

Effects of kick-start positions on 15-m start performance in Freestyle and Butterfly: A kinematic analysis using the OSB12 starting platform

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Abstract:

Background: The start phase in swimming is a critical determinant of overall performance, and the selection of kick-start position can considerably influence start outcomes, particularly in competitive swimmers. **Purpose:** This study examined the effects of three kick-start positions—front-weighted (FW), neutral (NW), and rear-weighted (RW)—on 15-m start performance in freestyle and butterfly using the OSB12 starting platform. **Materials and methods:** Ten male competitive swimmers (mean age: 17.6 ± 1.8 years) performed two randomized starts from each position in both strokes. Kinematic data were collected using a six-camera SwimPro system and analyzed with Dartfish software (v.4.0). Velocity data were obtained using the Speed RT velocity meter and Speed RT software (v.3.2). Repeated-measures ANOVA and paired t-tests were applied to compare conditions. Statistical analyses were performed using IBM SPSS Statistics (v.27.0.1.0). **Results:** The shortest 15-m times in both freestyle and butterfly were achieved in the NW position. In freestyle, the NW position was significantly faster than both the FW ($p = .001$) and RW ($p = .039$) positions. In the butterfly, it was significantly faster only when compared with the FW position ($p = .001$). Across all kick-start positions, 15-m times were significantly shorter in butterfly than in freestyle ($p < .01$). **Conclusion:** The NW position produced the fastest 15-m start times in both butterfly and freestyle, with butterfly consistently outperforming freestyle across all kick-start positions. Additionally, the NW position also resulted in the shortest 10-m times in both strokes, indicating that its performance advantage emerged early in the start phase and was reflected at 15 m. These findings highlight the importance of selecting an optimal start position to enhance swimming performance.

Keywords: biomechanics, block phase, flight phase, underwater breakout, competitive swimmers

Introduction

In sprint swimming, the start is a decisive determinant of performance because millisecond-level advantages accumulate during the initial phases of the race. This is particularly critical in short-distance events, where start-related components—including the block phase, underwater phase, and swim phase to 15 m—can considerably influence overall race outcomes and final rankings (Moraes et al., 2018). Using elite-level samples, Shepherd et al. (2023) demonstrated that body segment orientation and centre-of-mass (CoM) velocity at toe-off are strong predictors of start performance in both male and female swimmers. Complementing these findings, a phase-specific championship analysis by Gao et al. (2025) highlighted the importance of an explosive start and an efficient underwater phase, with sex-specific differences in their relative contributions to performance. With the introduction of angled back plates on OMEGA OSB-series starting blocks, start configuration has become an optimization problem involving back-plate position, stance width, and fore-aft weight distribution. Using OSB11 starting blocks, Barlow et al. (2014) reported faster 15-m times in neutral- (NW) and rear-weighted (RW) positions compared with the front-weighted FW position, despite no differences in instantaneous velocity at approximately 5 and 15 m—suggesting that performance gains may result from cumulative effects across start phases.

Similarly, in elite swimmers, Honda et al. (2012) found that shifting body mass further rearward increased off-block velocity but did not necessarily reduce the 7.5-m split time, supporting the need to evaluate start performance over the full 15-m distance. In this context, start performance is best interpreted using multiple early-distance measures (e.g., 5, 10, and 15 m) rather than relying on a single split time (Silveira et al., 2018). Building on this perspective, a systematic review by de Jesus et al. (2023) concluded that the use of wedges generally reduced block time and increased horizontal take-off velocity, while emphasizing the need for individualization based on swimmers' anthropometry and neuromuscular profiles. As a practical guideline, Cicienia et al. (2020) proposed using shin length to determine optimal kick-plate distance without compromising start mechanics. Similarly, Burkhardt et al. (2020) identified leg positioning as a key performance indicator of kick-start performance, reinforcing the practical importance of stance configuration and weight-distribution choices on OSB-type starting blocks. Mechanistically, the resultant take-off velocity in the kick-start reflects the coordinated impulses generated by the hands, front foot, and rear foot, each acting through separate interfaces.

Using three independent force platforms, Takeda et al. (2017) demonstrated distinct functional roles for the rear foot (kick plate) in generating the horizontal force component and for the front foot in contributing to the vertical component, with these effects modulated by the timing of hand impulses. From a kinematic perspective, Slawson et al. (2012) reported that rear-knee angles of 100°–110° during the block phase were associated with higher peak horizontal force on the OSB11 starting block, which may be advantageous when maximizing horizontal impulse. The management of angular momentum during the aerial phase further differentiates start techniques. Taladriz et al. (2016) demonstrated differences between kick- and grab-starts in rotation timing and angular characteristics, which influence entry orientation and the quality of the subsequent glide. Hydrodynamic factors then govern performance in the early underwater segment. Tor et al. (2015) compared shallow, medium, and deep post-entry trajectories and showed that a deeper trajectory reduces total drag—particularly wave drag—thereby allowing swimmers to maintain velocity for longer; the most effective trajectory reached a maximum depth of approximately 0.9 m. From a stroke-specific perspective, Gonjo and Olstad (2020) reported strong associations between selected underwater kinematic variables and start and turn performance in the butterfly.

