IDENTIFICATION OF MOVEMENT PATTERNS BY TIME DISCRETE VARIABLES AND ANALYSIS OF TIME COURSES

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Though movement is a process, it is unusual for adequate process oriented methods to be applied for movement analysis. Therefore the purpose of this study was to provide a comparison of movement pattern analysis based on time courses and time discrete variables. The subject was an experienced female basketball player, who practiced jump shots from different distances which were filmed in the sagital plane. The distance depending movement pattern changes of the successful shots were described by process oriented methods and time discrete variables. The comparison of the results obtained by the two methods show that it is necessary to describe movement pattern by time discrete variables and time courses. This takes into consideration the fact that it is possible to start a movement from the same initial position and to achieve an identical final position with different partial movements.

KEY WORDS: movement pattern, process oriented analysis, time discrete analysis

INTRODUCTION: In contrast to process oriented movement techniques (e.g. dancing, gymnastics, arobic), the aim of result oriented sport movements (e.g. throwing, jumping) is the achievement of optimal conditions at the end of the principal moving phase. Therefore the analysis of movement techniques usually is based on time discrete variables which are determined at the beginning and at the end of a moving phase or at the moments when the variables have their extreme values (minimum or maximum). However, optimal coordination of partial movements as well as the achievement of optimal conditions at the end of a movement phase depend on the preceding time courses of the investigated variables. The precision of movement, which means the repeated performance of the same movement and the repetiton of optimal conditions at the end of a movement phase, depends on the stability of a motor program characterized by typical time courses of biomechanical variables. Although this fact is recognized by characterizing, e.g. the basketball jump shot as a ”shooting process” (Miller & Bartlett, 1996), analysis of movement patterns are usually based on time discrete variables. This reduces the movement process and the time courses of variables to status. Also, it does not take into consideration that, due to the variety of mechanical degrees of freedom of the human movement system, it is possible to start from the same initial position and to achieve an identical final position with different partial movements. On the other hand, identical or similar time courses of the variables describing a movement may start from and finish in different positions. Therefore the identification of differences concerning time discrete variables is not sufficient for the differentiation of movement patterns.
In order to analyse movement patterns by the time courses, Schöllhorn (1995) proposes a time continuous oriented approach with orthogonal reference functions.
Based on the above considerations, the aim of this study was the comparison of movement pattern changes based on time discrete variables and the time courses of these variables. For this methodological comparison, the basketball jump shot was used because of the high degree of similarity between sucessful shots from the same distance and the change of movement pattern with increasing distance, proven by the analysis of time discrete variables (Elliott, 1992; Miller & Bartlett, 1993, 1996).

METHODS: The subject of the case study was a female athlete playing in the German Premier National League (centerplayer, height: 1,88 m). Jump shots from 4m, 5m, and 6m distance from the basket were filmed in the sagittal plane from the throwing arm side (16mm film,using a Locam high speed camera operating at 100 f/s). The jump shots were proceeded by a 5m. dribbling approach at a velocity established by the athlete. For each throwing position, three successful jump shots were digitized in order to determine the following 18 cinematic variables in the sagittal plane:

- angles and angular velocities of the knee, hip, shoulder and elbow of the throwing arm side;
- orientation angles and angular velocities of orientation of the thigh, trunk, upper arm, forearm and hand of the throwing arm side.

The displacement-time curves of the digitized landmarks were screened by a digital lowpass filter based on an algorithm of Winter (1974).

