# KINEMATIC DIFFERENCES BETWEEN TRACK AND KICK START IN SWIMMING

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**Keywords:**
- Starting block,
- OSB 11,
- Technique,
- Biomechanics,
- Performance.

**Abstract:**

Swim starts may be performed by using various techniques. In this systematic review study, we focus on the track start and kick start. The purpose of the study was to review current literature on differences in kinematic parameters of selected techniques of starts. We have also dealt with start performance in different start and thus aimed to inform a wide swimming public, from coaches to swimmers, about their effectiveness, especially due to performance optimization in starts of sprint races. The results of our study have shown that kick start is more advantageous than the track start because the rear kick plate enables swimmers to use the plate's potential, which increases horizontal takeoff velocity and shorter start reaction. These advantages have effect on the flight phase by increasing flight distance and shortening the flight duration. The times recorded at the distances of 5 m, 7.5 m, 10 m, and 15 m were shorter with kick start than with the track start. To improve start performance, both coaches and swimmers have to focus on the complex development of strength and lower-body performance in the kick start.

## INTRODUCTION

In swimming, winners frequently win by hundredths of a second. Therefore, all factors that limit the performance in a particular swim race have to be mastered perfectly. Every competitor aims to achieve the shortest time possible in a particular swimming event. This means that the swimmer must perform the start, swim specific lengths of the pool, execute turns, and finish the race in the shortest time possible [Okuno et al. 2002; Lyttle, Benjanuvatra 2005; Steifert, Vantorre, Chollet 2007; Slawson et al. 2010].

For instance, in the FINA Swimming World Cup 2018 in Budapest the times in the finals of 50m freestyle, 50m backstroke, 50m breaststroke, and 50m butterfly achieved by the swimmers were 20-21 s, 23 s, 25-26 s, and 21-22 s, and the differences in times of swimmers in all sprint races and swimming strokes differed by milliseconds. These results highlight the importance of the start (15 m) in the sprint races. The start consists of the following phases: basic position on the starting block, pull, takeoff, flight, water entry, gliding, and initial swimming movements. The movement on the starting block either kinematically or

dynamically influences subsequent phases. Therefore, it is essential that every swimmer perform an optimal takeoff from the starting block [Mason, Alcock, Fowlie 2006].

The technique of starts in swimming has developed over years, with two basic types of start – grab start and track start, which differ from each other in the leg position on the starting block. With the grab start, swimmers place their feet on the front part of the block. With the track start, swimmer places one of his legs in the front and the other one in the rear part of the starting block. This position leads to a more effective recruitment of upper- and lower-body during the block phase [Breed, McElroy 2000; Benjanuvatra et al. 2004].

These start techniques have been used at world-class swimming events since 2009. Swimmers at elite swimming events all over the world and in Slovakia have used the new starting block, manufactured by the Omega company, with an adjustable rear kick plate since 2009. This plate is adjustable in the anteroposterior direction in the rear part of the starting block (5 degrees in the range of 0.2 m) at a 30° angle (90° knee angle) [Omega 2016], which facilitates the take-off from the starting block.

The swim start from this starting block is referred to as the kick start, which is similar to the grab start. The starts differ in the rear leg angle and its better use when taking off compared with the start from the starting block without the rear kick plate. The swim start techniques differ in the assessment of kinematic parameters in elite swimmers, but these start techniques are one of the most popular with swimmers [Vantorre et al. 2010]. However, a variety of recent studies have shown [Welcher, Hinrichs, George 2008; Vint et al. 2009; Murrell, Dragunas 2012], swimmer should prefer the kick start to the grab start. On the other hand, some studies show that the best technique to be used by swimmers is the one they use regularly during the races [Vantorre et al. 2010; Cossor et al. 2010]. Therefore, in our study, we aim to analyze and compare kinematic parameters of the kick start and grab start in order to determine which swim start is more effective.

## MATERIAL AND METHODS

Literary searches were conducted in the following databases: Web of Science, PubMed, proceedings of international congresses and swimming databases. When searching for articles, the most frequent key words included swimming start, kinematic parameter, basic poistion, flight, gliding, first swimming movements, track start, and kick start. We also used Google scholar to find in particular articles in English language. We have excluded studies on other swimming strokes and water polo from the systematic review.

