

Kinematic Parameters of the Kick Start: A Systematic Review

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Abstract

This study aimed to analyse recent changes in the kinematic parameters of the kick start. Following PRISMA guidelines, a systematic review was conducted using Web of Science, Scopus, PubMed, and EBSCO. The primary search term kick start was combined with swimming, swimming start, biomechanics, and performance. After screening 665 studies and applying the inclusion criteria, 18 studies analysing kick-start kinematics were included. This research is part of VEGA project No. 1/0462/22, titled "The effect of starting block configuration on the kinematic parameters affecting starting performance in swimming." The review highlights differences across the block, flight, underwater, and swim phases by gender, swimming style, and performance level. Across studies, block time ranged from 0.68–0.91 s in junior swimmers, 0.66–0.72 s in senior swimmers, and 0.59–0.72 s in elite swimmers. Elite swimmers also achieved take-off horizontal velocities of 4.37–4.58 m·s⁻¹. The start performance at 15 m was 6.31–6.72 s in senior and 6.33–6.41 s in elite swimmers compared with 6.94–7.09 s in junior competitive swimmers, with women being approximately 1 s slower. Technique modifications associated with faster early-race performance consistently included kick-plate settings 3–4 and neutral-/rear-weighted set positions; a narrow stance improved time to 5 m by 0.08 s compared with a wide stance, and faster starters demonstrated a higher hip position at the start signal (1.56±0.05 m vs. 1.45±0.05 m). Findings provide valuable insights for swimmers and coaches, aiding in technique refinement. Given its use in elite competitions, optimising the kick start can lead to measurable performance gains, reinforcing the need for targeted training approaches.

Keywords: *biomechanics, performance, phase, kick plate, starting platform, starting block*

Introduction

Performance in sprint swimming disciplines is continually advancing, resulting in new milestones such as the 50-meter freestyle, where, for the first time in swimming history, Jordan Crooks from the Cayman Islands completed the race in under 20 seconds (19.90 s), setting a new world record at the 2024 World Championships in Budapest (WA, 2024). The swimming start is defined as the interval from the start signal to the moment the swimmer's head crosses the 15-meter mark (Cossor & Mason, 2001). A key aspect of this performance is the start (the first 15 meters), which is continuously evolving in the search for the optimal starting technique that allows swimmers to achieve the shortest possible time, particularly in sprint disciplines (Barlow et al., 2014; Tor et al., 2015). The technical execution of the swimming start is closely linked to the history of swimming performance and to the modernisation of starting blocks at elite swimming events (Taladriz Blanco et al., 2017). Initially, swimmers used the grab start technique, followed by the track start, and currently, with the

introduction of the new Omega OSB11 starting block (since 2009), which features an adjustable kick plate, swimmers use the kick start technique. This new starting block offers a position similar to the track start, with the advantage of placing the rear lower limb on a stable kick plate (adjustable to positions 1–5), which each swimmer can customise according to their preferences (Rundik et al., 2022; Swiss Timing, 2019). Ozeki et al. (2012) report a shorter time to 15 meters (0.14 s) in elite swimmers using the kick start technique than with the track start. Since the kick-start technique is now used at all major competitions, the grab-start and track-start techniques are becoming obsolete. Some studies have focused on evaluating the start without undulation and the first swimming movements at 5 meters (Matúš et al., 2022; Matúš et al., 2024b; Silveira et al., 2018). These studies aimed to assess the effectiveness of the basic position on the starting block in relation to time at 5 meters. Other studies have evaluated the start at 10 meters (Djurkovic et al., 2019) and 15 meters (Qiu et al., 2021; Rudnik et al., 2021; Rudnik et al., 2023; Sanchez et al., 2021; Shepherd et al., 2023), where at 15 meters,

the start as a whole was assessed in terms of the individual phases that follow one another – above-water phase (block and flight phase), underwater phase, and swim phase. The swim phase varies by stroke, with breaststroke swimmers exhibiting a longer underwater phase than freestyle swimmers (Matuš et al., 2024a; Matuš et al., 2024c). In the block phase, various studies have focused on the basic position on the starting block (Matuš et al., 2020; Matuš & Kandrác, 2020; Rudnik et al., 2022; Wardzyk et al., 2022). Optimisation has mainly focused on the basic setting of the kick plate and the swimmer's body position. In terms of phase duration, this is the second-shortest phase contributing to performance at the start, but it is also the initial phase that can influence performance in subsequent phases (Tor et al., 2014). Some studies recommend setting the kick plate to the 3-4 level with a neutral- or rear-weighted basic position (Matuš et al., 2020; Matuš et al., 2022; Matuš & Kandrác, 2020). Other studies suggest placing the stronger or non-preferred lower limb on the kick plate (Burkhard et al., 2020; Matuš et al., 2022), as swimmers with their preferred lower limb placed at the front edge of the starting block achieved a shorter time to 5 meters (Matuš et al., 2022). In Matuš et al. (2024b), narrow and wide positions were evaluated, with performance swimmers achieving shorter times to 5 meters in the narrow position. In the above-water phase, block time and take-off velocity were identified as reliable parameters for start-ups at 15 meters (Burkhard et al., 2020). Djurkovic et al. (2019) also reported a positive effect of block time on 10-meter time. The underwater phase, in terms of time, is one of the longest phases of the start (Tor et al., 2014). Djurkovic et al. (2019) noted the impact of underwater time on 10-meter time, where, in freestyle on the 50 meters, intersex differences were more evident in underwater time ($p < 0.01$) than in underwater distance ($p < 0.05$). Swimmers at depths of -0.9 to -1.1 meters achieved shorter times at 5 and 15 meters. The kinematic outcomes of the swimming start may vary across swimmer characteristics and race demands. However, evidence on kick-start kinematics is currently fragmented across studies that assess different distances (e.g., 5, 10, and 15 m), apply inconsistent phase definitions, and report heterogeneous outcome measures, which limits direct comparison and clear practical interpretation. Therefore, an up-to-date synthesis is needed to systematise the available findings and identify consistent patterns and remaining gaps in the literature. This study aimed to analyse recent changes in kinematic parameters of the kick-start technique. Based on this objective, 18 studies analysing kinematic parameters in the kick start were selected and reviewed. With this aim, the results in the discussion were divided into four phases – block, flight, underwater, and swim phase – from the perspectives of sex, stroke type, and performance.

Material and methods

The systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Haddaway et al., 2022). This systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD420251268896.

Search strategy

Data acquisition and processing consisted of several steps. The first step was to search the available resources related to our review study. The search was made in November 2024 and was restricted based on the publishing year. To obtain information concerning selected kinematic characteristics of kick start, was used scientific articles registered in databases: Web of Science, Scopus, PubMed, Ebsco. Consequently, the main search term keyword was kick start together with the following keywords and their combinations: swimming, swimming start, biomechanics, performance.

Inclusion and exclusion criteria

The results of the database searches were entered into the web-based programme Rayyan.ai (Ouzzani et al., 2016), which was used to screen the abstracts independently by all authors. The inclusion criteria for studies included in the systematic review were as follows: (a) the study was published in 2019-2024; (b) paper with an experimental analysis, which reported quantitative results of the analyzed variables; (c) studies involved the swimming sport reporting results of kick start techniques; (d) high competitive level of the sample, elite or international and national swimmers; (e) human participants without diseases of pathologies (f) written in English. Articles were excluded for the following reasons: (a) data aside kinematic characteristic; (b) irrelevant data for analysis; (c) unavailable full text; (d) duplicates; (e) systematic review. The included studies analysed the start performance by examining the block, flight, underwater, and swim phases, with respect to sex, stroke type, and performance level.

