USING SHIN LENGTH TO DETERMINE KICK PLATE POSITION OPTIMIZES SELECT SWIM START MECHANICS IN ELITE SWIMMERS

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The track start kick plate position is often decided by the level of comfort of the swimmer. The purpose of this study was to use shin length as a measure to determine kick plate position and effects on performance. 20 elite swimmers performed 3 starts at 3 kick plate distances (< shin length, shin length, and > shin length). Differences in reaction time, block phase time (BT), flight phase time, flight distance, underwater phase time, time to the 15 m mark, knee flexion and ankle dorsiflexion angles were examined between the positions. BT was significantly different, ($F(2,38)=4.264$, $p=.026$). BT was lower when the kick plate distance was one shin's length versus < shin length (0.691±0.055 vs 0.715±0.056 sec) and > shin length (0.691+0.055 vs 0.698±0.056 sec), $p<.05$. Shin length is a quick and individualized measure that can be used by coaches to set the kick plate position without compromising performance.

KEYWORDS: swimming, block time, swim start

INTRODUCTION: After the 2008 Beijing Olympics, the Fédération Internationale de Natation (FINA) approved the use of a new starting block with a 30^0 inclined kick plate (Omega, OSB11, Corgémont, Switzerland). Use has resulted in improvements of 0.14 seconds to the 15-meter mark (Ozeki et. al., 2012) and higher horizontal take-off velocities (Honda et. al,. 2010) when compared to the track start. The plate can be set at five locations along the starting platform with the decision as to where to set it relying on swimmer subjective comfort. The three elements of a swimming track start are: reaction time (RT), impulse force, and glide position in the underwater phase (Vantorre, 2010). RT is a component of Block time (BT). Honda and colleagues (2010) suggested that BT and the swimmer's propulsion during the block phase could be affected by the change of the position of the block. Data suggest that knee flexion angle is an essential criterion in the block performance because it is directly related to force production at the starting signal. According to Slawson and colleagues (2012) a rear limb (limb on the kickplate) knee flexion angle of 75-85° was the most efficient angle yielding a shorter BT and higher horizontal take-off velocity. Swimmers in the Slawson et al. (2012) study kept their knee flexion angle consistent although kickplate position was changed. Similar to the Omega official claims that the footrest enables the athlete to push-off with a rear knee angle of 90°, the best starts produced a peak vertical force at a rear knee angle of 80°–90° which is beneficial to starting performance, while knee angle of 100°–110° for the best starts to produce peak horizontal force (Slawson, Chakravorti, Conway, Cossor, & West, 2012). Limited studies exist on the impact of manipulating the position of the kickplate (Cicenia, Oster, & Mokha, 2019; Slawson, Chakravorti, Conway, Cosser, & West, 2012). Kick plate positioning may improve swimmers' performance. If coaches have a simple and objective method of determining kickplate position, they can reduce trial and error. Using shin length as an individualized, anatomical criteria may assist coaches in this endeavor. 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), time to the 15 m mark (TT15 m), and knee and flexion angles between three kick plate positions based upon shin length.

METHODS: Twenty elite, adult swimmers (males, 12; females, 8; age, 20.8 ± 1.9 yrs; height, 1.76 ± 0.08 m; mass, 74.1 ± 10.7 kg) participated in the study. Elite club or university sprinters

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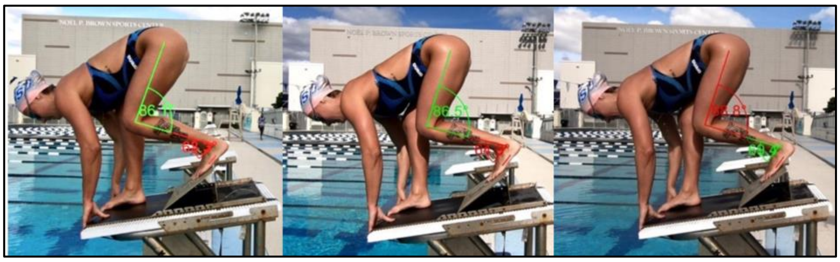
(25-100 m) having competed at a national level or higher volunteered for this study. Height, mass and shin length were measured in a laboratory. Shin length was determined with a tape measure (cm) as the distance between the lateral tibial condyle and the lateral malleolus. This was used to position the kickplate on the starting block at an outdoor competitive 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 and angles of the start were viewed. After a dynamic warm-up (200-500 m swim), participants executed 3 tracks starts in random order at each of the following kickplate positions: (a) one shin length distance from the front foot to the back of the kickplate, (b) distance of one notch greater than shin length (> shin length), and (c) distance of one notch less than shin length (< shin length) (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 asked to keep foot position at the back of the plate constant between trials. Starts were signaled with a Championship Start System (Colorado Time Systems, Loveland, CO, USA). Subjective feedback was provided by the participants by selecting one trial per position that they perceived as best. The best trials were analyzed using Dartfish (ver. 8.0; Dartfish USA, Inc., Alpharetta, GA, USA). Variables were defined as: (a) 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, (b) Block time (BT): 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): 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):horizontal distance between the end of the block to the point where the fingers entered the water (m), (e) Underwater phase time (UWT):time (sec) from the frame when the head entered the water to the frame when the first body part surfaced, (f) Time to the 15 m mark (TT15): time (sec) from the frame where the start signal light was detected to the frame where the hands reached the 15 m mark, (g) Knee flexion was the joint angle (deg) using the thigh and lower leg segments of the left knee placed on the kick plate one frame before the starting signal (light), and (h) Ankle dorsiflexion was the joint angle (deg) using the lower leg and foot segments of the left ankle placed on the kick plate one frame before the starting signal (light) (Figure 2a). Statistics Package for Social Sciences (ver. 25; IBM Corporation, New York, NY, USA) was used to analyze the data transferred to an Excel file. 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.



