EFFECT OF BLOCK DESIGN ON ROTATIONAL CHARACTERISTICS OF A SWIM START

Scott P. McLean, Sam I. Anderson, Riley A. Barlage, Carl P. Shaulis

Southwestern University, Georgetown, TX, USA

The purpose of this study was to examine the effect of start block design on the rotational characteristics of a swim start. Seven male and seven female university-level competitive swimmers (21.1±2.1 yrs, 1.79±0.08 m, 75.6±11.8 kg) completed three maximal effort swim starts under each of four conditions, flat block with no kick plate, flat block with a kick plate, inclined block with no kick plate and inclined block with a kick plate. Temporal and kinematic variables and angular momentum were determined for each start using a two-dimensional video analysis. Use of an inclined block significantly reduced block time by 4%, reduced time to 5m by 2.2% and reduced vertical velocity at entry by 4.9% compared to a flat block. Use of a kick plate significantly reduced block time by 3.4%, reduced time to 5m by 3.4%, increased horizontal velocity at takeoff by 3.7%, increased horizontal velocity at entry by 2.7% and increased the body orientation angle at takeoff by 2.7% compared to not using a kick plate. Neither block inclination nor use of a kick plate affected airborne whole body angular momentum. These data support using an inclined block platform and kick plate to improve start performance and suggest that experienced swimmers can adapt the rotational characteristics of their start to different conditions.

KEYWORDS: swimming, start, block design, angular momentum.

INTRODUCTION: A “kick start” in swimming is defined as the performance of a track start when using a block with a kick plate. Kick starts provide advantages in reducing block time and generating greater horizontal takeoff velocity and flight distance (De Jesus et al., 2022, Beretic et al., 2012). Vint et al. (2009) and Taladriz et al (2016) found that kick starts generate a more downward takeoff velocity compared to track starts. Takeda et al. (2012) found that positioning the kick plate further from the front of the block generated a more negative vertical takeoff velocity. Such a change in vertical takeoff velocity may indicate that the swimmer is developing more forward rotation due to increased forward angular momentum when using a kick plate. Given that a swim start requires 30-40 degrees of body rotation from takeoff to entry (Holthe & McLean, 2001), generating the appropriate forward angular momentum is necessary to achieve the desired body orientation at entry. The literature pertaining to angular momentum in swim starts is limited to comparisons between start techniques and has not considered the effect of block design. Vantorre et al. (2010) found that pike starts, which generate a more vertical body position at entry, generated more angular momentum than grab starts. McLean et al. (2000) demonstrated that whole body angular momentum at takeoff was related to the orientation of the body at entry. Contrary to their expectations, Taladriz et al. found no difference between whole body angular momentum between grab starts and kick starts. Because use of a kick plate places greater emphasis on the rear leg in the start, greater forward angular momentum may be generated in the start if hip extension is increased when using the kick plate. The purpose of this study was to examine how block design affects rotational characteristics of a swim start.

METHODS: Seven male and seven female university-level swimmers (21.1±2.1yrs, 1.79±0.08m, 75.6±11.8kg) experienced in performing kick starts provided informed consent prior to participation. Participants completed a 10-minute self-determined warm-up prior to data collection. Participants completed three maximal effort track starts under each of four conditions, flat block with no kick plate, flat block with a kick plate, inclined block with no kick plate and inclined block with a kick plate (12 starts total) in an order counterbalanced between participants with a minimum of 1 minute rest between starts. Participants were permitted to use a self-selected kick plate position with the stipulation that the same position

