EFFECTS OF HANDLE AND BLOCK CONFIGURATION ON SWIM START PERFORMANCE

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The purpose of this study was to quantify differences in swimming track start performances using side handle and front handle grip techniques and using an inclined platform at the rear of the starting platform. An instrumented starting block system was designed to allow front grip and side grip starting techniques and inclusion of a rear incline. Thirty male and 20 female junior elite swimmers completed three starts in each of four start block configurations: (1) Flat (traditional) block, front handle grip; (2) Flat (traditional) block, side handle grip; (3) Incline (new) block, front handle grip; (4) Incline (new) block, side handle grip. Force and video data were used to quantify parameters related to starting performance. Results indicated that use of side handles had a substantial impact on start performance while the effects of the rear incline were less pronounced. Compared to using a front grip technique, use of the side handles increased horizontal velocity at takeoff up to 18%, resulted in a more horizontal takeoff angle by up to 2°, increased contribution to horizontal impulse from arms up to 12%, increased peak horizontal power up to 28%, decreased time to 6 m by 4% and increased velocity at 6 m by 2.5%. These advantages were achieved at a cost of an 8% increase in propulsion time. Based on this study, we recommend swimmers develop familiarity with the use of side handles when performing a track start and to use this technique if handles are available on a starting block.

KEY WORDS: swimming, track start, incline, side handle, FINA

INTRODUCTION: LaRue (1985) suggested that using a track start in swimming would allow a swimmer to generate a greater horizontal impulse than the grab start thus increasing horizontal takeoff velocity. However, numerous comparisons between the grab and track start techniques used in competitive swimming have yielded equivocal kinematic and kinetic results suggesting that neither of these techniques is superior (Welcher et al., 2008; Breed et al., 2000; Blanksby et al., 2002; Holthe and McLean, 2001; Miller et al., 2002; Kruger et al., 2002; Vilas-Boras et al., 2002). Despite these findings, a preference among elite swimmers for the track start has emerged. During the 2008 Beijing Olympic Games, 77% of the swimmers in 15 of 22 finals heats chose to use a track start over the grab start including all eight of the men's 50m freestyle finalists.

Start technique preference and limited practice with unfamiliar techniques may compromise start performance (Blanksby et al., 2002) such that it may be difficult to identify a particular start as superior. Additionally, LaRue (1985) concluded that one weakness in the track start was the lack of a vertical support for the rear foot against which the swimmer could push to maximize the horizontal impulse. Recent changes in rules governing the design of starting blocks (FINA rule FR 2.7, 2005) now permit the addition of an inclined platform to the rear of a starting block and the addition of handles to the block which may lead to improved start performance. The purpose of this study was to evaluate the effect of using an inclined platform and side handles on the performance of a competitive track start. It was hypothesized that these changes will (1) increase horizontal velocity of the CM at takeoff; (2) improve the trajectory of the CM during the flight phase; (3) increase the contribution of the arms; (4) decrease time to 6 m; 5) increase horizontal velocity at 6 m.

METHODS: Thirty male and 20 female swimmers participating in the 2007 USA Swimming junior elite and national select camps completed a minimum of three maximum effort starts in each of the following four start block configurations: (1) Flat block, front handle grip; (2) Flat block, side handle grip; (3) Incline block, front handle grip; (4) Incline block, side handle grip.
A custom-built, instrumented start block system was designed using two AMTI force plates (model OR6-5-1) and two Kistler 3D force transducers (model 9347C) attached to handles which were configurable to allow front grip and side grip start techniques. A rear incline platform of 36° could be bolted to the top of the block such that the distance from the front of plate to the back of the rear incline was approximately 55.5 cm.
Athletes were allowed adequate practice to become familiar with each start block configuration, but received no specific training on any technique or configuration. None of the athletes had any prior experience with the rear incline and only two had prior experience using the side handle grips. Start order was counterbalanced across testing groups. Athletes were instructed to perform maximum effort starts upon hearing an audible “start” tone and, once in the water, to glide as far as possible without stroking or kicking.
During each start performance, force data were sampled at 600 Hz for 3 seconds while sagittal plane underwater video data were collected on the underwater glide phase. Video data were digitized at 60 Hz using Peak Motus and calibrated using a 70-point control object and a multistage, two-dimensional DLT reconstruction algorithm. Video and force data were synchronized by a common signal which actuated the data collection program (via digital trigger), below water LED (visible to the underwater camcorder), and the audible “start” tone heard by the athletes.
Since the start blocks were oriented at a 10° incline, force data from each plate were rotated back to a true horizontal-vertical reference frame. Body mass (kg) was calculated using force data collected during a quiet standing period prior to each start performance. Propulsion time (s) was defined from the first appreciable change in the net horizontal force until the instant of takeoff. Horizontal and vertical impulses (N·s) acting on the body during the start were calculated by numerical integration of the respective net forces over the propulsion time. Horizontal and vertical velocities (m/s) of the CM at takeoff were calculated by dividing the respective impulses by body mass. Takeoff angle (deg) was defined as the orientation of the resultant velocity vector at the instant of takeoff. Peak horizontal power (W/kg) was defined as the maximum value of the instantaneous product of net horizontal force and horizontal CM velocity during the propulsion phase and was normalized by body mass.
Based on procedures described by Welcher et al. (2008), total time and horizontal velocity at 6 meters were extracted from the underwater video data. Time to 6 m was defined as the time from the synchronization pulse until the athlete’s greater trochanter passed the 6-m mark. To find this time, the digitized and 2D DLT scaled horizontal position data for this landmark were fit with a 2nd order polynomial and solved for the roots when y (position) = 6.0. This time was subsequently used to find the horizontal velocity at 6 m by differentiation of the same polynomial.

