EFFECTS OF STANDARDIZING KICK PLATE POSITION ON TRACK START BIOMECHANICS IN ELITE SWIMMERS

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Kick plate position in the track start is arbitrary but may influence performance. The purpose of this study was to investigate the influence of standardizing kick plate position based on shin length. 15 elite swimmers performed 3 starts at 3 kick plate positions (< shin length, shin length, and > shin length). Differences in reaction time (RT), block phase time, flight phase time, flight distance, underwater phase time, and time to the 15 m mark were examined between kick plate positions. Only RT was significantly different, ($F(2,28)=4.713$, $p=.017$). RT was lower when the kick plate distance was one shin's length versus < shin length (0.173±0.034vs 0.194±0.061 sec) and > shin length (0.173±0.034 vs 0.195±0.047 sec), $p<.05$. Shin length may be an appropriate measure for kick plate position to enhance start performance.

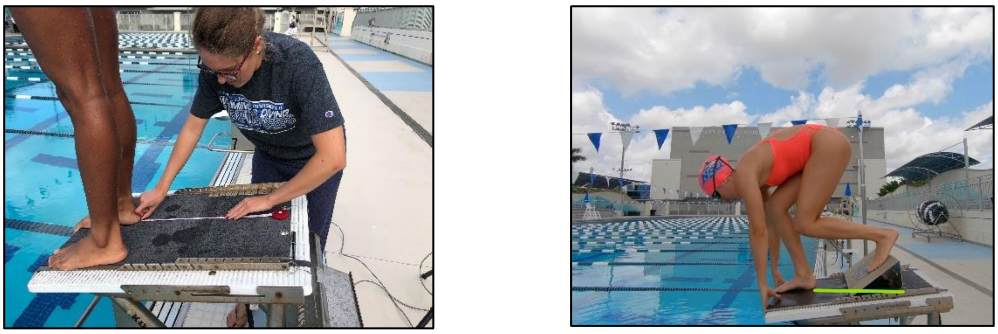
KEYWORDS: swimming, reaction time, swim start

INTRODUCTION: Successful execution of the swimming start impacts the overall race performance by as much as 26.1% (Cossor & Mason, 2001). In a sport where hundredths of a second often determine the winner of short distance races, it is crucial for a swimmer to take advantage of a biomechanically sound start (Jorgic´, 2010). The swimming start is typically defined as the time from the starting signal to when the center of the swimmer's head reaches the 15 meter mark (Cosser & Mason, 2001). It can be broken down further into 3 sub-phases (Tor, Pease & Ball, 2015). The first is the Block phase that occurs between the starting signal and when the swimmer's toes leave the block. It encompasses reaction time (time from the signal to the first instant of swimmer movement) and occurs in in 0.76±0.05 sec (Carradori, Burkhardt, Sinistaj, Taylor & Lorenzetti, 2015). A reduction in Block phase time has been shown to reduce time to 15 m (Garcia-Hermoso et al., 2013). However, some studies have suggested a trade-off between Block phase time and the horizontal velocity due to potentially smaller impulse production (Breed & McElroy, 2000; Vantorre et al., 2010). The second phase is the Flight phase which occurs from toe-off to when the swimmer's head enters the water, and takes 0.27±0.05 sec (Welcher, Hinrichs, & George, 2008). The Flight phase success is achieved by the high velocity produced at take-off during the Block phase, and is characterized by flight distance and time, with larger values in both being desirable. The third phase and longest phase is the Underwater phase and is the time from entry to when the swimmer resurfaces to begin free swimming, and occurs in 1.11±0.06 sec (Vantorre, Chollet, & Seifert, 2014). Pereira et al. (2006) suggested that time between water entry and the 15 meter mark is the most important variable in swim start performance.

The track start technique is commonly used by competitive swimmers and is characterized by positioning the feet in a staggered stance. Swimmers are often coached to place the kick plate closer to the front of the platform in shorter sprints versus longer sprints. Placement of the kick plate is largely decided upon via a swimmer's comfort or what "feels natural" with taller swimmers typically positioning it further back than shorter swimmers. Having a more objective and individualized anatomical criteria such shin length, may make kick positioning less arbitrary and positively impact start performance. Therefore, the purpose of this study was to determine the effects of three kick plate positions determined via shin length (<shin length, shin length, > shin length) on selected swim track start biomechanics. Specifically, we measured Reaction time (RT), Block phase time (BT), Flight phase time (FT), Flight distance (FD), Underwater phase time (UWT), and time to the 15 m mark (TT15 m) between three kick plate positions based upon shin length. We hypothesized that a kick plate position of one shin length would yield the shortest TT15 m with a concomitant longer FD.

