UPPER EXTREMITY KINEMATICS DURING DIFFERENT BREATHING PATTERNS AND SELECTED STROKE DRILLS IN FRONT CRAWL SWIMMING

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Some studies were developed trying to determine: how body roll affects the pulling path and the influence of breathing actions on stroke mechanics. The aim of this study was to determine the differences of arm movement kinematics in different breathing patterns and selected stroke drills in front crawl swimming. Whether breath-holding or breathing, swimmers do not change their amplitude of movement in the stroke depth, width and length. When the swimmer performs the stroke drill of one-arm front crawl with the resting arm extended in front, breathing on the moving side, the stroke depth is reduced due to the lack of body rotation. When a coach prescribes swimming drills he must consider their influence on body rotation and pulling path. Both can be greatly modified by the no moving arm position and breathing co-ordination.

KEY WORDS: arm motion, breathing, stroke drills, front crawl.

INTRODUCTION: Simulation studies (Hay *et al.* 1977; Payton *et al.* 1997) and experimental studies (Liu *et al.*1993) have demonstrated that body roll has a significant influence on the medio-lateral motion of the hand during front crawl swimming. However, more recent studies (Payton *et al.* 1999 a,b) have shown that body roll is not responsible for the medial hand movement and hand speed observed in the front crawl. The authors found how their body started to rollback to the neutral position either late in the downsweep or very early in the insweep. This indicates that body roll opposed medial hand motion, rather than assisted it, during the insweep (Payton *et al.*, 1999b). Payton *et al.* (1999a) concluded that body roll does not contribute to the production of hand speed during the insweep phase of the front crawl, reducing the hand speed about 46%. The effect of turning the head to breathe increases the body roll an average of 9° (Payton *et al.*, 1999b) or 10° (López-Contreras & Arellano, 2001). López-Contreras & Arellano (2001) measured the body rotation during front crawl swimming drills. Their results showed five times less body rotation compared with breath holding freestyle when the swimmer performed the drill of one-arm front crawl with the resting arm extended in front, breathing on the arm-moving side and half of the rotation when the drill was one arm front crawl with the resting arm close to the body, breathing on the arm-moving side. Similar body rotation as in freestyle was obtained when the swimmers performed the drill of one-arm front crawl with the resting arm close to the body breathing on the non-moving side. The aim of this study was to determine the differences of arm movement kinematics during different breathing patterns and selected stroke drills in front crawl swimming.

METHODS: *Subjects:* Eight Spanish national ranked age-group swimmers participated in the study with an age range from 14 to 18 years old. Two weeks before the experimental day the swimmers incorporated in their daily competitive swimming workouts a minimum of half-an-hour of practice performing the different breathing patterns and stroke drills. After a 1000 m warm-up and habituation to the experimental conditions each swimmer performed two randomised trials (15 m) on each breathing pattern and front crawl swimming drill. The swimmers were urged to swim at 100 m speed when that was possible. The best trial of each repeated exercise was selected for analysis. *Instrumental:* The underwater three-dimensional path of the swimmer's pull was recorded with two cameras located in 1 m below the water-surface, filming through two underwater windows. One camera was located perpendicular to the swimmer displacement and the other camera was located front-lateral to the swimmer frontal view. A calibration frame was located in the underwater displacement area (4 x 2 x 2 m) and video-recorded before the first repetition. A standard DLT calibration algorithm was utilized to obtain the three-dimensional body coordinates.

