PERIODICA POLYTECHNICA SER. MECH. ENG. VOL. 44, NO. 1, PP. 71–75 (2000)

INVESTIGATION OF THE CHANGES OF THE MASS MOMENTS OF INERTIA FOR CHARACTERIZING THE EFFICIENCY AND THE COORDINATION OF THE MOTION

László KOCSIS*, Tibor SZILÁGYI** and Krisztina KOVÁCS**

*Department of Applied Mechanics
Budapest University of Technology and Economics
H–1521 Budapest, Hungary
** Department of Biomechanics
Hungarian University of Physical Education
H–1123 Budapest, Hungary
e-mail: kocsis@mm.bme.hu

Received: Sept. 5, 1999

Abstract

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 characterize the efficiency and the neuro-muscular regulation of the motion. This paper presents a comparative analysis of two top swimmers (Sw1, Sw2) and points out the significant difference caused by their alternate motion pattern.

Keywords: biomechanics, motion analysis, eigensystem of the mass moments of inertia, breaststroke.

1. 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 insure correct kinematical and kinetical characteristics of the human body. A new method of the investigation of athletes' motion takes into consideration the changes of the eigensystem for the principal moments of inertia during the interval of the motion, because these characterize the changes and the loss of energy, and determine the efficiency and the nerve-muscular regulation of the motion [1],[2],[3]. 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 fact increases the accuracy of the kinematical investigation. 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 (*Fig. 1*), developed for determining the elements for the matrix of the mass moments of inertia [4],[5].

2. Methods and Procedures

Fig. 2 shows *5* 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 Biomechanical Department of the Hungarian University of Physical Education with three underwater and two overwater video cameras. To digitize the frames the APAS (Ariel Performance Analysis System) was used. The data of the digitized key points were further analyzed 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 mass centers (CG) for the two swimmers are shown in *Fig. 3*, and the vertical ones of the same points are in *Fig. 4*. On the horizontal axes of the figures the time is changing linearly in the interval $0 - 1.78$ sec. In *Fig. 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 digitized with the time interval 0.02 sec (50 Hz).

3. Results

The investigation of the changes of the principal moments of inertia and their directions during the interval of the motion can characterize 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 *Fig. 5*. *Figs. 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 *Fig. 3* in the sign of the horizontal velocity, as well.) *Figs. 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 *Fig. 11*. Their maximum values are also at the end of the stroke. *Fig. 12* shows the only nonzero 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 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 an alternate one from the previously mentioned pattern does. Swimmer 2 (Sw2) was not able to move his pelvis similarly to his shoulder and this affected on the kinematical parameters of his motion (*Fig. 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 visualized that Sw2 never moves parallel with the surface of the water (See *Fig. 7* and *Fig. 9*), and this fact increases his resistance. The alternate motion of the hips of the two swimmers