be used for all four start conditions. Participants were instructed to glide with no kick after water entry to control for the influence of propulsive kicking movements.
Two KDI Paragon (Cary, NC) Track Start Plus starting blocks with an adjustable kick plate were used in this study. One block was custom-made with a starting platform that was not inclined. Blocks were positioned in adjacent lanes. Markers, visible underwater, were placed on the pool bottom in the center of each lane at locations 5m and 7.5m from the wall. Two synchronized cameras (50 Hz) whose optical axes were perpendicular to the sagittal plane of the participant recorded above and below water movements during each start. The above water camera was calibrated using a projective scaling technique with a calibration object (1.7m x 3.2m) whose plane was positioned in the center of each lane with the origin of the object located at water level at the pool wall. The underwater camera was positioned such that the 5m and 7.5 m markers were in the center of the image. A starting system was positioned in the field of view of the above water camera. Time to 5m (T5) and 7.5m (T75) were determined as the difference between the time the starting light first became visible and the instant the tip of the hands passed the 5m and 7.5m underwater markers, respectively. Block time (BT) was measured as the time from start light to the instant of takeoff.
Twenty-one points were digitized to define a 14-segment body model. Analysis of each trial began ten video frames prior to the visible start signal and ended at the last video frame prior to the swimmer contacting water. Coordinate data were smoothed using a 4^{th}-order recursive Butterworth digital filter. Cutoff frequencies, individually determined for each coordinate ranged from 2 to 9Hz. Whole body and segmental centers of mass (CM) were determined using body segment parameters defined by Clauser et al. (1969) and adjusted by Hinrichs (1990). Segmental moments of inertia about a medial-lateral (ML) axis passing through the respective segmental centers of mass were computed from the mean data of Whitsett (1963) and corrected for height and body mass differences according to the method of Dapena (1978). These data were further adjusted for out of plane movement using the method reported by Hay et al. (1977). Whole body angular momentum (H) was calculated by summing the local and remote angular momentum terms of each body segment as described by Hay et al. (1977).
Horizontal (VX) and vertical (VY) velocity of the whole body CM was determined at takeoff and entry. Takeoff and entry body orientation (θ) were defined as the angle of the trunk segment relative to the horizontal. Rotational characteristics of a start were described using the average airborne whole body angular momentum about a ML axis through the whole body CM ($H_{AIRBORNE}$). 2X2 repeated measures ANOVA was used to examine the effect block inclination (flat or inclined) and use of a kick plate (with or without a kick plate) on start performance. Significance was evaluated at α=0.05. Partial eta-squared (η^2) was used to assess the effect size of mean comparisons.

RESULTS: Two-way interactions between block and plate were not significant (p>0.05) for comparisons of T5, T7.5 and BT. Use of an inclined block significantly reduced T5 by 2.2% ($F_{1,13}$=82.8, p<0.001, η^2=0.86) (Table 1). Use of a kick plate significantly reduced T5 by 3.4% ($F_{1,13}$=38.7, p<0.001, η^2=0.75). No significant main effects for block or kick plate were observed for T7.5 (p>0.05). Use of an inclined block significantly reduced BT by 4% ($F_{1,13}$=47.3, p<0.001, η^2=0.78). Use of kick plate significantly reduced BT by 3.4% ($F_{1,13}$=11.8, p=0.004, η^2=0.48).

Table 1. Temporal comparison of start performance between block conditions (mean (SD)).

	FLAT BLOCK		INCLINED BLOCK	
	NO KICK PLATE	KICK PLATE	NO KICK PLATE	KICK PLATE
T5 (s)	1.62 (0.15)	1.57 (0.15)	1.59 (0.16)	1.53 (0.15)
T7.5 (s)	2.75 (0.38)	2.64 (0.39)	2.71 (0.43)	2.63 (0.37)
BT (s)	0.79 (0.07)	0.77 (0.07)	0.76 (0.07)	0.74 (0.07)

Two-way interactions between block and plate were not significant (p>0.05) for comparisons of takeoff and entry velocities. Use of an inclined block did not significantly alter $VX_{TAKEOFF}$ (p>0.05) (Table 2). However, use of kick plate significantly increased $VX_{TAKEOFF}$ by 3.7%

($F_{1,13}$=16.0, p=0.002, η^2=0.55). No significant main effects for block or kick plate were observed for $VY_{TAKEOFF}$ (p>0.05). Use of an inclined block did not significantly alter VX_{ENTRY} (p>0.05). However, use of the kick plate significantly increased VX_{ENTRY} by 2.7% ($F_{1,13}$=5.0, p=0.04, η^2=0.28). Use of an inclined block significantly reduced VY_{ENTRY} by 4.9% ($F_{1,13}$=5.4, p=0.04, η^2=0.29). Use of kick plate did not significantly alter VY_{ENTRY} (p>0.05).

Table 2. Kinematic comparison of start performance between block conditions (mean (SD)).

