SCULLING TECHNIQUES IN SYNCHRONIZED SWIMMING

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The purpose of this study was to investigate sculling techniques in synchronized swimming based on three-dimensional motion analysis. Movements during sculling for ten elite synchronized swimmers were analyzed using a three-dimensional direct linear transformation method. Sculling techniques for more advanced synchronized swimmers included holding the elbows and upper arms stationary and changing the attack angles of the hands smoothly and evenly. When swimmers were given a 1.5-kg load, scull tempo increased and range of motion of the forearms was reduced.

KEY WORDS: sculling techniques, synchronized swimming, motion analysis.

INTRODUCTION: Sculling is a fundamental technique in synchronized swimming and can be introduced in the initial stages of a swimmer's career. Two kinds of sculls are used in synchronized swimming: a standard scull used in a layout position; and a support scull used in a vertical position. Both sculls can be used as propulsive and support techniques in synchronized swimming. This study focused on standard scull techniques.

Coaching manuals for synchronized swimming describe how to scull and how to improve sculling techniques (Davis, 1986; Zielinski, 2001). According to instructions in these manuals, hands perform a sideways figure-eight (∞) shape, and proper attack angles of the hands and proper sculling range and depth are required for efficient sculling. However, sculling techniques do not appear to have been studied using experimental data. As coaches require practical data and implications, the present study investigated sculling techniques in synchronized swimming based on three-dimensional motion analysis.

METHODS: Subjects comprised 10 female synchronized swimmers. Of these, 4 swimmers were silver medalists at the 2004 Athens Olympics (Olympic swimmers: mean age, 22.8 years; height, 1.64 m; weight, 55.4 kg). The remaining 6 subjects were skilled swimmers from the Japanese National B and Junior teams (Elite swimmers: mean age, 17.2 years; height, 1.58 m; weight, 49.7 kg). Written informed consent was received from each swimmer prior to inclusion in the study.

Swimmers maintained a stationary back layout position under two load conditions: no load; and a 1.5-kg load attached to the waists. A 1.5-kg load is usually used for sculling drills in training. Since the sculling movement is a repeated motion, only a stable single cycle was analyzed. In this experiment, one cycle of the standard scull starting from outside was analyzed. The motion from outside to inside was defined as "in-scull," and the motion from inside to outside was defined as "out-scull."

Two video cameras with a film speed of 30 frames/s and a shutter speed of 1/100 s were used: one set on the bottom of the pool; and one was set through the underwater window of the pool. Video cameras were synchronized by the frame counter and an external signal generated by the synchronizing device.

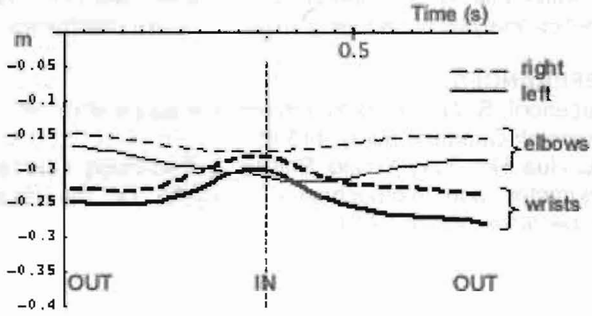

Figure 1 Sculling in a back layout position.

Videotapes were digitized manually using by an original software, "Movie digitizer" (Miyaji, 1998; Miyaji and Abbot, 2001), which linked the movie file to Mathematica version 5.1 (Wolfram Research, USA). Three-dimensional coordinates were obtained using a three-dimensional direct linear transformation (DLT) method. Axes of the inertial reference frame were defined relative to the pool (Figure 1). A rectangular parallelepiped (1.0 m × 1.0 m × 0.7 m) with 16 control object points was used as a three-dimensional DLT control object. Errors in the reconstructed coordinates of that object were 5.22 mm (X-axis), 4.6 mm (Y-axis) and 3.9 mm (Z-axis). All three-dimensional coordinate data were interpolated to 60 Hz using the Mathematica interpolate function, and then smoothed using a Butterworth lowpass digital filter with an 7.5 Hz cut off (Winter, 2005).

