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The Effect of Knee Angle on Force Production, in Swimming Starts, using the OSB11 Block

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Abstract

Work presented in this paper discusses the effect of knee angle, during the block phase of the start, on overall start performance using the Omega OSB11 block. Omega claims that the footrest enables the athlete to push-off with a rear knee angle of 90°, which is beneficial to starting performance. Published work to date supports the positive effect of starting performance using the footrest, compared to blocks without a footrest, however, reference is not specifically made to the knee angle of the athlete beyond set-up. Ten male, national-level, sprint swimmers were asked to perform maximal start trials using three different footrest configurations. Force and video data were collected for each trial at a rate of 125Hz. Analysis of the data focused on the effect of knee angle at set-up, on horizontal and vertical peak forces. For these data the best starts produced a peak vertical force at a rear knee angle of 80°-90°. More interestingly, this study suggests that, for the best starts, peak horizontal force production occurred with an obtuse knee angle of 100°-110°.

Keywords: Swimming; starts; performance; force; knee angle

1. Introduction

Four components contribute to overall race time in swimming: the start, free swimming, turns and the finish. The start can account for approximately a quarter of the race time in sprint events [1, 2, 3]. The close proximity of podium position finishing times in major competitions, for example in 50m male and female butterfly finals at the 2010 Commonwealth Games in Delhi, the difference between the 1st and 3rd finishing times were 0.09s and 0.05s respectively. In 2008, Omega released a new start block design, the

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OSB11, which featured a slanted, adjustable footrest and an increase in block angle from 5 to 10 degrees [4]. It was claimed, by Omega, that the wedge allowed the swimmer to push-off with a rear knee angle of 90°, which "drastically increases explosiveness" and "showed faster races versus a standard block" [4]. Research by Nomura et al 2010 [5] and Honda et al 2010 [6] supports the claims that the OSB11 provides an advantage with comparison to the standard block. However, neither reported the effect of knee angle on subsequent starting performance. Nomura et al 2010 reported that there was a significant difference in rear knee angle in the set-up position, with the rear knee angle reducing from 97° to 84° degrees with the use of the footrest, but reported no significant difference in the take-off velocity or distance of flight. Contrary to these findings, Honda et al 2010 [6] found starting with the OSB11 produced a significantly higher take-off velocity than the OSB9, 4.48m/s compared to 4.41m/s.

The aim of work presented within this paper is to explore the effect of rear knee angle on starting performance with specific reference to force production. In addition, it was hoped that further contribution to understanding the performance benefits of the OSB11 would be achieved.

2. Methods

Ten male, national-level, sprint swimmers were tested, all of which were familiar with using the OSB11 starting block. Swimmers were asked to perform their start maximally using different footrest positions intended to induce a change in rear knee angle. The footrest can be moved to one of five predefined positions, at 35mm separation, starting at 350mm from the front edge of the block. Swimmers were not given feedback during the session, just encouragement to produce a maximal effort, so that observations of how they naturally adapt to changes in the footrest set-up were not skewed between trials. Each swimmer performed nine starts: three using their preferred footrest position (Condition A), three using the position closer to the front of the block (Condition B) and three using the position further from the front of the block (Condition C). In the case of two of the athletes, where their preferred position was the furthest from the front of the blocks, each athlete performed only six starts: three in the preferred position and three in one position closer to the front. A total of 84 starts we captured during the testing session.

Athletes were marked with indelible ink on key boney landmarks, i.e. the ankle (lateral/medial malleolus), knee (lateral/medial epicondyle) and hip (greater trochanter), to enable ease and repeatability of digitizing the video of the starts. Knee angle defined as the angle between the hip, knee and ankle joints, angle α, Figure 1, was measured for each trial. An instrumented starting block was used to facilitate the measurement of force in 3 dimensions. The instrumented block design used a Kistler 9260AA force plate for the main part of the block and embedded four Kistler 9017B transducers in the footrest. A Photron SA1 high speed video camera was set-up perpendicular to the block to capture the movement of the athlete on the block through to entry. A digital trigger was used to synchronise the capture of force and video data. Data were captured at 125Hz/frames per second (fps) .

