ASYMMETRY IN FRONTCRAWL SWIMMING WITH AND WITHOUT HAND PADDLES

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The aim of this study was to determine whether asymmetry exists in underwater front crawl stroking patterns with and without hand paddles. Six senior national level male swimmers performed trials at 100m race pace, with and without large (480cm^2) hand paddles. Underwater motions for both right and left arms were filmed from the front and sides using three gen-locked video cameras and the video recordings were digitised at 50Hz to give three-dimensional coordinate data for a three segment model of the arm. The use of hand paddles significantly altered key temporal and kinematic features of the front crawl arm stroke for the left and right sides of the body. Specifically, the paddles increased time to complete the upsweep phase of the stroke on both sides. The paddles significantly reduced backward hand displacement on the left and right sides and altered the depth and lateral displacement of the stroke on the right side. Depth of stroke and elbow angle was also different without paddles on the right side and indicated asymmetry in technique, perhaps related to preferred breathing side.

KEY WORDS: Asymmetry, swimming, hand paddles, kinematics

INTRODUCTION: Specificity should be a key consideration in any strength or power development program (Payton and Lauder, 1995). Hand paddle swimming is seen by many as a specific form of strength training and enhancement of technique. The movement and speed specificity of hand paddles training has received limited attention in the literature. General conclusions indicate changes in these variables generated by paddles may compromise the training of specific muscles used in free swimming (Monteil and Rouard, 1992, 1994; Payton and Lauder, 1995). Regarding technique, the few studies that have been published are unanimous in their findings that paddles increase the stroke rate time from between 10% to 22% (Stoner and Luedtke, 1979; Monteil and Rouard, 1994; Payton and Lauder, 1995), thus, questioning the assumption that hand paddles are a specific form of training to enhance technique in front crawl swimming.

Previous studies in swimming have only evaluated one half of the body with presumed symmetry of the opposing side. However a symmetrical stroking pattern is assumed in elite swimmers and to date, no study has considered the effects of a possible imbalance between right and left arm pulling patterns. In other cyclic sports research has shown that imbalances can lead to overuse injuries (E.g. Kayaking: Lovell and Lauder, 2001). Therefore in light of the present review, the aims of this study were to determine whether asymmetry exists in underwater front crawl stroking patterns and to determine whether the use of hand paddles play a negative or positive role in the variation of stroke parameters with respect to training specificity.

METHODS: Participants: Participants for this study were six highly trained male competitive swimmers (mean age 21.5 ± 2.3 years). Best 100m front crawl performances ranged from 53.1s to 56.0s (mean time 54.9s ± 0.93s). Each subject was swimming approximately 5000 m a week with the hand paddles used in this study at the time of filming. All subjects' preferred breathing side was to the right.

Filming Procedure: After an appropriate warm-up and habituation to the experimental conditions, each subject swam front crawl trials through a performance volume that had been previously calibrated with a reference frame measuring 0.85m x 1.5m x 0.75m. The frame contained 52 control points of known location and distribution throughout the volume. Three cameras were used during filming. The first was positioned front-on to the swimming direction the second and third cameras were positioned to capture two separate halves of the calibration frame from the side view. The front-on camera filmed from an underwater

housing. Cameras 2 and 3 filmed from behind underwater windows. All cameras were aligned with the optical axis of the camera perpendicular to the glass/water interface.
Each subject swam a series of 25yard (22.9m) trials, with and without paddles, at the race pace. The hand paddles used were large WIN© paddles, which had a plan area of 480cm^2. The order of trials was randomised and subjects were given adequate time between trials to minimise the effects of fatigue.
Four trials per subject were selected for analysis; right hand with (RP) and without (RNP) paddles; left hand with (LP) and without paddles (LNP). Trials were selected on the criteria that the arm pull was executed naturally within the calibrated volume, no breath was taken whilst swimming through the volume and each swimmer achieved 95 ± 3% of their personal best time for the 100m front crawl sprint.
A three-segment model of the right and left arms: hand (including paddle), forearm, upper arm were defined by four body landmarks on each arm: the gleno-humeral joint centre, elbow joint, wrist joint and distal point of the third phalange. The estimated locations of these landmarks were manually digitised, at a sampling frequency of 50Hz, using a Panasonic VCR (NV- F75 HQ) editing system and an Archimedes 440 Computer equipped with Arvis Digitising card and KINE software (Bartlett and Bowen, 1993). Prior to filming, the skin overlaying these landmarks had been marked with black pen to help estimate their location.
Image coordinates were transformed to 3-D object space coordinates using a Direct Linear Transformation Algorithm correcting for linear lens distortion. These were then smoothed and differentiated using cross-validated quintic splines.