The post-entry glide has been examined in detail by Trinidad (2022), who linked entry angle, depth, and body alignment to glide distance (GD) and velocity profiles. These findings align with the systematic review on undulatory underwater swimming by Veiga et al. (2022), which synthesized key kinematic determinants and methodological considerations. Collectively, this body of literature supports a holistic approach to start performance, emphasizing the integration of on-block configuration and toe-off kinematics with flight organization, controlled water entry, and efficient underwater execution. However, direct evidence comparing FW, NW, and RW kick-start positions on the OSB12 starting platform across both freestyle and butterfly in a single experimental framework remains limited. Despite the clear need for position-specific guidance in applied coaching, evidence remains limited. It was hypothesized that 15-m start performance would differ among kick-start positions in both freestyle and butterfly, with a potential advantage for the NW position. In addition, the butterfly was expected to yield superior performance compared with freestyle, potentially owing to differences in the underwater phase. Accordingly, this study examined the effects of three kick-start positions—FW, NW, and RW—on 15-m start performance in freestyle and butterfly using the OSB12 starting platform.

Materials and Methods

Participants

The sample comprised 10 competitive swimmers (mean age: 17.6 ± 1.8 years; body height: 183.1 ± 8.1 cm; body mass: 80.1 ± 2.4 kg). At the time of testing, the swimmers' mean performance level was 587 ± 34 World Aquatics points in freestyle and 577 ± 42 points in butterfly. All participants were sprint specialists with 7–10 years of training experience, completing an average of 9–11 training sessions per week and regularly competing at national championships. Inclusion criteria were active participation in competitive swimming, absence of acute or chronic injuries, and the ability to complete the testing protocol. Swimmers who did not meet these criteria or had medical contraindications were excluded. All participants were informed of the study procedures and objectives and provided written informed consent in accordance with the Declaration of Helsinki. Ethical approval was granted by the Ethics Committee of the University of Prešov, Prešov, Slovakia (Approval No. ECUP042022PO).

Research Design

Testing was performed at the University of Prešov swimming pool, which is equipped with OSB12 starting platforms, during the main phase of the summer season. The pool was 25 m in length, with water temperatures maintained at 26°C–27°C. To minimize the influence of wave effects, testing was performed in the absence of other swimmers. A medical doctor from the Faculty of Sports, University of Prešov, placed reflective markers bilaterally on each swimmer at the following anatomical landmarks: lateral margin of the transverse tarsal joint, lateral malleolus, lateral femoral condyle, greater trochanter, lateral margin of the scapular spine, elbow epicondyle, ulnar styloid process, and medial side of the fifth metacarpophalangeal joint. Waterproof dermatological markers were used to identify anatomical landmarks. Swimmers then performed an individualized warm-up according to their usual pre-competition routine, completing at least 400 m of swimming, followed by two practice starts to ensure standardization. At the conclusion of the warm-up, each swimmer executed two additional practice starts. All starts were performed according to official swimming rules, with the standard commands "Take your marks" followed by an auditory starting signal. Swimmers adopted their preferred block configuration, including kick-plate placement, rear foot position, and stance width. Each participant performed two starts from the FW, NW, and RW positions on the OSB12 starting platform in both freestyle and butterfly over a 20-m distance. Race-pace efforts over 20 m were used to collect valid data for the 15-m segment. In total, each swimmer completed 12 starts, with a 20-min rest interval between freestyle and butterfly trials and a 2-min rest between attempts. These recovery intervals, determined from pilot testing, were designed to prevent fatigue from influencing performance. Any faulty starts were repeated.

The order of starts was randomized using a computer-generated random number sequence. Starting position on the block was determined by the location of the shoulder markers (lateral margins of the left and right scapular spines) relative to the front edge of the OSB12 starting platform: positions anterior to the block

edge were classified as front, aligned with the edge as neutral, and posterior to the edge as rear. Body weight distribution on the block was also emphasized. In the FW position, swimmers were instructed to place more weight on the front leg while maintaining stability; in the neutral position, weight was distributed evenly between both legs; and in the RW position, weight was shifted onto the rear leg. To ensure familiarity with each position, swimmers practiced all three block positions, performing five starts from each, across two weeks (Monday, Wednesday, and Friday) prior to testing.

Kinematic data were captured using a six-camera SwimPro system. The first two cameras were positioned perpendicular to the OSB12 starting platform, at a height of 1.5 m and a distance of 1.6 m from the center of the platform, to record swimmers' set positions on the block at the moment of the starting signal. The third camera was located 1.6 m from the pool edge at a height of 1.5 m and recorded the above-water phase. The fourth and fifth cameras were positioned underwater at a depth of -1.7 m, located 5 m and 10 m from the pool edge, respectively, to capture the underwater phase. The sixth camera was placed 15 m from the pool edge at a height of 1.5 m to record the swim phase. Cameras three and four were aligned perpendicular to the swimmer's plane of motion. The SwimPro system recorded at 50 Hz with a shutter speed of $1/1000$ s (Figure 1).