Figures 2. Knee flexion and ankle dorsiflexion between three kick plate positions

RESULTS: 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=20. The only statistically significant difference found was for BT ($F(2,38)=4.264$, $p=.026$).

Table 1. Start Performance Variables between Three Kick Plate Positions (N=20).

Variable	< Shin length	Shin length	> Shin length	*p* value
Reaction Time (sec)	0.188±0.058	0.176±0.032	0.188±0.046	0.268
Block Time (sec)	0.715±0.056	0.691±0.055	0.698±0.056	0.026*
Flight Time (sec)	0.337±0.167	0.302±0.073	0.302±0.068	0.314
Underwater Time (sec)	3.821±1.138	3.727±1.032	3.709±0.950	0.561
Flight Distance (m)	2.56±0.38	2.57±0.46	2.56±0.41	0.812
Time to 15 m (sec)	6.650±0.683	6.590±0.603	6.645±0.606	0.614

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

There are no significant differences in knee flexion and ankle dorsiflexion angles. See table 2.

Table 2. Rear Knee and Ankle Position Between Three Kick Plate Positions (N=13).

Variable	< Shin length	Shin length	> Shin length	*p* value
Knee flexion(deg)	80.37±8.23	79.55±7.70	81.27±9.88	0.490
Ankle dorsiflexion(deg)	74.72±6.59	75.28±7.45	75.02±7.50	0.769

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

Post hoc tests using the Bonferroni correction showed that BT was significantly lower when the kick plate distance was one shin's length versus > shin length (0.691±0.055 vs 0.698±0.056 sec) and < shin length (0.691±0.055 vs 0.715±0.056 sec), See Figure 2. BT was not significantly different between one shin length and > shin length. Other start performance variables including reaction time and time to the 15 meters were faster at one shin length. 10 out of 20 athletes had faster RT at one shin's length, 11 out of 20 had a faster block time at one shin's length, and 13 out of 20 were also faster to the 15 m mark at one shin length.

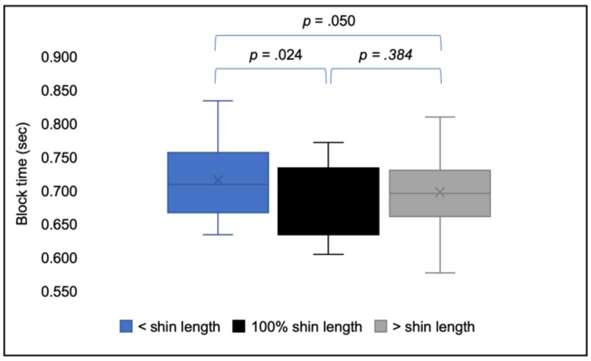


Figure 3: BT Differences between Kick Plate Positions.

DISCUSSION: The purpose of this study was to use a swimmer's shin length as an anatomical measure to position the kick plate behind the front foot on the starting block and determine effects on start performance. and perhaps improve performance. Ultimately, the kick plate position that allows the swimmer to reach the 15 meters the fastest may be the best. Results showed that BT was optimized at shin length. This position may have optimized muscle length enabling them to react quicker to the start signal. Cicenia et al. (2019) found similar results at one shin's length for RT. BT is crucial to generate high impulse but always maintaining an equilibrium 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). Interestingly, the one shin length trials showed 10/20 participants had faster RT at one shin's length, 11/20 had faster BT at one shin's length, and 13/20 had faster TT15 m. Thus, 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. Moreover, Slawson and collegues (2012) found that swimmers adjusted their body position to accommodate the movement to the different back plate stances obtaining the same knee angle values. 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 are applicable to swimmers and swim coaches seeking more objective means to determine kick plate position and enhance the start. BT was significantly faster for the group when the kick plate was placed one shin's length from the front foot. The change in kick plate position did not impact the knee flexion nor ankle dorsiflexion and this may lead us to believe that the leg tension was mainly involved at the hip. Coaches and swimmers may want to use one shin length as a measurement for where to place the kick plate to optimize the start.

REFERENCES:

Benjanuvatra, N., Edmunds, K., & Blanksby, B. (2007). *Jumping abilities and swimming grab-start performances in elite and recreational swimmers*. *International Journal of Aquatic Research and Education, 1*(3):231-241.

Cicenia, A., Oster, C., Mokha, M., (2019*). Kick Plate Position and Track Start Biomechanics in Elite Swimmers.* Journal of Exercise and Nutrition, 2(2), 1-5.

Honda, K., Sinclair, P., Mason, B., & Pease, D. (2010). *A Biomechanical Comparison of Elite Swimmers Start Performance Using the Traditional Track Start and the New Kick Start*. In P. Kjendlie, R.K. Stallman & J. Cabri (Eds.), XIth International Symposium Biomechanics and Medicine in Swimming (pp. 94-96).

Ozeki, K., Sakurai, S., Taguchi, M., & Takise, S. (2012). *Kicking the back plate of the starting block improves start phase performance in competitive swimming.* In E. J. Bradshaw, A. Burnett & P. A.Hume (Eds.), 30th Annual Conference of the International Society of Biomechanics in Sports (pp. 373-376).

Slawson, S. E., Chakravorti, N., Conway, P. P., Cossor, J., & West, A. A. (2012). *The effect of knee angle on force production, in swimming starts, using the OSB11 Block.* Procedia Engineering, 34(2), 801–806.

Vantorre, J., Seifert, L., Fernandes, R., Vilas-Boas J., Chollet, D. (2010). *Biomechanical Influence of start technique preference for elite track starters in front crawl*. The Open Sports Sciences Journal, 3,137-139.