Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

BIOMECHANICAL ANALYSIS OF STARTING PREFERENCE FOR EXPERT SWIMMERS

Julien Vantorre[1], Ludovic Seifert[1], J. Paulo Vilas-Boas[2,3], Ricardo Fernandes[2,3], Benoit Bideau[4], Guillaume Nicolas[4] and Didier Chollet[1]

Laboratoire CETAPS, Université de Rouen, Rouen, France[1]
Faculty of Sport, CIFI2D, University of Porto, Portugal[2]
Porto Biomechanics Laboratory, University of Porto, Porto, Portugal[3]
Laboratoire M2S, Université de Rennes 2, Rennes, France[4]

The purpose of this study was to compare kinetics, body angles and angular momenta during the swimming start for preferred and non-preferred technique of expert grab starters. Results showed that in preferred technique, starts were executed with less global angular momentum around the transverse axis. By searching further, less loss of angular momentum in the other dimensions was found for grab start as preferred technique, inducing a less efficiency in non-preferred technique (twisting effect in track start as non-preferred technique). Body angles showed that legs in non-preferred technique permit to increase quantity of body rotation during aerial phase. Finally, subject effect was found for arms movements (confirming that expert swimmers can organize themselves differently to achieve to an optimal performance.

KEY WORDS: swimming start, expertise, angular momentum.

INTRODUCTION: Most of the biomechanical studies of start time in swimming have used kinetic and kinematical analyses to compare the two main start techniques used in competition: the grab and the track start. Using a track start, swimmers tend to leave the block quicker (Ayalon et al., 1975) and to make a flatter flight trajectory due to higher horizontal velocity (Costill, 1992). With the grab start, swimmers spend more time on the block (Issurin and Verbitsky, 2003). Studies that compared the two start techniques showed that when comparing between grab starters and track starters, each swimmer performed best in his preferred technique. By consequence, these studies were particularly interested in the starting technique effect. However, studies that analyzed differences between start techniques and that take in consideration the swimmers start preference are scarce (Vilas-Boas et al., 2003). This study was the only one that studied it with a mixed approach both technique and preference at the same time. The use of the preferred technique may induce better performance to 15m, as well as other differences due to better technical management. It is interesting to compare, for a population that the preferred technique is known, the impact of this preference compared to the non-preferred technique. This problematic is different from the starting technique effect, and focus on the starting preference effect. Angular momentum can be a variable that showed differences between the two start techniques. McLean et al. (2000) calculated angular momentum generated during the aerial part of a relay start in a way to quantify the quantity of rotation. Analysis was made for different start relay techniques, without or with one or two steps before taking off the block. It was shown that swimming start is not only to generate the greatest forward impulse. The initial position of the swimmer on the block is a blocked forward unbalance, which permitted to obtain a couple of opposing forces and to influence the angular momentum. By consequence, angular momentum is an important variable to consider, in addition to the kinetic variables.
The aim of this study was to analyze the influence of start preference on the aerial phase of the start, where the difference between start techniques seemed most pronounced. In that way, body angles and angular momentum of body limbs were studied from the starting signal to water entry. It was hypothesized that swimmers performing its preferred technique have a better oriented impulse (more oriented in the direction of the movement) and a lower loss of angular momentum in other dimensions than the one measured (transverse rotation).

Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

METHODS: Five expert (23.2±1.5 years; 1.8±0.1 m; 78.6±8.2 kg; 89.3±3% WR of the 100-m front crawl) male Portuguese front crawl sprint specialists voluntarily participated in this study. For all of the swimmers, preferred technique of starting was the grab start. Each swimmer performed a 25-m front crawl six times at the 50-m race pace. Each swimmer performed three starts in each technique with a rest period longer than 5 minutes. The target time was expected to be within 2.5% of the race time. Trials were kept only if they respect the latter condition. Two lateral aerial video cameras and one lateral underwater video camera with rapid shutter speed (1/1000 s) were connected to an audio-visual mixer, a video timer, a video recorder and a monitoring screen to genlock and mix them on the same screen. The first camera (50 Hz, Sony® DCR-HC42E) was placed from the edge of the pool and videotaped the block and flight phases. Both other cameras (50Hz, JVC GR-SX1 SVHS-C PAL) were mounted on a specially designed support placed at the lateral wall of the pool, 3m from the edge of pool deck. One camera was placed above the water; elevated 30 cm above the surface, and the other was kept underwater (IKELITE BOX) at a depth of 30 cm, and exactly below water camera. The optical axes were kept perpendicular to the axis of swimmer's movement. A fourth camera was placed in front of the 15 m mark and videotaped the swimmer from the moment when the head broke the surface of the water to the end of the 15 m.
Kinematical analysis was processed using Simi-Motion (Simi Reality Motion Systems GmbH, Germany). Spatial model was composed by 20 anatomical landmarks digitalized in each frame, defining 14 body segments model (De Leva, 1996). From center of gravity (CG) of every segment, the CG of the body was calculated. A further calculation was made on limbs' parts (for arms until the legs) from the position of each body segment. Angle between arm and trunk (CG of arm-shoulder-hip), angle between leg and trunk (CG of leg-hip-shoulder) and angle between the takeoff angle (CG of the body-feet-horizontal axis) were determined for all the movement from start signal and feet entry in the water. To compare the trials, they were normalized by percentage calculations. In order to compute the angular momentum for each body segment mechanical parameters such as the segment mass and inertia were evaluated. We assumed that each body segment, except the head, can be modeled as a homogeneous cylinder. The head has been considered as a sphere. To obtain the body segment inertia, we have used the radius of gyration computed by Zatsiorsky and Seluyanov (1983). As the motions were modeled in 2D, we have computed the angular momentum along the transverse axis as follow:

$$L^{i}_{GZ/F*} = [I_i]w_i z + m_i\left(\left(GG_i x * V_{Giy/F*}\right) - \left(GG_i y * V_{Gix/F*}\right)\right)$$

where G is the center of gravity of the whole body, m_i is the mass of the ith segment, G_i is the center of mass of the ith segment, $F*$ is the barycentric frame, I_i is the inertial matrix of the ith segment, w_i is the angular velocity. Then the total angular momentum in the global frame is obtained by adding all the local angular momentum of each segment.
Angular momentum was calculated at takeoff (H, $kg.m^2.s^{-1}$) and mean standard deviation for H (ΔH, $kg.m^2.s^{-1}$) was calculated in our sample. Values were measured during the entire movement but were compared in four key points: first value after start signal (1), at takeoff (2), at entry of the hands into the water (3) and at entry of the feet into the water (4).
Kinetic analysis of starts was performed from a force plate (Bertec 4060-15, Bertec, Columbus, USA) mounted on a specially built support fixed to the pool wall that allowed the swimmers to assume starting positions in conformity with the FINA rules. The sampling rate was 1000Hz and the analogue signal was transmitted to a PC through a Biopac 16 bit A/D converter (Vilas-Boas et al., 2003). The starting signals complied with the swimming rules and were produced by a starter device (ProStart). The device simultaneously produced the starting sound, transmitted a LED signal (longer than 0.1s) to the video system, and triggered a signal to the A/D converter for data synchronization. ANOVA tests analyzed the variables that significantly differentiated the start techniques and subject effect. Statistics were performed with Minitab 14.10 (Minitab Inc., 2003) and the level of significance was set at $\alpha=0.05$.

Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

RESULTS: Results for the three body angles and angular momentums are displayed in Table 1. Curves of three body angles from the start signal and feet entry are illustrated in Figure 1. On the figure, takeoff was placed in 53rd and 55th data point, hand entry in 80th and 81st, respectively for trials in non-preferred and preferred technique (represented in Figure 1). Body angles on the block (CG arm-trunk 1 and CG leg-trunk 1) confirmed the different initial body organization during the different starting techniques. Body angles were also significantly different at takeoff (CG Arm-Trunk 2 and CG Leg-Trunk 2). Angular momentum measurements, values for the legs (H Leg) global angular momentum (H Total) and global loss of angular momentum (ΔH Total) were significantly different between start techniques.

Table 1
Comparison of Preferred and Non-preferred techniques

Variables		Preferred Technique	Non Preferred Technique
CG Arm-Trunk 1	(°)	93.22±10.12	105.88±10.54 *
CG Leg-Trunk 1	(°)	30.09±4.18	26.16±5.86 *
CG-Toe-Horizontal 1	(°)	112.04±9.22	118.59±13.67
CG Arm-Trunk 2	(°)	60.70±78.40	70.03±65.88 *
CG Leg-Trunk 2	(°)	169.32±10.20	148.64±34.27 *
CG-Toe-Horizontal 2	(°)	19.59±6.51	23.40±19.82
CG Arm-Trunk 3	(°)	152.15±15.53	150.98±16.88
CG Leg-Trunk 3	(°)	150.3±17.38	154.00±15.23
CG-Toe-Horizontal 3	(°)	-17.94±14.51	-16.84±16.36
CG Arm-Trunk 4	(°)	166.59±16.49	170.24±18.26
CG Leg-Trunk 4	(°)	163.20±9.63	164.64±9.23
CG-Toe-Horizontal 4	(°)	-32.40±32.70	-29.16±23.18
Horizontal Impulse	(N)	198.54±25.42	205.84±25.42
Vertical Impulse	(N)	805.36±73.94	735.72±89.96 *
HTrunk	($kg.m^2.s^{-1}$)	8.04±0.57	7.94±0.89
ΔH Trunk	($kg.m^2.s^{-1}$)	3.32±0.69	3.46±0.34
H Leg	($kg.m^2.s^{-1}$)	6.88±1.11	10.42±0.66 *
ΔH Leg	($kg.m^2.s^{-1}$)	3.88±1.43	5.34±1.10
H Arm	($kg.m^2.s^{-1}$)	-3.56±0.93	3.34±1.04
ΔH Arm	($kg.m^2.s^{-1}$)	1.06±0.13	1.52±0.19
H Total	($kg.m^2.s^{-1}$)	16.36±2.89	18.76±2.26 *
ΔH Total	($kg.m^2.s^{-1}$)	1.00±0.31	1.80±0.32 *

* : significant difference with elite swimmers at $p<0.05$

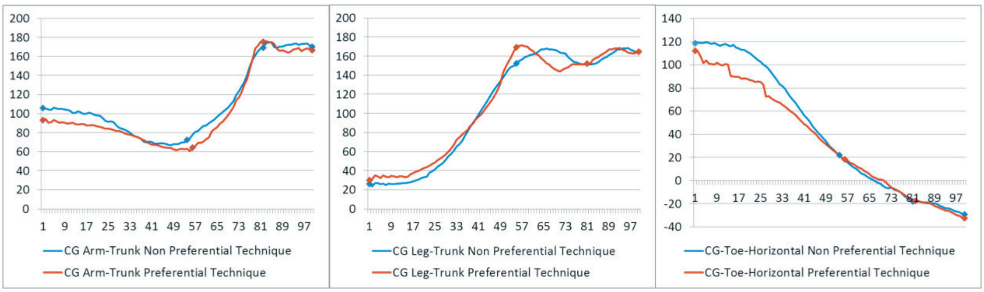

Figure 1: Evolution of the three body angles (in degree) from the start signal to feet entry in the water (horizontal axis: time in percentage of total motion).

