KINEMATICAL ANALYSIS OF THE SWIMMING START: BLOCK, FLIGHT AND UNDERWATER PHASES

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The purpose of this study was to analyze, through kinemetry, the block, flight and underwater phases of the swimming start. The sample was composed by 4 swimmers. Four VHS video cameras were used. Analyzed variables: block time, flight time and distance, angle of entry, maximum depth achieved, time, distance and average velocity of the underwater phase and total start time in 15 meters. Pearson's correlation was used to verify the relationship between the variables.Flight distance, angle of entry, depth achieved and average velocity under teh water presented significant correlation with the starting time (r = -0.482, 0.512, 0.515 and -0.645, respectively), being all important factors to be observed by athletes and coaches, who should look forward to reach best values of the variables in order to improve the execution of swimming starts.

KEY WORDS: biomechanics, swimming start

INTRODUCTION:

The 15m start times have been found to range from 0.8% to 26.1% of the overall race time, depending on the event (Cossor & Mason, 2001) and, on average, the improvement of the start technique can reduce the event's total time in at least 0,1s (Maglischo, 1999).
According to Seifert *et al*. (2006), most of the kinematical analyses of the start phases have focused on the reaction time on the starting blocks, and the flight and entry phases, comparing the grab with the track start technique. Despite of analyzing the variables related to those phases, authors recognize the importance and representation of the underwater phase regarding the performance of swimming starts.
Sanders (2002) emphasized that great consideration should be given to the underwater phase and also to the previous phases, because the performance below the water depends on the actions on the block and flight phases.
Thus, the purpose of this study was to analyze, through kinemetry, the block, flight and underwater phases of the swimming start.

METHOD:

The sample was composed by 4 swimmers of national and state levels, members of the swimming team of Doze de Agosto Club (Florianópolis, SC, Brazil), chosen deliberately by being specialists in strokes whose starts are performed from the starting block (freestyle, breaststroke and butterfly). The main characteristics of the subjects were: 20.0 (±3.7) years of age, 74.3 (±7.04) kg of mass, and 182.0 (±0.03) cm of height.
For data collection four VHS cameras (30Hz) were used. The first camera was positioned outside of the water to provide a lateral view of the starting block enabling the acquisition of the variables *block time* (time elapsed from the start signal to the moment of last contact); *flight time* (time elapsed from the last contact with the block to the contact of the swimmer's head with the water); *flight distance* (distance measured from the moment of last contact to the moment the swimmer's head touched the water); and *angle of entry* (between the trunk of the swimmer and the horizontal when the swimmer's head touched the water).
Second and third cameras were coupled to watertight boxes and were both positioned inside the water, distant 5 meters and 10 meters of the starting wall, enabling the acquisition of the variables *maximum depth achieved* (maximum depth reached by the swimmer after the water entrance, observed in the moment that the swimmer's head reaches the deepest point under the water surface); *underwater phase distance* (distance from the point of the head entrance

in the water to the point of the first arm stroke begins); *underwater phase time* (time elapsed from the moment of the head entrance in the water to the beginning of the first arm stroke); *average velocity of the underwater phase* (average velocity reached by the swimmer since the entrance in the water to the beginning of the first arm stroke).
The fourth camera was positioned outside of the water to provide a lateral view of the swimming pool in order to obtain the variable *total start time in 15 meters* (time elapsed since the start signal to the moment that the swimmer's head reached the mark of 15 meters).
To synchronize the start signal to the kinemetry a starter device was used. This equipment is instrumented to simultaneously produce the starting sound and export a LED signal to the video system, allowing data synchronization.
Data collection was carried out in the swimming pool of the Doze de Agosto Club (Florianópolis, SC, Brazil). Each swimmer performed 6 starts with a 5 minutes rest period. Immediately after the start, the athletes had to perform the Crawl stroke in maximum speed up to opposite wall, totaling up 25 meters. The starting procedures conformed to the swimming rules of an official competition.
The *InterVideo WinProducer 3* software was used to digitalize the data. According to the analyzed variable one selected the charts originating figures. The image files were exported and analyzed by Corel Photo Paint® 10 software.
Data were treated using common descriptive statistics and Pearson's Correlation (a=0.05).

RESULTS:

Table 1 presents the values of average ($\overline{X}$), standard deviation (*s*) and coefficient of variation (CV) of variables block time (BT), flight time (FT), flight distance (FD), angle of entry (AE), maximum depth achieved (DP), underwater phase distance (UPD), underwater phase time (UPT), average velocity of the underwater phase (UPV) and total start time in 15 meters (T15m).

Table 1: Values of average ($\overline{X}$), standard deviation (*s*) and coefficient of variation (CV) of variables of the study.