## KINEMATICS PARAMETERS OF START ON THE OSB 11

To provide information about swim starts, we used the results of kinematic analysis based on monitoring selected parameters. The start is an integral part of every swimming event. Several studies [Cossor, Mason 2001; Okuno et al. 2002; Lyttle, Benjanuvatra 2005; Slawson et al. 2010] have shown that start is defined as the time from the start signal to the head reaching the 15-m mark. The relation between start in a swim race depends on the distance, and the shorter the swim race the more relevant the start. The start consists of the following phases: basic position and movement of the swimmer on the starting block, flight phase, gliding phase, and leg kicking [Hay 1987; Cossor, Mason 2001; Villas-Boas 2010; Matúš 2016; Ružbarský, Matúš 2017].

## THE PHASE OF BASIC POSITION AND THE SWIMMER'S MOVEMENT ON THE STARTING BLOCK

This phase refers to the time from the start signal to initial movements of the swimmer on the starting block until the takeoff when the swimmer's legs leave the starting block. On-block time parameters that may be assessed include the start time, which is the resulting time consisting of the latent time, which is the reaction time, and movement time on the starting block until the takeoff. The percentage time contribution of the reaction time as one of the time parameters is 19 to 21% at the distance of 7.5 m, 21 to 23% at the distance of 10 m. The percentage reaction time contribution of the movement time is 79 to 81% at the distance of 7.5 m and 76 to 79% at the distance of 10 m. The contribution of the reaction time to overall performance is 11% at the distance of 15 m [Tor, Pease, Ball 2015b], from 34 to 36% at the distance of 7.5 m and from 20 to 22% at the distance of 10 m, which depends on the position of the body's center of gravity in the basic position on the starting block [Matúš 2012].

Several studies show that the basic position and movement of the swimmer on the starting block have effect on the subsequent phases of the start. Therefore, swimmers should be able to assume an optimal basic position on the starting block [Biel, Fischer, Kibele 2010; Honda et al. 2010; Honda et al. 2012, Slawson et al. 2012; Barlow et al. 2014; Matúš 2016; Ružbarský, Matúš 2017].

A swimmer who assumes a basic position in the track start on the starting block without the rear kick plate places one leg on the front part and the other leg on the rear part of the starting block, and the weight may be transferred on the front leg or the rear leg, or may be evenly distributed on both legs in the neutral position. The basic position of the kick start is similar to that of a track start. The only difference is that the leg placed in the rear part of the starting block rests against the kick plate. The rear kick plate enhances stability during the takeoff from the starting block, and, according to their anthropometric parameters, swimmers may choose 5 positions to set up the optimal position of the starting block, thereby minimizing the risk of false start, which improves their performance. The execution of the start should be as effective as possible because water is 800 to 1,000 times less dense than air. The results have shown that swimmers who used the kick start technique demonstrated shorter start times than those who used the track start [Villas-Boas et al. 2000; Blanksby, Nicholson, Elliott 2002; Kruger et al. 2003; Benjanuvatra et al. 2004; Takeda, Nomura 2006; Villas-Boas et al. 2003; Honda et al. 2010; Slawson et al. 2011; Honda et al. 2012; Matúš 2012; Garcia-Hermoso et al. 2013; Barlow et al. 2014; Tor, Pease, Ball 2015a; Taladriz et al. 2017], which was confirmed by statistically significant differences [Biel, Fischer, Kibele 2010; Honda et al. 2010; Ozeki et al. 2012; Beretic, Durovic, Okicic 2012] (Tab. 1).

Table 1 On-block kinematic parameters

| | Variant | Reaction time (s) | Motion time (s) | Start reaction (s) |
|---|---|---|---|---|
| Villas-Boas et al., 2000 | TSF | 0.17±0.04 | 0.73±0.06 | 0.9±0.1 |
| | TSR | 0.15±0.04 | 0.79±0.05 | 0.94±0.07 |
| Blanksby et al. 2002 | TS | 0.23±0.04 | 0.64±0.07 | 0.80±0.08 |
| Kruger et al. 2003 | TS | | | 0.91±0.1 |
| Benjanuvatra et al., 2004 | TS | | | 0.89±0.7 |