Data extraction, quality assessment and risk of bias

Two independent reviewers performed the search, screened the titles and abstracts from the search results using the web-based programme The Rayyan.ai (Ouzzani et al., 2016) and reviewed the selected full texts before inclusion. The sample size, the objectives and the main results of the kinematic characteristic of kick start were extracted from each selected study. Quality assessment was performed by two reviewers (K.N.; T.E.). A third reviewer was consulted to resolve any disagreements (I.M.).

The methodological quality and risk of bias of the included studies were independently assessed by two reviewers using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. This tool consists of 14 items evaluating key sources of bias, including clarity of the research question, study population definition, participant selection, sample size justification, outcome measurement validity and reliability, and appropriateness of statistical analyses. Each item was rated as "Yes", "No", or "Cannot determine/Not reported/Not applicable". Based on the overall assessment, studies were classified as good, fair, or poor quality, reflecting their overall risk of bias. Any disagreements between reviewers were resolved through discussion. When consensus could not be reached, a third reviewer was consulted.

Variables definitions

Several definitions of temporal, kinematic and kinetic variables have been used for a detailed biomechanical analysis of the swimming kick-start. In order to clarify the infor-

mation provided in this systematic review, a definition of the most common variables used in the different studies was provided (Table 1).

Table 1. Variables definition

Phase	Variables	Units	Definition	
Block phase	Front knee angle	FKA	°	Hip/ankle at the set position
	Front ankle angle	FAA	°	Knee/ankle/finger toe at the set position
	Rear knee angle	RKA	°	Hip/ankle at the set position
	Rear ankle angle	RAA	°	Knee/ankle/finger toe at the set position
	Hip angle	HA	°	Ankle/hip/shoulder
	Block time	BT	s	Starting signal—feet separation from the platform
	Reaction time	RT	s	The time interval between the starting signal and a change in starting block reaction force curve as a result of the initial movement
	Hands take-off	HTo	s	The time interval between the starting signal and the last contact of the hands with the starting block
	Hands take-off: reaction time	HTR	s	The time interval between the starting signal and the last contact of the hands with the starting block, reduced by the reaction time
	Rear foot take off	RFT	s	The time interval between the starting signal and the last contact of the rear foot with the starting block
	Rear foot take off: reaction time	RFTR	s	The time interval between the starting signal and the last contact of the rear foot with the starting block, reduced by the reaction time.
	Front foot support	FFS	s	The time interval between the last contact of the rear foot with the starting block and the moment when total vertical force fell to zero
	Movement time	MT	s	The time interval from the first visible change in starting block reaction force curve and the instant when total vertical force fell to zero
	Take off horizontal velocity	Vx	m/s	Magnitude of the horizontal velocity of the CoM vector at take-off
Take off vertical velocity	Vy	m/s	Magnitude of the vertical velocity of the CoM vector at take-off	
Take off velocity	Vt	m/s	The total velocity of swimmer's centre of mass at the instance of take-off.	
Flight phase	Entry angle	EA	°	Horizontal/fingertips/hip joint
	Entry velocity	EV	m/s	The horizontal velocity which the swimmer travels through the air during the entry phase.
	Take-off angle	TA	°	Ankle/hip/horizontal
	Take-off head position	HP	m	Water surface/head
	Time to 2 m	T2	s	Starting signal/head crosses the 2 m
	Flight time	FT	s	Take-off/hand entry
	Flight distance	FD	m	Take-off/hands touch the water
	Flight velocity	FV	m/s	Mean horizontal head velocity at time from loss of contact with starting block to submersion of head in water
Underwater phase	Glide time	GT	s	Hand entry/head crosses the 5 m
	Glide distance	GD	m	Hands touch the water/head crosses the 5 m
	Glide velocity	GV	m/s	Mean horizontal head velocity during glide phase
	Maximal depth	MaxH	m	Head reaches the maximum depth
	Time to 5-m	T5	s	Starting signal—head crosses the 5 m
	First kick time	FKT	s	Time from the swimmer's fingers first touching the water to the moment they completed the first underwater down kick.
	First kick distance	FKD	m	The horizontal distance between the wall and swimmer's head when they completed the first underwater down kick.
	Underwater time	UWT	s	The time of the first contact of the swimmer's hands with the surface of the water until the swimmer's head breaks the surface of the water.
Underwater distance	UWD	m	The distance of the first contact of the swimmer's hands with the surface of the water until the swimmer's head breaks the surface of the water.	

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Table 1. Variables definition

Phase	Variables	Units	Definition	
Swim phase	Time to 10-m	T10	s	Starting signal–head cross the 10 m
	Time to 15-m	T15	s	Starting signal–head cross the 15 m
	Time 5- 10-m	T 5-10	s	The time interval between the moment when the head crossed the 5-m mark and the moment when the head reached the 10 m distance from the starting line
	Time 10-15-m	T 10-15	s	The time interval between the moment when head crossed the 10-m mark and the moment when the head reached the 15-m distance from the starting line
	Swim time to 15 m	ST	s	The time of the swim from the time the swimmer’s head crosses the surface of the water until the swimmer’s head has again crossed the 15 m distance
	Swim distance to 15 m	SD	m	The distance of the swim from the time the swimmer’s head crosses the surface of the water until the swimmer’s head has again crossed the 15 m distance.

Results

Data search and characteristics of the studies

A total of 665 studies were screened; after applying the

inclusion criteria, 18 studies were included in the systematic review. The screening and selection processes are shown in Figure 1.