Force data were analysed to establish the Reaction Time (RT), Block Time (BT), Block Time Footrest (BTFR), Peak Horizontal Force (PFy, PFyFR) and Peak Vertical Force (PFz, PFzFR) for the main block and footrest. Video data were analysed to measure the rear knee angles at set-up, PFyFR and PFzFR and the Horizontal take-off velocity (HVel) of the swimmer off the blocks.

3. Results

Data were analysed to assess the impact of changing the footrest position on the front and rear knee angles of the swimmer at set-up. It was found that for the general population a change in footrest set-up did not significantly affect the rear or front knee angles. In one case the difference between the three setups was found to produce significant differences in rear knee angle at set-up, $p<0.005$. Interestingly, the rear knee angle in the swimmers preferred set-up (Condition A) and +1 position (Condition C) were the same, 99°, standard error +/- 0.58° and +/-1.33° respectively. Position -1 (Condition B) produced a higher knee angle, (on average 106°, +/-0.81°). This was unexpected it was assumed that by shortening the distance from the edge of the block to the back foot, the swimmer would be in a more “bunched up” position and therefore close the rear knee angle. Observations of the video demonstrate how this particular athlete has adjusted their set-up position to accommodate the shortened distance. In this case the athlete lowered their foot position on the footrest, see Figure 1. Similar adjustments by individual athletes were observed during the trial, i.e. athletes adjusted their body position to accommodate the movement in the footrest, explaining the non-significant impact of footrest position upon rear knee angle.

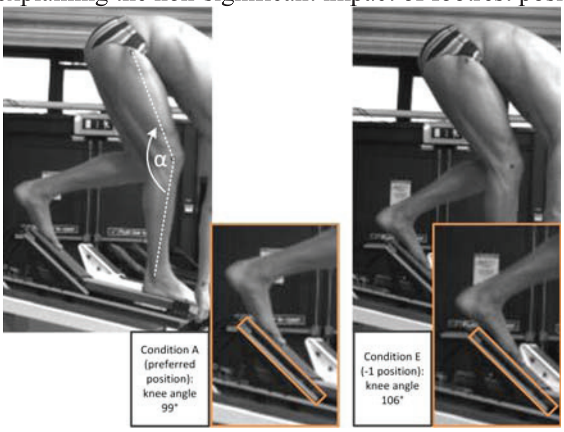

Fig.1. Comparisons of foot placement for an athlete using two different footrest positions, i.e. position 3 and position 2

Table 1. Summary of Pearson’s correlation co-efficients for Rear knee angle at Peak Force production

	Rear knee angle at PFzFR	Rear knee angle at PFyFR	PFyFR
Rear knee angle at PfyFR	0.407*		
PFyFR	0.701*	0.511*	
PFzFR	0.688*	0.378*	0.748*

*significant p<0.005

Pearson’s correlation coefficients revealed significant correlations between peak force values (PFyFR, PFzFR) and the rear knee angle of the athlete at the time of peak force production see Table 1. These data suggest a positive correlation between peak force production and rear knee angle, i.e. for these trials, higher peak forces were generated when the athlete had a higher rear knee angle. The average angle of the rear knee at Peak Fz, i.e. vertical, force (PFzFR) was 89° with a standard deviation of 16°. For Fy force, i.e. horizontal, this average was higher, 103° with a standard deviation of 14°.

Data were divided into categories of performance with regards to BT and HVel. The maximum and minimum values for each parameter were taken and threshold levels set at thirds to form the boundaries of each category, i.e. *Category a* = lowest third, *Category b* = middle third, *Category c* = highest third. For example, BT *Category a* represents the starts where the swimmer left the block the quickest, for HVel, *Category a* represented the starts with the lowest take-off velocity.

