A SYSTEM TO IMPROVE THE SWIMMING START TECHNIQUE USING FORCE RECORDING, TIMING AND KINEMATIC ANALYSES

Raúl Arellano, Susana Pardillo, Blanca De La Fuente and Francisco García[1]
Universidad de Granada, [1]CAR Sierra Nevada, Granada, Spain

The purpose of our study was to develop a system to improve the swimmer's starting technique integrating force and video data. A group of elite swimmers (n=17) took part in the study. Cinematic and kinetic variables of the start technique during the block, flight, and swimming phases until the end of the first 10 m were analysed. The horizontal velocity during the take-off (3,96 m/s) and peak horizontal force applied (917,2 N) did not correlate with the 5 m time (1,79 s). Only the value of the velocity vector before the moment of the hand entry (4,63 m/s) correlated with the 5 m time (r=-0.56). The transformation of the velocity components of the swimmer's centre of mass during the flight to a high horizontal gliding speed seems the more complex problem for the swimmer to resolve and where our future research will be directed.

KEY WORDS: swimming start, force plate, horizontal velocity

INTRODUCTION: The starting time is one of the race components in swimming competition. Its importance is relatively greater during the shorter race distances (50 and 100 m). The time that a swimmer spends starting is equal to the time from the starting signal being given until the feet leave the starting block (the block time), until first contact is made with the water (the flight time), plus the time from first contact with the water until the swimmer begins kicking and/or stroking (the glide time) (Bowers & Cavanagh (1975). Starting times were recorded during international swimming competitions using fixed distances. The results showed the time spent from the starting signal until the head crossed the 10 or 15 m line as was reported by Bowers & Cavanagh (1975) or more recently by Bowers & Cavanagh (1975). The new F.I.N.A. rules put limits to the underwater starting distance (15 m) and this length is now universally used to measure the total starting time. Some papers were published reporting data of the duration of the phases, centre of gravity trajectory, horizontal and vertical velocity of the body segments, force applied on the starting block and underwater propulsive actions (Zatsiorsky, Bulgakova, & Chaplinsky,1979; Lewis,1980;Guimaraes & Hay,1985;Pearson et al. 1998). Our study aim was to develop a system to improve the swimmer's starting technique integrating force and video data from all the starting phases.

METHODS: Subjects. A group of swimmers (n=17) with different elite swimming skill levels (international and national) took part in an altitude training camp and in one technical evaluation session organised by the Technical Evaluation Staff of the Royal Spanish Swimming Federation in the Altitude Training Center of Sierra Nevada. Each swimmer performed the 50 m plus turn test (57.5 m) with one all-out effort to record the split time for the 100-m event. Each subject's trial was video-recorded with the Temporal Swimming Analysis System (TSAS) described by Bowers & Cavanagh (1975).

Table 1 Means for Subject Age, Mass and Height, Correlation for Subject Mass and Height with Starting Times

	Mean	r with 5 m time	r with 10 m time
Age (years)	21		
Weight (kg)	72.3	-0.718***	-0.636**
Height (cm)	179	-0.580*	-0.501*

*** p<0.0011 ** p<0.01 * p<0.05

Instrumental. The TSAS was composed of five video cameras connected to a S-VHS video recorder (50 Hz) through a video-timer and a video selector (see Figure 1). The image from the first two video cameras was mixed to see the over- and under-water phases of the start in the same frame (until 10 m, see Figure 2). A third camera was used to measure the 15-m time. A fourth camera was put in the middle of the swimming pool (25 m) to record at least two complete underwater stroke cycles and the 25-m time (with the head). The fifth camera was placed at the end of the swimming pool for video recording the turning phase. All the images from the cameras were recorded at a distance of 15 m from the perpendicular plane of the swimmer displacement. The 1st camera was placed over the water. The rest of the cameras were placed 1 m below the water-surface filming thought three different underwater windows. One simple reference system was put in the vertical plane of the swimmer's displacement and video-recorded before the swimmer's performance. Thanks to this reference, it was possible to draw vertical lines on the computer to measure the time where the swimmer's head crossed these reference lines. The assessment was carried out after a swimming start following the FINA rules. The starting signal was synchronised with the video-timer (time code) and the swimming pool electronic timing system. The 50-m time was measured with this latter device when the swimmer touched the timing wall. After video recording, the timing data was collected directly from the tape, reading the time code recorded with a PC connected to the video player. A specific database was developed for collecting the data and to produce the printout with the analysis for information for coaches and swimmers. As our study aim was to analyse a set of variables related only to the start the data obtained from the first and second cameras were analysed (to the 10 m line).
A force plate (Kistler submergible model 9253) was adapted to the swimming starting block keeping the same height from the water (0.7 m) and inclination (6º) as a standard starting block. The force plate was added to the TSAS system and was used to measure the forces applied by the swimmer during the block time. Both systems were synchronised thanks to a voltage change introduced by the starting switch to one of the recording channels of the A/D converter connected to the force plate and to the video timing system.