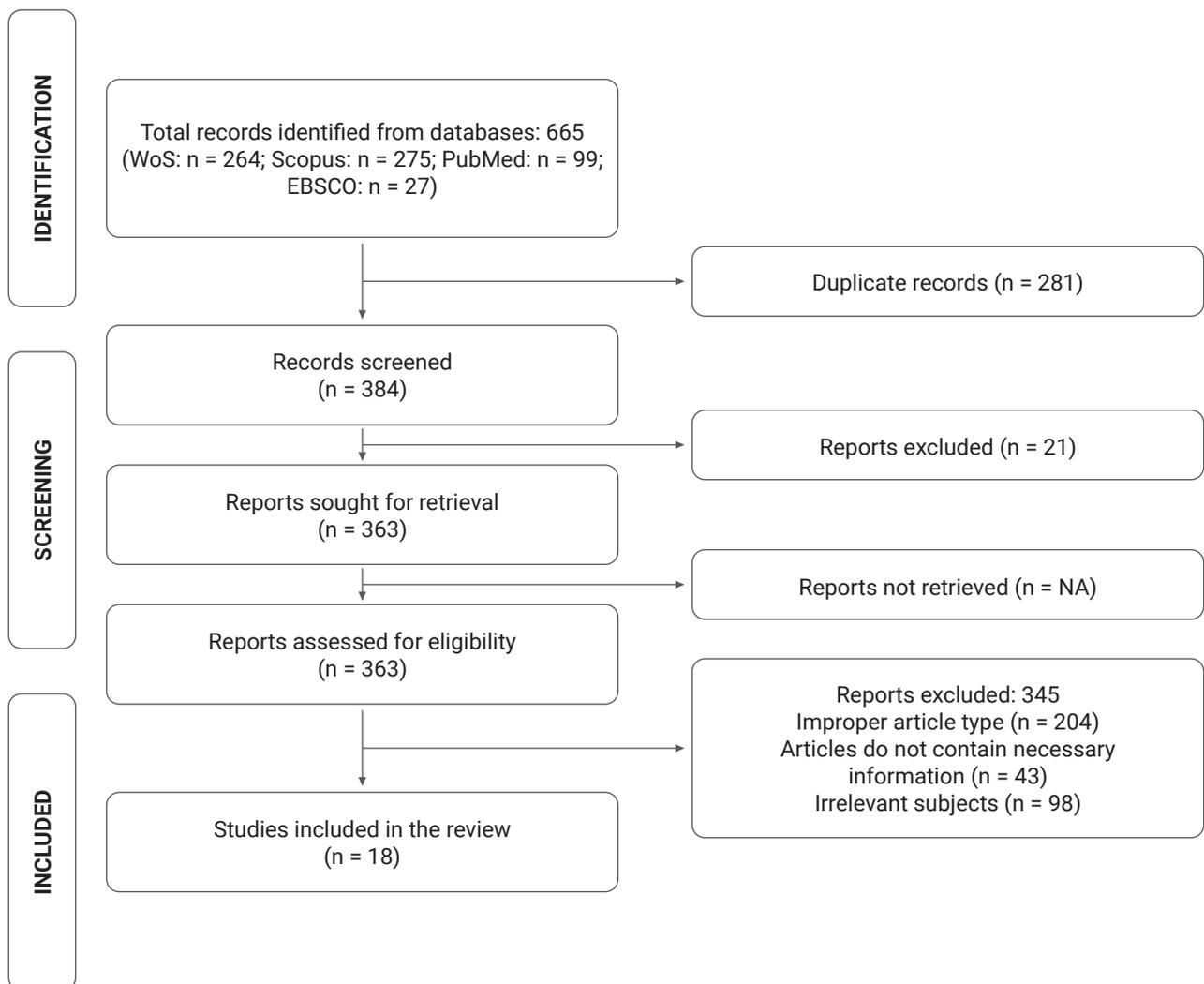


Figure 1. Prisma Flow diagram

Quality of the Studies

The methodological quality of the included studies was generally high. According to the NIH Quality Assessment Tool, 12 studies were rated as good quality and 6 as fair quality. No study was classified as poor. The most common sources of potential bias were the absence of sample size justification, relatively small sample sizes, and limited reporting

of assessor blinding. In contrast, outcome measurement bias was considered low, as the majority of studies used validated biomechanical measurement systems (e.g., force plates, high-speed cameras, and 3D motion analysis). Overall, the risk of bias across studies was judged as low to moderate and was unlikely to substantially affect the main conclusions of this review (table 2).

Table 2. Methodological quality and risk of bias assessment of included studies (NIH tool)

Study	Study design	NIH score (0–14)	Quality rating	Overall risk of bias
Djurovic et al. (2019)	Cross-sectional	10	Good	Low–moderate
Burkhardt et al. (2020)	Cross-sectional	11	Good	Low
Cicenia et al. (2020)	Cross-sectional	9	Fair	Moderate
Matuš et al. (2020)	Cross-sectional	10	Good	Low–moderate
Matuš & Kandrác (2020)	Cross-sectional	10	Good	Low–moderate
Qiu et al. (2021)	Cross-sectional	11	Good	Low
Matuš et al. (2021a)	Cross-sectional	10	Good	Low–moderate
Matuš et al. (2021b)	Cross-sectional	10	Good	Low–moderate
Sánchez et al. (2021)	Cross-sectional	11	Good	Low
Matuš et al. (2022)	Cross-sectional	9	Fair	Moderate
Rudnik et al. (2022)	Cross-sectional	11	Good	Low
Wardzyk et al. (2022)	Cross-sectional	9	Fair	Moderate
Hyodo & Wada (2023)	Cross-sectional	8	Fair	Moderate
Rudnik et al. (2023)	Cross-sectional	11	Good	Low
Shepherd et al. (2023)	Cross-sectional	10	Good	Low–moderate
Matuš et al. (2024a)	Cross-sectional	11	Good	Low
Matuš et al. (2024b)	Cross-sectional	10	Good	Low–moderate
Matuš et al. (2024c)	Cross-sectional	11	Good	Low

Summary of included study

The studies focused on the start, block, flight, underwater, and swim phases, considering factors such as sex, stroke type, and performance level. A detailed summary of each in-

cluded study is presented in Table 3.

Tables 4 and 5 present detailed values of individual kinematic parameters in the block, flight, underwater and swim phases by sex.

