THE INFLUENCE OF SWIMMING VELOCITY ON THE KINEMATIC CHARACTERISTICS OF BACKSTROKE SWIMMING

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INTRODUCTION: In standard workout conditions, swimmers spend most of their time swimming at intensities significantly lower than race pace. Specificity of training must not be faced merely from a metabolic point of view, but also as a technical and kinesiological problem. Alves & Madeira (1995) have shown that during a maximal bout of 400 m backstroke, intended to be swum at a constant velocity, swimming velocity was actually significantly lower in the last lap of 50 meters than in the first one, and this difference was concomitant with a decrease in distance per stroke and a maintenance of stroke rate, a pattern often described in competitive situation (Alves, 1994). Contrary to what was expected, however, a decrease in the relative duration of the final downsweep was the only significant change observed. Regardless of the effects of fatigue, it is of most interest, thus, to verify whether the increase in velocity in a broader amplitude is followed by changes in the intracycle temporal structure or in the range of limb movements.

Several basic descriptors of swimming technique have been found to influence energy cost and performance in well-trained swimmers, such as distance per stroke and intracycle velocity variation (Smith et al., 1988; Klentrou & Montpetit, 1992; Alves et al., 1996). Propulsive force in swimming shows a periodic variation during each stroke, resulting in either acceleration or deceleration of the body. The greater the amplitude of speed fluctuation relative to the mean value, the greater the force consumption. Due to the instrumental difficulty in assessing total body center of gravity displacement in swimming, the study of hip joint point kinematics has often been considered an acceptable approach (Costill et al., 1987). Maglischo et al., (1987) have proposed that the horizontal velocity of the hip can be used as a tool for technical evaluation because the velocities of the hip and center of gravity follow similar patterns in the four competitive strokes. In the non-simultaneous strokes, the horizontal velocity of the trunk is less subject to the inertial forces generated by the body section above the water, as happens, for instance, in the breaststroke (Colman & Persyn, 1993).

Therefore, the purposes of this study were: a) to verify to what extent swimming the backstroke at different speeds implied a change in the stroke pattern and in the kinematics of the propulsive movements; b) to determine which were the technical characteristics that showed some association with performance in short distance efforts, and c) to compare the intracycle velocity variation of the center of gravity of the body to the intracycle velocity variation of the hip point at maximal swimming velocity.

METHODS AND PROCEDURES: Seven well trained male swimmers participated in this study (age: 14.71±0.76 years, height: 1.74±0.39 m, body mass: 63.14±5.52 kg, %FAT: 15.40±1.81). Each subject performed 3 x 50 m backstroke repeats with 15 min of rest, at a velocity corresponding to 90% (v90), 95% (v95) and 100%

(vmax) of best performance in the 50 m backstroke. For every swimming bout, swimmers were instructed to keep a constant pace, following a light tracer.

The swimmers were filmed in the sagittal plane, underwater and above the water, with 2 synchronised cameras (JVC-SVHS, 60 Hz, 1/250 of shutter speed), placed one above the other 60 cm, with their optical axes oriented convergently. Both cameras were fixed to the lateral wall of the pool, 10 meters away from its top, 7.5 m from the swimmer. Images were mixed at real time using a Panasonic WJ-MX-50 mixing table.

Digitizing and posterior analysis of the images were done using the APAS system, in order to determine the pull kinematic characteristics, the body center of gravity and the hip velocity and acceleration curves. A digital filter with a cut-off frequency of 5 Hz were used to smooth the kinematic data (Winter, 1990).

A complete underwater stroke cycle, from entry to entry of the same hand in the water, was digitized. Marks were fixed on the joint axes of the arms and legs, on the hand, at the level of the head of the metacarpal bones, on the feet and at the hip (trocantherion). Two points identified the head position: the ear and the vertex. The identification of each of the four phases of the underwater hand path in the backstroke, the initial downsweep (IDS), the upsweep (US), the final downsweep (FDS) and finish/exit (F), was made from the underwater hand path. Absolute durations of each phase were calculated in milliseconds and expressed as a percentage of the duration of the total underwater armstroke. Mean pulling length and mean pulling depth (cm), as defined by Schleihauf et al. (1988), distance between the point of entry in the water and point of exit of the hand from the water (cm) were measured.

Anthropometric measurements were made following standard procedures.