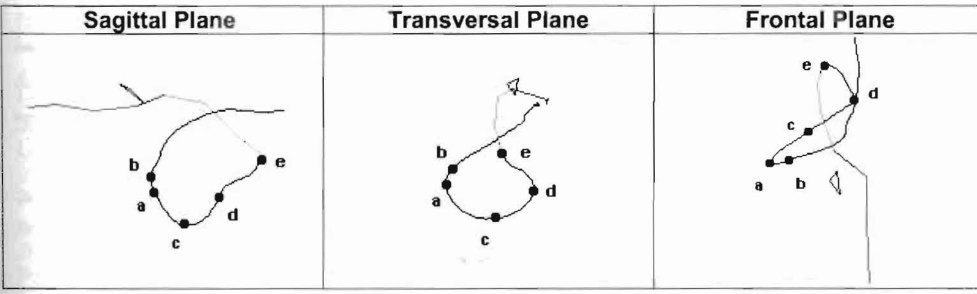

Figure 1. Sample of pulling paths projected on three planes. Points description: a) more external point; b) more forward point; c) deeper point; d) more internal point; e) more backward point.

Variables measured: The three-dimensional coordinates of the stroke pattern let us obtain the projected dimensions on each reference plane. The pulling action was divided into four phases: 1) entry and stretch, 2) downsweep; 3) insweep and 4) upsweep. *Independent variables*: The trials were performed on the following front crawl breathing and stroke variations: 1) front crawl swimming (FCS); 2) front crawl swimming breathing on the non-preferred side (FCSN); 3) front crawl swimming and breath-holding (FCNB); 4) one arm front crawl with the resting arm extended in front, breathing on the arm-moving side (C1B); 5) one arm front crawl with the resting arm close to the body; breathing to the no-moving side (C1BNE); 6) one arm front crawl with the resting arm close to the body, breathing on the arm-moving side (C1BE). *Dependent variables:* Stroke width (Sw): medial (x-axis) displacement of the hand during insweep. Stroke depth (Sd): vertical (z-axis) displacement of the hand from the entry to the deepest point. Pulling length (Pl): horizontal (y-axis) displacement of the hand from entry to the exit of the hand. Hand velocity at the end of entry and stretch (V_1). Hand velocity at the end of downseep (V_2). Hand velocity at the end of insweep (V_3). Hand velocity at the end of upsweep (V4). Maximum hand velocity during the front crawl pull (Vmax). Percentage of the total pulling time where the maximum hand velocity was obtained (%Vmax). Each dependent variable was measured for each stroke when both arms were pulling. *Statistical analyses:* Averages and standard deviations were calculated for all variables. Comparison between the different levels of the independent variables were developed calculating the *t*-Test for dependent samples. Normality testing was performed using the Kolmogorov-Smirnov test to ensure the use of parametrical statistics.

RESULTS AND DISCUSSION: The results of spatial characteristics of the pulling path are shown in table 1. We did not find significant differences between the independent variables in the pulling length and the stroke width. The range of values of pulling length was between 0.62 and 0.68 m. The range of values of stroke width was between 0.39 and 0.48 m. The only significant differences were found in the stroke depth. While the swimmers performed the full stroke front crawl swimming with breathing variations (FCS, FCSN and FCNB) the depth values were similar among them and different from C1B and C1BE. The C1B exercise showed lower values than C1BE. Only C1BNE had similar depth values than full stroke trials. The influence of body rotation can explain our results. López and Arellano (2001) found five times lower values on the body rotation angle on C1B compared with normal front crawl swimming. Also these authors found half values on body rotation on C1BE. The body rotation angles were similar in C1BNE than full crawl stroke. The obtained results concerning arms' movement in each full stroke are similar to those cited by Payton *et al.* (1999b) where, despite the increased body roll, there was no notable change in stroke depth or stroke width compared to breath-holding swimming. Our values on stroke width were approximately 0.14 m higher than the obtained by Payton *et al.* (1999b) and 0.06 m higher than in Schleihauf *et al.* (1988). This difference can be explained by the stroke width definition of the present study where dimension measurements are not restricted to the insweep phase.

Table 1. Projected displacement of the hand on the reference planes. R= right and L= left arm.