Table 3. Summary of each study included in the review

Authors	Subjects	Objective	Kinematics	Start block	Main results
Djurović et al. (2019)	25 male, competitive	Examine the influence of starting parameters on time to 10 m which determines the efficiently executed swimming start.	RT, FT, FD, FV, EV, UWT	SO2-X starting block	The results indicated the significant statistical influence of all system of predictors variables on swimming start up to 10 m (F=1353.9, p=0.000). Influence of starting parameters in the function of the swimming start efficiency are represented by: Under-water time (t=66.1, p=0.000). Entry_Velocity (t=-13.174, p=0.000). Flight_time (t=9.541, p=0.000). Reaction_time (t=2.877, p=0.010). Flight_distance (t=-2.667, p=0.016) and Flight_Velocity (t=2.528, p=0.021), respectively.
Burkhardt et al. (2020)	15 (13 male, 2 female), competitive	Investigate the reliability of the KISwim with its kinematic and kinetic parameters and to identify the Key Performance Indicators for the kick-start using a Principal component analysis; to determine whether the most beneficial position of the strong leg is in the front or at the back of the starting block and investigate the effect of an acute reversal of the leg positioning.	T1.5BT, MaxH, 7.5, Vx	Omega OSB11 starting block	Kinematic and kinetic parameters showed high reliability (ICC>0.75) from which principal component analysis identified seven KPI (i.e., time to 15 m, time on-block, depth at 7.5 m, horizontal take-off velocity, horizontal impulse back plate, horizontal peak force back plate and vertical peak force front plate). For the preferred start position, the back plate showed a higher horizontal peak force (0.71 vs. 0.96 x body mass; p<0.001) and impulse (0.191 vs. 0.28Ns/BW, p<0.001) compared to front plate. Plate-specific kinetic analysis revealed a larger horizontal peak force (p<0.001) and impulse (p<0.001) for the back compared to the front plate in any start position investigated.
Cicenia et al. (2020)	20 (8 female, 12 male), elite	Use shin length as a measure to determine kick plate position and effects on performance.	RT, BT, FT, FD, UWT, T15, RKA, RAA	-	BT was significantly different, (F(2,38)=4.264, p=0.026). BT was lower when the kick plate distance was one shin length versus shin length (0.691±0.055 vs 0.715±0.056 sec) and shin length (0.691±0.055 vs 0.698±0.056 sec), p<0.05.
Matuš et al. (2020)	10 male, competitive	Determine differences in the front and rear knee angles depending on the body and kick plate positions during the kick start from OSB12.	BT, FKA, RKA, TA, EA, FD, GD, T5	OSB12 starting block	Changes in all studied swim start parameters between the front-weighted position and rear-weighted position for all kick plate positions (p<.05). Swimmers produced shorter times to 5 meters when the front knee angle and rear knee angles in the starting position ranged from 1300 - 1320 and 760 - 820, respectively. The rear-weighted position produced higher takeoff and entry angles, shorter glide distance than the front-weighted or neutral-weighted position.
Matuš, Kandrác (2020)	8 male, performance-level	Determine kinematic parameters underlying the kick start from OSB12 in terms of the kick plate position and shoulder positioning at the start.	FKA, RKA, HA, BT, EA, TA, HP, T2, FT, FD, G1GD, MaxH	OSB12 starting block	Significant differences (p<0.05) in the selected kinematic parameters in all phases, which depended on the OSB12 kick plate position and basic starting position (front-, neutral-, and rear-weighted). The greatest differences in the parameters measured were found between the front-weighted start and rear-weighted start.
Qiu et al. (2021)	12 male, elite	To compare the kinematic characteristics of individual and relay swimming starts and to relate the kinematic variables of both starts to the 5 m start performance.	BT, FT, Vx, Vy, Vt, EA, EV, TA, FT, MaxH, MaxHT, T5, FKt, FKd, UWT, UWD, T10	Omega OSB11 starting block	The results indicated moderate to much faster 5 m, 10 m, 15 and 15 m times (29.4, 10.7 and 6.5%) for relay than individual starts as well as the differences at specific parameters, but no differences in take-off horizontal velocity between start techniques. Large correlations to performance times were found in block time, horizontal take-off velocity, take-off velocity and entry angle (r=0.77 to 0.83), 20 for individual start, but in changeover time, take-off height and entry distance (r=0.69 to 0.90) for relay start. Differences on swim start regulations between individual and relay events were in line with different key parameters related to start performances in each event.
Matuš et al. (2021)	18 male, competitive	Determine the key parameters affecting kick start performance expressed as the time to 5 m without underwater undulating and kicking. And to identify the contribution of particular start phases to the time to 5 m.	FKA, RKA, FAA, RAA, HA, SP, BT, EA, TA, HP, T2, FT, FD, GT, GD, MaxH, T5	OSB12 starting block	Significant correlations (p<0.01) between the front ankle angle and block time was found. Statistically significant correlations (p<0.01) between block time and rear ankle angle, respectively, to time to 2 m; rear-knee angle and glide time; block time and time to 5 m; time to 2 m and time to 5 m; and flight distance and glide distance. The multiple regression analysis showed that the on-block phase and flight phase parameters, respectively, contributed 64% and 63% to the time to 5 m.
Matuš et al. (2021)	20 females, competitive	Examine differences in starting and kick-plate positions, pointing to an effect on kick-start performance with the dominant and non-dominant feet placed on the front edge of the OSB12 starting block.	FKA, FAA, RKA, RAA, HA, BT, TA, HP, T2, EA, FT, FD, GT, GD, MaxH, T5	OSB12 starting block	The results demonstrate the importance of leg dominance and positioning on the OSB12 starting block. When the dominant leg was placed on the front edge of the starting block (p<0.05; Cohen's d=large effect), swimmers produced shorter block times and times to 2 and 5 m. For most of the tested swimmers, the optimal basic position on the starting block included neutral- and rear-weighted positions with the kick plate set to positions 3-4 and the right leg placed on the front edge of the OSB12 starting block.
Sánchez et al. (2021)	234 (132 male, 102 female), national	Analyse the influence of the breaststroke underwater phase on 50 and 100m performance.	T15	-	High correlations were obtained for both events and genders between start time and final time (r=0.76-0.91). The emersion velocity was higher in 50 m than in 100 m (p<0.001; d=1.0) and in 70 males (50m: 2.18±0.10 m·s ⁻¹ ; 100m: 1.87±0.08 m·s ⁻¹) than in females (50 m: 1.92±0.09 m·s ⁻¹ ; 100 m: 1.71±0.08 m·s ⁻¹). Performance in both events was influenced significantly by turn velocity (r≥0.85), and combined with the start, contributed to around 55% of the final time.
Matuš et al. (2022)	12 male, competitive	Identify correlations between jumping abilities and time to 5-m distance during the OSB12 kick start.	FKA, FAA, RKA, RAA, HA, SP, BT, EA, TA, HP, T2, FT, FD, GT, GD, MaxH, T5	OSB12 starting block	For THTR, a correlation with time to 5-m distance was observed (p<0.05). There was a correlation (p<0.05) between SJ and time to 5-m distance. For CMJRA, a correlation with time to 5-m distance was observed (p<0.05). The highest correlation (p<0.01) was found between CMJRA and time to 5-m distance.

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Table 3. Summary of each study included in the review

Rudnik et al. (2022)	38 (19 males, 19 females), international	Evaluate the ventral start performance using different back plate positions and to observe the eventual movement pattern adaptations of swimmers associated with those changes.	BT, RT, Hto, RFT, RFT, FFS, MT, T15	OMEGA OSB 14 starting block	In males, the 15 m start time was 0.1 s shorter for the preferred position compared with the backward position (p<0.05). Regardless of the back plate positioning, the swimmers spent a similar time on the block. A more forward position of the back plate postponed the rear foot take-off and consequently reduced the front foot stand duration. A back plate position effect was revealed for those variables with a larger effect size in males whereas in females, a change of about two positions was needed to reach a significance level.
Wardzyk et al. (2023)	20 male, -	Analyse kinematic parameters of above- and underwater kick start phases among young male swimmers.	FKA, RKA, BT, EA, TA, FT, FD, GT, GD, GV, MaxH, T15	OSB11 starting block	F and ss demonstrated differences (p<0.05) regarding hip joint height at starting signal (1.56±0.05 m vs. 1.45±0.05 m), push-off angle (23.89±6.50° vs. 35.12±3.43°), hip joint angle upon completing push-off (163.83±8.37° vs. 149.73±9.93°), and horizontal velocity during flight (3.70±0.35 m/s vs. 3.24±0.22 m/s), submerison (4.88±0.09 m/s vs. 4.36±0.22 m/s), and glide phase (3.40±0.17 m/s vs. 2.99±0.29 m/s)
Hyodo, Wada (2023)	14, not mention	Clarify the effect of the presence or absence of upper limb movement on the propulsion direction body velocity (TPV) leaving the platform at kick start.	Vy, TA	SEIKO starting block	In the movement speed at the time of leaving the platform, the standard trial had a significantly higher value in the propulsion direction and a significantly lower value in the vertical movement speed than the lower trial. The standard trial had a significantly lower value in the jumping angle when leaving the platform, the role of the upper limb movement in kick start is to promote by making the jumping angle closer to the horizontal when leaving the platform.
Rudnik et al. (2023)	52 (22 male, 30 female), international	Explore sex diversity with regard to the variability of the spatiotemporal variables of the kick-start technique and to determine the effect of sex heterogeneity on the biomechanical characteristics of swimming start by investigating the determinants of its performance.	FKA, FAA, RKA, RAA, HA, BT, TA, HP, T2, EA, FT, FD, GT, GD, MaxH, T5	OMEGA OSB 14 starting block, replica	A sex effect was exposed for temporal variables describing all swimming start phases (p<0.015). Male swimmers, by spending less time during the push-off from the starting block (p=0.002; np2=0.18), reaching higher take-off velocity (p<0.001; np2=0.29), traveling longer distances during flight (p<0.001; np2=0.40), and swimming faster in the water phase (p<0.001; np2=0.40). Male participants were faster than females (p<0.001; np2 ≥ 0.40). Significant correlation between variables describing overall starting performance (5-m, 10-m, and 15-m times), and variables commonly highlighted as starting performance determining factors (block phase duration, take-off horizontal velocity, and flight distance) was found in male.
Shepherd et al. (2023)	24 (14 female, 10 male), elite	Understand how a swimmer's body segment orientations and mass centre velocity at toe off, entry distance and flight time affect start performance.	Vx, Vy, FT, T5, T10, T15	-	Whilst time to 5 m (starting performance) differed by 0.17 s between genders, body position at toe off showed no significant differences. The difference in start performance was mainly due to a difference in horizontal velocity at toe off. The relationship between arm angle and start performance warrants further investigation as there was a range of techniques adopted but no clear link to performance. The trunk angle at toe off was correlated to starting performance for both males and females.
Matuš et al. (2024)	194 (99 male, 95 female), national	Show the differences in kinematic parameters of the start and performance in the sprint event of 50 m breaststroke from the perspective of gender in different age groups at international competitions organized in Slovakia.	BT, FT, FD, UWT, UWD, ST, SD, T15	OSB 11 starting blocks	Statistically significant differences (p<0.01) in females were found in the above-water phase in BT, FT, and FD between K3 and K1. The underwater phase in UWT showed differences between K3 to K1, K2 to K1 whereas for UWD - between K3 and K2 and between K2 and K1. For T15 and T25, there were differences (p<0.01) between all categories, but in the final time (T50), the differences occurred between K3 and K2 and between K3 and K1. In males, there was a significant difference in the above-water phase between K3 and K1 and between K2 and K1. In UWD, ST, SD, T15, T25, and T50, there were significant differences between all categories. Differences (p<0.01) between males and females by category in the above-water phase were measured in FT (K1) and FD (K2, K1). In the underwater phase, the differences were found in UWT (K2) and UWD (K1). For T15, T25, and T50, significant differences were shown in all categories.
Matuš et al. (2024)	15 male, competitive	Analyze the effect of the foot in the base position on the block start on performance in the 5 m distance start.	FKA, FAA, RKA, RAA, HA, BT, EA, TA, T2, FT, FD, GT, GD, MaxH, T5	OSB 12 starting blocks	Swimmers were found to have significant differences (p<0.05) between foot widths in block time (0.02 s), time to 2 m (0.05 s), flight and glide time and distance, maximal depth, and time to 5 m (0.08) in favor of the narrow baseline position.
Matuš et al. (2024)	369 (189 males, 180 females)	Reveal the differences in kinematic parameters of start and performance in the sprint 50 m freestyle discipline based on gender in different age categories of competitive swimmers at international competitions organized in Slovakia.	BT, FT, FD, UWT, UWD, T15, ST, SD	OSB 11 starting blocks	In the phase above water level, there were greater differences (p<0.01) in females than in males. Inter-sex differences (p<0.01) were evident in FT in K3, K2 and in FD across all categories. In the underwater phase, differences (p<0.01) were evident in both sexes. Inter-sex differences were more evident in UWT (p<0.01) than UWD (p<0.05). There were inter-sex differences (p<0.01) in ST and SD between all categories except K3. At T15, T25 and T50, differences (p<0.01) were most pronounced between K3 and K2, K1 in females and between all categories in males. Inter-sex differences (p<0.01) were also evident across all categories.