	FLAT BLOCK		INCLINED BLOCK	
	NO KICK PLATE	KICK PLATE	NO KICK PLATE	KICK PLATE
$VX_{TAKEOFF}$ (m/s)	4.04 (0.52)	4.11 (0.42)	3.95 (0.49)	4.18 (0.41)
$VY_{TAKEOFF}$ (m/s)	-0.59 (0.43)	-0.60 (0.34)	-0.56 (0.40)	-0.65 (0.37)
VX_{ENTRY} (m/s)	4.00 (0.57)	4.03 (0.43)	3.92 (0.49)	4.11 (0.41)
VY_{ENTRY} (m/s)	-3.69 (0.52)	-3.63 (0.32)	-3.45 (0.29)	-3.52 (0.19)

Two-way interactions between block and plate were not significant for comparisons of $H_{AIRBORNE}$, $\theta_{TAKEOFF}$, and θ_{ENTRY}. Neither use of an inclined block nor a kick plate significantly changed $H_{AIRBORNE}$ (p>0.05) or θ_{ENTRY} (p>0.05) (Table 3). Altering the inclination of the block did not affect $\theta_{TAKEOFF}$ (p>0.05). However, use of the kick plate significantly but modestly increased $\theta_{TAKEOFF}$ by 2.7% or 0.1 degrees ($F_{1,13}$=5.0, p=0.04, η^2=0.28).

Table 3. Rotational characteristic comparison of start performance between block conditions (mean (SD)).

	FLAT BLOCK		INCLINED BLOCK	
	NO KICK PLATE	KICK PLATE	NO KICK PLATE	KICK PLATE
$H_{AIRBORNE}$ (kg·m^2/s)	-29.9 (11.1)	-27.7 (8.1)	-26.6 (9.0)	-26.8 (8.2)
$\theta_{TAKEOFF}$ (degrees)	4.0 (0.6)	4.0 (0.4)	3.9 (0.5)	4.1 (0.4)
θ_{ENTRY} (degrees)	-28.8 (5.0)	-28.2 (5.2)	-28.5 (5.6)	-27.6 (5.1)

DISCUSSION: The statistical design employed for this study permitted independent consideration of the effect of block inclination and use of a kick plate on start performance. Inclining the block platform reduced block time and time to 5m. Furthermore, the use of a kick plate also reduced block time and time to 5m. Comparing the use of both block inclination and kick plate to the use of neither (i.e., flat block with no kick plate), block time was reduced by 0.05s and time to 5m was reduced by 0.09 s. These results compare favorably with de Jesus et al. (2022) and Beretic et al. (2012) and suggest that both features positively influence start performance. However, these differences were not maintained to the 7.5m mark suggesting that alterations in the swimmer's path between 5m and 7.5 m should be considered in future work. This would align well with Tor et al.'s (2015) suggestion that in addition to generating maximal horizontal takeoff velocity it is important to also identify the ideal underwater trajectory for the start.

Takeoff velocity was not affected by block inclination. Takeda et al. (2012), found that positioning the kick plate further from the front of the block increased horizontal takeoff velocity, but that use of a kick plate provided little benefit over not using a kick plate. Conversely, the present study found a significant increase in horizontal takeoff velocity when using the kick plate compared to not using the kick plate similar to de Jesus et al. (2022). Considering Tor et al.'s (2015) conclusion that horizontal takeoff velocity is one of two critical determinants of start performance, our data emphasize the importance of the use of the kick plate for improving start performance.

Rotational characteristics of the start have not been studied extensively. No literature exists to evaluate what effect block design has on the rotational characteristics of the start. A kick start is effectively a track start performed using an inclined kick plate. In addition to providing a more favorable orientation of the surface against which the rear leg can push during the start, this plate may facilitate enhanced hip extension during the start. Such a movement must be managed by the swimmer to maintain overall rotational characteristics of the start or risk generating more forward angular momentum which could cause the swimmer to rotate downwards more. The current study, with an independent examination of block inclination and kick plate use on rotational aspects of the start, found neither design element affected the angular momentum generated during the block phase of the start. Similar to Taldriz et al. (2016), it appears that experienced swimmers are adept at managing the generation of the angular momentum during the start such that they are able to produce similar amounts under different conditions or with different techniques. This is also reflected in the relatively stable body orientations at takeoff and entry observed in the current study.

CONCLUSION: These data support using an inclined block platform and kick plate improve start performance. Concerns for producing exaggerated forward rotation which might produce a steeper entry angle are not supported by these data. Furthermore, the remarkable similarity in whole body angular momentum between conditions suggests that these swimmers were able to adapt to the block conditions with ease. This may suggest that start performance will transfer well between block designs. However, to better evaluate the effect of block design on start performance, underwater trajectory should be considered. The lack of extensive analysis of the underwater phase of the start prevents the complete explanation of why benefits provided by the kick plate were not maintained through the 7.5 m mark.

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ACKNOWLEDGEMENTS: This work was supported by KDI-Paragon.