All data are expressed as means ± S.D. Coefficients of variation ($SD.mean^{-1}.100$) were calculated for intracycle hip and body center of gravity velocities. The correlations performed were the Pearson Product Moment, and the ANOVA for repeated measures was used to test the significance of statistical differences. Statistical significance was accepted at the level: $p < 0.05$.

RESULTS AND DISCUSSION: Kinematic analysis of the underwater hand path revealed great inter-individual variability in the spatial and temporal patterns used. It has often been mentioned that individual propulsive optimization strategies suffer great variation, the same results being obtained by rather different movement spatial and temporal patterns. Underwater hand path patterns found in elite swimmers with similar performance levels are a good example of this inter-individual variability (Schleihauf et al., 1988; Maglischo, 1993).

Table 1. Mean velocity of body center of gravity per stroke phase ($m.s^{-1}$) at the three intensity levels.

	v90	**v95**	**Vmax**
IDS	1.06 ± 0.15	1.14 ± 0.12	1.26 ± 0.11
US	1.36 ± 0.21	1.31 ± 0.17	1.54 ± 0.20
FDS	1.30 ± 0.12	1.30 ± 0.09	1.43 ±0.11
F	1.19 ± 0.20	1.17 ± 0.26	1.24 ± 0.26

Peak mean horizontal velocities of the hand occurred during the upsweep at v90 and v95 and during the finish/exit at vmax. Stroke total duration decreased from v90 to v100 due to the shorter duration of the dowsweep, the final downsweep and the finish/exit, but the relative duration of the phases did not show any significant changes. Increasing velocity caused an increase in the distance between the point of entry into the water and point of exit of the hand from the water, but mean pulling horizontal length decreased.

Swimming velocity at submaximal intensities correlated well to mean body velocity at the upsweep, but at vmax, the highest association was to body velocity at the final downsweep. Body center of gravity variation per phase showed peak values during the US and negative values during the FDS, in spite of huge inter-individual variability. These results confirm a previous study (Alves, 1996) with 12 backstrokers, where average body horizontal resultant impulse during the US was estimated to be 16.66 Ns (ranging from -1.92 Ns to 76.64 Ns), indicating that the propulsive force created was broadly superior to body drag, but showed negative values during the FDS, the last propulsive phase of the underwater hand path, with large interindividual differences (ranging from -53.37 Ns to 30.77 Ns).

Table 2. Mean acceleration of body center of gravity per stroke phase ($m.s^{-2}$) at the three intensity levels.

	v90	**v95**	**Vmax**
IDS	1.41 ± 1.26	1.20 ± 1.04	0. 89 ± 1.05
US	3.09 ± 5.67	1.29 ± 1.73	2.37 ± 3.61
FDS	-0.56 ± 1.42	-0.59 ± 1.42	-1.04 ±1.63
F	0.50 ± 2.93	-0.21 ± 0.69	0.84 ± 2.08

Maximal velocity in the 50 m backstroke was inversely correlated to the range of intracycle velocity variation of the body center of gravity ($r = 0.79$, $p < 0.05$). A positive correlation between intracycle horizontal velocity fluctuation measured at the hip and energy cost at submaximal velocities has been found by Alves et al. (1996), but not with performance in short distance events. Confirming several studies, performance in the short distance backstroke seems strongly associated with morphological characteristics of linearity.

Table 3 Correlations between anthropometric measurements and performance at vmax.

	r	**P**
Height	-0.83	<0.05
Hand length	-0.81	<0.05
Foot length	-0.79	<0.05
% Fat	0.83	<0.05

The intracycle velocity variation of the body center of gravity showed a poor individual correlation to the hip velocity variation ($r=0.58 \pm 0.18$). Correlation between the coefficient of variation of the hip and of the center of gravity intracycle velocities had, on the contrary, a high significance ($r = 0.99$, $p<0.001$).

CONCLUSIONS: Movement temporal and spatial structures seem to vary little with velocity changes in swimmers who have attained a good stabilization of motor execution. In fast swimming, nevertheless, swimmers apparently achieve a greater antero-posterior stabilization of the hand, which may indicate more pronounced lift oriented sculling actions, and performance becomes more dependent on the final portion of the underwater path.

The variation of the mean velocity of the hip cannot be used for quantification of the changes from phase to phase in body velocity, but a coefficient of variation ($SD \cdot mean^{-1} \cdot 100$) of the intracycle hip velocity seems to be an acceptable indicator of the intracycle velocity variation of the body center of gravity.

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