TECHNIQUE CHARACTERISTICS OF ELITE BREASTSTROKE SWIMMERS

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INTRODUCTION

Following the introduction of the 'wave action' technique by Joseph Nagy (Muckenfuss, 1989) major changes have occurred in the technique used by elite breaststroke swimmers. The wave action technique, otherwise known as the 'undulating breaststroke technique', is distinguished from conventional or 'flat' breaststroke by a high shoulder action and forward lunge of the upper body across the top of the water during the period between the pull and kick.

The reasons for the success of the wave action technique have yet to be established. Persyn (1991) suggested that breaststroke technique is evolving towards more 'dolphin-like' styles in which undulations of the body are used. Undulations in butterfly swimming have been shown to exhibit wave characteristics that assist in generating propulsion (Sanders, Cappaert, and Devlin, 1995). A two-beat wave pattern from the hips was superimposed on a one-beat wave initiated at the head. The average velocity of the one-beat body wave with respect to the body was greater than the swimmer's forward velocity and the wave accelerated as it moved from the trunk towards the feet. Thus, it was hypothesised that wave-like motions in the breaststroke confer similar advantages.

As yet, the wave characteristics of breaststroke swimming have not been investigated thoroughly. The purpose of this study was to investigate the wave characteristics of breaststroke performed by elite breaststroke swimmers during competition.

METHODS

Eight elite breaststroke swimmers (5 females and 3 males) were recorded on videotape at the 1992 Olympics in Barcelona. Swimmers were recorded while competing in the preliminary heats of the 100m, 200m breaststroke as well as the 400m medley relay. Only those trials in which the subject completed one complete stroke cycle within the calibrated space were used for later analysis. Due to the small numbers of subjects who could be analysed, and no a priori reason why gender per se would affect the relationships among the variables of interest, subjects were pooled across gender.

Video data were collected simultaneously from four cameras. To record motion above the water, two cameras were positioned at the two corners of the 50m end of the pool (turning end of the pool) and elevated approximately 5m above the water surface. The remaining two cameras were placed on the floor of the pool underneath the lane lines on either side of lane four approximately 5m away from the 50m wall to record motion below the water. All cameras viewed the swimmer at the 40m mark of the pool. These positions allowed clear views of all the required body landmarks of the swimmers, in particular, both sides of the body were visible to all cameras throughout the stroke cycle. Three-dimensional videotaping and data reduction techniques similar to those described by Sanders, Cappaert, and Devlin (1995) were applied. Although three-dimensional data were obtained, only the x and z coordinates were used to describe the motion of the body parts and centre of mass (CM) in the vertical plane in the direction of motion. Coordinates of the CM were determined using segment proportional mass and center of gravity position data of Dempster (1955).

Fourier analysis techniques described by Sanders, Cappaert, and Devlin (1995) were used to determine the amplitude, phase, and frequency content of the vertical undulations of the vertex, shoulders, hips, knees, ankles, and CM. Velocity of wave travel was determined for the fundamental frequency (H1) and the second harmonic (H2) from the vertex to shoulders, shoulders to hips, hips to knees, knees to ankles, and vertex to ankles. The last of these was a measure of the average wave velocity. The wave characteristics of the breaststroke swimmers were compared to those of the butterfly swimmers in the Sanders, Cappaert, and Devlin (1995) study.

Maxima, minima, and ranges of vertical motion of the vertex, shoulders, hips, knees, CM, ankles, and the angular motion of the trunk were determined. Trunk angle was defined as the angle between horizontal and the line joining the midpoints of the shoulders and hips. Average CM velocity was also calculated by dividing CM displacement during the the stroke cycle by the duration of the stroke cycle. A Pearson product moment correlation was performed to establish the relationships among the variables.

RESULTS

The Fourier amplitude of H1 for the vertex and the shoulders (mean = 0.107 m, and 0.083 m respectively) were generally greater than those of the butterfly swimmers (0.082 m and 0.066 m respectively). A very high percentage of the total power in the waveform was contained in H1 of the vertex (mean = 98.5%; SD = 0.81%) and shoulder motions (mean = 96.4%; SD = 1.8%).

The Fourier amplitude of H1 for the hip undulations was variable, ranging from 0.006 m to 0.046 m (mean = 0.019 m; SD = 0.013 m). Two of the swimmers had H1 contributions to hip motion that were as great as those of the butterfly swimmers (0.027 m), while the other swimmers had H1 contributions less than the mean of the butterfly swimmers. Unlike the butterfly swimmers, those with relatively large hip undulations had a high percentage of power contained in H1.

The amplitude of the H1 contribution to the knee undulations was substantial (mean = 0.069 m; SD = 0.011 m) and was larger than the mean H1 contributions to knee motion of the butterfly swimmers (0.052 m). However, whereas the amplitude of H2 and H1 were similar for the butterfly swimmers, the contribution of H2 was very small among the breaststroke swimmers. There was a high percentage of power contained in H1 of the knees (mean = 88.9%; SD = 8.3%). This was very different from butterfly where the knee undulations had a strong contribution from H2.

