

# Optimizing individual stance position in the swim start on the OSB11

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## 1 Introduction

Since 2010, the OSB11 starting block model has been used for national and international championships. It provides clear advantages in swim start performance as compared to the previously used OSB9 device (e. g. Honda et al., 2010; Biel et al., 2010). However, there is scarce knowledge on the optimal stance position for swimmers with respect to their individual body length or leg preference (e. g., Slawson et al., 2011; Takeda et al., 2012). For example, Slawson et al. (2011) conducted a study on 32 British elite swimmers analyzing the effects of the stance width (feet placed in tandem position and feet placed shoulder wide in parallel position), the foot rest positions, and the preferred front leg. One of the most striking results in this study was that the optimal stance position on the new OSB11 was different for males and females. For example, these authors showed for the male swimmers that a wide stance width was associated with increases in block time and attenuated horizontal and vertical take-off forces in conjunction with a decreased horizontal take-off velocity. Thus, a narrow stance with a tandem foot position is beneficial for male swimmers. However, for the female swimmers, a wide stance position was associated with increased horizontal take-off forces and decreased absolute and relative flight distances. In a separate, single case study, Slawson and coworkers confirmed that the side preference for the front leg, the stance width, and the wedge position are the most important variables for the stance position on the block.

The study of Slawson et al. identified some important general trends with regard to the gender-specific effect of varying the width of stance on starting performance, as well as wedge position and preference for the front leg. However, general trends are likely insufficient to identify the optimal foot positioning for each individual separately. Aside from gender and leg preference, leg strength and body weight must be considered as well since peak forces during the block phase have been identified as major predictors of swim start performance (Kibele et al. 2007; Slawson et al., 2013; Beretic et al., 2013; Fischer, 2013). In addition, according to the study of Welcher et al. (2008), the weighting of the legs during the stance must be considered. These authors showed that the rear-weighted track start had a better combination of time and velocity than the front-weighted track start. Finally, the centre of mass (CM) height must be accounted for as this measure as it has been shown to determine block time which in turn is major prerequisite for swim start performance (Hay & Guimaraes, 1983; Fischer, 2013). In conclusion, according to the individual anthropometry and the swimmer's strength abilities, the start block set-up and stance cannot be evaluated by simple univariate analyses.

For a first approach to this problem, a systematic variation of the preferred stance position in the track start of elite swimmers on the OSB11 was used to evaluate their swim start performance (time between the starting signal and the head-passage at 5 m). In this regard, variations of the individually preferred stance were examined regarding the front leg (left vs. right), the CM height (low vs. high), the stance width (narrow vs. wide), and a weighted stance (rear vs. front) estimated by the horizontal distance of the hip joint to the front edge of the block. The magnitude of the variations was expressed relative to the individual leg length. Kinematic and kinetic measures were analyzed to evaluate the swim start performance.

## 2 Method

### 2.1 Subjects

Fourteen male and five female elite swimmers (females:  $24,8 \pm 2,7$  y age;  $1,74 \pm 0,02$  m height,  $63,8 \pm 5,09$  kg body mass; males:  $23 \pm 1,5$  y age;  $1,88 \pm 0,06$  m height,  $83,6 \pm 10,7$  kg body mass) participated in the study. Fifteen subjects preferred freestyle while one male and one female preferred butterfly and one male and one female preferred breaststroke.

### 2.2 Instrumentation

For the kinematic data analysis, 2 video cameras (Sony DCR-TRV900E Pal operated at 50 Hz) were placed vertically at a height of 1,35 m above the water level and horizontally in parallel to the front edge of the block, and at 5 m after the block. While the first camera was used to analyze the take-off behaviour on the block, the second camera was utilized to capture the time between the starting signal and the head passage at 5 m. A 2D-strain gauge equipped starting block (Kibele, 2005) with an OSB11 surface measured the horizontal and vertical ground reaction forces.