Figure 1. SwimPro six-camera system

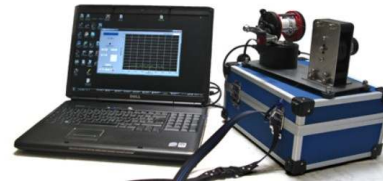


Figure 2. Speed RT velocity meter

Kinematic data from the SwimPro camera system were analyzed using Dartfish ProSuite 4.0 software (2005; Fribourg, Switzerland). In addition, swimmer velocity was recorded using the Speed RT velocity meter (APLab, Rome, Italy), a cable-based system with an encoder, sampling at 100 Hz. The device is connected to a computer via USB without requiring an external power supply. Using Speed RT software (version 3.2, 2021; APLab, Rome, Italy; Figure 2), the system allowed accurate measurement and analysis of swimmer velocity across all phases of the start. The accuracy of the Speed RT velocity meter was verified prior to data collection, demonstrating measurement accuracy of 0.11% for distance and 0.45% for velocity over the 5–25 m range. For distances shorter than 5 m, accuracy was reduced, likely owing to the time required for the cable system to achieve tension at movement onset. Therefore, the device was used starting from 5 m from the pool wall and was synchronized with both the starting signal and the camera system. The Speed RT velocity meter was positioned directly behind the starting block at a height that prevented the cable from contacting hard surfaces, including the block. The cable was attached via a clip to a waist belt worn by the swimmer. A detailed overview of the analyzed kinematic parameters is presented in Table 1.

Table 1. Detailed description of kinematic parameters measured in the kick-start

Phase	Parameter	Description
Block	FKA - Front knee angle (°)	Hip, knee, ankle angle of the front leg at the set position / Dartfish
	RKA - Rear knee angle (°)	Hip, knee, ankle angle of the rear leg at the set position / Dartfish
	RHA - Rear hip angle (°)	Angle between ankle, hip, and shoulder / Dartfish
	FHA - Front hip angle (°)	Angle between ankle, hip, and shoulder / Dartfish
	HH - Hip height (m)	Height of hips on the block relative to water surface / Dartfish
	RT - Reaction time (s)	Interval between the starting signal and a change in block reaction force curve due to initial movement / Dartfish
	MT - Motion time (s)	Interval between the first movement and the frame when the swimmer is no longer in contact with the block / Dartfish
Flight	BT - Block time (s)	Sum of reaction time and movement time / Dartfish
	TA - Take-off angle (°)	Angle between horizontal axis, block edge, and hip joint at take-off / Dartfish
	EA - Entry angle (°)	Angle between horizontal axis, fingertips, and hip joint at hand entry into water / Dartfish
	FT - Flight time (s)	Interval between last toe contact with the block and first hand contact with water / Dartfish
	FD - Flight distance (m)	Horizontal distance between start line and hip entry point into water / Dartfish
	TS - Time of submersion (s)	From head contact with water to toe submersion / Dartfish
	GT - Glide time (s)	From toe submersion to start of downward movement initiating underwater dolphin kick / Dartfish
Underwater	GD - Glide distance (m)	Horizontal head displacement during glide phase / Dartfish
	T5 - Time to 5 m (s)	Interval between starting signal and head crossing 5-m mark / Speed RT
	TFK - Time of first kick (s)	Time at which the first underwater kick was completed / Speed RT
	DFK - Distance of first kick (m)	Distance from starting wall where the first underwater dolphin kick was initiated / Speed RT
	BD - Breakout distance (m)	Distance at which the swimmer's head first breaks the water surface / Speed RT
	BoT - Breakout time (s)	Time at which the swimmer's head first breaks the water surface / Speed RT
	UWT - Underwater time (s)	Total time spent underwater from entry to breakout / Speed RT
	T10 - Time to 10 m (s)	Interval between starting signal and head crossing 10-m mark / Speed RT
	AV5-10 - Average velocity 5–10 m (m/s)	Average swimmer velocity between the 5-m and 10-m marks / Speed RT
	AV10-15 - Average velocity 10–15 m (m/s)	Average swimmer velocity between the 10-m and 15-m marks / Speed RT
Swim	T15 - Time to 15 m (s)	Interval between starting signal and head crossing 15-m mark / Speed RT

Statistical Analysis

To examine differences among the three kick-start positions, a repeated-measures analysis of variance (ANOVA) was performed. Prior to analysis, the Shapiro–Wilk test was used to verify the assumption of normality. Effect sizes were reported as partial eta squared (η^2p), with standard interpretative thresholds following Cohen (1988) and Richardson (2011): $\eta^2p = 0.01$ indicated a small effect, $\eta^2p = 0.06$ a medium effect, and $\eta^2p \geq 0.14$ a large effect. Post hoc pairwise comparisons were performed using the Bonferroni test to identify statistically significant differences between the FW, NW, and RW start positions. To compare performance between freestyle and butterfly, paired t-tests were applied, with effect sizes expressed as Cohen's d. Following Cohen (1988), $d = 0.20$ was considered a small effect, $d = 0.50$ a medium effect, and $d = 0.80$ a large effect. For all main outcomes, 95% confidence intervals were reported. Statistical analyses were performed using IBM SPSS Statistics, version 27.0.1.0 (IBM Corp., Armonk, NY, USA).

