ROLLING ACTIONS OF SHOULDERS AND HIPS IN FREESTYLE SWIMMING

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The purpose of this study was to determine accurately the magnitude of shoulder roll (SR) and hip roll (HR) in freestyle swimming, to assess the significance of the differences between these parameters and to examine whether they are associated with swimming velocity (V). Six male swimmers of national and international level performed a maximum freestyle swim. One non-breathing stroke cycle was selected for analysis. It was shown that swimmers rolled their shoulders significantly more than their hips. Faster swimming velocities were associated with smaller magnitudes of SR, but no significant correlations were found for V and HR. These results indicated that SR and HR need to be examined separately in freestyle swimming, as the measurement of body roll for the whole trunk does not represent with validity the rolling characteristics of the trunk.

KEY WORDS: Biomechanics, body roll, velocity, three-dimensional

INTRODUCTION:

Body roll, the rolling action of the trunk around its longitudinal axis, appears to have important functions in freestyle swimming and to be linked to swimming performance. It has been suggested that body roll facilitates the breathing action, influences the hand displacement and velocity and might increase the potential of the hand to develop propulsive lift forces (e.g. Payton *et al*., 1997). In view of the possibility that body roll may play an important role in improving performance, researchers have tried to determine its effect on the velocity (V) of freestyle swimming. In some studies body roll has been found to decrease with V (e.g. Castro *et al*., 2003; Yanai, 2003). Contradictory results were reported in other studies, with differences in the rolling action of hips but not the rolling action of shoulders for different swimming velocities (e.g. Cappaert *et al*., 1995).

The discrepancy in the findings of the studies in this area could be related to the limitations of the methods used. Some investigators measured body roll for the whole trunk, by attaching a wooden fin on the swimmers' backs and calculating its deviation from the vertical axis using one camera and two-dimensional analysis (e.g. Payton *et al*., 1997; Castro *et al*., 2003). However, Cappaert *et al*. (1995) showed that the assumption that the whole trunk rolls as a rigid segment might not be tenable because the shoulders and hips might roll to different extents and/or with different phase. Thus, body roll needs to be examined with methods that do not rely on that assumption.

Despite that shoulder roll (SR) and hip roll (HR) were calculated separately in some studies (e.g. Cappaert *et al*., 1995; Yanai, 2003), the significance of the differences in the magnitude of SR and HR and their association with swimming V were not assessed statistically. Furthermore, while these studies provided some useful data on SR and HR, methodological limitations reduce the value and generalisability of the reported data. Improved methods are required to reduce errors associated with: not considering the influence of breathing actions in SR/HR; not specifying the rolling side and not considering possible bilateral asymmetries in SR/HR; extrapolating beyond small calibration volumes; reduced reliability of digitising due to a limited number of cameras and; adjustments made for combining above and below water data.

The main purpose of the study was to determine accurately the magnitude of SR and HR in freestyle, to assess the significance of the differences between these parameters and to examine whether SR and HR are associated with swimming V.

METHOD:

Data Collection: Six male freestyle swimmers of national and international level participated in this study. The descriptive characteristics of the swimmers [mean ± standard deviation (SD)] were: age: 17.3 ± 1.0 years; height: 180.1 ± 2.7 cm; body mass: 72.1 ± 4.0 kg. All tests were conducted in a 25 m indoor pool. The space of interest was calibrated with a 6.75 m^3 frame with orthogonal axes (4.5 x 1.5 x 1.5 m, for the X, Y and Z axes respectively), which was positioned in the midsection of the pool with half the frame above and half below the water. The X axis of the frame aligned horizontally in the direction of swim, with the Y and Z axes being vertical and lateral respectively. The calibration set-up and the accuracy and reliability procedures have been described in details by Psycharakis *et al*. (2005). Six stationary and synchronised JVC KY32 CCD cameras (four below and two above the water) recorded a space 6.5 m long, extending 1 m beyond each side of the frame for the X axis. The frame was then removed and participants swam one trial of freestyle at maximum effort. To eliminate the effect of breathing on shoulder and hip roll, swimmers were instructed to avoid breathing while swimming through the calibrated space. Figure 1 shows the field of view recorded by each of the six cameras.