In order to analyse the time courses of these variables, they were correlated with four orthogonal reference functions which results in a (18 x 4) matrix representing the movement pattern of each analysed jump shot. The orthogonal reference functions are 4 TAYLOR functions (Figure 1).

$$\int_{-1}^{+1} f(t)\,g(t)\,dt = \begin{cases} 1 \,\forall f(t) = g(t) \\ 0 \,\forall f(t) \neq g(t) \end{cases}$$

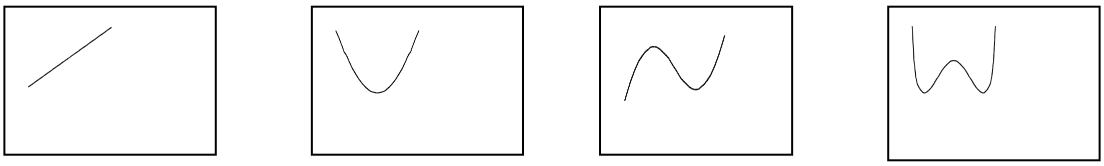

Figure 1 - Orthogonal TAYLOR reference functions.

Subsequently, the correlation matrices were compared, calculating a similarity coefficient for every pair of matrices (Gebhardt, 1967). In this way, a matrix of similarity coefficients was created that was then structured by a hierarchical cluster analysis. In order to identify those variables which define the differences of the coordination pattern of the main branches of the dendrogram (Figure2), the time courses of all variables and shots were analysed by the s-factor analysis. Different factors of the s-factor analysis represent different time courses of the analysed variable.

RESULTS: The hierarchical cluster analysis shows that the movement structure of shots from the same distance is more similar than between shots of different distances. The movement patterns of all throws are seperated into two main clusters (Figure 2), representing the 4-m shots in one main branch and the 5-m and 6-m shots in the other one. The similarity of the movement structure is greater between the 5-m and 6m-shots than between the 4-m and 5-m (6-m) shots.

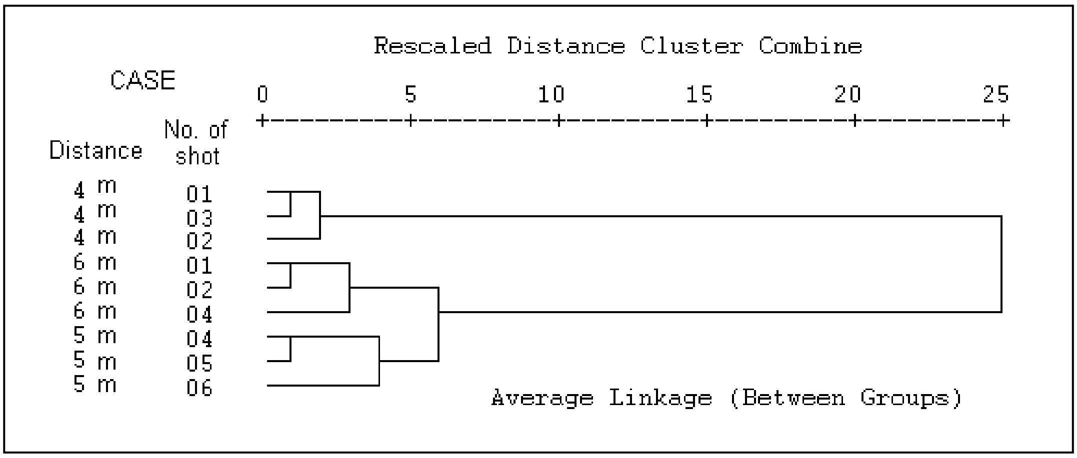

Figure 2 - Results of the cluster analysis.

The results of the s-factor analysis show differences between the two main clusters concerning the time courses of the angular velocity of the hip and shoulder and the orientation angle of the forearm. The time courses of all shots have a 2-factor structure.
One factor represents the time course of the 4m shots and the other factor the time courses of the 5m and 6m shots. The figures 3 to 5 show the time characteristics which represent the corresponding factor.

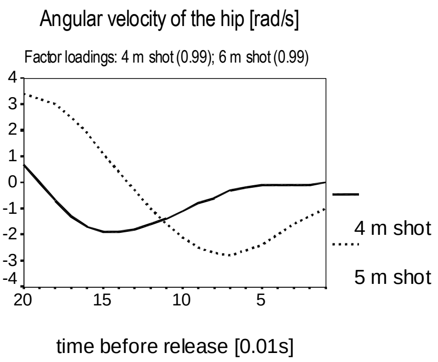

Figure 3 - Time course of the angular velocity of the hip.

