BODY ROLL AND STROKE KINEMATICAL CHANGES DURING A RACE-PACE SWIM IN BACKSTROKE

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The purpose of this study was to verify the behaviour of body roll during a 200m event race-pace effort in backstroke swimming. Six international swimmers performed 6 x 50m with 10" interval at a swim velocity corresponding to the race pace of 200m backstroke. The swimmers were videoed whole body at the 2nd and 6th repetitions, for a complete stroke cycle, with four video cameras (two underwater, two above the water) for 3D kinematical analysis (APAS). Shoulder roll (SR) and hip roll (HL) were used to describe body roll. Maximal SR (48° to 52°) and HL angles (51° to 54°) coincided with the end of the initial downsweep, the variation of body roll followed a rather symmetrical and in phase pattern. In spite of a clear decrement of swim velocity from 2nd to 6th repetition ($p<0.05$) there were no changes in the stroke cycle or in the body roll pattern.

KEY WORDS: backstroke, fatigue, technical analysis, body roll.

INTRODUCTION: The extent of body roll in backstroke swimming is associated with the positioning of upper limbs to generate propulsion, the diagonal propulsive movement of lower limbs and the stabilization of lateral movements of the body. It enhances arm recovery, with the shoulder leading the movement, and promotes a deep catch in the beginning of the pull, permitting a subsequent hand movement diagonally directed upwards. To date, the relationship between body roll, active drag and swimming performance has not been established and the controversy concerning the generation of propulsive forces in human swimming cast some doubt on the necessity of having marked hand sculling actions during the arm stroke.

In front crawl, both simulation (Hay et al., 1993; Payton et al., 1993) and experimental studies (Liu et al., 1933) have demonstrated that body roll has a significant influence on the medio-lateral motion of the hand during the arm pull, explaining its curved path. In a subsequent study Yanai (2003) established a dependency of body roll mainly on external torque caused by fluid forces applied on both the upper and lower limbs, which may be the reason why swimming with less stroke frequency for the same velocity is more efficient reducing forces in the non-propulsive directions.

The purpose of this study was to characterize shoulder and hip roll during backstroke swimming and verify if during a 200 m race pace intermittent swim there are alterations of rotational body movement patterns along the stroke cycle.

METHOD: Six international level swimmers participated in this study, two females (age: 21.7±5.7 years, height: 1.7±0.6 m, body mass: 60.2±5.4 kg, %FAT: 19.01±1.81) and four males (age: 22.5±5.1 years, height: 1.83±0.76 m, body mass: 70.68±12.16 kg, %FAT: 6.45±1.21). International point scores (FINA) corresponding to 200 m backstroke best times in long course were 868.3 ±28.6.

Each subject performed 6 x 50 m repeats with 10 s of rest, in a 50 m pool, at a velocity corresponding to race pace of best performance in the 200 m backstroke. Oblique underwater front views from below and from both sides were taken by two fixed digital cameras (JVC 6800, 50 Hz, 1/250 of shutter speed), in underwater housings (Ikelite), covering the whole body for one complete stroke cycle. Two other fixed digital cameras were positioned on the pool deck, one in front and one lateral in order to video the swimmers above the water (Figure 1). A set of lights (above and underwater) were used for synchronizing the video recordings. Images from the 2nd and 6th repetitions were retained for 3D kinematical analysis (APAS).

A volume of 4.42 in length, 1,41 in width and 2.00 in height was calibrated prior to the swimming trials by placing a control object with 30 points of known coordinates integrating the space the swimmers would use for one complete stroke cycle. A global reference system was constructed.

Eighteen body landmarks were manually digitised: vertex, chin-neck intersect, joint centers of shoulders, elbows, wrists, hips, knees and ankles, tip of the toes, tip of the fingers, corresponding to a 14-segment model of the human body.
Shoulder roll (SR) and hip roll (HL) were defined as the angular displacement about the long axis of the body of the lines connecting, respectively, the shoulder joint centers and the hip joint centers, projected onto the medio-lateral plane of the body. These two variables were used to describe body roll.

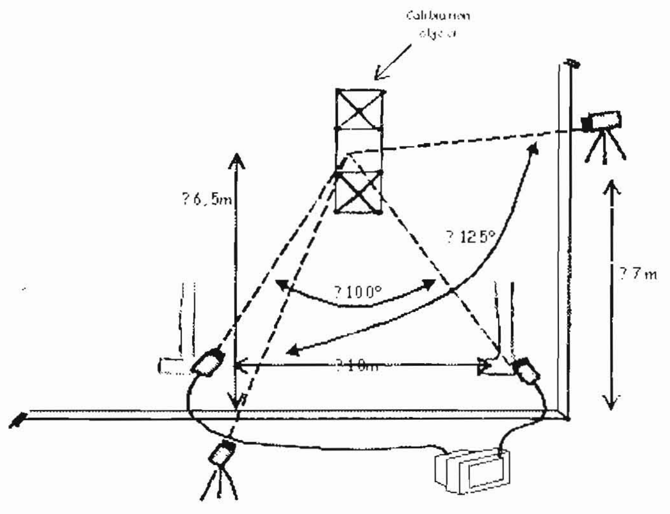

Figure 1: Underwater and above the water filming set-up.

A digital filter (Butterworth) with a low pass cut-off frequency of 5 to 8 Hz was used to smooth kinematic data (Winter, 1990).
A complete underwater stroke cycle, from entry to entry of the same hand in the water, was digitised. The identification of each of the four phases of the underwater hand path in backstroke, the initial downsweep (IDS), the upsweep (US), the final downsweep (FDS) and finish/exit (F), was made from the underwater hand path. Absolute duration of each phase were calculated in milliseconds and expressed as a percentage of the duration of the total underwater armstroke.
All data are expressed as means ± S.D. Differences between means were evaluated using a Wilcoxon test and significance was set at $p<0.05$.

