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Kick Plate Position and Track Start Biomechanics in Elite Swimmers

Original Research

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Abstract

Introduction: 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 positioning based on shin length. **Methods:** 15 elite swimmers participated in the study. Shin length was measured between the tibia's lateral condyle and lateral malleolus. Participants were filmed with two 120Hz cameras while performing three starts at three kick plate positions (< shin length, shin length, and > shin length). We determined reaction time, block phase time, flight phase time, flight distance, underwater phase time, and time to the 15-m mark via Dartfish software. Data were reduced using repeated measures analysis of variance, $p<.05$ **Results:** Only reaction time (RT) was significantly different between the three kick plate positions ($F(2,28)=4.713$, $p=.017$). Post-hoc analysis showed RT was lower when 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), $p<.05$. Finally, 9/15 (60%) participants produced faster 15-m times with the kick plate at shin' length. **Conclusion:** Coaches and athletes may consider using shin length as a guide for positioning the kick plate to enhance performance.

Key Words: swimming, reaction time, swim start.

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Introduction

Successful execution of the swimming start impacts the overall race performance by as much as 26.1%.[1] 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.[2] The swimming start is defined as the time from the starting signal to when the center of the swimmer's head reaches the 15-m mark.[1] There are three sub-phases.[3] 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 0.76+0.05 sec.[4] A reduction in Block phase time has been shown to reduce time to 15-m.[5] However, some studies have suggested a trade-off between Block phase time and the horizontal velocity due to potentially smaller impulse production.[6,7] 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.[8] 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.[9] Pereira et al.[10] suggested that time between water entry and the 15-m 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. The toes of the forward foot curl around the front of the starting block and the rear foot is positioned at the back of the block. The Fédération Internationale de Natation (FINA), swimming's international governing requires that starting blocks be constructed with a 0- to 10-degree slope and a height between 0.5 and 0.75 meters above the water.[11] In 2009 FINA approved the Omega

OSB11 starting block for use in international competitions. This block has an inclined rear footrest (termed, kickplate) that can be moved forward and backward at set positions on the starting block. Swimmers are often coached to place the kick plate closer to the front of the platform in shorter sprints versus longer sprints. The fore-aft distance between the kick plate and the swimmer's front foot has been minimally investigated,[12,] and is largely decided upon via a swimmer's comfort or what "feels natural." Using a constructed back plate to mimic the OSB11, Takeda and colleagues[12] demonstrated that BT and 5-m times were significantly longer with a close position (0.29 m from front of the block) than those at 0.44-m or 0.59-m; horizontal take-off velocity at 0.29-m was significantly slower than that of 0.44-m. However, they did not consider individual the swimmers' physical characteristics in selecting the plate positions. Slawson and colleagues[13] studied back knee angle position and force production by manipulating kick plate position. They reported that horizontal force production was greatest when the swimmer's back knee was flexed to 100-110 degrees, and vertical force greatest at 90 degrees. In practice, coaches suggest a 90 degree angle for the back knee. The kick plate position must be close enough to keep reaction time low but far back enough to facilitate force production. Thus, taller swimmers typically position the kick plate farther back on the block to achieve the desired knee flexion. Having an individualized, anatomical criteria such shin length, may make kick positioning more objective 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.

Methods

Participants

Fifteen elite, adult swimmers (males, 10; females, 5; age, 21.3 + 1.7 years; 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 whereby shin length was determined with a cloth 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.

Protocol

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 one was positioned perpendicular to the block at a 5-m distance. Camera two was positioned on the pool deck perpendicular and midway to the subject's lane so that all phases of the start were in view. One meter was marked in the view of Camera two for spatial reference. Participants completed a dynamic warm-up consisting 200-500 m swim and whole body stretching. Then, participants performed three track starts at each of the following conditions: (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. Notches are indentations at each side of the block base that allow movement of the kick plate forward and backward. Each block is composed of 5 notches, and each notch is 4 cm apart. More specifically, for the "at shin length" trials, the back, vertical portion of the kick plate was positioned at the notch closest to one shin length from the participant's heel (Figure 1). The plate was moved forward one notch for < shin length, and back one notch for > shin length. Placement of the rear foot on the kick plate was not dictated by the researchers but was kept constant per swimmer for each trial and condition. Starts were signaled using a Championship Start System (Colorado Time Systems, Loveland, CO, USA) that provided the auditory and visual (light) signals. Swimmers received no other instructions other than to perform their starts with maximal effort, and they were unaware of how kick plate position corresponded to shin length when they stepped onto to the block. To aid the researchers in selecting which trial per condition to analyze, after each condition, participants were asked to select the one that they perceived they reached maximal effort.[12] This method of trial selection was valued over the researchers randomly choosing a trial to analyze. Video were downloaded to a laboratory computer and analyzed frame-by-frame with Dartfish (ver. 8.0; Dartfish USA, Inc., Alpharetta, GA, USA). The dependent variables (DV) were defined according to Vantorre and colleagues[9] and are described as follows:

Reaction time (RT) - 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.

Block time (BT) - time (sec) from the frame in which the signal (light) was detected to the frame when the swimmer's toes left the block.

Flight time (FT) - time (sec) from the frame corresponding to when the toes left the block to the frame when the head entered the water.

Flight distance (FD) - horizontal distance (m) between the end of the block to the point where the fingers entered the water.

Time to 15 m (TT15m) - time (sec) from the frame where the start signal (light) was detected to the frame corresponding to when the swimmer's fingertips reached the 15 m mark.