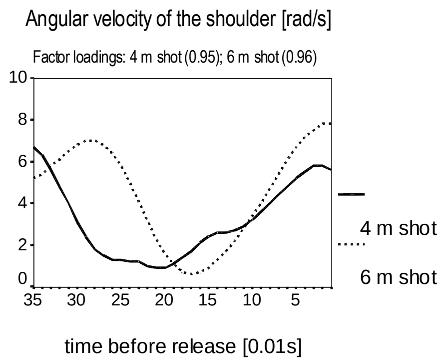

Figure 4 - Time course of the angular velocity of the shoulder.

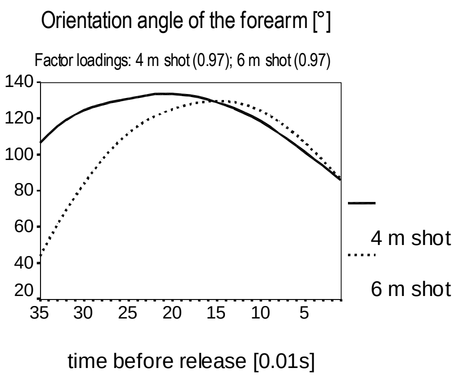

Figure 5 - Time course of the angle of orientation of the forearm.

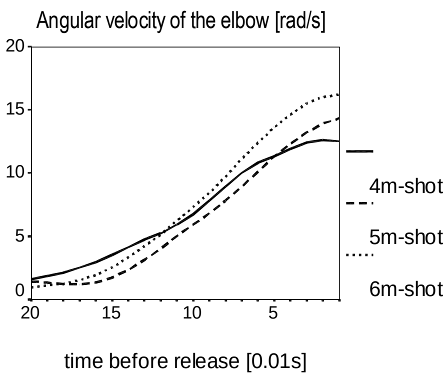

Figure 6 - Time course of the angular velocity of the elbow.

The time courses of the other variables are very similar and do not represent differences as shown in Figure 6 for the time course of the angular velocity of the elbow.

DISCUSSION: Based on the analysis of time courses, only three variables define different coordination patterns according to distance, which are ”angular velocity of the hip”, ”angular velocity of the shoulder” and ”angle of orientation of the elbow”. As a result of former studies investigating the effects of increased shooting distance on movement technique by time discrete variables, ”increased values for elbow extension angular velocity...” were found (Miller & Bartlett, 1993), which is in accordance with the results of this study shown in Figure 6. Nevertheless these differences of the angular velocity of the elbow at the time of release are not a consequence of different time courses. On the other hand, the angle of orientation of the forearm remains the same at the time of release (time discrete variable) for all shots of different distances, while significant differences could be detected for the time courses of this variable (Figure 5).

CONCLUSION: The results of this study show that a complete description of movement pattern should be based on time discrete variables and the time courses. While the time discrete variables inform about a status at different times during a movement phase, the time courses describe how one status is changed into another. For movement optimization and motor learning, the time discrete information is necessary to describe initial and final conditions of movements and movement phases, while the time course information is necessary to describe the transformation process.
Depending on the biomechanical objective of the movement, the analysis of time courses provides the possibility to identify optimal coordination patterns and movement strategies for the achievement of the final conditions at the end of a movement phase. Recently published studies analyzing movement pattern in javelin throw by time courses (Menzel, 1998, 1999) already has shown that interindividual different movement patterns may result in the same performance level while intraindividual differences can be related to performance.
If it is necessary to determine the degree of similarity of movements, the above described method based on time courses (Schöllhorn, 1995) seems to be more adequate than analysis of movement pattern by time discrete variables.

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Acknowledgments
This study was made possible by a grant from FAPEMIG (Fundação de Amparo à Pesquisa do Estado de Minas Gerais).