontal velocity, and shorter time to 5 m (Taladriz 2017; Ozeki, Suito, & Sakurai, 2018; Silveira et al. 2018) and 15 m (Barlow et al., 2014; Yang, 2018) compared to previous or other swim starts or their modifications. When starting from the OSB12 starting platform, swimmers may assume front- and neutral-weighted positions (with body weight distributed evenly over both legs) and a rear-weighted position. According to Honda et al. (2012), rear-weighted start was associated with longer reaction time, higher horizontal velocity, and longer flight phase than neutral- and front-weighted starts with no significant differences in time to 7.5 m. Block times produced by the swimmers were shorter for the front-weighted kick start (Barlow et al., 2014; Kibele et al., 2014). However, the rear-weighted position produced higher horizontal velocity was higher. High position of the center of mass and a narrow stance may offer the best chance in terms of the swim start performance (Kibele, Biel, & Fischer, 2015). All three studies had different approaches for determining the position on the starting block. Therefore, it is necessary to study the kick start's temporal and angular parameters with the emphasis on knee and leg angles relative to both front and rear sections of the starting platform

(Nomura et al., 2010; Slawson et al., 2012; Burkhardt et al., 2020; Matúš&Kandráč, 2020; Tanaka et al., 2020). The purpose of this study was to determine differences in the front and rear knee angles depending on the body and kick plate positions during the kick start from OSB12.

Materials and methods

Participants

A total sample of 10 non-randomly recruited competitive swimmers (whose mean age, height, and weight were 17.5 ± 1.9 years, 184.2 ± 3.6 cm, and 83 ± 4.0 kg, respectively) participated in this study. The swimmers regularly competed in the Slovak regional and national swimming championships, starting in particular sprint races and freestyle races. Before testing, none of the swimmers reported any health problems. All swimmers provided their written informed consents after reading an information leaflet about testing.

Test protocol

Swimmers attended the morning testing session at the swimming pool facility at the Faculty of Sports, University of Presov, Presov, Slovakia. The testing procedure was as follows:

1. Provision of information about the testing conditions to all swimmers
2. Performance of the standard warm-up protocol
3. Swimming 500m
4. Application of 16 waterproof adhesive markers on the swimmers' bodies:
 - medial sides of the 5th metacarpal-phalanx joint
 - lateral margins of the left and right transverse tarsal joint
 - lateral left and right malleolus
 - ulnar styloid processes of the left and right wrist
 - lateral left and right knee condyles
 - lateral left and right elbow epicondyles
 - lateral margin of the left and right scapular spine
 - left and right greater trochanters
5. Weighted starting positions (Figure 1)
6. 3 starts front-, neutral-, and rear-weighted positions by setting the kick plate to positions 1–5.
7. Overall 45 kick start / rest 2 min/

Figure 1 Starting position – block phase

We used the SwimPro five-camera system (60 fps; shutter speed 1/1000 s) to measure the swim start parameters. We placed the cameras as follows:

- 1st position camera - 1 camera – perpendicular to the starting block at the 0-m distance from the edge of the pool and 1.5 m above the water surface and another camera on the other side
- 2nd position camera – 1.6 m from the edge of the pool and 1.5 m under the water surface
- 3rd position camera – 1.6 m from the edge of the pool and 1.7 m below the water surface;
- 4th position camera – 5 m away from the edge of the pool and 1.7 m below the water surface.

Using the Dartfish© software (Dartfish ProSuite 4.0, 2005; Switzerland), we subsequently assessed the 2D analysis video recordings. To determine differences in the kinematic data with regard to the kick plate and starting positions, we used the analysis of variance (ANOVA). The statistical software used was Statistica 12.

Results

Block phase

We measured the shortest BT for the FW and NW positions (0.800–0.904 s) for all kick plate positions on the OSB12 starting blocks. When the kick plate was set to 3FW position was used (Table 1), swimmers produced the fastest block times (0.800 s). Angular changes in the front and rear leg show that changing the basic starting position on the starting block affects the FKA and RKA. In the basic starting position, the FKA on the starting block increased depending on the shoulder positions and kick plate position on the OSB12 starting block.