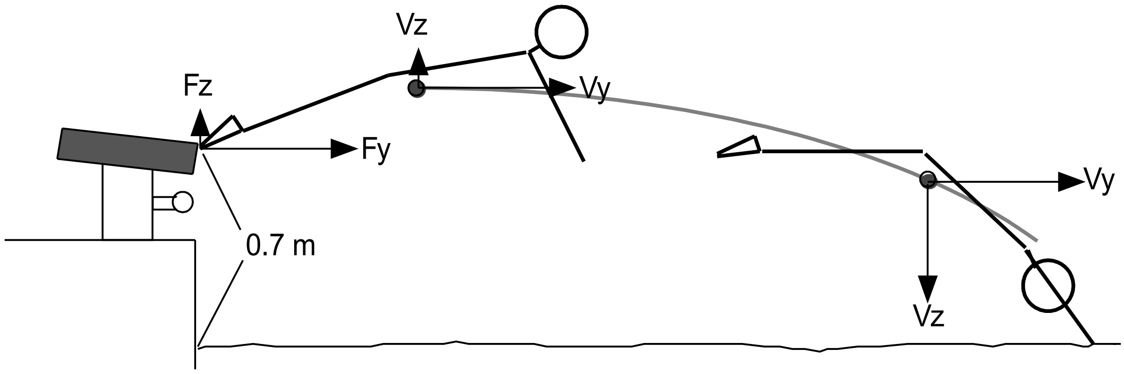

Figure 1 - Graphical representation of the variables studied related with the force applied in the starting block and the parabolic trajectory during the flight.

Variables measured. The start time was measured for 5m (T5) and 10 m (T10) when the head of the swimmer crossed these reference lines. The duration of the block time (BT), flight time (FT) and entry time (ET) were measured as parts of the start time. Mean speed was measured between 0 to 5 m, in order to compare the starting technique without the influence of the stroke selected for testing. Complementary data from 5 to 10 m were analysed as well. A bi-dimensional trajectory of the centre of mass (CM) was calculated during the block and flight time using the anthropometric data published by Bowers & Cavanagh (1975). Thanks to this trajectory it was possible to obtain the CM horizontal (Vy) and vertical (Vz) velocities during the take-off and during the first contact with the water surface. The parabolic equation was calculated using an algorithm developed by Bowers & Cavanagh (1975). The resultant velocities during the take-off (V0) and during the first water contact (Ve), and the take-off angle (φ) were calculated as well. Horizontal (Fy) and vertical (Fz) peak forces during the block time were obtained from the force plate records. The resulting force data consider the weight of the swimmer as zero value.

Statistical analyses. The data from each performance were filed in a specifically designed database. Selected variables were exported to a statistical computer software (STATISTICA/ Mac 4.1, Statsoft™) performing the calculations in a Macintosh computer. Averages were determined for all variables as presented in Tables 1 and 2. Partial correlation coefficients with subject mass partialled out was calculated between selected variables and shown in Table 2.

RESULTS AND DISCUSSION: The mean data obtained in the timing analysis (see Table 2) are similar to those obtained in our previous studies. When the timing data phases are related to the force records, we found: a) a negative value of Fz before the hands leave the block; b) a progressive increase of Fy before the hands leave the block; c) peak values of Fz just after the hands leave the block; d) a rapid increase of Fy between the time the knees make an angle of almost 90º and the feet leave the block and; e) Fy peak value is almost twice the Fz peak value and it is produced just before to leave the block (see figure 2).

Table 2 Means, Standard Deviations and Partial Correlation Coefficients with T5 for the Variables Analysed.

	Mean	SD	partial r		Mean	SD	partial r
BT (s)	0.850	0.112	ns	Vy (m/s)	3.961	0.438	ns
FT (s)	0.387	0.146	ns	Vz (m/s)	-0.225	0.568	ns
ET (s)	0.192	0.111	ns	V0 (m/s)	3.898	0.484	ns
T5 (s)	1.788	0.150	1	Ve (m/s)	4.627	0.389	-0.56*
T10 (s)	4.506	0.546	0.85***	Fy (N)	917.2	161.4	ns
V0_5 (m/s)	2.814	0.236	-0.99***	Fz (N)	515.4	213.1	ns
V5_10 (m/s)	1.881	0.295	-0.78**	φ (deg.)	-3.26	8.55	ns

*** $p<0.0011$ ** $p<0.01$ * $p<0.05$

The Vz and Fz variables correlated between them (r=0,863 $p<0.01$) but each of them separately did not correlate with T5. Only Fz correlated significantly with T10 (r=-0.522 $p<0.05$). Our results were similar to those reported by Bowers & Cavanagh (1975) that found very low correlation values between Vz and horizontal impulse with the starting time.