Results

Block Phase

In freestyle, front knee angle (FKA) differed significantly across kick-start positions ($F_{2,18} = 25.56$, $p = .001$, ES = large), with the largest difference observed between the FW and RW positions ($p = .001$). In the butterfly, differences were more pronounced ($F_{2,18} = 90.99$, $p = .001$, ES = large), with significant differences among all three positions: FW vs. NW ($p = .002$), FW vs. RW ($p < .001$), and NW vs. RW ($p < .001$). Regarding RKA in freestyle, significant differences were also found across positions ($F_{2,18} = 10.86$, $p = .001$, ES = large), with the RW position differing from both FW ($p = .019$) and NW ($p = .001$). In the butterfly, all pairwise comparisons for RKA were significant ($F_{2,18} = 25.79$, $p < .001$, ES = large), with the RW position differing from both FW ($p = .002$) and NW ($p = .001$) positions. In freestyle, hip angles differed significantly across all positions for both rear hip angle (RHA: $F_{2,18} = 934.39$, $p < .001$, ES = large) and front hip angle (FHA: $F_{2,18} = 921.70$, $p < .001$, ES = large). A similar pattern was observed in the butterfly, with significant differences for RHA ($F_{2,18} = 273.31$, $p < .001$, ES = large) and FHA ($F_{2,18} = 362.83$, $p < .001$, ES = large). In all cases, pairwise comparisons were significant ($p < .001$). In freestyle, hip height (HH) also differed significantly between positions ($F_{2,18} = 11.23$, $p = .001$, ES = large), with differences observed only between FW and RW positions ($p = .001$). In the butterfly, a significant effect of position on HH was found ($F_{2,18} = 62.53$, $p < .001$, ES = large), with differences observed between FW and NW ($p = .001$), NW and RW ($p = .006$), and FW and RW ($p = .001$). No statistically significant differences between positions were found for reaction time or motion time. In contrast, block time (BT) differed significantly across positions in both strokes (freestyle: $F_{2,18} = 3.90$, $p = .035$, ES = large; butterfly: $F_{2,18} = 4.65$, $p = .024$, ES = 0.34). In freestyle, significant differences were observed between FW and RW ($p = .041$) and between NW and RW ($p = .037$), whereas in butterfly, a significant difference was found only between NW and RW ($p = .030$).

When comparing freestyle and butterfly, no significant differences were found in block-phase angles, HH, or temporal parameters, except for RKA in NW ($p = .045$) and marginally in RW ($p = .050$), both associated with a large effect size.

Flight Phase

In the flight phase, significant differences were observed for take-off angle (TA) in both freestyle ($F_{2,18} = 11.30$, $p = .001$, ES = large) and butterfly ($F_{2,18} = 19.55$, $p = .001$, ES = large). In freestyle, TA was lower in the FW position compared with NW ($p = .023$) and RW ($p = .007$), whereas in butterfly, TA was higher in RW compared with both FW and NW (both $p = .001$). Significant differences were also found for entry angle (EA) in freestyle ($F_{2,18} = 41.56$, $p = .001$, ES = large) and butterfly ($F_{2,18} = 10.63$, $p = .001$, ES = large), with all positions differing significantly from one another in both strokes ($p \leq .023$). For flight distance (FD), significant differences were observed in freestyle ($F_{2,18} = 9.73$, $p = .001$, ES = large) between FW and RW positions ($p = .001$), and in butterfly ($F_{2,18} = 7.77$, $p = .004$, ES = large), also between FW and RW ($p = .020$). No significant differences in flight time (FT) were found across positions in either stroke. When comparing freestyle and butterfly during the flight phase, a significant difference was detected only for TA in the NW position ($p = .010$, ES = small), while no other parameters showed significant differences (Table 2).

Underwater Phase

In the underwater phase, significant differences were observed in GD for both strokes (freestyle: $F_{2,18} = 7.62$, $p = .004$, ES = large; butterfly: $F_{2,18} = 10.43$, $p = .001$, ES = large), with the RW position producing greater GD than the FW position ($p \leq .008$). Significant differences were also found in time to 5 m (T5) (freestyle: $F_{2,18} = 10.63$, $p = .001$, ES = large; butterfly: $F_{2,18} = 43.53$, $p = .001$, ES = large), where the NW position was faster than both FW and RW in both strokes ($p \leq .005$). Differences were further confirmed for time to the first kick (TFK) (freestyle: $F_{2,18} = 44.86$, $p = .001$, ES = large; butterfly: $F_{2,18} = 24.82$, $p = .001$, ES = large), with RW achieving greater distance compared with FW and NW ($p \leq .003$). In freestyle, underwater time (UWT) also differed significantly ($F_{2,18} = 7.45$, $p = .003$, ES = large), with RW being longer than both FW ($p = .029$) and NW ($p = .049$). Key differences were observed in time to 10 m (T10) (freestyle: $F_{2,18} = 11.97$, $p = .001$, ES = large; butterfly: $F_{2,18} = 59.16$, $p = .001$, ES = large). In freestyle, NW was faster than FW ($p = .003$) and RW ($p = .002$), whereas in butterfly, NW was faster than both FW ($p = .001$) and RW ($p = .008$). Additionally, in the butterfly, significant differences were found in average velocity 5–10 m (AV5–10) ($F_{2,18} = 10.87$, $p = .001$, ES = large),