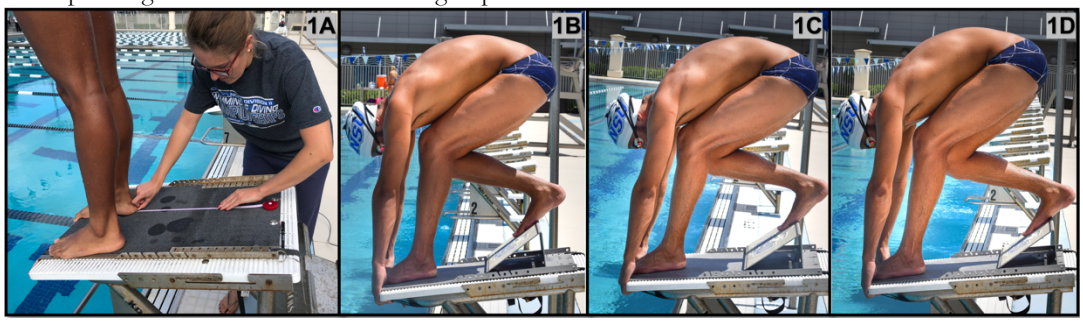

Figure 1. Using Pre-measured Shin Length to Determine Kick Plate Positions. (A) Measuring the linear distance corresponding to one shin length from the heel of the front foot. (B) Start with the kick plate positioned < shin length. (C) Start with the kick plate positioned one shin length. (D) Start with the kick plate positioned > one shin length.

Statistical Analysis

Data were 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 three kick plate positions, $p<.05$.

Results

Table 1 shows the means and standard deviations for the DVs 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).

	< 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

Data are Means ± SD

*Significantly smaller RT at shin length, $p\leq.05$.

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 and versus > shin length. See Figure 2. RT was not significantly different between < shin length and > shin length.

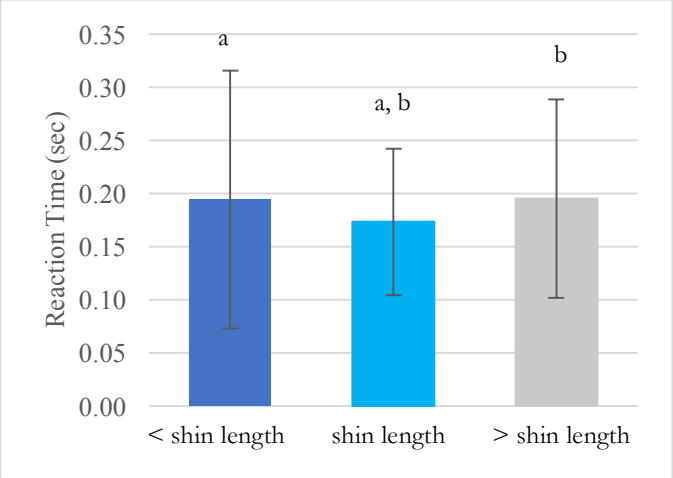

Figure 2. RT Mean ±SD by Kick Plate Position.
[a]Significant difference between shin length and < shin length, p=0.036.
[b]Significant difference between shin length and> shin length, p=0.006.

Discussion

We investigated the use of an individualized anatomical measure, shin length as a method to guide kick plate position during the track start in elite swimmers. Results showed placing the kick plate at a distance of one shin length from the front foot significantly decreased RT over positions smaller and larger than one shin length. Eight of 15 athletes had faster BT at one shin's length and nine out of 15 were also faster at the 15-m mark at shin length. 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.[14] The position of the kick plate dictates the anterior-posterior distance between the front and back foot, and it is largely determined by individual swimmer comfort. A less arbitrary, but still individualized method may illuminate the best position for the kick plate. Results showed there was a significant difference in RT favoring BT. Results were surprising since RT is not expected to improve over time.[15] Appropriate RT is crucial in sprint events provided there is adequate BT to generate high impulse. There is a mechanical balance between spending the least amount of time on the block and having enough time to generate the maximum force necessary to produce high horizontal velocity.[7,16] BT was not statistically different between kick plate positions. However, the p-value of 0.055 demonstrates further investigation. 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. Interestingly, when participants were asked which set of trials (first, second or third) felt the most comfortable, 11 out of 15 selected the set corresponding to the starts completed at one shin length. The interplay of comfort and optimal biomechanics warrants further study. This investigation is not without limitations. The uses of 120Hz cameras (versus high speed) and low technology analysis software may have affected the results. However, within subject differences still hold importance, and mean values of the dependent variables were in agreement with previous studies utilizing elite swimmers cited in this paper. The reported comfort of the majority of the participants at one shin length may have also influenced the positive results at this position. Finally, forces under the feet were unable to be measured limiting a complete biomechanical analysis of the kick plate positions.

In summary, RT significantly decreased for the group, and nine of 15 swimmers were faster to the 15 m mark 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.

Media-Friendly Summary

Hundredths of a second often differentiate between winning and losing short distance swimming races. The start is a crucial part of a swimmer's success, especially in the shorter distance races. The position of

the kick plate on the block is largely determined from a swimmer's comfort. A more objective but still individualized method of determining its position may impact start performance. Results of this study showed positioning the kick plate at a distance of one shin's length (versus longer or shorter than one shin's length) may optimize track start biomechanics, specifically reaction and block time.

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