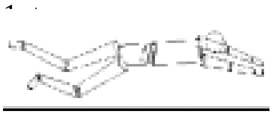

Fig. 1. Refined Hanavan model of the swimmer

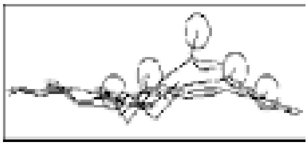

Fig. 2. Different phases of the motion during the investigated time interval

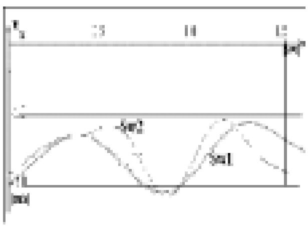

Fig. 3. Changes of the horizontal component of the velocity of CG

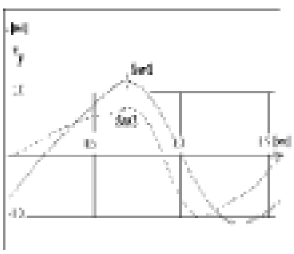

Fig. 4. Changes of the vertical component of the velocity of CG

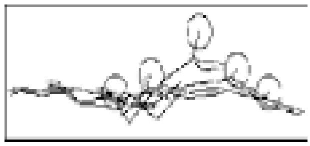

Fig. 2. Different phases of the motion during the investigated time interval

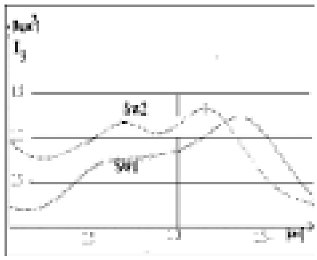

Fig. 5. The changes of the value of the third principal moment of inertia

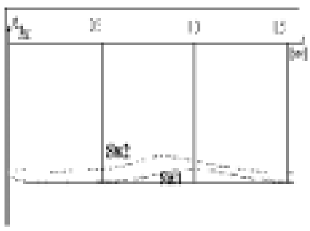

Fig. 6. The changes of the x coordinate of the third eigenvector

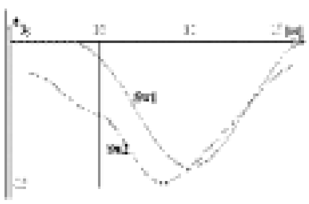

Fig. 7. The changes of the y coordinate of the third eigenvector

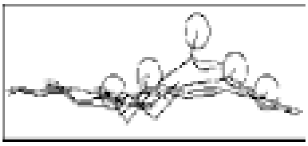

Fig. 2. Different phases of the motion during the investigated time interval

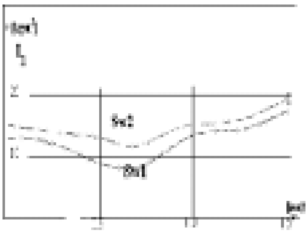

Fig. 8. The changes of the value of the first principal moment of inertia

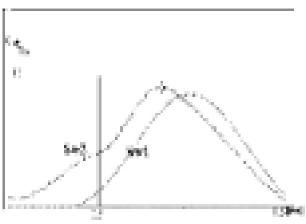

Fig. 9. The changes of the x coordinate of the first eigenvector

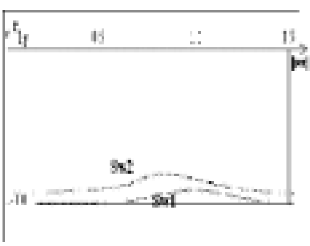

Fig. 10. The changes of the y coordinate of the first eigenvector

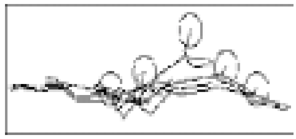

Fig. 2. Different phases of the motion during the investigated time interval

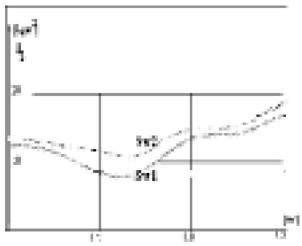

Fig. 11. The changes of the value of the second principal moment of inertia

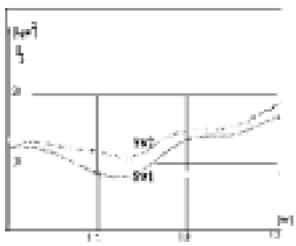

Fig. 12. The changes of the only nonzero z coordinate of the second eigenvector

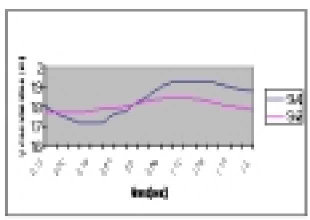

Fig. 13. Comparison of the vertical displacements of the hips

can be seen in *Fig. 13*, where the vertical displacements of the hips are compared.

4. Conclusions

Recording and analyzing more swimmers gave us a final conclusion that synchronized 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 to the position of swimmer 2.

This is the first of those investigations (according to the knowledge of the authors) that numerically characterize the principal moments of inertia and their directions during the interval of a breaststroke. These data can be taken as standard because we analyzed 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.

References

[1] HILDEBRAND, F. (1993): Die Drehbewegungen des Menschlichen Körpers im Raum. *Angewandte Biomechanik in Sport und Rehabilitation. Beiträge des Biomechanik-Symposiums in Leipzig*, (S. 74–81).

[2] KNOLL, K. – HILDEBRAND, F. (1993): Entwicklungsstand der Drei- und Vierfachspuge im Eiskunstlaufen. *Leistungssport*, Vol. 23, (S. 11–14).

[3] KOCSIS, L. – SZILÁGYI, T. (1998): Investigation of the Changes of the Mass Moments of Inertia during a Double Step of Running, in *Proceedings I of ISBS'98*, Konstanz (pp. 351–354).

[4] KOCSIS, L. (1994): Refining of the Hanavan Body Model for Kinematics Investigation of Athletes' Motion, in *Proceedings of ISBS'94*, Budapest (pp. 61–64).

[5] KOCSIS, L. (1998): Modified Model for Determining the Motion of Athletes, *Gépészet '98* Budapest, Springer (pp. 142–146).