METHODS: Fifteen elite, adult swimmers (males, 10; females, 5; age, 21.3 ± 1.7 yrs; height, 1.79 ± 0.08 m; mass, 77.4 ± 10.4 kg) participated in the study. All participants were members of a university or club swim team. To be eligible for the study, they had to have competed at a national level or higher, were familiar with the track start, and were classified as sprinters (25-100 m distances). The University's Institutional Review Board approved the study, and subjects provided written informed consent. Height, mass and shin length were collected in a university laboratory. Shin length was determined with a tape measure (cm) as the distance between the lateral tibial condyle and the lateral malleolus. This measurement was used to determine the kick plate position on the starting block at the pool.

Swim start data were collected at an outdoor university competition pool. Two GoPro 120 Hz cameras (Hero6 Black; Los Angeles, CA, USA) synchronized using a GoPro Wi-Fi Smart Remote captured the data. Camera 1 was positioned perpendicular to the block at a 5 m distance. Camera 2 was positioned on the pool deck perpendicular and midway to the subject's lane so that all phases of the start were viewed. One meter was marked in the view of Camera 2 for spatial reference. Participants completed a dynamic warm-up consisting 200-500 m swim and whole body stretching. Then, participants performed 3 track starts in random order at each of the following kick plate positions: (a) distance of one shin length from the front foot (shin length), (b) distance of one notch greater than shin length (> shin length) from the front foot, and (c) distance of one notch less than shin length (< shin length) from the front foot. More specifically, for the "at shin length" trials, the back, vertical portion of the kick plate was positioned one shin length from the participant's heel (Figures 1a and 1b). The plate was moved forward one notch(4 cm) for < shin length, and back one notch(4 cm) for > shin length. Participants were instructed and monitored to keep the foot placement on the kick plate constant between trials. Starts were signalled using a Championship Start System (Colorado Time Systems, Loveland, CO, USA) that provided the auditory and visual (light) signals. Participants provided subjective feedback by selecting one trial per position in which they perceived as the best, and these trials were analysed. Video were downloaded to a laboratory computer and analysed with Dartfish (ver. 8.0; Dartfish USA, Inc., Alpharetta, GA, USA). The dependent variables (DV) were defined as follows: (a) Reaction time (RT) was the time (sec) from the frame in which the starting signal (light) was detected to the frame corresponding to the first instant of the swimmer's movement, (b) Block phase time (BT) was time (sec) from the frame in which the starting signal (light) was detected to the frame when the toes left the block, (c) Flight phase time (FT) was the time (sec) from the frame corresponding to when the toes left the block to the frame when the head entered the water, (d) Flight distance (FD) was determined using the 1 m reference and measured as the horizontal distance between the end of the block to the point where the fingers entered the water (m), (e) Underwater phase time (UWT) was the time (sec) from the frame when the head entered the water to the frame when the first body part surfaced, and (f) Time to the 15 m mark (TT15 m) was the time from the frame where the start signal (light) was detected to the frame corresponding to when the swimmer's hands reached the 15 m mark. Data were transferred to an Excel file and then analyzed with Statistics Package for Social Sciences (ver. 25; IBM Corporation, New York, NY, USA). Repeated measures analysis of variance (RM ANOVA) were used to determine within subject differences in the DVs between the 3 kick plate positions, $p<.05$.



Figures 1a and 1b. Determining kick plate position based upon shin length measurement.

RESULTS DISCUSSION: Table 1 presents the means and standard deviations for RT, BT, FT, UWT, FD and TT15 m for the three kick plate positions during the swimming track start, N=15. The only statistically significant difference found was for RT ($F_{(2,28)}$=4.713, *p*=.017).

Table 1. Means of Track Start Performance Variables between Three Kick Plate Positions (N=15).