| | | | | |
|---|---|---|---|---|
| Takeda, Nomura 2006 | TS | | | 0.78±0.71 |
| Villas-Boas et al. 2003 | TS | 0.18±0.05 | | 0.90±0.07 |
| | TSR | 0.15±0.04 | | 0.94±0.07 |
| Vantorre et al 2010 | TS | | | 0.89±0.07 |
| Honda et al. 2010 | TS | | | 0.80±0.01 |
| Nomura et al. 2010 | TS | | | 0.78±0.03 |
| Matúš 2012 | TSF | 0.19±0.4 | 0.72±0.8 | 0.9±0.6 |
| | TSR | 0.18±0.4 | 0.76±0.6 | 0.94±0.7 |
| Beretic et al 2012 | TS | | | 0.76±0.05 |
| Ozeki et al. 2012 | TS | | | 0.74±0.04 |
| Garcia-Hermosos et al. 2013 | TS | | | 0.73±0.06 |
| | | | | |
| Nomura et al. 2010 | KS | | | 0.76±0.04 |
| Honda et al. 2010 | KS | | | 0.77±0.01 |
| Slawson et al. 2011 | KS | | | 0.76±0.01 |
| Honda et al. 2012 | KS | 0.14±0.01 | 0.63±0.01 | 0.77±0.01 |
| Ozeki et al. 2012 | KS | | | 0.74±0.04 |
| Beretic et al. 2012 | TS | | | 0.73±0.04 |
| Garcia-Hermosos et al. 2013 | KS | | | 0.7±0.06 |
| Barlow et al. 2014 | KSF | 0.2±0.3 | 0.5±0.6 | 0.7±0.07 |
| | KSN | 0.2±0.5 | 0.52±0.5 | 0.72±0.07 |
| | KSR | 0.2±0.4 | 0.56±0.5 | 0.77±0.07 |
| Tor et al. 2015 | KS | | | 0.71±0.04 |
| Taladriz et al. 2016 | KS | | | 0.66±0.06 |

*Note: KS- kick start; TS- track start; TSF- front-weighted track start;*

*TSR- rear-weighted track start; KSF- front-weighted kick start;*

*KSN- neutral-weighted kick start; KSR - rear-weighted kick start*

One of the important parameters used for the assessment of start performance is the horizontal takeoff velocity because higher values of this parameter during the takeoff phase and water entry may increase the swimmer's velocity upon entry into water. Compared with the track start, the kick start technique increases both horizontal velocity and vertical takeoff velocity of the swimmer during the takeoff from the starting block [Biel, Fischer, Kibele 2010; Villas-Boas et al. 2003; Slawson et al. 2010; Honda et al. 2012; Lee, Huang, Lee 2012; Ozeki et al. 2012; Tor, Pease, Ball 2015b; Taladriz et al. 2017], which was confirmed by statistically significant differences reported by Biel, Fischer, Kibele [2010] and Ozeki et al.

[2012]. Omega has reported similar results stating that the rear kick plate enables the swimmer to adopt a 90-degree knee angle. To achieve maximal horizontal force and horizontal takeoff velocity at takeoff from the new starting block, the knee angle ranged from 75 to 85 degrees for the rear leg and from 135 to 145 degrees for the front leg [Slawson et al. 2012; 2013]. Further studies dealing with the basic position on the starting block have shown that swimmers should keep their center of mass in the neutral position or to transfer the center of mass to the rear part of the OSB 11 starting block [Barlow et al. 2004]. Kibele, Biel, Fischer [2016] studied stance width on the starting block. The authors of the study found that, compared with the wider stance on the new starting block, new narrower basic position causes shorter start reaction, higher values of horizontal force and more effective use of the center of mass during takeoff (Tab. 2).

Table 2 Takeoff velocities for the swim starts

| | Variant | Take-off velocity (m/s) |
|---|---|---|
| Benjanuvatra et al., 2004 | TS | 4.19±0.37 |
| Villas-Boas et al. 2008 | TS | 3.46±0.3 |
| Honda et al. 2010 | TS | 4.41±0.03 |
| Ozeki et al. 2012 | TS | 4.29±0.12 |
| Lee et al., 2012 | TS | 4.3±0.1 |
| | | |
| Slawson et al. 2011 | KS | 4.67±0.00 |
| Honda et al. 2010 | KS | 4.48±0.04 |
| Ozeki et al. 2012 | KS | 4.41±0.18 |
| Tor et al. 2015 | KS | 4.65±0.24 |
| Taladriz et al. 2016 | KS | 4,12±0.31 |

*Note: KS- kick start; TS- track start*

## THE PHASE OF FLIGHT

The flight phase is characterized by taking off from the starting block unti when the feet leave the edge of the starting block and the hands or head enter the water surface. The contribution percentage time of the flight phase to the overall time is 5% at the distance of 15 m [Tor, Pease, Ball 2015b].