with NW outperforming both FW ($p = .021$) and RW ($p = .035$). When comparing freestyle and butterfly during the underwater phase, significant differences in glide distance (GD) were observed in FW ($p = .041$) and RW ($p = .009$), with butterfly showing greater values. Distance to first kick (DFK) was significantly higher in butterfly for FW ($p = .004$). BD was longer in butterfly across all positions (FW: $p < .001$; NW: $p = .035$; RW: $p = .001$). In contrast, breakout time (BoT) was shorter in freestyle across all positions ($p = .005-.035$). UWT was consistently longer in butterfly for all positions ($p < .001$). For T10, the butterfly was faster in RW ($p = .025$) (Table 2).

Swim Phase

In time to 15 m (T15), significant differences were observed in both strokes (freestyle: $F_{2,18} = 15.14$, $p = .001$, ES = large; butterfly: $F_{2,18} = 10.69$, $p = .001$, ES = large). In freestyle, NW was faster than both FW ($p = .001$) and RW ($p = .039$), whereas in butterfly, NW was faster than FW ($p = .001$). Additionally, significant differences in T15 were found between freestyle and butterfly across all positions (FW: $p = .003$; NW: $p < .001$; RW: $p = .006$), with butterfly demonstrating faster performance (Table 2).

Table 2. Comparison of kinematic start variables across front-, neutral-, and rear-weighted positions in freestyle vs. butterfly