The following items were analyzed: elbow depth, relative depth from the water surface to the elbow; wrist depth, relative depth from the water surface to the wrist; upper arm angle, two dimensional angle on x-y plane between the upper arm and a vertical line through both shoulders; elbow angle, three dimensional angle between the forearm and upper arm; sculling time, sculling time during one cycle scull; attack angles of the hand, changes in attack angle of the hand to the direction of motion; and paths of the fingertips and wrist, tracks of the middle fingertip and wrist drawn during one cycle scull.

RESULTS: Elbow and wrist depths and upper arm and elbow angles under no load and 1.5-kg load conditions for Olympic and Elite swimmers are shown in Table 1. No significant differences were noted between no load and 1.5-kg load conditions, or between Olympic and Elite swimmers. Elbow depth for Olympic swimmers with no load was about -0.18 to -0.20 m and wrist depth was -0.22 to -0.25 m. Elbows were higher than wrists during sculling except at inside positions (Figure 2). Wrist depth showed a brief decrease during in-sculling. Upper arm angles for Olympic swimmers were about 60° outside and 50° inside. Upper arms and elbows were relatively stationary for Olympic swimmers under 1.5-kg load conditions. The wrists reached the line of the shoulder at the in-scull. Elbow angle for Olympic swimmers with no load was about 176° outside compared with 126-127° inside. Elbow angle for Olympic swimmers with 1.5-kg load was about 173-177° outside and 130° inside, and range of motion for elbow angles was slightly smaller compared to no load conditions.

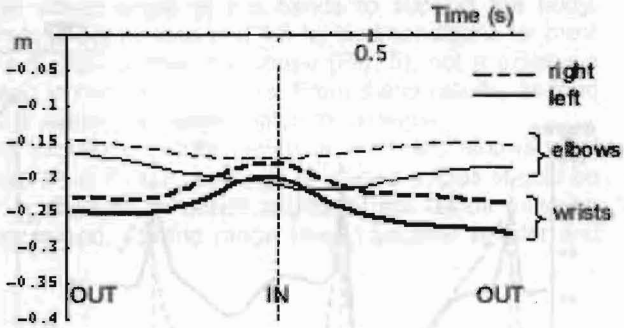

Figure 2 Changes in depth of elbow and wrist during sculling for Sub.F, Olympic swimmer with no load. Zero (0) m indicates the water surface.

Table 1 Elbow and wrist depth and upper arm and elbow angle depend on no load and 1.5-kg load conditions for Olympic swimmers (n=4) and Elite swimmers (n=6).

		Mean relative elbow depth(m)		Mean relative wrists depth(m)		Upper arm angle (°)						Elbow angle (°)					
						R			L			R			L		
		R	L	R	L	max	min	max-min	max	min	max-min	max	min	max-min	max	min	max-min
Olympic swimmers(n=4)	no load	-0.182	-0.199	-0.223	-0.250	59.1	51.5	7.7	57.9	47.4	10.6	175.9	126.8	49.1	176.2	125.5	50.6
	1.5 kg	-0.176	-0.181	-0.206	-0.215	61.1	54.0	7.1	57.7	47.5	10.2	173.2	129.1	44.1	177.2	129.5	47.7
Elite swimmers (n=6)	no load	-0.173	-0.200	-0.210	-0.234	59.6	46.5	8.3	54.5	43.9	10.7	173.1	127.2	45.9	172.2	125.7	46.5
	1.5 kg	-0.174	-0.190	-0.209	-0.219	57.3	48.7	8.8	54.6	43.0	11.7	172.4	131.8	40.5	173.3	130.8	42.4

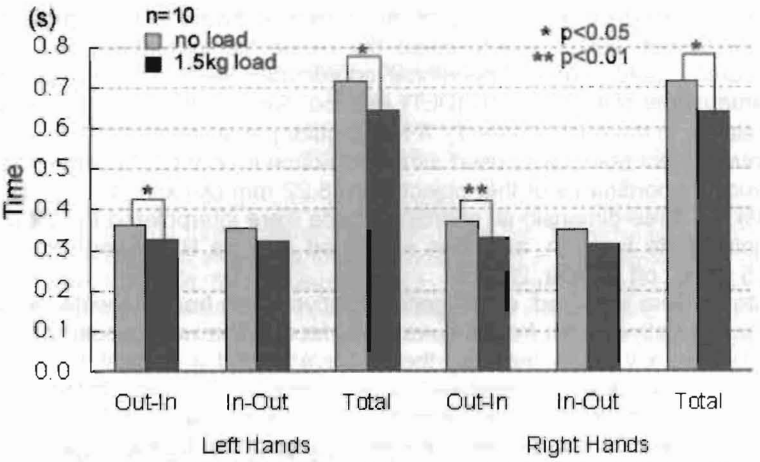

Figure 3 **Mean time for Out-to-In scull (Out-In), In-to-Out scull (In-Out) and total scull cycle (Total) under no load and 1.5-kg load for right and left hands. Significant differences between no load and 1.5-kg conditions: *p < 0.05, **p < 0.01.**