FKA (125–128°) for the FW position were lower than those for the NW (127–130°) or RW positions (130–133°). When the swimmers started from the 3FW, we recorded the highest FKA of 132.82° in the basic starting position. We measured the lowest FKA (125.04°) for the 2FW position.

Both the kick plate position and shoulder position decreased the RKA on the OSB12 footrest. We measured the higher RKA (87–96°) for the FW position than those for the NW (80–86°) and RW positions. For the basic starting position, we recorded the highest RKA of 95.80° when the swimmers started from the 5FW. We measured the lowest RKA (76.66°) for the 2RW position (Table 1). We observed changes in the FKA and RKA between the FW position and RW position across all kick plate positions ($p < .05$) (Table 2).

Flight phase

The basic starting position and kick plate position on the OSB12 starting block affect the TA and EA. We measured lower TA values (33–35°) for the FW position than those for the NW (34–38°) and RW positions (38–40°). We recorded the highest TA values (40.12°) for the 4RW position. We recorded the lowest TA values (33.00°) for the 1FW position.

The basic starting position and the OSB12 kick plate position also affect the EA. The EA for the FW position across all kick plate positions were lower (34–35°) than those for the NW (34–38°) and RW positions (36–39°). When the swimmers started from the 5RW position, the EA (39.48°) were the highest. However, we recorded the lowest EA when swimmers started from the 2FW position (Table 1).

The basic starting position and the OSB12 kick plate also affect the FD and angular changes during the flight phase. The FW position for all kick plate positions was associated with shorter FDs (2.47 m – 2.73). The NW positions produced FDs ranging from 2.49 m to 2.74 m. The longest FDs ranging from 2.51 m to 2.79 were found for the RW position. We observed the shortest FDs for the 1FW position (2.47 m) and the longest for the 4RW position. We observed changes in the TA, EA, and FD between the FW position and RW position across all kick plate positions ($p < .05$). (Table 2).

Underwater phase

The glide distance is the distance between the water entry and 5 m. The values of glide phase were opposite to the flight phase values. When the swimmers started from the FW position regardless of the kick plate position, the GD was longer (2.27–2.53 m) than those recorded for the NW (2.26–2.51 m) or RW positions (2.21–2.49 m). The shortest GD (2.22 m) was recorded for the 4RW. The longest GD was recorded for the 1RW position (Table 1). T5 was shortest for the RW position ranging from 1.749 s to 1.837 s. In the NW and FW positions, T5 ranged from 1.783 s to 1.859 s and from 1.805 s to 1.889 s, respectively. The longest T5 was observed for the 1FW position (1.889 s) and the shortest for the 3RW position (1.749). We observed changes in the GD and T5 between the FW position and RW position across all kick plate positions ($p < .05$). (Table 2).

Table 1. Differences in the selected kinematic parameters during the kick start

		BT	FKA	RKA	TA	EA	FD	GD	T5	
		(s)	(°)	(°)	(°)	(°)	(m)	(m)	(s)	(m/s)
1FW	<i>M</i>	0.896	125.7	87.38	33	33.76	2.47	2.53	1.889	2.647
	<i>SD</i>	0.04	1.23	1.14	0.76	0.662	0.06	0.04	0.06	0.096
1NW	<i>M</i>	0.898	129.12	86.74	34.44	34.46	2.49	2.51	1.859	2.690
	<i>SD</i>	0.033	1.26	1.16	1.37	1.03	0.13	0.11	0.103	0.166
1RW	<i>M</i>	0.917	131.08	77.84	38.38	35.66	2.51	2.49	1.837	2.722
	<i>SD</i>	0.071	1.39	0.89	0.61	0.23	0.08	0.06	0.086	0.143
2FW	<i>M</i>	0.904	125.04	90.8	36	33.62	2.66	2.34	1.832	2.729
	<i>SD</i>	0.033	1.85	0.79	0.73	1.21	0.08	0.06	0.048	0.083
2NW	<i>M</i>	0.899	127.02	82.56	38.22	35.7	2.73	2.27	1.789	2.795
	<i>SD</i>	0.06	1.39	0.84	1.02	0.74	0.2	0.18	0.07	0.12
2RW	<i>M</i>	0.905	130.48	76.66	39.74	36.22	2.75	2.25	1.781	2.807
	<i>SD</i>	0.048	1.51	1.4	0.91	0.86	0.11	0.09	0.041	0.077
3FW	<i>M</i>	0.800	128	90.2	36.94	34.58	2.71	2.29	1.805	2.770