RESULTS: Maximal shoulder and hip roll angles for the second and the sixth repeats are shown in Table 1.
Maximal SR angles found in this study were very similar to what has been reported in the literature: 45 to 48° (Cappaert et al., 1996). Maximal hip roll angles, on the contrary, were larger than the shoulder ones ($p< 0.05$) and consistently higher then the values indicated by this author (45°) in the case of a particularly well succeeded backstroke swimmer.
Maximal SR angles occurred in the end of the initial downsweep and transition to the upsweep, a little earlier than what is described as optimized technical models (Maglischo, 2003). Maximal HR angles showed similar phase, with some swimmers presenting a slight anticipation in relation to shoulder rotational movement. Peak angular velocities for both shoulder and hip roll were attained during the FDS of each arm, immediately before the exit of the shoulder from the water.
In spite of a clear decrement of swim velocity from 2nd to 6th repetition ($p<0.05$) no significant changes occurred between repeats neither for stroke rate nor for the variables describing body roll.

Table 1 Maximal shoulder roll and hip roll angles.

		Right side	Left side
Maximal SR (°)	2nd repeat	48.19 ± 4.07	48.11 ± 4.28
	6th repeat	48.15 ± 3.30	49.98 ± 8.51
Maximal HR (°)	2nd repeat	51.93 ± 10.02	54.02 ± 8.87
	6th repeat	52.47 ± 9.34	52.38 ± 7.26

All the swimmers of this study showed a pattern of timing of the arms and legs of 6 kicks per stroke cycle.

DISCUSSION: Caeppert et al. (1995) comparing elite (finalists) and non-elite freestyle swimmers during the 1991 World Championships and the 1992 Olympic Games, reported that the latter showed strong twisting of the trunk with shoulders and hips rolling in opposite directions, contrarily to what happened with the former who exhibited symmetrical body roll and almost equal amplitudes. Curiously, similar results were found in backstroke events (Caeppaert et al., 1996). More recently, Yanai (2001) revealed similar phase angles for the shoulder roll and hip roll in a group of college swimmers, in freestyle, but with consistently lesser amplitude for the hip roll angles. All the swimmers in this study showed shoulder and hip roll with similar phase angles, which seem to be a characteristic of a good technique (Cappaert et al., 1996).
It is common conception among coaches that backstroke swimmers must spend most of each stroke cycle duration on their side with only a very short transition period on their back and that the initiation of body rotation begins with the hip synchronized with a strong 6 beat kick. In fact, successful backstroke swimmers roll their bodies accompanying the arm stroke, reaching maximal positive roll angle at mid recovery of the arm of the same side, and complete horizontality when each arm enters the water (Maglischo, 2003).
Due to anatomical constraints, body roll in backstroke swimming keeps a different relation to the arm pull comparing to what happens in freestyle. In fact, the acceleration of the hand downwards during FDS seems to be the main source of body roll from the position where shoulder and hip angles are in a deepest position onto the regaining of horizontal body position continuing with the exit of the shoulder from the water and the opposite hand reaching for a deep catch. The FDS of one arm is concomitant with a strong kick every third beat that possibly has a major role enhancing angular acceleration of the body about the long axis.
Further research must verify if backstroke body roll has the same dependency as freestyle in what regards external torque caused by fluid forces (Yanai, 2003).
In spite of more pronounced rotational amplitude of the hips when compared to the shoulder's, there was no consistent evidence that body roll originated from the hips, although in some subjects the beginning of the hips rotation anticipated that of the shoulders (see Figure 2 for example).
Fatigue induced by a race pace interval set does not seem to disturb body roll patterns in this group of well-trained swimmers. It should be noted however that stroke rate remained also unchanged and that the swimmers managed to keep swim velocity rather constant from the 2nd to the 6th repeat.

CONCLUSION: Body roll in backstroke swimming is an important component of technical proficiency and competitive swimmers attain rather large maximal angles both in shoulder and in hip rotation about the longitudinal axis of the body using a symmetrical and synchronized pattern.

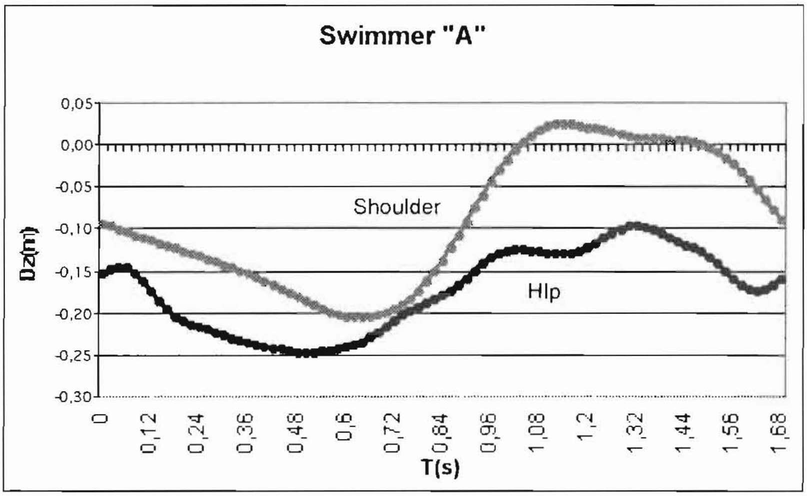

Figure 2: Same body side shoulder and hip vertical displacement (Dz): an example.

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