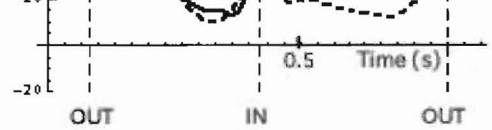

Figure 4 Changes in attack angle of the hand during sculling. An angle of 0° indicates a flat hand parallel to the direction of motion.

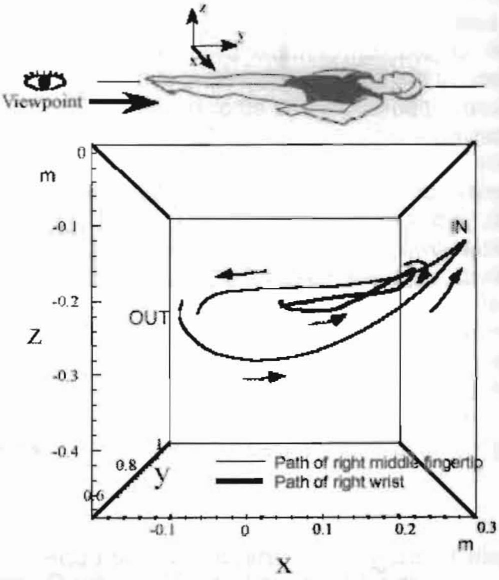

Figure 5 Path of right middle fingertip and right wrist for Sub.F, Olympic swimmer under 1.5-kg load condition. The locus of wrist is a slanting sideways figure-eight. The locus of middle fingertip is a sharp-pointed elliptical figure like a drop shape.

Regarding sculling time per scull cycle, in-sculling and out-sculling took almost the same length of time (Figure 3). Sculling with a 1.5-kg load resulted in significantly shorter times than sculling with no load. Attack angles of the hands for Olympic swimmers were about 70-80° outside and 40-60° inside (Figure 4). More advanced swimmers changed attack angles smoothly and evenly.

With no load and a 1.5-kg load, paths of the fingertips and wrists for most swimmers drew a sharp-pointed elliptical figure like a drop shape, not a sideways figure-eight. In paths of the wrists, only a few swimmers showed a slanting sideways figure-eight shape (∞) (Figure 5).

DISCUSSION: Elbow depth was slightly shallower than wrist depth, suggesting that swimmers stick out their elbows while sculling. This suggestion does not agree with Zielinski's instruction (2001), in which correct position is with the elbows pointing down and incorrect position is with elbows pointing to the sides. The upper arms and elbows for Olympic swimmers were relatively stationary. This result supports Zinzen's suggestion from an electromyographic study (1992), that the sculling propulsion effect is initiated by the elbow rather than the shoulder. It is therefore said that holding upper arms and elbows stationary is a tip of sculling technique.

With a 1.5-kg load, time for a single scull cycle was shortened and sculling range was reduced, suggesting that sculling tempo increases and sculling range shortens as load is increased.

In the present study, attack angles of the hands for Olympic swimmers were about 70-80° outside and 40-60° inside, much larger than the angles described by Maglischo (1993), in which the proper attack angles for hands to produce efficient propulsive force during swimming was considered to be 40°. Sculling on the back layout position in synchronized swimming appears to require a larger attack angle of the hands to support the body. Moreover, the middle fingertips and wrists under no load and 1.5-kg load conditions for most swimmers in this study traced a slanting elliptical drop-like shape (Fig. 5), not a sideways figure-eight shape in which are described in coaching manuals. From these results, as load increases, hands pressure increases and swimmers need to catch much water.

In conclusion, coaching tips for sculling technique include: 1) upper arms and elbows must be stationary; 2) upper arm angle should be at 50-60°; 3) range of elbows angles should be about 175° outside and 130° inside; 4) changes in attack angles of the hands must be smooth and even; and 5) as load is increased, sculling range should become smaller and sculling tempo is increased.

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