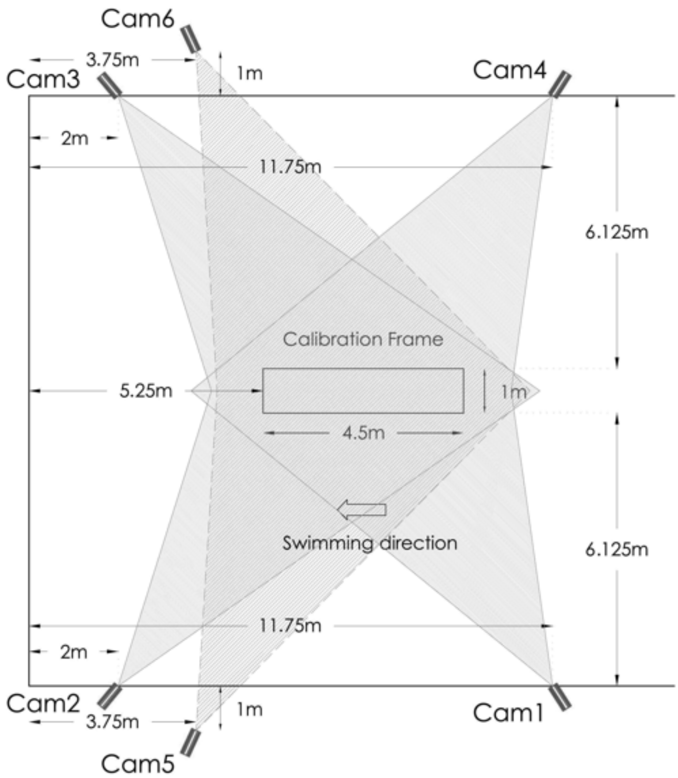

Figure 1: Cameras' field of view in the set up used for data collection

Data Analysis: One stroke cycle (SC) was selected for analysis and 19 body landmarks (vertex; shoulder, elbow, wrist, hip, knee, ankle and metaphalangeal joints; the end of the middle fingers and the big toes) were digitised for each field (50 fields per second) in the Ariel Performance Analysis System (APAS). The three-dimensional (3D) reconstruction was performed using the Direct Linear Transformation method (Abdel-Aziz & Karara, 1971) incorporated in APAS.

The trunk vector was defined by connecting a line from the midpoint of the shoulder to the midpoint of the hip joints. The normal to the shoulder/trunk plane was defined as the cross product of the trunk unit vector and the unit vector in the direction of the line connecting the shoulder joints. The SR angle (degrees) was calculated as the angle between the vertical and the projection of the normal onto the YZ plane. The HR angle (degrees) was calculated in the same manner as the shoulder roll, except that the normal to the hip/trunk plane rather than the normal to the shoulder/trunk plane was projected onto the YZ plane. The unit vector representing the line of the hips was in the direction of the line joining the hip axes. The magnitude of SR and HR, being the sum of the roll to the right and left sides, were calculated for the SC that was analysed.

To assess the influence of digitising reliability on the variables measured in this study, one complete SC of one swimmer was digitised 10 times for all six cameras. Reliability was assessed by calculating the SD and coefficient of variation (CV) for average V, SR and HR.

Pearson correlation coefficients were determined to indicate the strength of the relationships between SR, HR and average V. A paired samples t-test was performed to identify significant differences between SR and HR. For all statistical calculations, significance was accepted for $p<.05$.

RESULTS AND DISCUSSION:

The repeated digitisations of the variables of interest indicated good reliability. The SD and CV values for each variable were: 0.002 $m \cdot sec^{-1}$ and 0.09 % for average V; 2.41° and 1.88 % for SR and; 1.85° and 3.92 % for HR.

Figure 2 shows the roll-time profiles of the shoulders and the hips for one of the swimmers tested. The profiles are clearly very different in terms of the magnitude of SR and HR.

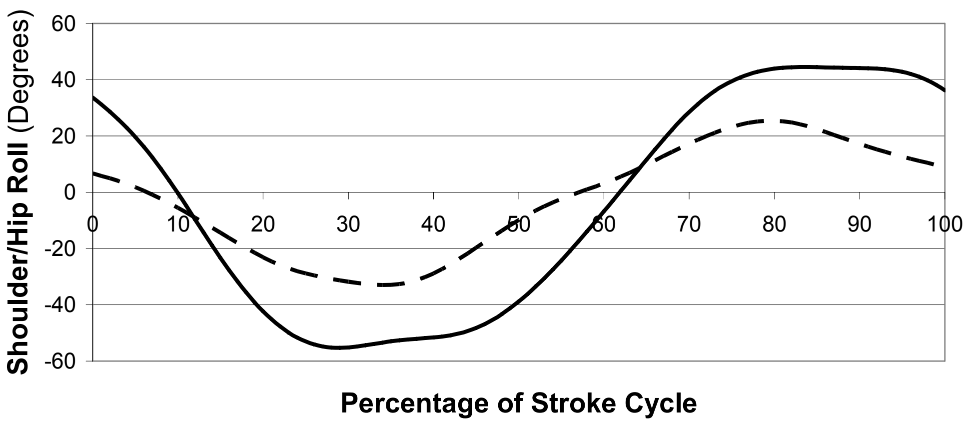

Figure 2: Patterns of shoulder (continuous line) and hip roll (dashed line) for one swimmer (Positive/negative roll values represent roll to the right/left side, respectively).

The values for average V and the magnitude of SR and HR for the swimmers were 1.70 ± 0.05 $m \cdot sec^{-1}$, 104.9 ± 8.4° and 40.4 ± 5.4°, respectively. The paired t-test showed that swimmers were rolling their shoulders significantly more than their hips ($p<0.001$). Moreover, the Pearson correlation coefficient for SR and HR was low and not significant ($r=0.315$, $p=0.491$), suggesting that the magnitudes of SR and HR were not associated. Considering the increased accuracy of the 3D methods used in the present study, these findings indicated that the measurement of body roll for the whole trunk does not represent with validity the rolling characteristics of the trunk.

Average V and SR had a negative and significant correlation ($r=-0.764$, $p=0.046$), indicating that faster swimmers were rolling their shoulders less than slower swimmers. The relationship between average V and HR was also negative but not significant ($r=-0.580$, $p=0.172$). The former is not necessarily interpreted as that swimmers should reduce the magnitude of SR to increase swimming V, as it is possible that the reduced SR is associated with less time spent for the SC by the swimmers swimming in faster velocities.

CONCLUSION:

This study indicated that the measurement of body roll for the whole trunk does not represent with validity the rolling characteristics of the trunk, as swimmers rolled their shoulders significantly more than their hips. It was also shown that faster swimmers rolled their shoulders more than slower swimmers, while no significant difference was found in the rolling magnitude of the hips. These results emphasised that shoulder and hip roll need to be examined separately to allow for accurate investigation of the rolling actions of the body and their association with swimming performance.

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