Table 2. Summary of Knee Angles at set-up for categories a-c (BT and HVel)

	Category a	Category b	Category c	P value
	Block Time (BT)			
Front Leg (mean)	142°	131°	117°	<0.005
(standard error {SE})	[3.02]	[2.08]	[3.06]	
Rear Leg (mean)	78°	79°	66°	0.023
(SE)	[2.19]	[1.94]	[2.61]	
	Take-off Velocity (HVel)			
Front Leg (mean)	111°	138°	133°	<0.005
(SE)	[2.19]	[2.10]	[2.54]	
Rear Leg (mean)	66°	83°	76°	<0.005
(SE)	[0.67]	[2.19]	[0.42]	

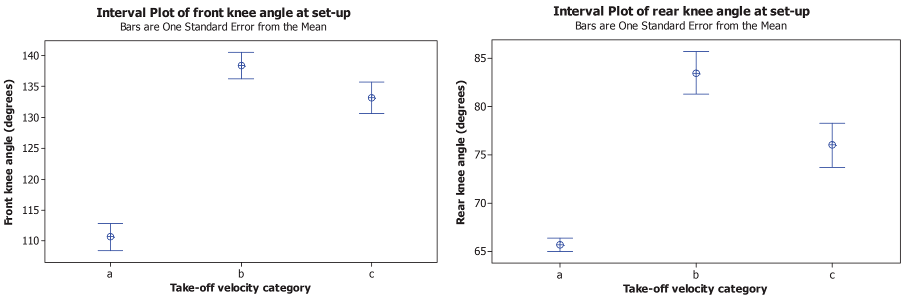

Fig. 2. (a) Interval plot of Front knee angle at set-up; (b) Rear knee set-up: for HVel categories a-c

The set-up angles of the swimmer on the block were analysed with respect to the three categories for BT and HVel, summarised in Table 2. One way ANOVA tests were carried out to establish whether the groups produced significantly different results. It was observed that athletes with the lowest BT, *Category a*, had more open angles, i.e. lower, for front and rear knees than those in *Category b* and *Category c*, + 12° and +25° respectively.

Similarly, the set-up angles of the front and rear knees were different for the different HVel categories. In this case, however, the quickest starts, *Category c*, displayed set-up angles that fell between the slowest and middle categories, see Figure 2. For the front leg, *Categories b* and *c* displayed very similar set-up angles, 138° +/-2.80° and 133° +/-2.54° respectively (+/- = standard error in the mean{SE}), Figure 2(a). For the rear knee angle this difference was more pronounced, 83° and 76° respectively. *Category a* starts used a lower set-up angle for the front and rear knees, this difference with respects to the highest velocity category, *c*, was 22° for the front leg and 10° for the rear leg, Figure 2(b).

The angle of the rear knee at peak force production, PFyFR and PFzFR, has been assessed for each BT and HVel category, and the results are summarised in Table 3. For BT, *Category a* and *Category b* showed similar angles at Peak Fy force, 104°, +/-1.60° (SE), and 106°, +/-2.12°(SE), respectively, whereas *Category c* showed a more acute angle of 85°, +/-7.23°(SE), i.e. ~20° lower. The difference in knee angle for each category at Peak Fz force displayed a different trend, with a 10° difference between *Category a* and *Category b* (SE =+/-2.05) and a 16° difference between *Category b* and *Category c* (SE =+/-3.22), see Figure 4(a).

Table 3. Summary of Knee Angles at Peak Force production for categories a-c (BT and HVel)

		Category a	Category b	Category c	P value
			Block Time (BT)		
PFyFR	(mean)	104°	106°	85°	<0.005
	(SE)	[1.60]	[2.12]	[7.23]	
PfzFR	(mean)	99°	89°	73°	<0.005
	(SE)	[1.51]	[1.39]	[2.91]	
			Take-off Velocity (HVel)		
PFyFR	(mean)	95°	101°	109°	<0.005
	(SE)	[4.19]	[2.16]	[1.75]	
PfzFR	(mean)	79°	97°	85°	<0.005
	(SE)	[2.24]	[2.48]	[2.47]	