DISCUSSION: The differences of CG Arm-Trunk 2 and CG Leg-Trunk 2 between the two techniques showed that swimmers had arms stretched forward more in preferred technique than in the non-preferred one. However, differences for CG Arm-Trunk were due, as shown by previous research of Seifert et al. in 2009, to a subject effect. Indeed, it was showed that expert swimmers can organize themselves differently to achieve an optimal performance (arms stretch forward at takeoff versus Volkov style, where arms are behind the trunk). For the legs (CG Leg-Trunk) the opposite was found and, in this case, differences were linked to a preference effect. After that, for the two last key points, no significant difference was found for CG Leg-Trunk angle. These two last assessments showed that legs moved more in aerial phase in non-preferred technique than in preferred technique in order to asses to a non-significantly different CG Leg-Trunk angle at hand entry. This is confirmed in terms of quantity of rotation by a significantly higher angular momentum for the legs. Indeed, the fact that the legs are staggered in the track start permits the swimmer to exert an impulse further from the center of gravity (with the rear foot). Moreover in preferred technique, the impulse had a more vertical impact than rotation (shown in non-preferred technique). This is shown by a significant difference in vertical impulse (805.36±73.94 and 735.72±89.96 respectively for preferred and non-preferred technique).
Values of total angular momentum (H Total), values were significantly different and showed a higher loss of it (in the two other axes than the one measured) in non-preferred technique. This can be linked with a study on measurement of symmetry during force development on the block during swimming start (Benjanuvatra et al., 2004). Indeed, the results showed that, for a population of expert swimmers, some of them had symmetrical and some had asymmetrical development of force. An asymmetry in track start can induce a twisting effect and result a higher value of delta total angular momentum (loose of angular momentum in body axis). This last point was reported by Vilas-Boas et al. (2003) by explaining that the grab start technique is a starting position with a higher stability. In addition to observed preference effect, it is possible that the swimmers (all grab starters) chose their preferred technique because have not determined how to keep themselves from rotating in the other axes and have realized that the result decreases their overall performance.

CONCLUSION: This study analyzed the impact of starting preference on kinetics and angular momentum. For these parameters, angular momentum was the variable most significantly different between the two conditions of starting.

REFERENCES:

Ayalon, A., Gheluwe, B., & Kanitz, M. (1975). A comparison of four styles of racing in swimming. In: Clarys, J.P., Lewillie, L. (Eds.) *Swimming Science II*. Baltimore: University Park Press (pp. 233-40).

Benjanuvatra, N., Lyttle, A., Blanksby, B., & Larkin, D. (2004). Force development profile of the lower limbs in the grab and track start in swimming. In: *XXII International Symposium on Biomechanics in Sports*, Ottawa: Faculty of Sciences, University of Ottawa (pp 392-402).

De Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Applied Biomechanics*, 29, 1223-1230.

Issurin, V., & Verbitsky, O. (2003). Track start versus grab start: Evidence from the Sydney Olympic Games. In Chatard, J.C. (Ed.) Biomechanics and Medicine in *Swimming IX*. Saint Etienne: University of Saint Etienne (pp. 213-217).

McLean, S.P., Holthe, M.J., Vint, P.F., Beckett, K.D., & Hinrichs, R.N. (2000). Addition of an approach to swimming relay start. *Journal of Applied Biomechanics*, 16: 342-355.

Seifert, L., Vantorre, J. & Chollet, D. (2009). Different profiles of the aerial start phase in front crawl. *Journal of Strength and Conditioning Research*, 24, 507-516

Vilas-Boas, J.P., Cruz, M.J., Sousa, F., Conceiçao, F., Fernandes, R., Carvalho, J. (2003). Biomechanical Analysis of Ventral Swimming Starts: Comparison of the Grab Start with 2 Track Start Techniques. In: Chatard, J.C. (Ed). *Swimming Science IX*, University of Saint Etienne, Saint Etienne, France (pp 249-253).

Zatsiorsky, V. & Seluyanov, V. (1983). The mass and inertia characteristics of the main segments of the human body. In *Biomechanics VIII*, 8, 1152-1159.