Table 4. Kinematic characteristics of male swimmers

Authors (year)	Djurković et al. (2019)	Matuš et al. (2020)	Matuš, Kandrác (2020)	Qui et al. (2021)	Matuš et al. (2021)	Sánchez et al. (2021)	Matuš et al. (2022)	Rudnik et al. (2022)	Wardzyk et al. (2022)	Rudnik et al. (2023)	Shepherd et al. (2023)	Matuš et al. (2024)	Matuš et al. (2024)	Matuš et al. (2024)							
Participants (number, level)	25, competitive	10, competitive	8, performance level	12, elite	18, competitive	61, national	71, national	12, competitive	19, international	20, not mention	22, international	10, elite	27, competitive	33, competitive	39, competitive	56, competitive	68, competitive	56, competitive			
Years of participants	21.5± 3.6	17.5± 1.9	17.4± 1.8	16.3± 1.4	17.8± 1.5	23.2± 5.1	21.7± 3.9	15.7± 1.1	20.8± 4.2	16.8± 0.80	18.3± 1.8	22± 4	13/14	15/16	17+	17.0± 2.0	13/14	15/16	17+		
Position on starting block	-	Rear-weighted, position 3	Rear-weighted, position 3	-	Rear-weighted, position 3	-	-	Preferred	Forward	Preferred Backward	Rear-weighted, position	-	-	-	-	Narrow	Wide	-	-	-	
Other characteristics	-	Fast time to 5-m	Fast time to 5-m	-	-	50-m Breaststroke	100-m Breaststroke	-	-	Faster starters, freestyle	Slower starters, freestyle	-	-	50-m Breaststroke	-	-	-	-	-	50-m Freestyle	
FKA (°)		132.82± 1.13	132.70± 1.8		133.20± 1.4			132.10± 1.1		132.32± 12.95	119.81± 9.71			133.19± 3.08	132.67± 3.26						
FAA (°)					128.40± 0.90			127.20± 0.80						127.33± 4.52	126.84± 4.58						
RKA (°)		79.44± 1.34	79.50± 1.20		79.50± 1.10			78.50± 1.00		90.47± 9.07	87.25± 6.81			82.45± 2.40	82.06± 2.35						
RAA (°)					96.60± 1.70			95.10± 1.50						100.03± 3.31	99.41± 3.44						
HA (°)					44.70± 1.00			43.60± 1.00						43.70± 2.02	43.40± 1.63						
SP (°)					5.70± 0.50			5.50± 0.40													
BT (s)		0.88± 0.07	0.91± 0.07	0.59± 0.05	0.79± 0.06			0.80± 0.08		0.71± 0.04	0.72± 0.04	0.83± 0.04	0.89± 0.09	0.72± 0.12	0.66± 0.10	0.66± 0.09	0.77± 0.03	0.79± 0.02	0.71± 0.13	0.71± 0.09	
RT (s)										0.17± 0.04	0.18± 0.03	0.17± 0.03	0.17± 0.03								
HTo (s)		0.72± 0.08								0.45± 0.07	0.46± 0.08	0.45± 0.07	0.45± 0.08								
HTR (s)										0.28± 0.07	0.28± 0.08	0.28± 0.07	0.28± 0.07								
RFT (s)										0.61± 0.04	0.62± 0.05	0.59± 0.05	0.59± 0.05								
RFR (s)										0.45± 0.05	0.44± 0.05	0.42± 0.04	0.42± 0.04								
FFS (s)										0.11± 0.02	0.12± 0.02	0.13± 0.02	0.13± 0.02								
MT (s)										0.56± 0.05	0.56± 0.05	0.55± 0.05	0.55± 0.05								
Vx (m/s)				4.08± 0.26																	
Vy (m/s)				-0.35± 0.42																	
Vt (m/s)				4.11± 0.25																	

(continued from previous page)
Table 4. Kinematic characteristics of male swimmers