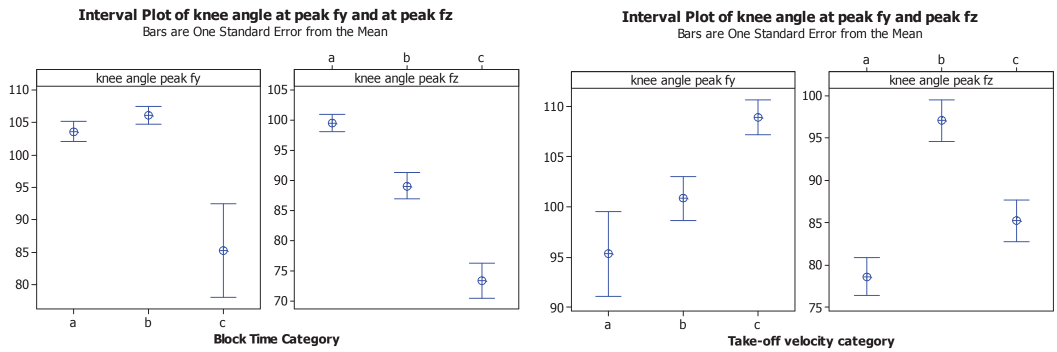

Fig. 4. (a) Interval plot of Front knee and rear knee angle at Peak Fz; (b) at Peak Fy for HVel categories a-c

HVel Categories were also found to have different angles at peak force production, with the highest take-off velocities (*Category c*) associated with the highest rear knee angles at Peak Fy, 109°, +/-1.75°(SE), compared with 101° and 95°, for categories *a* and *b*, Figure 4(b). Knee angles at Peak Fz were highest in *Category b*, 97°, +/-2.48°(SE), but remained the lowest for *Category a*, 79°. *Category c* starts produced Peak Fz force with a knee angle of 85°, +/-2.47°(SE), on average.

4. Discussion

The aim of work presented in this paper was to determine the effect of rear knee angle on starting performance. Analysis of the data was based on the determination of front and rear knee angles at set-up (i.e. at "take your marks") and rear knee angle at peak force production, in both Fy and Fz directions. Swimmers were asked to perform starts in different footrest positions, intended to affect a change in rear knee angle. Analysis of these data found that changing the footrest position, did not significantly change the angle of the front and rear knees in the set-up or peak force positions. Instead it was observed that athletes adapted their set position to accommodate the shortening or lengthening of the "cockpit", by changing their rear foot position on the footrest.

Pearson's correlation co-efficients showed significant relationships between the peak force values and the rear knee angle at the time of this peak force production. Positive correlations were strongest for the rear knee angle and peak force produced in both Fy, horizontal, and Fz, vertical, directions, 0.701, 0.688. The rear knee angle at Peak Fy was also correlated to the Peak Fy, horizontal, force, 0.511. For these data, a higher rear knee angle at peak force production was associated with for higher force production. It is not expected that this trend would hold for all knee angles, it is expected that a threshold will be present whereby beyond a given angle, peak force would tend to drop off.

Data were divided into categories relating to each start's Block Time (BT) and Horizontal Take-off Velocity (HVel). Categories *a*, *b* and *c* were defined by dividing the data into equal thirds using the maximum and minimum values as limits. Analysis of the angle of the front and rear knee at set-up and the rear knee at peak force production was then undertaken with reference to these categories. These data suggest that athletes performed better starts when they adopted a high (*Category c*) front knee angle, of ~135°-145° and rear knee angle of ~75°-85° at set-up. It is speculated that by opening the angle of the legs, muscles are in a more effective position for force production at the start signal. In addition, the athlete has a smaller range of movement to travel through before leaving the block. The ability of an athlete to utilise these angles will be highly dependent on their flexibility, particularly of their hamstrings. Data from this testing suggest that rear knee angles of ~100°-110° and 80°-90° were the most effective angles, at Peak Fy and Peak Fz force production, for quickest block times and take-off velocities.

It is important to note that the level of test subject, although competent, was sub-elite and therefore observations may not extrapolate to the elite population. Indications from this testing are that the footrest on the OSB11 block enables the athlete to adopt a rear knee angle tending towards 90° at set-up, although, similar to reports by Nomura et al 2010, of knee angles at set-up = 84° [5], this study found the angle to be lower, ~75°-85°. The best starts produced a peak vertical force at a rear knee angle of 80°-90°. More interestingly, this study suggests that, for the best starts, peak horizontal force production occurred with an obtuse knee angle of 100°-110°. Further work to extend analysis to include a more complete biomechanical analysis is underway. Future studies are scheduled to collect repeated data sets and data sets from a larger population of participants.

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