Performance during this phase (time, velocity, takeoff angle and entry angle, height of the center of mass and entry distance) is affected by the previous phase – basic position and on-block movement.

The swimmer needs to jump as far as possible and travel the maximum distance at the high velocity and under an optimal angle [Vantorre et al. 2010; 2011]. It is necessary to preserve this velocity upon entry into water and connect it with the first swimming

movements. The flight distance may be increased by the basic position on the starting block [Slawson et al. 2011] because in the narrow stance, swimmers demonstrated a longer flight time, which means that they generated higher values of peak horizontal force [Kibele, Biel, Fischer 2016].

The results of a variety of studies have shown that differences in the flight phase between the track start and kick start were minimal [Villas-Boas et al. 2000; Blanksby, Nicholson, Elliott 2002; Kruger et al. 2003; Takeda, Nomura 2006; Nomura et al. 2010; Vantorre et al. 2010; Beretic, Durovic, Okicic 2012; Honda et al. 2012; Lee, Huang, Lee 2012; Ozeki et al. 2012; Tor, Pease, Ball 2015a; Taladriz et al. 2017]. Statistically significant differences in the flight phase between the track start and kick start have been reported by Ozeki et al. [2012], Nomura, Takeda, Takagi [2010], and Beretic Durovic, Okicic [2012]. Another important parameter that affects start performance is the angle under which enters the water. The differences in the water entry angles between the track start and kick start were minimal, and the differences were insignificant [Beretic Durovic, Okicic 2012; Ozeki et al. 2012], which means that these swim start techniques will have a similar gliding phase.

Table 3 Kinematic parameters during the phase of flight

| | Variant | Flight time | Entry distance |
|---|---|---|---|
| Villas-Boas et al., 2000 | TSF | 0.36±0.05 | |
| | TSR | 0.34±0.06 | |
| Blanksby et al. 2002 | TS | 0.28±0.08 | 3.20±0.39 |
| Kruger et al. 2003 | TS | 0,34±0.08 | |
| Takeda, Nomura 2006 | TS | | 3.15±0.20 |
| Vantorre et al. 2010 | TS | 0.30±0.05 | |
| Nomura et al. 2010 | TS | | 3.00±0.19 |
| Ozeki et al. 2012 | TS | | 2.69±0.20 |
| Lee et al., 2012 | TS | 0.29±0.06 | 2.38±0.20 |
| Beretic et al. 2012 | TS | 1.07±0.06 | 2.41±0.15 |
| | | | |
| Nomura et al. 2010 | KS | | 2.99±0.18 |
| Beretic et al. 2012 | KS | 1.02±0.07 | 2.37±0.15 |
| Honda et al. 2012 | KS | | 2.74±0.03 |
| Ozeki et al. 2012 | KS | | 2.69±0.20 |
| Tor et al. 2015a | KS | 0.34±0.05 | 2.94±0.15 |
| Taladriz et al. 2016 | KS | 0.22±0.05 | |

*Note: KS- kick start; TS- track start; TSF- front-weighted track start;*

*TSR- rear-weighted track start*

## THE PHASE OF GLIDING AND BEGINNING OF SWIMMING MOVEMENTS

This phase refers to the time from when the head or head touch the surface of water at entry until the head or hands break the water surface. The glide phase may be defined as the time from the initial contact with the water surface to the first leg kicking movements. The leg kicking phase is the time between the beginning of leg propulsion or arm propulsion until the first stroke. Performance in this pase is affected by previous phases and significantly correlates with start reaction [Vantorre et al. 2010].

Underwater phase significantly differs by stroke, and according to the FINA rules, the maximum underwater distance may not exceed 15 meters. The swimmer's head must break the water surface at 15-meter distance [Fina 2018]. The percentage time contribution of the underwater phase for the start is 56% at the distance of 15 meters [Tor, Pease, Ball 2015b].