Variables	Strokes	Front-weighted (M±SD)	Neutral-weighted (M±SD)	Rear-weighted (M±SD)	ES (η^2p)	Mean differences freestyle vs. butterfly (MD ± SD, ESd)		
						Front-weighted	Neutral-weighted	Rear-weighted
FKA (°)	Freestyle	136.74 ± 4.88 ³	138.42 ± 3.93 ³	141.47 ± 4.05 ^{1,2}	0.74	0.85 ± 2.08	0.14 ± 1.08	0.22 ± 1.57
	Butterfly	135.89 ± 4.50 ^{2,3}	138.27 ± 4.01 ³	141.25 ± 4.60 ^{1,2}	0.91	(0.41)	(0.14)	(0.04)
RKA (°)	Freestyle	86.28 ± 2.90 ³	85.32 ± 3.20 ³	84.26 ± 3.33 ^{1,2}	0.55	-0.09 ± 0.91	-0.49* ± 0.66	0.69* ± 0.96
	Butterfly	86.37 ± 3.10 ^{1,3}	85.81 ± 3.20 ^{1,3}	83.57 ± 3.00 ^{1,2}	0.99	(-0.09)	(-0.74)	(0.72)
RHA (°)	Freestyle	56.15 ± 2.29 ^{1,3}	53.09 ± 2.22 ^{1,3}	51.05 ± 2.19 ^{1,2}	0.99	-0.14 ± 0.41	0.34 ± 0.49	0.04 ± 0.46
	Butterfly	56.29 ± 2.58 ^{1,3}	52.75 ± 2.58 ^{1,3}	51.01 ± 2.51 ^{1,2}	0.97	(-0.34)	(0.69)	(0.09)
THA (°)	Freestyle	38.53 ± 1.94 ^{1,3}	37.47 ± 1.77 ^{1,3}	35.35 ± 1.86 ^{1,2}	0.99	-0.16 ± 0.35	-0.04 ± 0.16	-0.20 ± 0.32
	Butterfly	38.69 ± 1.92 ^{1,3}	37.51 ± 1.70 ^{1,3}	35.55 ± 1.77 ^{1,2}	0.98	(-0.45)	(-0.25)	(-0.63)
HH (cm)	Freestyle	153.1 ± 1.79 ³	151.16 ± 2.94	149.90 ± 1.84	0.56	-0.16 ± 1.90	0.23 ± 1.35	1.03 ± 2.27
	Butterfly	153.31 ± 1.90 ^{2,3}	150.92 ± 2.50 ^{1,3}	148.87 ± 2.40 ^{1,2}	0.87	(-0.08)	(0.17)	(0.45)
RT (s)	Freestyle	0.20 ± 0.01	0.19 ± 0.02	0.19 ± 0.02	0.11	-0.01 ± 0.02	0.01 ± 0.02	0.01 ± 0.04
	Butterfly	0.20 ± 0.02	0.19 ± 0.02	0.19 ± 0.01	0.21	(-0.09)	(0.04)	(0.01)
MT (s)	Freestyle	0.52 ± 0.04	0.53 ± 0.05	0.54 ± 0.04	0.22	0.01 ± 0.04	0.01 ± 0.04	-0.01 ± 0.02
	Butterfly	0.51 ± 0.04	0.52 ± 0.04	0.54 ± 0.05	0.24	(0.16)	(0.03)	(-0.09)
BT (s)	Freestyle	0.71 ± 0.06 ¹	0.72 ± 0.07 ¹	0.73 ± 0.06 ^{1,2}	0.26	-0.01 ± 0.06	0.01 ± 0.07	0.01 ± 0.07
	Butterfly	0.71 ± 0.03	0.72 ± 0.04 ¹	0.73 ± 0.04 ²	0.34	(-0.02)	(0.03)	(0.07)
TA (°)	Freestyle	35.34 ± 0.93 ^{1,3}	36.45 ± 0.75 ¹	37.00 ± 1.05 ¹	0.56	-0.23 ± 0.66	0.25* ± 0.24	0.05 ± 1.10
	Butterfly	35.57 ± 1.01 ³	36.20 ± 0.70 ³	36.95 ± 0.68 ^{1,2}	0.69	(-0.35)	(1.04)	(0.05)
EA (°)	Freestyle	34.05 ± 1.5 ^{1,3}	34.89 ± 1.58 ^{1,3}	35.68 ± 1.51 ^{1,2}	0.82	0.07 ± 0.83	0.28 ± 0.89	0.11 ± 0.88
	Butterfly	33.98 ± 1.52 ^{1,3}	34.61 ± 1.29 ^{1,3}	35.56 ± 1.33 ^{1,2}	0.54	(0.08)	(0.31)	(0.14)
FT (s)	Freestyle	0.31 ± 0.05	0.32 ± 0.04	0.33 ± 0.04	0.09	-0.01 ± 0.02	0.01 ± 0.04	-0.01 ± 0.01
	Butterfly	0.32 ± 0.04	0.32 ± 0.04	0.33 ± 0.05	0.08	(-0.19)	(0.11)	(-0.01)
FD (m)	Freestyle	2.84 ± 0.17 ¹	2.93 ± 0.20	3.00 ± 0.21 ¹	0.52	-0.02 ± 0.09	0.02 ± 0.16	0.04 ± 0.09
	Butterfly	2.86 ± 0.16 ³	2.90 ± 0.18	2.96 ± 0.17 ¹	0.46	(-0.22)	(0.14)	(0.47)
TS (s)	Freestyle	0.31 ± 0.02	0.31 ± 0.03	0.32 ± 0.02	0.09	0.00 ± 0.02	0.00 ± 0.02	0.00 ± 0.02
	Butterfly	0.31 ± 0.02	0.31 ± 0.02	0.32 ± 0.02	0.16	(0.15)	(0.15)	(0.15)
GT (s)	Freestyle	0.46 ± 0.03	0.46 ± 0.05	0.48 ± 0.10	0.15	0.01 ± 0.02	-0.02 ± 0.09	-0.01 ± 0.12
	Butterfly	0.44 ± 0.04 ^{1,3}	0.48 ± 0.05 ¹	0.49 ± 0.08 ¹	0.44	(0.58)	(-0.24)	(-0.09)
GD (m)	Freestyle	1.95 ± 0.28 ¹	2.03 ± 0.30	2.07 ± 0.28 ¹	0.46	-0.07* ±	-0.03 ± 0.09	-0.04* ± 0.04
	Butterfly	2.01 ± 0.28 ¹	2.06 ± 0.28	2.10 ± 0.27 ¹	0.54	0.09 (-0.75)	(-0.35)	(-1.05)
T5 (s)	Freestyle	1.62 ± 0.04 ¹	1.57 ± 0.04 ^{1,3}	1.60 ± 0.03 ²	0.54	0.02 ± 0.06	0.00 ± 0.06	0.02 ± 0.04
	Butterfly	1.60 ± 0.04 ^{1,3}	1.57 ± 0.04 ¹	1.58 ± 0.03 ¹	0.83	(0.25)	(0.04)	(0.56)
TFK (s)	Freestyle	1.91 ± 0.16	1.93 ± 0.18	1.96 ± 0.15	0.14	-0.01 ± 0.09	-0.02 ± 0.09	-0.03 ± 0.04
	Butterfly	1.93 ± 0.19 ²	1.95 ± 0.18 ¹	1.98 ± 0.14	0.12	(-0.13)	(-0.20)	(-0.60)
DFK (m)	Freestyle	6.73 ± 0.18 ^{1,3}	6.89 ± 0.14 ^{1,3}	7.02 ± 0.17 ^{1,2}	0.83	-0.09* ±	-0.04 ± 0.13	-0.04 ± 0.08
	Butterfly	6.82 ± 0.17 ^{1,3}	6.93 ± 0.18 ¹	7.06 ± 0.16 ¹	0.73	0.07 (-1.22)	(-0.32)	(-0.47)
BD (m)	Freestyle	10.76 ± 1.45	10.94 ± 1.52	11.00 ± 1.63	0.09	-0.95* ±	-1.03* ± 1.31	-1.14* ± 0.73
	Butterfly	11.71 ± 1.42	11.97 ± 1.44	12.14 ± 1.52	0.12	0.25 (-3.84)	(-0.79)	(-1.57)
BoT (s)	Freestyle	4.83 ± 0.72	4.57 ± 0.78	4.64 ± 0.81	0.04	-0.59* ±	-0.68* ± 0.87	-0.70* ± 0.73
	Butterfly	5.42 ± 0.70	5.25 ± 0.72	5.33 ± 0.76	0.03	0.50 (-1.17)	(-0.78)	(-0.95)
UWT(s)	Freestyle	3.46 ± 0.43 ¹	3.45 ± 0.47 ¹	3.70 ± 0.43 ^{1,2}	0.40	-0.71* ±	-0.62* ± 0.35	-0.60* ± 0.34
	Butterfly	4.17 ± 0.31	4.07 ± 0.36	4.30 ± 0.31	0.30	0.20 (-3.47)	(-1.75)	(-1.78)
T10 (s)	Freestyle	4.10 ± 0.10 ¹	3.98 ± 0.12 ^{1,3}	4.07 ± 0.13 ²	0.57	0.07 ± 0.18	0.12 ± 0.18	0.17* ± 0.20
	Butterfly	4.07 ± 0.10 ^{2,3}	3.86 ± 0.09 ^{1,3}	3.91 ± 0.11 ^{1,2}	0.87	(0.39)	(0.67)	(0.85)
T15 (s)	Freestyle	6.99 ± 0.20 ^{1,3}	6.81 ± 0.20 ¹	6.86 ± 0.21 ¹	0.63	0.17* ±	0.17* ± 0.09	0.18* ± 0.16
	Butterfly	6.82 ± 0.15 ¹	6.64 ± 0.18 ¹	6.68 ± 0.19	0.54	0.13 (1.30)	(1.90)	(1.12)
AV 5–10 m (m/s)	Freestyle	2.00 ± 0.24	2.10 ± 0.27	2.02 ± 0.19	0.16	-0.04 ± 0.34	-0.10 ± 0.34	-0.14 ± 0.33
	Butterfly	2.04 ± 0.19 ^{2,3}	2.20 ± 0.19 ¹	2.16 ± 0.20 ¹	0.55	(-0.12)	(-0.30)	(-0.43)
AV 10–15 m (m/s)	Freestyle	1.82 ± 0.24	1.81 ± 0.27	1.82 ± 0.23	0.00	0.01 ± 0.24	0.01 ± 0.26	0.01 ± 0.19
	Butterfly	1.83 ± 0.14	1.80 ± 0.08	1.81 ± 0.12	0.02	(-0.01)	(0.05)	(0.06)