	Pulling length		Stroke width		Stroke depth	
	Aver.	***s.d.***	**Aver.**	***s.d.***	**Aver.**	***s.d.***
FCS-R	0.63	*0.07*	0.45	*0.15*	0.77	*0.15*
FCS-L	0.68	*0.10*	0.41	*0.10*	0.78	*0.18*
FCSN-R	0.67	*0.14*	0.39	*0.18*	0.79	*0.17*
FCSN-L	0.64	*0.12*	0.44	*0.12*	0.75	*0.16*
FCNB-R	0.64	*0.10*	0.40	*0.14*	0.75	*0.15*
FCNB-L	0.62	*0.06*	0.45	*0.11*	0.68	*0.15*
C1B-R	0.64	*0.08*	0.42	*0.13*	0.61	*0.12*
C1B-L	0.67	*0.09*	0.41	*0.19*	0.61	*0.11*
C1BNE-R	0.65	*0.10*	0.48	*0.14*	0.72	*0.12*
C1BNE-L	0.67	*0.11*	0.41	*0.17*	0.78	*0.11*
C1BE-R	0.64	*0.08*	0.43	*0.19*	0.65	*0.12*
C1BE-L	0.65	*0.11*	0.44	*0.22*	0.64	*0.13*

Table 2. Averages and st. deviations of hand speed at the end of pulling phases. V_1: entry and stretch; V_2: downsweep; V_3: insweep and V_4: upsweep. R= right arm and L= left arm.

	V_1 (m/s)		V_2 (m/s)		V_3 (m/s)		V_4 (m/s)	
	Aver.	***s.d.***	**Aver.**	***s.d.***	**Aver.**	***s.d.***	**Aver.**	***s.d.***
FCS-R	10.64	*0.44*	20.38	*0.75*	20.05	*0.59*	30.04	*0.84*
FCS-L	20.02	*0.39*	20.27	*0.66*	10.94	*0.60*	20.99	*0.79*
FCSN-R	10.98	*0.47*	20.44	*0.71*	10.87	*0.38*	20.88	*0.79*
FCSN-L	10.93	*0.25*	20.43	*0.49*	10.82	*0.44*	30.37	*0.99*
FCNB-R	20.16	*0.39*	20.21	*0.77*	20.13	*0.70*	30.23	*0.91*
FCNB-L	20.06	*0.38*	20.32	*0.84*	20.14	*0.84*	30.93	*0.88*
C1B-R	10.66	*0.52*	20.15	*10.22*	10.71	*0.50*	20.92	*0.46*
C1B-L	10.81	*0.62*	20.35	*0.85*	10.68	*0.44*	30.18	*0.66*
C1BNE-R	10.85	*0.50*	20.03	*10.03*	10.91	*0.30*	20.81	*0.51*
C1BNE-L	10.82	*0.28*	20.31	*0.78*	10.69	*0.18*	20.71	*0.86*
C1BE-R	10.64	*0.40*	20.13	*10.02*	10.53	*0.40*	20.77	*0.64*
C1BE-L	10.75	*0.49*	20.21	*10.10*	10.73	*0.48*	20.68	*0.71*

The stroke depths were similar in our study to those reported by the previous references. The hand speed obtained at the end of each pulling phase showed (see table 2) a particular behaviour where the speed increased from phase one to phase two, decreased in phase three and the maximal values were obtained in the last phase. The results showed lower hand speed values of the one-arm exercises compared to the front crawl swimming.

CONCLUSIONS: The following conclusions can be drawn from the results of this study: 1) Whether breath-holding or breathing, swimmers do not change their amplitude of movement in the stroke depth, width and length; 2) when the swimmer performs the stroke drill of one-arm front crawl with the resting arm extended in front, breathing on the moving side, the stroke depth is reduced due to the lack of body rotation and 3) when the swimmer performs the stroke drill of one-arm front crawl with the resting arm close to the body, breathing to the no-moving side, the stroke variables show a similar value than normal front crawl swimming. When a coach prescribes swimming drills he must consider their influence on body rotation and pulling path. Both can be greatly modified by the no moving arm position and breathing co-ordination.

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