EA(°)	38.28± 0.97	37.70± 1.10	220.81± 2.58	37.50± 0.90	36.50± 0.80	39.98± 10.48	43.54± 1.70	37.30± 4.00	36.80± 0.85	36.69± 1.35
EV (m/s)	5.16± 0.60		5.40± 0.25							
TA	39.94± 1.13	40.60± 1.30	184.90± 5.82	40.60± 1.50	39.80± 1.20	23.89± 6.50	35.12± 3.43	33.80± 4.40	39.77± 2.39	39.67± 2.67
Flight phase (°)										
HP(m)		1.33± 0.01		1.30± 0.00	1.20± 0.00				0.94 ± 0.02	0.99± 0.02
T2 (s)		1.05± 0.06		1.50± 0.05	1.06± 0.05				0.37± 0.01	0.41± 0.01
FT (s)	0.30± 0.07	0.35± 0.03	0.30± 0.05	0.35± 0.03	0.36± 0.03	0.32± 0.08	0.39± 0.03	0.29± 0.04	0.29± 0.10	0.27± 0.10
FD(m)	3.03± 0.18	2.75± 0.11	2.74± 0.11	2.73± 0.11	2.71± 0.10	2.92± 0.22	2.80± 0.15	2.83± 0.20	2.93± 0.18	2.61± 0.16
FV (m/s)	10.61± 2.23								0.07 0.07	0.07 0.07
GT (s)		0.53± 0.05		0.55± 0.04	0.57± 0.03	0.43± 0.11	0.48± 0.26		0.52± 0.02	0.55± 0.02
GD(m)		2.25± 0.13	2.26± 0.11	2.27± 0.11	2.29± 0.10	1.46± 0.33	1.38± 0.61		2.31± 0.07	2.39± 0.07
GV (m/s)						3.40± 0.17	2.99± 0.29			
MaxH (m)		-0.91± 0.03	-0.73± 0.00	-0.90± 0.02	-0.89± 0.03	1.50± 0.55	1.33± 0.52		-0.89± 0.02	-0.92± 0.02
T5 (s)		1.75± 0.07	1.79± 0.09	1.60± 0.12	1.73± 0.07			1.53± 0.12	1.67± 0.03	1.75 0.03
FKT (s)			1.01± 0.26							
FKD (m)			5.40± 0.48							
UWT (s)	3.32± 0.25		3.65± 0.84					4.24± 0.80	4.70± 0.78	4.67± 0.41
UWD (m)			7.71± 1.71					6.66± 1.92	8.50± 1.18	9.53± 1.75
T10 (s)	3.98± 0.23		4.41± 0.38					3.51± 0.24		
T15 (s)			7.20± 0.57			6.51± 0.39	6.43± 0.47	6.41± 0.45	7.53± 0.58	7.09± 0.66
T5-10 m (s)								2.95± 0.18		
T10-15 m (s)								2.56± 0.23		
ST (s)								4.34± 0.78	2.96± 0.74	1.89± 0.40
SD (m)								5.56± 1.81	3.57± 1.08	2.41± 1.66
								4.24 0.93	6.95± 1.53	5.15± 1.52
									2.95± 0.90	2.35± 0.69
									7.95± 0.70	7.09± 0.66
									5.12± 1.51	6.81± 1.49
									2.72± 0.75	3.14± 0.71
									5.12± 1.51	7.52± 1.09

Discussion

The purpose of this systematic review was to synthesise recent evidence on kinematic determinants of the swimming kick start by integrating findings from 18 eligible studies. The evidence was organised according to the main start phases (block, flight, underwater, and swim) and interpreted with respect to key moderators reported in the literature, including sex, stroke type, performance level/age category, and starting block/platform configurations. Across studies, start performance (typically assessed at 5–15 m) was most consistently associated with above-water parameters, including block time/reaction-related measures, take-off horizontal velocity, and flight distance/entry characteristics. In comparison, the underwater phase accounted for the largest proportion of time from 15 m and was particularly influential in stroke-specific contexts (e.g., breaststroke). However, direct comparability between studies is constrained by methodological heterogeneity (tested distance, phase definitions, and starting block models), which should be considered when translating these findings into applied settings.

Block phase

The block phase can be characterized as the time from the start signal until the swimmer's feet leave the starting block. The percentage of this phase relative to the overall start performance is 11% for men and 12% for women at 15 meters (Tor et al., 2014). For the 5-meter distance, this phase accounts for 46–56% (Matuš & Kandrác, 2020). This initial phase determines the flight phase and the subsequent phases. Optimising movement on the starting block and the kick start take-off have been the focus of several studies referenced in our review. These studies utilized various starting blocks or platforms, including Omega OSB11 (Matuš et al., 2024a, 2024c; Qui et al., 2021; Wardzyk et al., 2022), Omega OSB12 starting platform (Matuš et al., 2021a, 2021b; Matuš et al., 2020; Matuš et al., 2022; Matuš et al., 2024b; Matuš & Kandrác, 2020), Omega OSB14 (Rudnik et al., 2022; Rudnik et al., 2023), SEIKO starting block (Hyodo & Wada, 2023), SO2-X, Agle Timing (Djurkovic et al., 2019), and KiSwim (Burkhardt et al., 2020). All Omega starting blocks share the same surface treatment and kick plate (adjusted the kick plate to positions 1–5) and are commonly used at major events such as the Olympic Games. Starting blocks from other manufacturers or their models may differ in this aspect, which could potentially affect the resulting kinematic parameters in the block phase. However, no study has specifically addressed this issue.

The swimmer's initial set position may influence performance in the kick-start block phase. Variations in arm placement can shift the body's centre of mass. At the same time, the kick-plate setting can further modify the initial body configuration and joint angles, which together may affect block-phase mechanics. For descriptive purposes, we classify the set position on the starting block as front-, neutral-, and rear-weighted. Among junior swimmers, comparisons of these set positions revealed the most significant differences in block-phase kinematics between the front- and rear-weighted positions across all kick-plate settings. Moreover, the rear-weighted po-

sition combined with kick-plate settings 3–4 was associated with the fastest time to 5 m and characteristic set-position angles (FKA 131–133°, RKA 80–82°, trunk angle 40–43°) (Matuš et al., 2020; Matuš et al., 2021a; Matuš & Kandrác, 2020).

Junior swimmers achieved similar angular values in the basic position as male swimmers (Matuš et al., 2021b). The trunk angle at toe-off was correlated with starting performance for both elite male and female swimmers (Shepherd et al., 2023). Wardzyk et al. (2022) divided swimmers into two groups: fast swimmers (FS) and slow swimmers (SS). FS swimmers achieved a higher hip position at the start signal ($p > 0.05$, 1.56 ± 0.05 meters vs. 1.45 ± 0.05 meters). Other differences were observed in the entry angle ($23.89 \pm 6.50^\circ$ vs. $35.12 \pm 3.43^\circ$). From this perspective, competitive swimmers should focus on setting the kick plate, arm position, and increasing hip elevation in the initial position, which may help maximise horizontal take-off velocity.

In terms of time parameters in the block phase, block time ranged from 0.68–0.91 seconds in junior swimmers (Matuš et al., 2020; Matuš et al., 2020c; Matuš et al., 2021; Matuš et al., 2024a; Matuš et al., 2024b; Matuš & Kandrác, 2020; Wardzyk et al., 2022), 0.66–0.72 seconds in senior swimmers (Djurkovic et al., 2019; Matuš et al., 2024a, 2024b; Sánchez et al., 2021), and 0.59–0.72 seconds in elite swimmers (Rundik et al., 2022; Rudnik et al., 2023; Shepherd et al., 2023). Differences in swimmer performance can correspond to a 0.09-second difference in block time. Elite swimmers achieved a reaction time of 0.17–0.18 seconds (Rudnik et al., 2022). Burkhardt et al. (2020) identified high reliability ($ICC > 0.75$) for block time from the start to 15 meters. Djurkovic et al. (2019) reported a significant effect of block time ($t = 2.88$; $p = 0.010$) on 10 meters. Women showed longer block times ($p = 0.002$; $\eta^2 = 0.18$) and shorter reaction times than men (Matuš et al., 2021a; Matuš et al., 2021b; Matuš et al., 2024a, 2024c; Rudnik et al., 2022; Rudnik et al., 2023). Cicienia et al. (2020) observed differences in block time among elite swimmers ($F(2, 38) = 4.264$, $p = 0.026$). Block time was shorter when the kick plate distance was one shin's length versus $<$ shin length (0.691 ± 0.055 seconds vs 0.715 ± 0.056 seconds) and $>$ shin length (0.691 ± 0.055 seconds vs 0.698 ± 0.056 seconds, $p < 0.05$). The results of the aforementioned studies indicate that reaction time and block time depend on the starting position on the block, with junior and elite swimmers achieving shorter reaction times in a front-weighted position. In Rudnik et al. (2022), elite female swimmers had the shortest block time and reaction time when the kick plate was shifted one level back from their preferred position. Across stroke types, swimmers achieved shorter block times in freestyle than in breaststroke (Matuš et al., 2024a, 2024c). For the 50-meter and 100-meter breaststroke starts, high correlations ($r = 0.76$ – 0.91) were found between block time and final time for both genders (Sánchez et al., 2021).

