COMPARATIVE ANALYSIS OF THE CHANGES OF THE MASS MOMENTS OF INERTIA DURING A BREAST-STROKE

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A new method of investigation of athletes' motion takes into consideration the changes of the principal moments of inertia and their directions during the interval of the motion, because these characterise the efficiency and the neuro-muscular regulation of the motion. This paper presents a comparative analysis of two top swimmers (Sw1=Rozsa, Sw2=Guttler) and points out the significant difference caused by their alternate motion pattern.

KEY WORDS: biomechanics, motion analysis, eigensystem of the mass moments of inertia

INTRODUCTION: Improvement in computer technology has enabled rapid analysis of human movement patterns, equally important for both biomechanist and coach. To carry out exact investigations the applied model has to ensure correct kinematic and kinetic characteristics of the human body. A new method of investigation of athletes' motion takes into consideration the changes of the principal moments of inertia and their directions during the interval of the motion. These characterise the changes and the loss of energy, and determine the efficiency and the nerve-muscular regulation of the motion (Hildebrand, 1993; Knoll and Hildebrand, 1993; Kocsis and Szilagyi, 1998). The base of these investigations is the position of the athlete which can be determined by special points of the human body, and there is no need to use the derivative of the applied functions. This paper presents a comparative analysis of two top swimmers and points out the significant difference caused by their alternate motion pattern. The applied model is a refined Hanavan model representing the human body by 16 simple geometric solids determined by the spatial co-ordinates of 20 key points (Figure 1), developed for determining the elements for the matrix of the mass moments of inertia (Kocsis, 1994; Kocsis, 1998).

METHODS AND PROCEDURES: Figure 2 shows five different phases of the breaststroke in the same picture. The time-interval between the first and the last phase is 1.78 sec. The records were made by the Biomechanics Department of the Hungarian University of Physical Education with three under-water and four over-water video cameras. To digitise the frames the APAS (Ariel Performance Analysis System) was used. The data of the digitised key points were further analysed by the system MAS (Motion Analysis System), developed for PC at the Department of Applied Mechanics of the Technical University of Budapest. The figures in this paper are from the above-mentioned system. The horizontal components of the velocities of the centre of gravity (CG) for the two swimmers are shown in Figure 3, and the vertical ones of the same points are in Figure 4. On the horizontal axes of the figures the time is changing linearly in the interval 0 - 1.78 s. In Figure 2 the time-interval among the 5 phases is the same, and this Figure helps to identify the appropriate position of the swimmers. During the analysis 89 frames were digitised with the time-interval 0.02 s.

RESULTS: The investigation of the changes of the principal moments of inertia and their directions during the interval of the motion can characterise the changes and the loss of energy, and determine the efficiency and the neuro-muscular regulation of the motion. The changes of the principal moments of inertia according to the longitudinal axis of the swimmers are shown in Figure 5. Figures 6-7 show the horizontal and vertical components of the eigenvectors according to these principal moments of inertia (the direction of the motion is opposite to the x axis, and this is reflected in Figure 3 in the sign of the horizontal velocity, as well). Figures 8-10 represent the other principal moments of inertia and their directions in the plane of motion. The maximum values are in the outstretched phase of the breaststroke. The changes of the values of those mass moments of inertia, which are perpendicular to the plane of the motion, are represented in Figure 11. Their maximum values are also at the end of the stroke. Figure 12 shows the only non-zero z component of their eigenvectors. This direction is always perpendicular to the xy plane during the time-interval of the investigated motion. According to our investigations higher horizontal velocity of the CG can be achieved if the shoulder and the pelvis of the swimmer move on parallel sinusoidal paths. The sinusoidal motion of the swimmer's body requires less energy than the previously mentioned pattern. Swimmer 2 (Sw2) was not able to move his pelvis similarly to his shoulder and this affected the kinematic parameters of his motion (Figure 3). In this research the investigation of the changes of the mass moments of inertia gave an enormous support. Only by the investigation of the changes of the eigenvectors can be visualised that Sw2 never moves parallel with the surface of the water (See Figure 7 and Figure 9), and this fact increases his resistance.

CONCLUSIONS: Recording and analysing more swimmers gave us a final conclusion that synchronised motion (in phase and in amplitude) ensures higher horizontal velocities and less water resistance. The limited mobility of the vertebral column determines the motion's possibility of the pelvis and also influences the position of Sw2.
This is the first of those investigations (according to the knowledge of the authors) that numerically characterise the principal moments of inertia and their directions during a breaststroke cycle. These data can be taken as standard because we analysed the motion of professional swimmers. These data compared with others can give useful information to the coaches, which they can use to improve their swimmers.