	$\overline{X}$	**s**	***CV (%)***
BT (s)	0,85	0,06	7,72
FT (s)	0,34	0,03	8,04
FD (m)	2,97	0,12	4,20
AE (°)	32,51	6,24	19,21
DP (m)	1,10	0,18	16,98
UPD (m)	5,75	0,87	15,11
UPT (s)	2,18	0,53	24,39
UPV (m/s)	2,70	0,36	13,42
T15m (s)	6,97	0,25	3,65

In order to verify the relationship of the variables of the study Pearson's correlation was used ($p<0.05$). Table 2 presents the values of "*Pearson's R*" for the correlation between the total start time in 15 meters (T15m) and the variables block time (BT), flight time (FT), flight distance (FD), angle of entry (AE), maximum depth achieved (DP), underwater phase distance (UPD), underwater phase time (UPT) and average velocity of the underwater phase (UPV).

Table 2 - Values of *Pearson's R* for the correlation between variables of the study.

CORRELATED VARIABLES	n	R
BT x T15m	24	- 0,115
FT x T15m	24	0,039
FD x T15m	24	- 0,482*
AE x T15m	24	0,512*
DP x T15m	24	0,515*
UPD x T15m	24	0,109
UPT x T15m	24	0,376
UPV x T15m	24	- 0,645**
* p<0,05	** p<0,01	

n = number of analyzed starts

DISCUSSION:

Table 1 shows that the total start time in 15 meters presents the smaller variation (3,65%) when compared to the other variables, indicating that, even performing similar starting times, the swimmers presented heterogeneous values for the other variables, specially those related to the underwater phase. Bonnar (2001) showed that 96% of the variance in start time in 9,5m was explained by the duration of the period from first water contact to 9,5m. The same was verified by Guimarães and Hay (1985), when the glide time accounted for 95% of the variance in starting time. The results suggest that underwater phase is intimate connected to the individual characteristics of each subject, like the streamline position and the underwater stroke technique used, being still influenced by several factors and actions that happen since the instant of entrance in the water to the beginning of the first kicking and the first stroke movements.

Regarding the relationship between the variables, Table 2 shows that total start time in 15m was significantly correlated with flight distance (r=-0,482), angle of entrance in the water (r=0,512), maximum depth achieved (r=0.515) and average velocity of the underwater phase (r= -0,645).

Cossor and Mason (2001) observed a significant correlation between flight distance and starting time. They showed that in 200m Medley and 400m freestyle events for women, the further the distance attained in the flight phase, the faster the 15m time. The same trend was observed in this study, when higher values of FD corresponded to faster starts.

Regarding the angle of entry, higher values of AE corresponded to higher values of T15m. According to Miller *et al.* (2003), the angle of entrance may influence the depth of glide, suggesting a correlation between these variables. Because of this, one suggests the angle of entry may influence all of the subsequent variables and consequently the starting time.

The significant coefficient of correlation observed between T15m and DP indicates that higher values of maximum depth correspond to higher values of T15m. Counsilman *et al.* (1988), even without carrying out the correlation between these variables, verified that, on average, the slowest starts were performed when the swimmers presented higher values of depth achieved. According to Sanders (2002), the depth affects the amount of wave drag and this has implications for the desired trajectory below the water. Pereira *et al.* (2006) carried out the correlation between the maximum depth achieved by the swimmer and the variables of the underwater phase, showing that distance, time and average velocity below the water were influenced by depth, mainly the average velocity (r=-0,838).

Average velocity of the underwater phase was negatively correlated at a significant level (p<0.01) to the total start time in 15 meters, which indicates that higher values of average velocity during the underwater phase correspond to slower starts. Despite of UPV is a derived variable from UPD and UPT, these did not present significant values for the correlation with T15m (r=0,109 and r=0,376 respectively). This fact suggests that, more important than the distance traveled or the time elapsed under the water, is the great combination between those variables, requiring from the swimmer the ability of minimizing the water resistance and maximizing the propulsion during the underwater phase, performing a longer distance in a shorter time. Cossor and Mason (2001) combined the variables flight distance and flight time; underwater distance and underwater time; and time and distance of the first arm stroke. They verified that the combination of underwater distance and underwater time was the one which more affected the total time in 15m, suggesting that there is a strong relation between the velocity during the underwater phase and the start performance.

CONCLUSION:

An efficient start, in all of the swimming events, depends on the great combination of the actions on the block and the swimmer's projection to the water in order to positively influence the subsequent phases.

The flight distance, angle of entry, depth achieved after the water entrance and the velocity performed under the water are all important factors to be observed by athletes and coaches, which should look forward to reach best values of those variables in order to improve the execution of swimming starts.

It suggests that the swimming start analyses should contemplate the block, the flight and the underwater phases, which have essential variables to be considered for the determination of performance parameters of swimming starts.

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