Only Ve showed a significant correlation with T5 (r=-0.56 $p<0.05$). The value of Vy is increased during the flight due to the external force gravity and when it is added to Vz (kept constant because it was assumed that air resistance was negligible) the result is a Ve higher than V0 (nearly 25% more). Bowers & Cavanagh (1975) reported similar differences between V0 and Ve.

The absolute values obtained for Fy are smaller than Fz as was shown in the recorded graph samples in Bowers & Cavanagh (1975). Different results were obtained by Bowers & Cavanagh (1975). Their results showed that Fy was surprisingly higher than Fz. This occurred because of the use of a special starting block with handles attached to the side of the block modifying the initial position of the body on the starting block and the forces applied on it. The values obtained in the take-off angle showed a high variability. The negative mean value produces a parabolic motion of the centre of mass forward and downward. A negative (φ) was also obtained by Bowers & Cavanagh (1975) in the two swimming starts compared in their study.

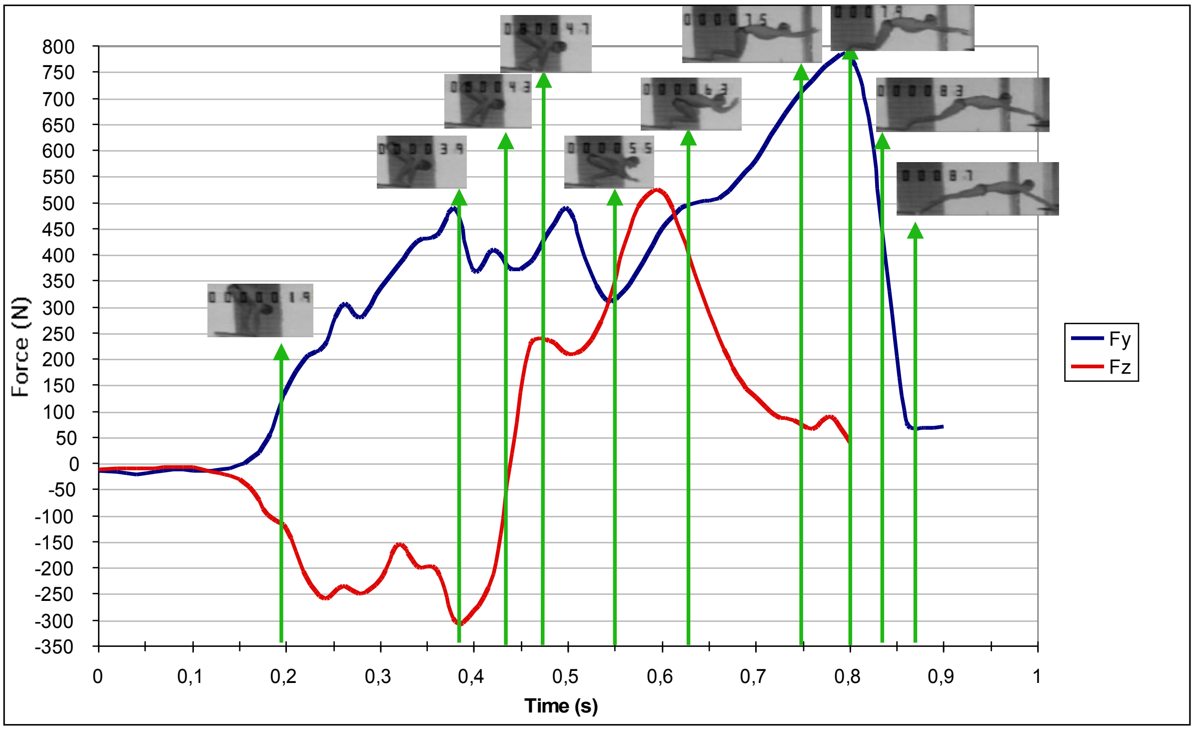

Figure 2 - Sample of the records obtained from the force plate and pictures of the related movement phases.

CONCLUSION: Combining the cinematic and kinetic information of the swimming start seems the only way to help the swimmer to improve the swimming start. The low correlation values obtained in this and previous studies between the kinetic, parabolic variables and the different starting times suggest the need to use a very individual analysis to provide appropriate start feedback. The transformation of the velocity components of the swimmer's centre of mass in the flight phase to the higher horizontal gliding speed seems the more complex problem to be resolved by the swimmer and where our research will be directed in the future.

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