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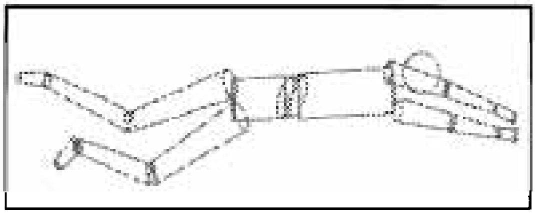


Figure1 - Refined Hanavan model of the swimmer

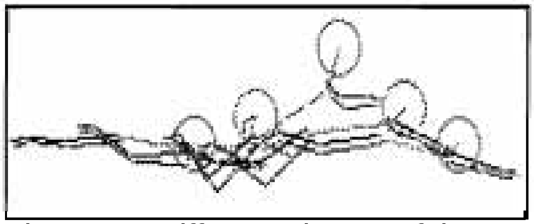


Figure 2 - Different phases of the motion during the investigated time interval

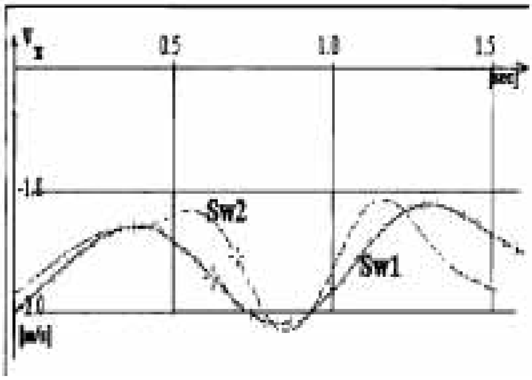


Figure 3 - Changes of the horizontal component of the velocity of CG

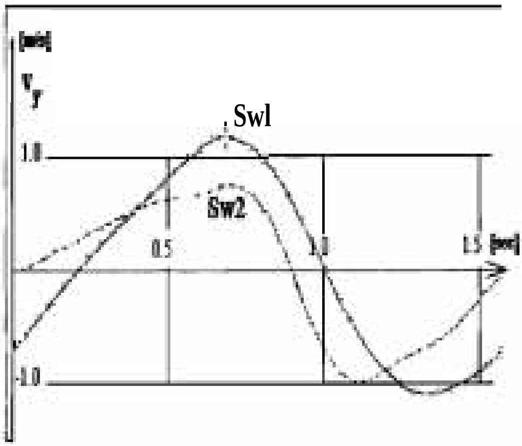


Figure 4 - Changes of the vertical component of the velocity of CG

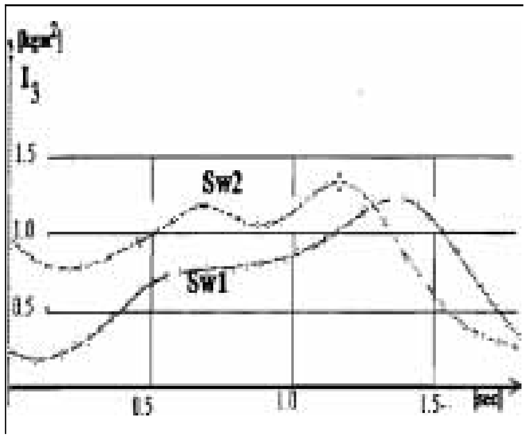


Figure 5 - The changes of the value of the third principal moment of inertia

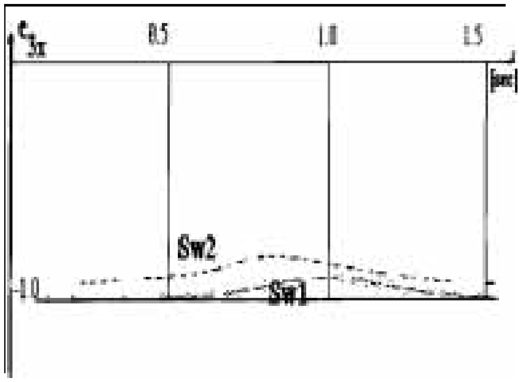


Figure 6 - The changes of the x coordinate of the third eigenvector

