ARM MOVEMENTS KINEMATICS DURING DIFFERENT BREATHING PATTERN AND SELECTED STROKE DRILLS IN FRONT CRAWL SWIMMING

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Some studies were developed trying the determine: how the body roll affects the pulling path, the influence of breathing actions on stroke mechanics and how the body roll is modified by the use of different front crawl drills. 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. Eight Spanish national ranked age-group swimmers participated in the study. Video recordings were digitised at 50 Hz and the 3D coordinates of the upper extremity obtained using a DLT algorithm. 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 to the moving side, the stroke depth is reduced due to the lack of body rotation.

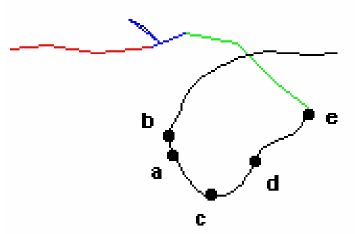
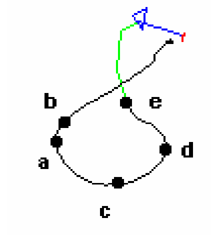
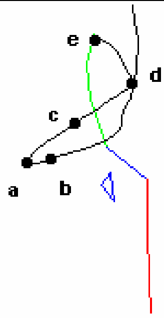
KEY WORDS: arm motion, breathing, stroke drills, front crawl.

INTRODUCTION: Simulation studies (Hay, Wilson, Dapena, & Woodworth, 1977; Payton, Hay, & Mullineaux, 1997) and experimental studies (Liu, 1993 #1679] have demonstrated that body roll has a significant influence on the medio-lateral motion of the hand during the front crawl swimming. However, more recent studies [Payton, 1999 #1765; Payton, 1999 #1904) suggested that body roll is not responsible for the medial hand movement and hand speed observed in the front crawl. The authors found how the body start to roll-back 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, Bartlett, Baltzopoulos, & Coombs, 1999b). (Payton, Bartlett, & Baltzopoulos, 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 a 46%. The effect of turning the head to breathe increases the body roll an average of 9º (Payton et al., 1999b) or 10º (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 no breathing freestyle when the swimmer performed the drill 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 than freestyle was obtained when the swimmers performed the drill one arm front crawl with the resting arm close to the body breathing to the no-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 analyses.
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 the three planes. Points description: a) more external point; b) more forward point; c) deeper point; d) more internal point; e) more backward point

Sagital View	Frontal View	Horizontal View
		

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 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.

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 y 0.68 m. The range of values of stroke width was between 0.39 y 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 between them and different from C1B and C1BE. The C1B exercise showed lower values as in C1BE. Only C1BNE had similar depth values than full stroke trials. The influence of body rotation can explain our results. López y 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 lack of differences obtained between the arm spatial movements of each full stroke variation based on breath, are similar to those obtained by Payton et al. (1999) where there was no notable change in stroke depth or stroke width compared to when breath-holding, despite increased body roll.

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*

Table 3: 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*

Our values on stroke width were approximately 0,14 m higher than obtained by Payton et al. (1999) and 0,06 m higher than 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. 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 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 to the moving side, the stroke depth is reduced due to the lack of body rotation.

REFERENCES

Costill, D.L., Maglischo, E. W. & Richardson, A.B. (1994). *Natación*. Hispano Europea, ed. Barcelona

Counsilman, J.E. & Wasilak, J. (1982) The importance of hand speed and hand acceleration. In Ousley,R.M. (ed). 1981 *ASCA World Clinic Yearbook*. Fort Lauderdale, Florida: American Swimming Coaches Association. 41-55

López-Contreras, G., & Arellano, R. (2001). Analysis Of Stroke Variations On Body Rotation In Front Crawl Swimming. *Investigación en Ciencias del Deporte, In press*.

Miyashita,M. (1971) Analysis of fluctuations of swimming speed. *In Biomechanics in swimming, waterpolo, and diving*. Universite libre de Bruxelles, Lab. de l'effort, p. 53-58

Hay, J., Wilson, B., Dapena, J., & Woodworth, G. (1977). A computational technique to determine the Angular Momentum of a Human Body. *, 10*, 269-277.

Payton, C. J., Bartlett, R. M., & Baltzopoulos, V. (1999a). The contribution of body roll to hand speed in front crawl swimming - an experimental study. In K. L. Keskinen, P. V. Komi, & A. P. Hollander (Eds.), *Biomechanics and Medicine in Swimming VIII* (1 ed., Vol. 1, pp. 65-70). JyvasKyla, Finland: Department of Biology of Physical Activity, University of Jyvaskyla.

Payton, C. J., Bartlett, R. M., Baltzopoulos, V., & Coombs, R. (1999b). Upper extremity kinematics and body roll during preferred-side breathing and breath-holding front crawl swimming. *J Sports Sci, 17*(9), 689-696.

Payton, C. L., Hay, J. G., & Mullineaux, D. R. (1997). The effect of body roll on hand speed and hand path in front crawl swimming - A simulation study. *Journal of Applied Biomechanics, 13*, 300-315.

Schleihauf, R.E. (1974). A Biomechanical Analysis of Freestyle. *Swimming Technique*. 11,(3x), 89-96.

Schleihauf, R.E., Gray,L. & De Rose, J. (1983). Three-dimensional analysis of hand propulsion in the sprint front crawl stroke. In Hollander, Huijing & de Groot (eds) *Biomechanics and Medicine in Swimming.* Champaing, Illinois: Human Kinetics. 173-183.

Schleihauf, R.E. (1984) Biomechanics of swimming propulsion. In Johnston, Woolger & Scheilder.(eds) 1983 ASCA World Clinic Yearbook. Fort Lauderdale, Florida; American Swimming Coaches Association. 1924.

Schleihauf, R.E., Higgins, J.R., Hinrichs, R. et al. (1988). Propulsive techniques: front crawl stroke, butterfly, backstroke and breaststroke. In Ungerechts, Wilke & Reischle (eds) *Swimming Science V*. Champaing, Illinois: Human Kinetics. 53-60.

ACKNOWLEDGMENTS

This study obtained a grant from The National Sport Council (Ministry of Education).