### 2.3 Procedures

Systematic variations of the preferred stance position accounting for the CM heights and distances relative to the front edge of the block, as well as the stance width, were related to the standard deviations (SD) found in a preceding pilot study (Experiment 1 in Kibele, Biel, & Fischer, 2013) with six male and seven female elite swimmers (females:  $22,1 \pm 4,0$  y age;  $1,78 \pm 0,06$  m height,  $65,2 \pm 5,4$  kg body mass; males:  $23,8 \pm 2,3$  y age;  $1,90 \pm 0,03$  m height,  $85,8 \pm 5,4$  kg body mass). In this experiment, the individually preferred stance configurations in elite swimmers were analyzed. The means and SDs were expressed relative to the individual leg lengths of the male and female swimmers separately. For example, the CM height, relative to the individual leg lengths, was  $0,72 \pm 0,04$  for the females and  $0,73 \pm 0,04$  for the male swimmers. Furthermore, relative step lengths, expressing the horizontal distances between the toes of both feet, of  $0,66 \pm 0,07$  were found for the females and  $0,63 \pm 0,08$  for the males. For the present study, the SDs were reconverted relative to the gender and the leg length of each subject. These SDs were then added and subtracted respectively to the preferred stance configurations (Fig. 1 left side). For example, a low CM height for a subject was determined by his CM height in the preferred stance position minus one SD reconverted to the subject's leg length. Thus, in addition to the preferred stance, 8 configurations were possible for each leg: CM height (low vs. high) x CM distance (rear vs. front weighted stance), and stance width (narrow vs. wide). However, because of motor coordination demands, for each leg, only four of the eight possible configurations could be eventually maintained on the block. These configurations are as follows:

- narrow stance with CM position high-front (No.1),
- wide stance with CM position high-back (No.2),
- wide stance with CM position low-front (No.3), and
- wide stance with CM position low-back (No.4).

Therefore, aside from the preferred stance, a total of eight swim start variations were analyzed. Three trials were used for each configuration. Prior to the swim start variations, the subjects performed their preferred stance conditions. Subsequently, the variations of the stance configuration were analyzed in random order and across three non-consecutive days.

For simplicity reasons, the hip-joint landmark was used as an estimate of the CM location. For the stance width of a male subject, for example, the SD 0,66 from the pilot study was multiplied with the given leg length of a subject and the result was added to the preferred stance width (wide) or subtracted (narrow). Then, the closest wedge position was used for the swim start trial. A video display was used to control the required stance configurations. Here, an overlay reference grid (Fig. 1 right side) was used to indicate the various hip joint positions.

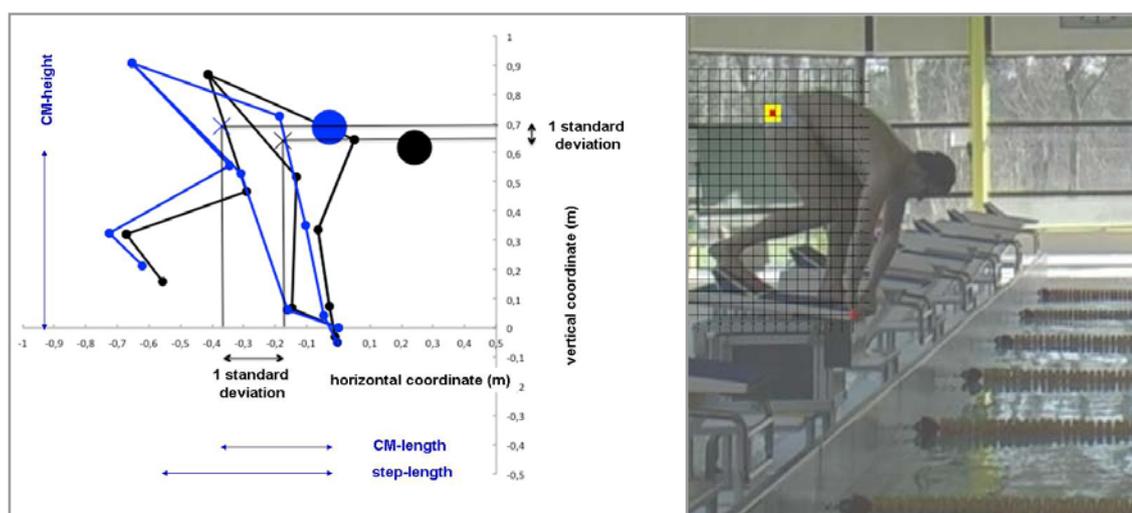


Fig. 1: left side: stance parameters: CM-length (rear weighted vs. front weighted start), CM-height (high vs. low), and step length (narrow vs. wide), right side: video display to control for the required CM location.

## 2.4 Parameters

For each subject, the mean values across valid trials were evaluated for the following kinematic take-off parameters: block time, horizontal take-off velocity (mean velocity across the first three images in the flight phase), take-off angle (inclination of CM trajectory during the first 3 images in the flight phase), flight distance (between front end of the block and the point of hip entry) relative to the body height, entry angle (inclination of the CM-hand interconnection), and hip angle at entry (angle between shoulder, hip, and knee joint at hand entry). For take-off dynamics, the vertical and horizontal peak forces were evaluated across the valid trials.