Variable	< Shin length	Shin length	> Shin length	*p* value
Reaction Time (sec)	0.194±0.061	0.173±0.034	0.195±0.047	.017*
Block Time (sec)	0.715±0.058	0.690±0.056	0.702±0.061	.055
Flight Time (sec)	0.300±0.074	0.304±0.079	0.309±0.074	.436
Underwater Time (sec)	4.045±0.987	3.964±0.908	3.980±0.880	.761
Flight Distance (m)	2.43±0.23	2.39±0.22	2.37±0.22	.189
Time to 15 m (sec)	6.739±0.660	6.746±0.471	6.786±0.577	.917

*denotes statistically significant difference, $p \leq .05$.

Post hoc tests using the Bonferroni correction showed that RT was significantly lower when the kick plate distance was one shin's length versus < shin length (0.173±0.034 vs 0.194±0.061 sec) and > shin length (0.173±0.034 vs 0.195±0.047 sec). See Figure 2. RT was not significantly different between < shin length and > shin length.

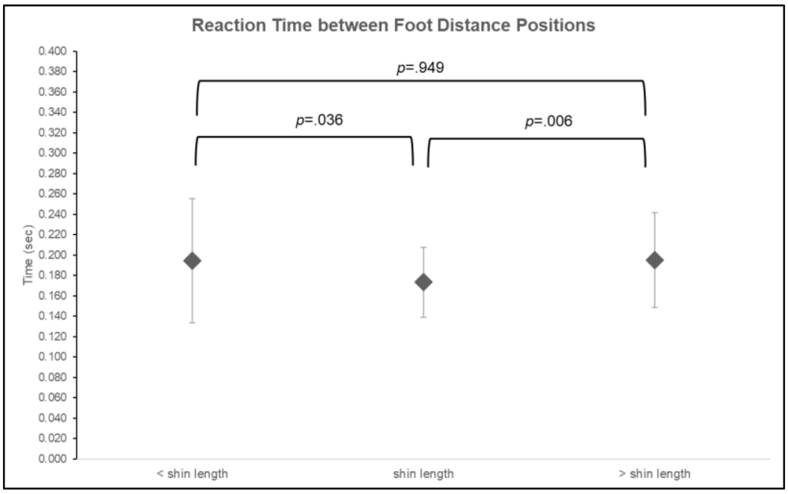


Figure 2: RT Differences between Kick Plate Positions.

The purpose of this study was to investigate how components of the start in swimming were affected by manipulating kick plate position based upon swimmers' shin length. The three groups were composed of one shin's length, one notch < and lastly, one notch >. Furthermore, the main goal was to find which setting got the athlete to the 15 m mark the fastest. A swimmer's intentions are to react rapidly to the starting signal, leave the blocks in a fast motion generating as much horizontal velocity as possible, gain maximal flight distance while using an optimal projection angle on entry, and maintain a streamline position that will minimize the loss of horizontal velocity associated with drag on water entry (Pearson et al., 1998). Results showed that there was a significant difference in RT favoring BT. RT was better at shin length possibly because this distance optimized the length of the muscles enabling them to react quicker to the start signal. RT is crucial in sprint events as long as there is enough BT to generate high impulse. Taking into account the importance of spending the least amount of time possible on the block and spending enough time to be able to generate the maximum force in order to have a high horizontal velocity (Benjanuvatra et al., 2007; Vantorre et al., 2010).

Other important trends in our results were that 8 out of 15 athletes had faster BT at one shin's length and 9 out of 15 were also faster at the 15 m mark at shin length. Shin length may be an adequate guide for positioning the kick plate; it may provide the swimmer optimal use of the length-tension relationship of the lower limb muscles. This study is not without limitations given the use of only 120Hz cameras and low technology analysis software. However, within subjects differences still hold importance, and mean values of the dependent variables were in agreement with previous studies cited in this paper.

CONCLUSION: Results of this study provided specific findings to elite swimmers with regard to the track start. RT significantly decreased for the group when the kick plate was placed at a distance of one shin's length from the front foot. Coaches and swimmers may want to use one shin length as a measurement for where to place the kick plate to optimize the start. However, they should monitor the effects of reducing RT on BT so swimmers may take advantage of the force generated off the block, horizontal velocity and angle of entry. Further research on the positioning of the kick plate and the effects on start performance is needed.

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