	<i>SD</i>	0.049	0.89	1.19	0.74	0.93	0.15	0.13	0.066	0.112
3NW	<i>M</i>	0.861	130.16	79.98	37.9	35.44	2.71	2.29	1.783	2.804
	<i>SD</i>	0.044	1.28	1.22	0.88	1.11	0.11	0.09	0.1	0.179
3RW	<i>M</i>	0.880	132.82	79.44	39.94	38.28	2.75	2.25	1.749	2.859
	<i>SD</i>	0.07	1.13	1.34	1.13	0.97	0.15	0.13	0.073	0.128
4FW	<i>M</i>	0.856	125.16	93.54	35.4	35.26	2.73	2.27	1.848	2.706
	<i>SD</i>	0,085	1,36	1,59	0,98	1,12	0,13	0,11	0,042	0,072
4NW	<i>M</i>	0.857	128.2	85.86	36.18	37.32	2.74	2.26	1.789	2.795
	<i>SD</i>	0.086	1.12	0.9	0.91	1.09	0.1	0.08	0.103	0.172
4RW	<i>M</i>	0.859	130.72	80.06	40.12	37.92	2.79	2.21	1.758	2.844
	<i>SD</i>	0.041	1.27	0.87	1.01	0.8	0.13	0.11	0.047	0.088
5FW	<i>M</i>	0.872	127.58	95.8	35.12	34.34	2.72	2.28	1.854	2.697
	<i>SD</i>	0.032	1.32	1.5	1.64	0.99	0.15	0.13	0.046	0.077
5NW	<i>M</i>	0.899	130.08	86.1	36.56	38.24	2.72	2.28	1.828	2.735
	<i>SD</i>	0.057	1.68	1.86	1.18	1.38	0.17	0.15	0.068	0.112
5RW	<i>M</i>	0.902	132.36	81.86	38.32	39.48	2.74	2.26	1.822	2.744
	<i>SD</i>	0.036	0.87	1.03	0.83	1.67	0.14	0.12	0.026	0.05

Note: 1-5 kick plate position; FW – forward; NW – neutral; RW – rear; BT – block time; FKA – front knee angle; RKA – rear knee angle; TA – takeoff angle; EA – entry angle; FD – flight distance; GD – glide distance; T5 – time to 5 m

Table 2. Significant differences in the kinematic parameters relative to the body and kick plate positions

	BT	FKA	RKA	TA	EA	FD	GD	T5
Significant differences $p < .05$								
1FW	1RW, 3RW, 4RW	3RW, 5RW		1RW, 2RW, 3RW, 4RW	1RW, 2RW, 3RW, 4RW	1RW, 2RW, 3RW, 4RW, 5RW	1RW, 2RW, 3RW, 4RW, 5RW	2RW, 3RW, 4RW
1NW				2RW, 3RW, 4RW	2RW, 3RW, 4RW			
1RW	2FW, 3FW, 4FW	4FW	2FW, 3FW, 4FW, 5FW			4FW, 5FW	4F, 5FW	
2FW		3RW, 5RW	2RW			2RW, 3RW, 4RW	2RW, 3RW, 4RW	2RW, 3RW, 4RW
2NW		3R						
2RW	3FW, 4FW, 5FW		3FW, 4FW, 5FW					4FW, 5FW
3FW	2RW, 3RW, 4RW							3R, 4R
3NW			5FW					
3RW		4FW	3FW, 4FW, 5FW	4FW, 5FW	4FW, 5FW			4FW, 5FW
4FW		5RW	4RW	4RW	4RW			4RW
4NW								
4RW			5FW	5FW	5FW			5FW
5FW								
5NW								
5RW								

Note: 1-5 kick plate position; FW – forward; NW – neutral; RW – rear; BT – block time; FKA – front knee angle;

RKA – rear knee angle; TA – takeoff angle; EA – entry angle; FD – flight distance; GD – glide distance; T5 – time to 5 m