These phases are affected by the position of the hips, arms, and legs upon entry into water, and the loss of swimmer's velocity underwater depends on their position [Elipot et al. 2009; Cossor, Mason 2001; Tor, Pease, Ball 2014; Tor, Pease, Ball 2015a,b]. Another important parameter is the swimmer's trajectory, which, if too deep or shallow, has negative effect on start performance. The optimal depth after the swim start is from 0.50 to 0.92 m at the velocity of 1,9 m/s [De et al. 2011; Houel et al. 2010; Houel et al. 2013; Tor, Pease, Ball 2015b]. The glide phase should end at the distance between 5.5 to 6.6 meters [Elipot et al. 2009; Seifert, Vantorre, Chollet 2007]. Shorter times at a set distance (7.5 m, 10 m. and 15 m) depend also on the transformation of the greatest force impulse at takeoff possible into gliding velocity and execution of first swimming movements [De et al. 2011]. One of the most used parameters for the assessment of the entire start and the underwater phase in various start techniques is the time at the distances of 7.5 m, 10 m, and 15 m. As for the track start and grab start, in the studies that compared starts with one another, swimmers who used the kick start achieved shorter times at a set distance [Honda et al. 2010; Beretic, Durovic, Okicic 2012; Ozeki et al. 2012] (Tab. 3).

Table 3 Resultant times at 5 m, 7.5 m, 10 m, and 15 m

| | Variant | Time to 5 m | Time to 7,5 m | Time to 10 m | Time to 15 m |
|---|---|---|---|---|---|
| Blanksby et al. 2002 | TS | | | 4.67±0.33 | |
| Kruger et al. 2003 | TS | | | 3.56±0.35 | |
| Vantorre et al 2010a | TS | | | | 6.6±0.3 |
| Honda et al. 2010 | TS | 1.66±0.01 | 2.73±0.02 | | |
| Matúš 2012 | TSF | | 2.65±0.18 | 4.47±0.40 | |
| | TSR | | 2.63±0.17 | 4.36±0.36 | |
| Beretic et al 2012 | TS | | | 3.99±0.84 | |
| Ozeki et al. 2012 | TS | | | | 6.92±0.34 |

| | | | | | |
|---|---|---|---|---|---|
| Honda et al. 2012 | KS | 1.62±0.01 | 2.69±0.02 | | |
| Ozeki et al. 2012 | KS | | | | 6.78±0.33 |
| Beretic et al. 2012 | TS | | | 3.84±0.27 | |
| Barlow et al. 2014 | KSF | 1.47±0.68 | | | 7.57±1.51 |
| | KSN | 1.44±0.69 | | | 7.42±1.55 |
| | KSR | 1.38±0.70 | | | 7.39±1.57 |
| Tor et al. 2015 | KS | 1.54±0.09 | 2.59±0.18 | 3.91±0.29 | 6.62±0.40 |
| Taladriz et al. 2016 | KS | 1.56±0.15 | | | |

*Note: KS- kick start; TS- track start; TSF- front-weighted track start;*

*TSR- rear-weighted track start; KSF- front-weighted kick start;*

*KSN- neutral-weighted kick start; KSR - rear-weighted kick start*

## CONCLUSION

The results of the studies presented in this paper have provided a certain overview of the literature on kinematic differences between the track start and kick start. The results of the studies have shown differences between the two starts, favoring the kick start. The rear kick plate on the starting block improves swimmer's stability in the basic position, shorter reaction time, higher takeoff velocity with comparable flight distance for track start. This causes shorter times at the distances of 5 m, 7.5 m, 10 m, and 15 m, respectively. To use the kick start, it is necessary to provide swimmers with the starting block because these starting blocks are not available in all swimming pools. By doing so, we may ensure that the swimmer will sufficiently use the advantages of this swim start technique, especially in the sprint races. When assessing starts, both coaches and swimmers should focus on the most important parameters such as start reaction, flight time, flight distance, takeoff angle, entry angle, takeoff velocity, depth and gliding time and the resultant time at a particular distance the swimmer is to swim.

## ACKNOWLEDGEMENTS

This review study was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences No. 1/0793/18 "The effect of basic position on the starting block on changes in kinematic parameters of track start in swimming ".

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