Regarding the hands take-off, elite swimmers achieved shorter times in forward and backward positions one level from their preferred kick plate position, while hands take-off reaction time was the same for all kick plate positions. Elite female swimmers achieved the shortest times in the preferred position (Rudnik et al., 2022). In the study by Hyodo and

Wada (2023), the involvement of the upper limbs in body velocity during the start jump was evaluated. Swimmers who engaged their arms during the start jump from the starting block achieved significantly higher vertical velocities ($p > 0.05$) at a smaller take-off angle than in starts without arm involvement. This may affect the directional velocity.

Regarding the time characteristics of the lower limbs on the Omega OSB14 starting block, elite swimmers achieved the shortest rear-foot take-off and rear-foot take-off reaction times in the rear position of the kick plate, one level from the preferred position ($p > 0.05$). Conversely, in the front foot support, this was the slowest position ($p > 0.05$). Similar results were found for elite female swimmers. In this basic position, the shortest block movement time was measured (0.55 ± 0.05 seconds). Elite female swimmers had a more extended movement time by 0.05-0.06 seconds. Regardless of the kick plate position, swimmers achieved similar times on the starting block. The forward position of the kick plate delayed rear-foot take-off and shortened the duration of the front-foot stand (Rudnik et al., 2022). Elite swimmers achieved a take-off horizontal velocity of 4.37-4.58 m/s, a take-off vertical velocity of -0.61 m/s, and a final take-off velocity of 4.63 m/s. For elite junior swimmers, take-off parameters were lower (Qiu et al., 2021; Rudnik et al., 2023; Shepherd et al., 2023). Compared to women, men achieved higher take-off velocities ($p < 0.001$; $\eta^2 = 0.29$) (Rudnik et al., 2023). Shifting the kick plate one level forward from the preferred position reduced rear-foot take-off and shortened the front-foot stand. A kick plate position effect was observed for those variables, with larger effect sizes in males, whereas in females, a change of approximately two positions was required to achieve significance (Rudnik, 2022). Significant correlations ($p < 0.01$) were also found for elite junior female swimmers between take-off horizontal and vertical velocity (Qiu et al., 2021) and time to 5 meters. Take-off velocity was identified as a reliable kinematic parameter ($ICC > 0.75$) in the start to 15 meters (Burkhardt et al., 2020).

Other studies have explored lower-limb positioning in the basic position, such as strong front vs. back (Burkhardt et al., 2020), non-preferential vs. preferential (Matuš et al., 2021b), and wide vs. narrow (Matuš et al., 2024b). Burkhardt et al. (2020) recommend that swimmers (of varying performance levels, men and women together) place their stronger lower limb on the kick plate. On the other hand, Matuš et al. (2021b) highlight the importance of lower limb dominance and its placement on the OSB12 starting platform. For most tested female swimmers, the optimal basic position on the starting block was neutral- or rear-weighted, with the kick plate set to positions 3–4 and the right leg placed on the front edge of the OSB12 platform. In the study by Matuš et al. (2024b), wide vs narrow basic positions on the starting block revealed significant differences ($p < 0.05$) in block time (0.02 second), time to 2 meter (0.05 second), flight and glide time and distance, maximal depth, and time to 5 meter (0.08 s) in favor of the narrow position. They recommend that starting blocks or their platforms feature a central line to help swimmers better orient themselves and correctly position their feet in the basic starting position.

Flight phase

The flight phase can be characterised as the time from the last contact of the lower limbs with the starting block to the first contact with the water surface. At a distance of 15 meters, this phase accounts for 4% in men and 5% in women (Tor et al., 2014). For the 5-meter distance, the phase represents 19-22% (Matuš & Kandrác, 2020). When determining differences in the selected flight phase parameters among junior competitive swimmers, significant differences ($p < 0.05$) were found between the front-weighted start (kick plate in position 1) and other starts. The most extended flight phase (2.74-2.80 meters), ranging from 0.35 seconds to 0.37 seconds, was recorded when the takeoff angle was between 40° and 41° . The head distance from the water surface ranged from 1.33 meters to 1.38 meters, with subsequent water entry at 38° following the rear-weighted start with the kick plate in positions 3 and 4. These parameters resulted in the shortest times to 5 meters (Matuš & Kandrác, 2020). With a higher hip joint position in the basic position on the starting block, swimmers achieved a more extended flight phase by 0.12 meters in a shorter time of 0.07 seconds and a smaller takeoff angle of 11.23° and entry angle of 3.56° compared to swimmers with a lower position (Wardzyk et al., 2022). Regarding flight time and distance, junior swimmers achieved 0.27-0.41 seconds at 2.61-3.40 meters, seniors 0.31 seconds at 3.25-3.60 meters, and elite swimmers 0.29-0.34 seconds at 2.83 meters. For juniors, the takeoff angle ranged from 23° to 41° , and the entry angle was 36° to 39° , while elite swimmers had a takeoff angle of 34° and an entry angle of 37° (Matuš et al., 2021a; Matuš et al., 2022; Matuš et al., 2024a; Matuš et al., 2024c; Rudnik et al., 2022; Rudnik et al., 2023; Sánchez et al., 202; Shepherd et al., 2023; Wardzyk et al., 2022). Gender differences ($p < 0.01$) were observed in women, with a shorter flight phase ($p < 0.001$; $\eta^2 = 0.40$), as well as a shorter flight distance (Matuš et al., 2021b; Matuš et al., 2024a, 2024c; Rudnik et al., 2022; Rudnik et al., 2023). Among junior elite female swimmers, a significant correlation ($p < 0.05$) was found between the length of the flight phase, entry angle, and time to 5 meters (Qiu et al., 2021). Djurkovic et al. (2019) highlighted the impact of flight phase parameters on the final time to 10 meters: entry velocity ($t = -13.17$; $p = 0.000$), flight time ($t = 9.54$; $p = 0.000$), flight distance ($t = -2.67$; $p = 0.016$), and flight velocity ($t = 2.53$; $p = 0.021$). The differences observed during the flight phase are attributable to the swimmers' starting block position and performance levels. When comparing swimming styles, swimmers in freestyle and breaststroke exhibited similar flight-phase times. However, differences were observed in flight distance, with swimmers in breaststroke achieving up to 3.60 meters (Matuš et al., 2024a, 2024c).