¹ Significantly different to front-weighted FW, $p < 0.05$; ² Significantly different to neutral-weighted NW, $p < 0.05$; ³ Significantly different to rear-weighted RW, $p < 0.05$; *Significantly differences freestyle vs. butterfly, $p < 0.05$; MD - mean differences; ES - effect size (partial eta squared); ESd - effect size (Cohen's d)

Discussion

This study examined the effects of three different kick-start positions on 15-m start performance in freestyle and butterfly using the OSB12 starting platform. The results indicated that the NW position was, on average, the most effective for achieving optimal start performance in both strokes. Across all positions, butterfly consistently outperformed freestyle, with statistically significant differences observed particularly during the underwater phase ($p < 0.05$). These findings highlight the importance of even weight distribution between the front and rear legs and demonstrate that start performance is determined not by a single phase, but by the integrated interaction of the block, flight, underwater, and swimming phases.

Block Phase

In the block phase, our results demonstrated that the NW position provided an optimal combination of vertical and horizontal force components, resulting in significantly shorter start times at 5, 10, and 15 m ($p < 0.05$). Similarly, Barlow et al. (2014) reported on OSB11 starting blocks that both NW and RW positions produced faster 15-m times compared with the FW position. Rudnik et al. (2022, 2023) further highlighted the importance of kick-plate positioning and gender-specific differences, with men benefiting from stronger rear-leg drive. These findings suggest that appropriately adjusting the kick-plate to individual preferences can substantially improve both the block phase and overall start performance. Previous studies have consistently highlighted the distinct roles of each leg during the kick-start. Ozeki et al. (2012), Ikeda et al. (2016), Takeda et al. (2017), and Ozeki et al. (2017, 2018) reported that the front leg primarily generated vertical force, whereas the rear leg, in combination with the kick-plate, produced horizontal acceleration. This functional division supports the effectiveness of the NW position, where the synergy of both components is optimally used. Burkhardt et al. (2020) emphasized the rear leg's role in generating horizontal impulse, while Shepherd et al. (2023) identified horizontal velocity of the center of mass at take-off as a key predictor of start performance. Other findings indicate that an RW position may enhance take-off velocity without necessarily producing faster start times. Honda et al. (2012) and Kibele et al. (2015) demonstrated that shifting the body into the RW position increased take-off speed and prolonged the flight phase, yet did not consistently lead to shorter times at 7.5 or 15 m—an outcome also observed in our data. Reaction time (RT) did not differ significantly between positions in our study, consistent with Silva et al. (2019), who reported stable RT values at championship events. In contrast, Silveira et al. (2018) identified rear-leg impulse and BT as the main predictors of kick-start performance. García-Ramos et al. (2013, 2015) further demonstrated that horizontal velocity and acceleration during take-off are closely associated with 5–15 m times, in agreement with our results. More recent studies by Cicienia et al. (2020) and Kao et al. (2018) have emphasized the importance of individualized kick-plate settings and strength preparation. Yang (2018) additionally highlighted that adapting the technique to the newer OSB11/12 starting blocks is crucial, providing context for the methodology used in our study.