Definition of variables

The complete underwater motion of the arm, from hand entry to hand exit, was subdivided into four phases (Figure 1)

1&2 Downsweep phase from hand entry (A) to the most lateral position of the hand (B)
3 Insweep phase from (B) to the most lateral position of the hand (C)
4 Upsweep phase from (C) to hand exit (D)

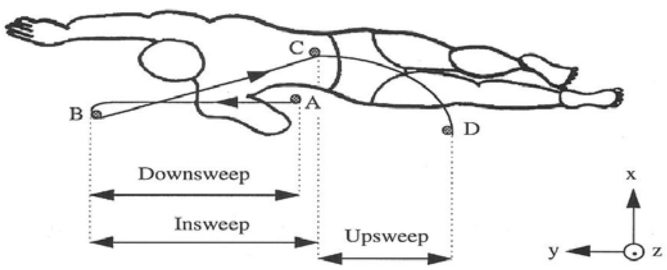

Figure 1. Swimming phases (Payton and Lauder, 1995)

The following variables were used to describe the kinematics of the underwater pull (Payton and Lauder 1995): Pull Width - Medial displacement (x-axis) of the hand during the Insweep phase; Pull Length - Backward (y-axis) displacement of the hand from its most forward position to its most backward position relative to the water; Pull Depth - Vertical displacement (z-axis) of the hand from entry to its' deepest point; Lateral Displacement - Entry (x-axis) to the widest point laterally; Elbow Angle - Maximum flexion during the Insweep Phase; Hand Velocity - Maximum velocity taken at the most distal point (third phalange) during Phase 3 and Phase 4

Statistical Analysis

Due to the small sample size, all variables were assumed to be normally distributed. To reasonably determine any significant differences in technique between the right and left underwater hand pulling patterns (arm condition) and differences in technique between free and hand paddle swimming (paddle condition), Paired Samples T-Tests were employed with a two-tailed level of significance set at 0.05, as the validity in running more complex parametric tests in relation to the power of those tests for the sample size would be questionable.

RESULTS AND DISCUSSION: Significantly longer pull times were shown for the phase 4 with and without paddles irrespective of sides and a significantly longer total pull time was shown without paddles for the right side (Figure 2). The findings of longer pull times in phases 4 (upsweep) are in line with previous research (Payton and Lauder, 1995), however it would appear that without paddles the swimmers pull for a longer time on the right side.

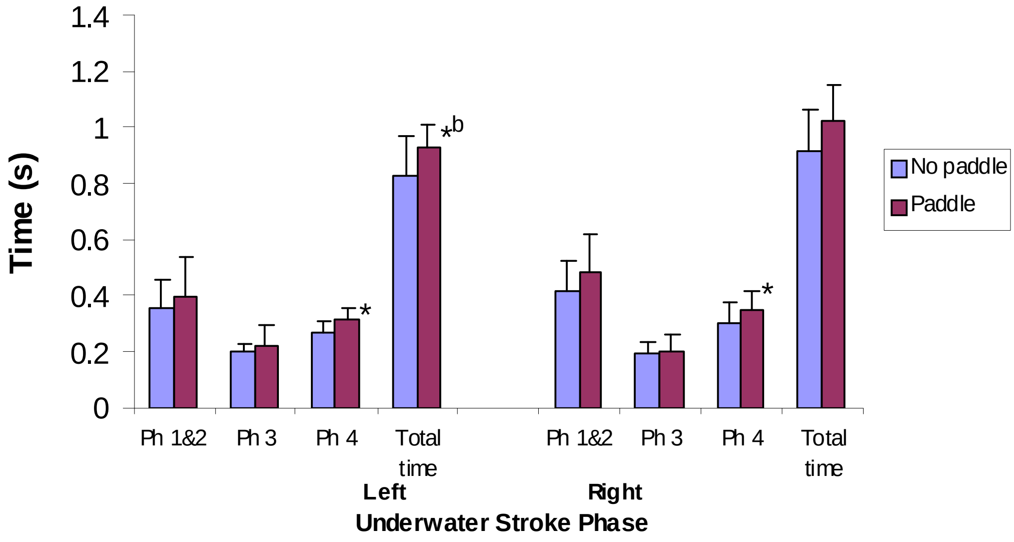

Figure 2. Durations of underwater phases for left and right sides, with and without paddles (mean ± SD). Significant at *P*=0.05 between: *with paddles and without paddles; [a]left and right with paddles; [b]left and right without paddles.