Underwater phase

This is one of the longest phases of the start phases. The underwater phase can be characterised as the period from the swimmer's entry into the water until resurfacing to resume swimming. Overall, this phase accounts for 61% in men and 52% in women for the start-to-15-meter phase (Tor et al., 2014). The underwater phase can be divided into gliding and the first swimming movements, during which the swimmer

reaches the water's surface and begins swimming. For the first 5 meters, gliding contributes 30-33% to the final time (Matuš & Kandrác, 2020). In the 50-meter freestyle, the contribution was 42% for men and 41% for women. In the 50-meter breaststroke, the contribution was 54% for men and 49% for women, depending on the age category (Matuš et al., 2024a; Matuš et al., 2024c). Performance in this phase can also be influenced to some extent by performance in the previous phases (block and flight). In studies in which performance was monitored only at 5 meters, competitive swimmers exhibited only gliding without undulation (Matuš et al., 2020; Matuš et al., 2021a; Matuš et al., 2021b; Matuš et al., 2022; Matuš et al., 2024b; Matuš and Kandrác, 2020). In these studies, glide time ranged from 0.52 to 0.55 seconds, glide distance from 2.27 to 2.39 meters, and maximum depth from -0.89 to -0.92 meters. In the study by Wardzyk et al. (2022), a shorter glide time and distance were recorded with a deeper maximum depth (-1.05 to -1.11 meters). The authors point out that competitive swimmers with a higher hip position at the start signal had a shorter glide time by 0.05 seconds. The differences between the studies were attributable to methodological differences: in this study, swimmers performed starts up to 15 meters, whereas in the other study, they performed starts up to 5 meters. This means their glide distance and time were shorter, as the subsequent first kick, undulation, first arm movements, resurfacing, and swimming began. Elite junior female swimmers reached a smaller maximum depth of -0.73 meters, with the first kick occurring at a distance of 5.40 ± 0.48 meters (Qiu et al., 2021). Competitive junior female swimmers also reached a smaller maximum depth (Matuš et al., 2021). Djurkovic et al. (2019) highlighted the impact of underwater time on the final time to 10 meters ($t=66.09$; $p=0.000$). In freestyle for 50 meters, inter-sex differences were more evident in underwater time ($p<0.01$) than in underwater distance ($p<0.05$). Senior swimmers (both men and women) had a more extended underwater phase than juniors. Similarly, this was also the case in the breaststroke swimming style. A greater underwater distance was observed among swimmers in the 50-meter breaststroke discipline (Matuš et al., 2024a, 2024c), as this swimming style is not limited to 15 meters, unlike other swimming styles. In the study by Sánchez et al. (2021), during the 50-meter breaststroke start, senior swimmers achieved a shorter distance (12.50 ± 0.92 meters) than at the 100-meter breaststroke start (13.37 ± 1.28 meters). Women achieved approximately 1 meter shorter underwater distance. Regarding the time to 5 meters, junior swimmers achieved a shorter time when the rear support was at the 3rd or 4th level, with a neutral or rear-weighted position (Matuš et al., 2020; Matuš et al., 2021b, Matuš et al., 2024; Matuš and Kandrác, 2020), when the hip joint position was higher during the start signal (Wardzyk et al., 2022) and with a narrower basic position on the starting block (Matuš et al., 2024b). The key parameters determining performance to 5 meters during the above-water phase include rear knee angle, block time, take-off angle, and time to 2 meters (Matuš et al., 2021a).

Swim phase

The swim phase is the period following the underwater phase, extending from the moment the swimmer's head resur-

faces to the water's surface until the head reaches the 15-meter mark. The percentage contribution of this phase to the total time at 15 meters was 22% for men and 33% for women (Tor et al., 2014). In the 50-meter freestyle, the contribution was 44% for men and 47% for women. In the 50-meter breaststroke, the contribution was 35% for men and 41% for women, depending on the age category (Matuš et al., 2024a; Matuš et al., 2024c).

Regarding performance in the 15-meter start, senior (6.31-6.72 seconds) and elite (6.33-6.41 seconds) swimmers recorded shorter times than junior competitive swimmers (6.94-7.09 seconds) (Matuš et al., 2024c; Rudnik et al., 2022; Rudnik et al., 2023; Sánchez et al., 2021; Wardzyk et al., 2022). Women recorded times approximately 1 second slower (Qiu et al., 2021; Rudnik et al., 2022; Rudnik et al., 2023; Sánchez et al., 2021; Shepherd et al., 2023). The time between T5 - 10 meters was 2.35 seconds, and the time between T10 - 15 meters was 2.56 seconds. For women, the times were slightly longer (Rudnik et al., 2023). A shorter time to 15 meters was also influenced by the starting position on the block and the position of the rear support (Rudnik et al., 2022; Wardzyk et al., 2022).

This suggests that the acceleration gained during the underwater and above-water phases gradually decreases during the swim phase, as the swimmer transitions from the air to the water environment, with the swimmer achieving the greatest acceleration during the block phase. A significant correlation was found between variables describing overall starting performance (times to 5-meter, 10-meter, and 15-meter) and variables commonly identified as determinants of starting performance (block phase duration, take-off horizontal velocity, and flight distance) in male swimmers (Rudnik et al., 2023).

Practical implications

The present synthesis suggests that coaches and swimmers should prioritise start-phase elements that were most consistently linked to performance across studies. In practical terms, this includes the systematic individualisation of the set position (kick-plate setting, arm placement, and hip height) to improve take-off mechanics (particularly horizontal velocity) and to control entry characteristics that subsequently shape the underwater trajectory. Given the stroke-specific contribution of the underwater phase (notably in breaststroke), start optimisation should be aligned with the race demands and the swimmer's ability to maintain efficient underwater speed. Where possible, practitioners should use repeated trials and reliable kinematic indicators (e.g., block time, take-off velocity, flight distance) to monitor start changes over time rather than relying on a single trial.

Strengths

A key strength of this review is the phase-based organisation of the kick-start literature, which enables coaches and researchers to interpret findings within a coherent performance framework (block, flight, underwater, swim). By summarising evidence across different populations (junior, senior, elite; male and female) and stroke contexts, the review provides an applied overview of which kinematic parameters

most consistently relate to start performance and which appear more dependent on protocol and equipment.

Limitations and future directions

The conclusions of this review should be interpreted in light of methodological heterogeneity across studies, including differences in tested distances (e.g., 5 m vs. 15 m), phase definitions, measurement systems, sample sizes, and starting block/platform models. This limits direct quantitative comparability and may partially explain conflicting results for some parameters. In addition to methodological heterogeneity, the overall quality and potential risk of bias of the included studies should also be considered when interpreting the present findings. The included studies were of good to fair methodological quality with a generally low to moderate risk of bias. The most common limitations were small sample sizes, lack of sample size justification, and limited reporting of assessor blinding, which are typical in biomechanical studies of elite athletes. Future research should aim to standardise reporting (clear phase definitions and consistent outcome metrics), directly compare starting block models and kick-plate configurations under controlled conditions, and include more stroke-specific and sex-specific analyses. Longitudinal/intervention designs are also needed to determine whether targeted changes in start mechanics translate into meaningful improvements in competition performance.

Conclusion

The results of the studies included in this review highlight differences across the block, flight, underwater, and swim phases with respect to sex, stroke type, and performance. The reviewed evidence suggests that several technique modifications can optimise the kick start: a kick-plate setting at level 3 or 4; a narrow stance with a neutral- or rear-weighted set position; and a higher hip position at the start signal, tailored to sex, stroke, and performance level. Collectively, these adjustments were associated with improvements in above-water and underwater execution, resulting in shorter times to 5 m, 10 m, and 15 m. Overall, the most consistent performance benefits across studies appear to come from optimising the set position and take-off mechanics to support an effective entry and a faster underwater transition. Therefore, the start optimisation should primarily target the block-to-entry sequence and the quality of the underwater phase, as these elements most directly translate into faster early-race performance. Insights into the kick-start technique should assist coaches and swimmers in achieving a more effective kick start, which is commonly used in elite swimming competitions.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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