Flight Phase

In our study, the RW position extended the flight phase and increased the take-off angle, with flight distance being significantly greater than in the FW position for both freestyle and butterfly ($p < .05$). However, these differences in the flight phase did not translate into improved start performance because they did not result in shorter 15-m times. This finding aligns with our observation that the NW position provided greater stability and efficiency in linking the flight and underwater phases. Previous research has highlighted key biomechanical determinants of flight effectiveness. Van Dijk et al. (2020) demonstrated that the horizontal velocity of the center of mass and the entry angle are key factors influencing 15-m performance. Taladriz et al. (2016) reported that the control of angular momentum during flight determines the body angle at water entry and the subsequent glide trajectory, which in turn affects the underwater phase. Hyodo and Wada (2020) further showed that actively engaging the upper limbs shifts the take-off vector closer to horizontal, thereby promoting a more efficient transition into the underwater phase.

Underwater Phase

The greatest statistically significant differences ($p < 0.05$) between positions were observed in GD and the first kick. The RW position extended both the glide and the distance to the first kick, whereas the NW position produced the highest start performance at 10 and 15 m. Hermosilla et al. (2021) identified flight distance, mean velocity between 5–10 m, and maximum hip depth as the primary predictors of glide-phase effectiveness. Tor et al. (2015) confirmed that an entry depth of approximately 1 m most effectively minimized drag. Trinidad (2021) highlighted that the key to a successful underwater phase was the timing of the first kick and the efficient transition from glide to kicking. Gonjo and Olstad (2020) highlighted the greater significance of the underwater phase in butterfly compared with freestyle, which helps explain why butterfly swimmers in our sample achieved significantly faster performance ($p < 0.05$). Wądrzyk et al. (2022) recommended adopting a higher hip position at the start signal to extend GD. A similar effect was observed in our swimmers; however, the prolonged glide did not translate into improved 15-m performance. This suggests that glide length alone is not decisive unless accompanied by sufficient horizontal velocity and optimal breakout timing, as previously highlighted by Tor et al. (2014) and Hermosilla et al. (2021). In line with this, Veiga and Roig (2016) and Arellano et al. (2022) demonstrated that the quality of the underwater phase directly influenced overwater velocity after breakout, reinforcing the importance of analyzing the entire 15-m segment.

Swim Phase

In our results, butterfly was significantly faster than freestyle across all positions ($p < .05$). However, Tor et al. (2014) reported that, although butterfly involved a longer and deeper underwater phase, the overall 15-m time in elite swimmers did not differ from freestyle because freestylers compensated for a shorter underwater phase with higher overwater velocity. Our swimmers did not demonstrate this compensatory ability, which accentuated the advantage of the butterfly. Morais et al. (2018) further showed that men achieve higher start velocities in butterfly, consistent with our findings. Vantorre et al. (2014) emphasized that technical variability in the start serves a functional role, allowing swimmers to adapt to their individual strength and kinematic profiles. This aligns with our results, which indicated that while the NW position was generally the most effective, some swimmers benefited from alternative configurations. These findings underscore the importance of technical variability and highlight the need for a personalized approach to start training.

Conclusions

This study showed that the NW position on the OSB12 starting platform produced the best overall start performance in both freestyle and butterfly. In addition to achieving the shortest 15-m time, the NW position was linked to faster early-distance outcomes (5-m and 10-m), indicating that its advantage appeared early and persisted throughout the 15-m distance. Across all three positions, butterfly achieved significantly faster 15-m times than freestyle ($p < 0.05$), with the most pronounced between-stroke differences observed in underwater-phase characteristics. These findings highlight the practical importance of underwater execution for optimizing start performance. Although the RW position increased flight distance and extended glide-related distances, including the distance to the first kick, these changes did not lead to improved 15-m performance. This suggests that maximizing aerial or underwater distance alone is insufficient unless it supports higher velocity and an effective transition to swimming. From an applied perspective, coaches may adopt the NW kick-start position as a practical baseline on the OSB12 platform and then individualize adjustments based on each swimmer's characteristics. Importantly, optimization should consider the start as an integrated sequence—including block, flight, underwater, and swimming phases—rather than focusing on isolated phase outcomes. Future research should validate these findings in larger and more diverse samples, including female swimmers, under competition-like conditions, and using combined kinematic and kinetic analyses to better understand how individual technique interacts with start configuration.

Declaration of generative AI and AI-assisted technologies in the writing process

The author(s) declare that no generative AI or AI-assisted technologies were used in the preparation of this manuscript.

Conflicts of interest The authors declare that they have no conflicts of interest.

Limitations

This study has several limitations that should be considered when interpreting the results. First, the relatively small sample size ($n = 10$), although appropriate for a repeated-measures design, limits the generalizability of the findings to the broader swimming population. Second, only male swimmers participated, preventing any conclusions regarding potential sex-related differences. Third, the laboratory-based testing design enabled detailed kinematic analysis but may not fully reflect competitive swimming conditions.

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