## 2.5 Statistics

A two-way repeated measures analysis of variance (ANOVA) was calculated to identify main effects and interaction effects for the selection of the front leg and for the four stance configurations. Post-Hoc tests were calculated with Bonferroni corrections for the Tukey-test. To assess reliability, Cronbach's  $\alpha$  was calculated for all parameters measured.

### 3 Results

Across all stance configurations, the deviations for the hip joint landmark from the target position were  $-0,049 \pm 0,039$  m in the vertical direction and  $-0,040 \pm 0,053$  m in the horizontal direction. Accordingly, the mean deviations for the CM coordinates from the target position were  $-0,041 \pm 0,036$  m in the vertical direction and  $-0,027 \pm 0,051$  m in the horizontal direction. To prevent overlapping in CM locations in the different stance configurations, trials were excluded from the statistical data analysis if their CM deviation from the target was larger than the smallest difference between the various target CM locations. Subsequently, 12 % of all the trials were excluded.

For the remaining trials, 13 of the 19 subjects showed swim start improvements for the stance alternatives better than or equal to the preferred stance position. However, for 6 swimmers, any alteration of their preferred stance configuration caused a deteriorated swim start time. For half of the subjects, at least one stance alternative provided a better swim start time than the preferred stance. The mean improvements were found as large as 0,06 s. The largest increase in the swim start time was 0,14 s. Tab. 1 lists the number of cases where swim start performance improved due to changes in stance configuration. Although a systematic tendency for an optimal stance configuration was not detected, a narrow stance with a high CM position (No.1) showed the most improvements to the preferred stance condition (see Tab. 1).

Tab. 1: Number of subjects and their stance configurations with a swim start performance better than for the preferred stance posture (multiple counts included).

stance configuration with CM position and step length	high-front narrow (No.1)	high/back wide (No.2)	low-front wide (No.3)	low-back wide (No.4)
preferred leg in front position	8	2	5	2
non-preferred leg in front position	8	4	4	2

Aside from the hip angle at entry ( $r_{IC} = 0,60$ ), strong reliability values were found for the block time ( $r_{IC} = 0,93$ ), the horizontal take-off velocity ( $r_{IC} = 0,68$ ), the take-off angle ( $r_{IC} = 0,86$ ), the flight distance relative to the body height ( $r_{IC} = 0,94$ ), and the entry angle ( $r_{IC} = 0,84$ ). For take-off dynamics, Cronbach's  $\alpha$  values for the vertical peak force ( $r_{IC} = 0,97$ ) and the horizontal peak force ( $r_{IC} = 0,99$ ) were assessed.

For ANOVA data analysis, a significant main effect for the leg factor leg was identified in the block time ( $F = 7,7$ ;  $p < 0,05$ ; -2,8 % difference between the legs), the swim start time at 5 m ( $F = 12,1$ ;  $p < 0,01$ ; -3 %), the horizontal take-off velocity ( $F = 28,5$ ;  $p < 0,01$ ; +4,2 %), and the vertical peak force ( $F = 11,6$ ;  $p < 0,01$ ; +4,8 %). For these parameters, superior results were found for the preferred leg. For the hip angle at first water contact, a significant main effect was identified as well ( $F = 9,7$ ;  $p < 0,05$ ) demonstrating mean values for the preferred leg of  $163 \pm 10,6^\circ$  and for the non-preferred leg of  $158 \pm 11,4^\circ$ .

Tab. 2: Mean values and standard deviations for the kinematic and dynamic parameters with significant main effect for the stance configurations. Significant differences in the post-hoc analysis are indicated by superscripted stance configuration numbers.

stance configuration with CM position and step length	high-front narrow (No.1)	high/back wide (No.2)	low-front wide (No.3)	low-back wide (No.4)
block time (s)	0,77 ± 0,04 <sup>2,4</sup>	0,85 ± 0,05 <sup>1,3,4</sup>	0,76 ± 0,04 <sup>2,4</sup>	0,88 ± 0,05 <sup>1,2,3</sup>
swim start time (s)	1,61 ± 0,14 <sup>4</sup>	1,67 ± 0,11	1,59 ± 0,10 <sup>4</sup>	1,70 ± 0,13 <sup>1,3</sup>
entry angle (°)	39,6 ± 1,9	40,1 ± 2,2 <sup>4</sup>	39,8 ± 2,6	38,5 ± 1,5 <sup>2</sup>
flight distance relative to body height	1,56 ± 0,1	1,58 ± 0,08 <sup>3</sup>	1,54 ± 0,09 <sup>2</sup>	1,57 ± 0,09
horizontal take-off velocity (m/s)	4,34 ± 0,35	4,42 ± 0,34	4,30 ± 0,31 <sup>3</sup>	4,40 ± 0,32 <sup>4</sup>
horizontal peak force (N/kg) in BW	1,24 ± 0,22 <sup>2,4</sup>	1,05 ± 0,16 <sup>1,3</sup>	1,21 ± 0,23 <sup>2,4</sup>	1,01 ± 0,15 <sup>1,3</sup>