Two-way repeated measures ANOVAs were used to detect statistical differences ($p<.05$) in a set of key swim start performance variables as a function of grip type (front or side handle) and block configuration (“flat” or incline).

RESULTS: Compared to the more traditional track start configuration (flat block, front grip technique), use of the side handles had a significant and substantial effect on several important start performance variables (Table 1). Specifically, use of the side handles increased horizontal velocity at takeoff 16-18%, resulted in a more horizontal takeoff angle, increased contribution to horizontal impulse from arms 10-12%, increased peak horizontal power 18-28%, decreased time to 6 m by 4% and increased velocity at 6 m by 2.5%. These advantages were achieved at a cost of an 8% increase in propulsion time.
Use of the rear incline also affected start performance but not as dramatically. Using the rear incline increased horizontal velocity at takeoff <2% with a 3% reduction in propulsion time. Takeoff angle was more downward by ~2°. Contribution to horizontal impulse from the arms

was decreased 2.5-5% but peak horizontal power increased 5-11%. Time to 6 m was essentially unchanged when using the incline with side handles but decreased by 2.6% when the inclines were combined with the front grip. Use of the incline resulted in an insignificant increase (~0.5%) in velocity at 6 m.

Table 1. Mean (± SD) kinematic and kinetic measures of swim start performances as a function of hand orientation and block design (n=50).

		Flat (traditional) Block		New (rear incline) Block	
	Sig	Side handles	Front grip	Side handles	Front grip
Propulsion Time (s)	*†	0.67 ± 0.09	0.62 ± 0.06	0.65 ± 0.08	0.62 ± 0.08
Hor. Takeoff Velocity (m/s)	*	4.72 ± 0.52	4.00 ± 0.31	4.73 ± 0.52	4.07 ± 0.28
Takeoff Angle (deg)	*†‡	–0.36 ± 6.35	–4.73 ± 6.73	–2.51 ± 6.30	–5.68 ± 7.31
Hor. Peak Power (W/kg)	*†	38.99 ± 8.11	30.44 ± 5.55	41.18 ± 9.40	33.66 ± 6.14
Hor. Impulse from Arms (%)	* ‡	24.87 ± 11.81	12.04 ± 8.66	19.49 ± 9.73	9.54 ± 7.55
Time to 6 m (s)		2.97 ± 0.36	3.08 ± 0.40	2.99 ± 0.40	3.00 ± 0.33
Hor. Velocity at 6 m (m/s)	* ‡	2.05 ± 0.32	2.00 ± 0.29	2.06 ± 0.33	2.01 ± 0.29

*Side handle significantly different than front handle ($p<.05$). †Incline block significantly different than flat block ($p<.05$). ‡Significant two-way interaction ($p<.05$). All tests: $F(1,48)$.

DISCUSSION: Prior to the 2008 Beijing Olympics, Omega™ debuted a new block design that included a rear incline feature intended to allow swimmers to perform a track start similar to those used in track and field. However, due to concerns raised within the international swimming community (Nicole, retrieved, 23-03-2009) FINA decided to delay the introduction of this block. In addition to the rear foot incline, FINA had previously approved the use of side handles on the block (FINA rule FR 2.7, 2005). The present study sought to document the effect of each of these design features on a track start.

Use of side handles had a more substantial effect than use of the rear incline on takeoff characteristics in a track start. Horizontal takeoff velocity was vastly improved using the side handles likely due to an increased contribution from the arms during the start. This improvement was accompanied by a slightly longer propulsion time but despite this, time to 6 m was still 0.1 s faster ($p=.161$) with a significantly faster horizontal velocity ($p=.018$) at this point. The minimally improved time to 6 m was unexpected given the improved power and takeoff velocity. However, these changes may be attributable to what occurs underwater. The altered flight dynamics frequently had an observable, although unmeasured, impact on the swimmer's entry and the subsequent body position during the glide phase. It is reasonable to assume that with additional practice swimmers would be able to refine that transition to achieve better times and velocities at 6 m. Furthermore, as Welcher et al. (2008) argued, the fact that when using side handles swimmers reached the 6-m mark in the same time but with higher horizontal velocity suggests that the starts incorporating the use of side handles were best.

To better present the effect of these design features, it is useful to consider the trajectory of the center of mass during the flight phase of the start. Given that the flight of the center of mass is governed by the laws of projectile motion, the flight distance may be estimated if the relative height of projection, projection angle and projection velocity are known. Although not measured in the present study, data do exist to suggest that the relative height of projection is approximately 0.7 m for adult male swimmers competing on a national level (McLean et al., 2000). Using the measured values for projection velocity and angle and McLean et al.'s estimate of relative height, it was possible to compare the trajectories of the various start conditions. Based on this analysis, the use of side handles produced 30-40 cm of additional flight distance. Given that this distance was covered with negligible resistance due to travelling in the air, this portion of the race was covered faster than if it had been travelled underwater. Considering Cossor and Mason's (2001) observation that better starters spent less time from entry to 9.5 m, using the side handles with or without an incline would result in the swimmers needing to cover less distance from entry to a pre-determined distance.

CONCLUSION: In light of the minimal instruction and practice provided in the study, the substantial improvement offered by the use of side handles suggests that side handles should be used with a track start whenever they are available. However, the more modest improvements afforded by the use of the rear foot incline suggests that additional work is required to understand the true potential of this design feature in the swimming track start.

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