Discussion

Kick start is a superior technique compared with the track start and glide start due to the larger base of support on the block to improving the stability of start and the larger take-off velocity as well as time advantages in the different start periods (Yang 2018). The kick plate enables the swimmer to push off with a rear knee angle of 90°, which allows for optimal force production. As a result of the perceived benefits, this start is now used by most swimmers during competition (Tor 2017). The kick-start's shorter block time was explained by exertion of horizontal force by the hands and rearfoot at the beginning of starting motion (Takeda et al., 2017). When using the kick plate, the sum of horizontal impulses from both legs became relevant to performance instead of the back foot only. Thus, using the kick plate may have "forced" swimmers to apply forces horizontally on the starting block, which is reflected by a reduced variance for this parameter (Silveira et al., 2018). It was concluded that shorter block times and rotational displacements of the lower limbs on the block and flight phase are the key of the best performance for kick-start at 5m distance (Taladriz et al., 2016). A larger front leg knee angle and a closer alignment of the arms to the torso for kick start are required to increase the angular momentum at take-off. As a result, larger body rotations are produced during the flight phase, such that the swimmers are able to obtain an optimal water entry (Taladriz, 2017). Kibele, Biel and Fischer (2017) studied the systematic variations of the preferred stance positions of 17 elite swimmers on the OSB11 were analyzed in regard to block time, swim start times to 5 m, horizontal take-off velocities, and horizontal vs. vertical peak force values. Shortest block times were found for the front-weighted CM positions. Best swim start times to 5m were found in for the front-weighted CM positions as well. There was a clear tendency showing that a forward shift to high CM position with a narrow stance would provide best biomechanical conditions for a fast swim start to 5m. Here, subjects were able to produce large horizontal peak forces while block times remained small. As reported by Ozeki, Suito, Sakurai (2018), 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 order to shorten 15-m time, a forward start position should be adopted with a large horizontal velocity at take-off. An optimal starting performance for the rear-weighted kick start could be achieved by a large flight distance, high vertical impulse applied by the back foot, high horizontal impulse applied by the front foot, a large angle between ankle, hip and shoulder at takeoff and a small angle between the horizontal axis, hip and ankle at hip entry in the water (Silveira et al., 2018). As for the dynamic variables (e.g., mean horizontal force for the kick start compared with other swim starts), it appears that the kick plate affected both the force generated by the rear leg at takeoff and the overall stability of body position during the block phase (Benjanuvatra et al., 2004; Vantorre et al. 2010a; Vantorre et al. 2010b; Honda et al., 2010). Another parameter that affects the swim start performance is the horizontal takeoff velocity. Tor et al. (2015) analyzed the kick start and determined that 81% of variance in start performance was accounted for by the take-off horizontal velocity. The adjustment of the kick plate position had as significant effect on differences in the rear knee angle with no significant differences in the takeoff velocity and flight distance (Nomura et al., 2010). In our study, the front knee angles, compared with the results reported by Slawson et al. (2012), were smaller (5–13°). On the contrary, the values of rear knee angles were identical. We observed changes in the front and rear knee angles and time to 5 meters between the front-weighted position and rear-weighted position for all kick plate positions ($p < .05$).

Conclusion

The present study deals with the differences in the front and rear knee angles relative to the body and kick plate positions during the kick start from OSB12. Using the OSB12 starting block, the kick plate enables the swimmers to take off with a 90° rear knee angle; however, the results of our study showed shorter time to 5 m when the front and rear knee angles respectively were 133° and 79° in the rear-weighted position with the kick plate in position 3. The rear-weighted position produced higher take-off and entry angles and shorter glide distance than the front- or neutral-weighted positions. However, the swimmers' block time was shorter when the front- and neutral-weighted positions were used. The swimmers should start from the rear-weighted position and set the kick plate on the OSB12 starting block to positions 3–4. We observed changes in all studied swim start parameters between the front-weighted position and rear-weighted position for all kick plate positions ($p < .05$) (Table 2). In the future, further research needs to be conducted to study the foot positioning on the OSB kick plate and its effects on particular phases of the kick start in terms of kinetic changes.

Acknowledgements

This study was conducted within the VEGA research project no. 1/0793/18 entitled "The effect of basic position on the starting block on changes in kinematic parameters of track start in swimming". The authors would like to thank Falcon Scientific Editing (<https://falconediting.com>) for proofreading the English language in this paper."

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