The amplitudes of H1 and H2 for the ankle were highly variable among subjects. In general, both the H1 (mean = 0.034 m, SD = 0.017 m) and H2 (mean = (0.026 m, SD = 0.009 m) amplitudes were smaller than those of the butterfly swimmers (H1 mean = 0.046 m; H2 mean = 0.058 m). There was also great variability among subjects in the frequency composition of the ankle undulations.

The H1 component of the CM undulation (mean = 0.028 m; SD = 0.007) was generally greater than that of the butterfly swimmers (mean = 0.015 m). However, the H2 contribution (mean = 0.007 m; SD = 0.003 m) was much smaller than that of the butterfly swimmers (mean = 0.012 m). Despite the small contribution by H2, the overall range of motion of the CM (mean = 0.12 m; SD = 0.029 m) was large. Most of the power was contained in H1 (mean = 90.6%; SD = 6.7%) whereas the H1 and H2 contributions to CM undulation in butterfly were approximately equal.

There was a negative correlation ($r = -0.66$; $p = 0.05$) between CM amplitude and whole body velocity implying that fast speeds are associated with minimising the vertical motion of the CM. This is a different result to that obtained for the butterfly swimmers where there were indications that speed increased as the amplitude of CM vertical motion increased.

The range of CM motion was related to stroke frequency ($r = -0.69$; $p < 0.05$). That is, the slower the stroke, the greater the CM undulation. There was a strong negative relationship ($r = -0.70$; $p < 0.05$) between the range of hip motion and range of CM motion. That is, the larger the hip vertical motion, the less the CM motion.

The velocity of wave travel from the vertex to shoulder in breaststroke (mean = 2.23 $m.s^{-1}$; SD = 0.52 $m.s^{-1}$) was very similar to that in butterfly (mean = 2.1 $m.s^{-1}$). Phase differences and velocities of H1 wave travel between the shoulder and hip were variable among subjects. However, the mean velocity of H1 wave travel from the shoulders to hips (mean = 1.67 $m.s^{-1}$; SD = 0.89 $m.s^{-1}$) was similar to that in the butterfly (1.35 $m.s^{-1}$).

The velocity of wave travel between the hips and knees (0.88 $m.s^{-1}$; SD = 0.43 $m.s^{-1}$) was variable among subjects and considerably slower than that for butterfly swimmers (2.0 $m.s^{-1}$). Similarly, the velocity of wave travel from knees to ankles (mean = 0.64 $m.s^{-1}$; SD = 0.23 $m.s^{-1}$) indicated that there was a much slower progression of the H1 wave from knees to ankles that in the butterfly kick (2.95 $m.s^{-1}$).

H1 phase difference from vertex to ankles (mean = 386 degrees; SD = 63 degrees) and average wave velocity (mean = 0.98 $m.s^{-1}$; SD = 0.17 $m.s^{-1}$), together with the progressive phase differences between adjacent body parts described, indicated that there was a progression of a wave from vertex to ankles. However, the average velocity was slower than the average velocity of H1 wave travel in butterfly (1.75 $m.s^{-1}$) and, unlike the wave in butterfly, was slower than the forward motion of the swimmer. This suggests that the wave motion itself was not propulsive.

There was a strong relationship ($r = -0.79$; $p < 0.01$) between average wave velocity and range of vertical CM motion. That is, with increasing velocity of H1 wave travel the range of vertical motion of the CM decreased. There was also a modest relationship between average wave velocity and whole body velocity ($r = 0.65$; $p = 0.06$) indicating that a fast wave velocity was associated with a fast CM velocity. However, this relationship was less strong than the relationship between H1 wave velocity and CM velocity in butterfly swimming.

Maximum trunk angles ranged from 41 degrees to 52 degrees (mean = 45.5 degrees; SD = 3.7 degrees) while minimum trunk angles ranged from -16 degrees to 4 degrees. The mean range of trunk angular motion for this group was 48 degrees (SD = 9.2 degrees). These results indicated that there was substantial variability among elite breaststroke swimmers in the range of angular motion of the trunk. It was clear that the range of angular motion of the trunk had a strong influence on the range of motion of all the body parts including the knee and ankle. However, this motion did not tend to increase the undulation of the CM, in fact, there was a modest negative correlation ($r = -0.51$; not significant) between the range of trunk angular motion and the vertical undulation of the CM. There was also a trend ($r = 0.56$; not significant) towards increasing CM velocity with increasing trunk range of motion.

CONCLUSION

It may be concluded that the wave action breaststroke is characterised by wave-like motion of the body parts. There was some evidence of caudal transmission of a wave with frequency equivalent to the stroke frequency. This wave motion was somewhat disrupted due to the complex nature of the breaststroke. However, among the more successful breaststroke swimmers there appeared to be a transmission of a wave that was not propulsive in itself but was likely to confer advantages with respect to streamlining the body and reducing the requirement to input energy to raise the CM. The most successful swimmers were characterised by a large range of trunk angular motion and large vertical undulations. In particular, these swimmers allowed their hips to undulate freely compared to the less successful swimmers.

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