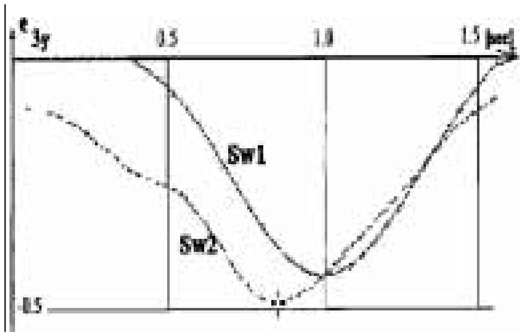


Figure 7 - The changes of the y coordinate of the third eigenvector

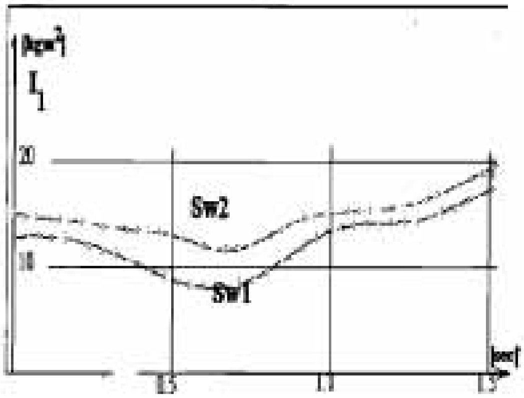


Figure 8 - The changes of the value of the first principal moment of inertia

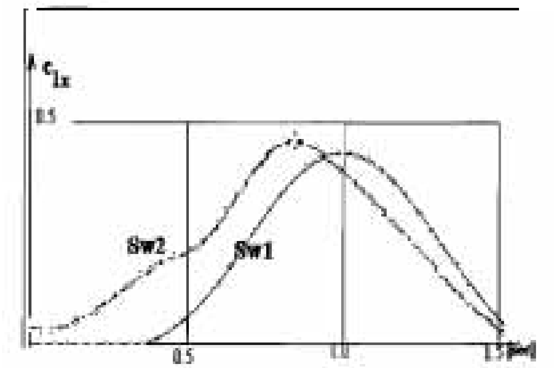
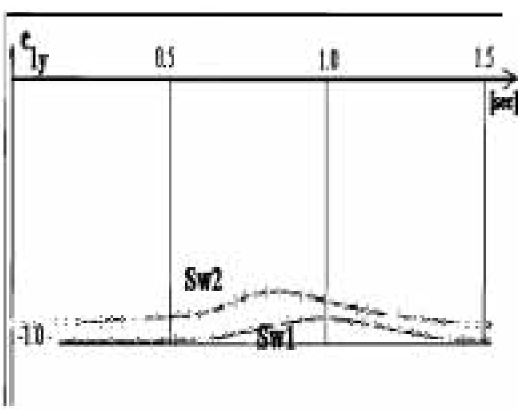


Figure 9 - The changes of the x coordinate of the first eigenvector



Figurel0 - The changes of the y coordinate of the first eigenvector

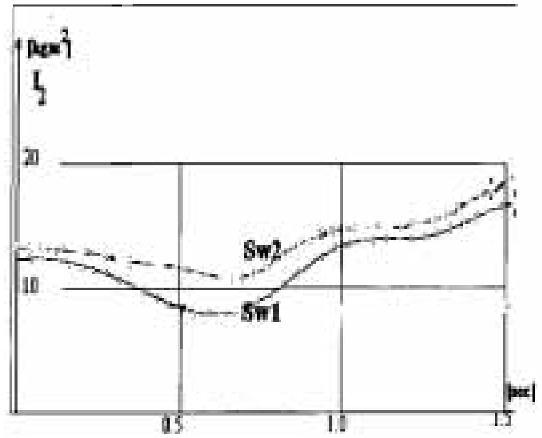
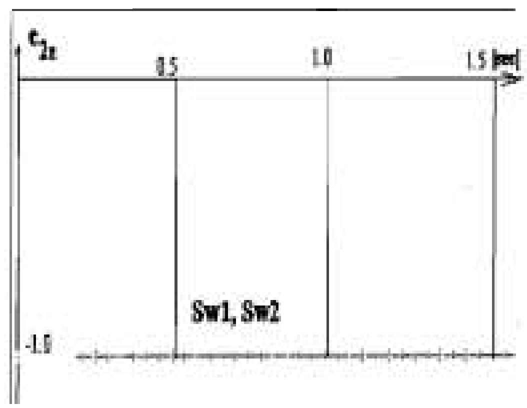


Figure 11 - The changes of the value of the second principal moment of inertia



Figurel2 - The changes of the only nonzero **z** coordinate of the second eigenvector