Significant main effects for the four stance configurations were found for the block time ( $F = 31,0$ ;  $p < 0,01$ ), the swim start time ( $F = 12,1$ ;  $p < 0,01$ ), the entry angle ( $F = 3,8$ ;  $p < 0,05$ ), the relative flight distance ( $F = 4,4$ ;  $p < 0,05$ ), the horizontal take-off velocity ( $F = 3,7$ ;  $p < 0,05$ ), and the vertical peak force ( $F = 29,7$ ;  $p < 0,01$ ). The main effect for the swim start time, however, is solely based on the differences in the block times. For the post-hoc analysis, the mean values and SDs with significant differences are listed in Tab. 2. A significant statistical interaction between the factors front leg and stance configuration was found for the horizontal take-off velocity only.

## 4 Discussion

In this study, two thirds of the subjects displayed either improvements or no changes in swim start performances based on stance variations in comparison to their preferred stance configuration. The average improvements in the swim start performance were found to be 0,06 s with extreme values as large as 0,14 s. While these values appear insignificant, a number of Olympic races were won within milliseconds. For example, during the Olympic freestyle races for women in Beijing 2008, Britta Steffen (Germany) won the 100-m-race by 4 ms to Lisbeth Trickett (Australia). For the 50-m-freestyle-race, Britta Steffen won by as little as 1ms to Dara Torres from the USA. Therefore, even it seems worthwhile to analyse the optimal stance configuration for the individual swimmer.

Aside from issues related to the spatial precision of the stance configurations, a major objection to the present study was that the swimmers' preferred stance configuration might have been optimal from the beginning. This possibility could have been true for the 30 % of subjects decreasing their swim start time through a change in their stance configuration. In this case, this approach would aid in improving swim start times.

In the past, for the traditional OSB9 starting block, an inverse relationship between block time and horizontal take-off velocity was found independent of the starting technique used. In this regard, larger take-off velocities were observed in line with longer block times (e. g., Blanksby et al., 2002; Miller et al., 2003; Vilas-Boas et al., 2003). Therefore, for each swimmer's anthropometry and strength abilities an optimal relationship between block time and horizontal take-off velocity was needed. As

the increased length in the new OSB11 starting block offers a better opportunity for the acceleration of the CM, this problem is raised once again.

The results from the present study show that for the majority of the swim starts improvements were associated with a narrow stance with an elevated CM. For this stance configuration, shorter block times were observed. Therefore, on the new OSB11, the impact of reducing block time on the swim start performance might be increased. In contrast, on the OSB9 starting block, Welcher and colleagues (2008) showed the rear-weighted track start to be superior to the front-weighted track start. For the rear-weighted track start, longer block times in line with longer acceleration pathways were observed. The same argument is supported by Fischer (2013). In his PhD thesis, a structural equitation model was used to analyze the swim start predictors on the OSB9 block. According to Fisher's analysis, to improve swim start performance, longer block times may be tolerated to increase the horizontal take-off velocity. This strategy might be reversed for the new OSB11. Here, the slanted footrest provides enhanced conditions for the horizontal force development within a short amount of time. Therefore, keeping the block time short may pay off. According to Tab. 2, short block times and large horizontal peak forces were found for the front-weighted stance positions (No.1 and No.3). For these two stance configurations, due to slightly higher horizontal peak forces, a narrow step length with an elevated CM position (No. 1) could prove to be more beneficial than a wide step length with a low CM position (No.3). In fact, preceding studies showed that wide step lengths were associated with a deferred force development in both legs (Fischer, 2013).

## 5 Conclusion

The study shows that, for a random sample of elite swimmers, preferred stance could be improved substantially through a variation of the stance parameters. A general trend for an optimal stance position was not detected. However, from the number of improvements observed in the different stance alternatives, it appears that a high CM position with a narrow stance width and a front-weighted start provides substantial opportunities for swim start improvements.

## 6 Literature

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