Right side differences were also shown for pull displacements (Figure 3). Between with and without paddle conditions, significantly shorter stroke lengths were shown on both the left and right sides. This finding is again in line with previous research where reduced stroke length has been shown to be as much as 28% when wearing paddles (Monteil and Rouard, 1992 &1994; Payton and Lauder, 1995). With paddles, the right side showed a deeper pull depth but less lateral displacement. Previous research has indicated that the use of paddles indicates a drag dominated approach to propulsion and it would appear that the kinematics for the right side support this. Without paddles the pull depth was deeper on the right side compared to the left. These findings may indicate that the right side is the stronger side and that the stroke kinematics reflects this strength difference.

Similarly, the results showed significantly slower pull velocities with paddles in phase 3 with paddles for both sides (Left NP: 2.53 ± 0.45 $m.s^{-1}$; Left P: 1.56 ± 1.05 $m.s^{-1}$; Right NP: 3.12 ± 1.06 $m.s^{-1}$; Right P: 1.46 ± 1.09 $m.s^{-1}$). No differences were shown for the velocity data when comparing left and right sides with paddles and left and right sides without paddles.

Elbow angle results showed only a significantly greater flexion of the elbow with paddles on the right side compared to the left (Right NP: 112.1 ± 6.7^o; Right P: 105.7 ± 10.5^o; Left NP 110.9 ± 7.6^o; Left P: 111.4 ± 7.9^o). This may indicate a greater degree of trunk motion or ‘body roll’ when wearing paddles as this finding does not support the earlier findings of a deeper pull on the right side when wearing paddles. This may also be related to the swimmers preferred breathing side as this was the right side for all the swimmers tested.

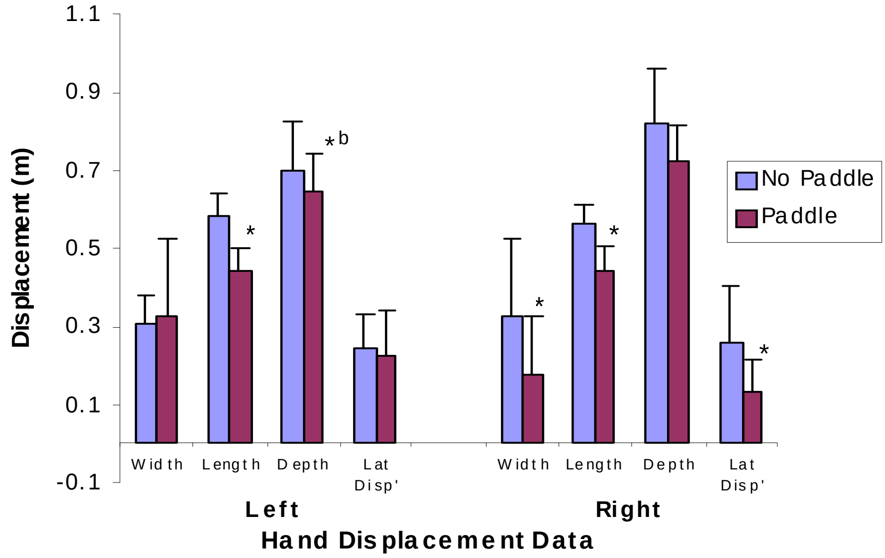

Figure 3. Hand displacement data for left and right sides, with and without hand paddles. Significant at *P*=0.05 between: *with paddles and without paddles; [a]left and right with paddles; [b]left and right without paddles.

CONCLUSION: The use of hand paddles significantly altered key temporal and kinematic features of the front crawl arm stroke for the left and right sides of the body. Specifically, the paddles increased time to complete the upsweep phase of the stroke on both sides. The paddles significantly reduced backward hand displacement on the left and right sides and altered the depth and lateral displacement of the stroke on the right side. Depth of stroke and elbow angle was also different without paddles on the right side and indicated asymmetry in technique, perhaps related to preferred breathing side.

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