INTRA-INDIVIDUAL DIFFERENCES OF MOVEMENT PATTERNS IN THE JAVELIN THROW

Hans-Joachim Menzel,
Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

KEY WORDS: process oriented analysis, movement patterns, javelin throw

INTRODUCTION: One of the central aims of biomechanical movement analyses of top class athletes is the acquisition of valid data for movement and performance optimization. However, the methodical procedure of movement analysis of javelin throwing presents two deficiencies concerning the selection of analyzed parameters and the reduction of the movement processes to statuses.

Generally, the selection of analyzed parameters can be characterized as a shotgun-approach, where various biomechanical variables are arbitrarily determined without theoretical considerations that might justify the selection. As it is impossible to identify a single parameter that, taken in isolation, predicts release velocity or throwing distance to a satisfactory degree, a complex interaction of limb movements with compensatory mechanisms seems to determine performance. However, to avoid arbitrary selection of performance parameters, it is necessary to apply a deterministic and mechanically based model of the thrower's movement.

Usually individual performance diagnosis is based on the comparison of time discrete variables between different performance level groups (inter-individual performance trends). The problem of this method is that it requires coincidence between inter- and intra-individual performance trends and that it reduces the movement and the time-course of the variables to statuses. 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 achieve identical final position with different partial movements. Recently published studies (e.g., Bauer & Schöllhorn, 1997) suggest process oriented analysis of human movement patterns as the most appropriate method for individual movement technique optimization.

Based on these considerations, the aim of this study was the identification of changes of individual movement patterns in the javelin throw and their correlation with performance based on a mechanical model of the throwing movement and process oriented analysis methods.

METHODS: Nine throws (57.96m – 68.80m) by one female javelin thrower were filmed in 3D during competition (16mm film, two Locam high speed cameras, 200f/s).

In order to establish a functional relation between the release velocity of the javelin (dependent variable) and the variables which describe the movement of the thrower's limbs, a three dimensional model of the thrower's body was constructed (Menzel 1990). It consists of 6 segments with simple articulation representing shank, thigh, hip axis, trunk, upper arm and forearm. The lower end of the shank (ankle joint) is assumed to be stationary during the delivery phase (Fig. 1).

The variables of this model describing the thrower's movement are:

Three dimensional angles φ_i between the segments, which result in the vectors $\boldsymbol{p_i}$ between the ankle (origin of the reference system) and the corresponding

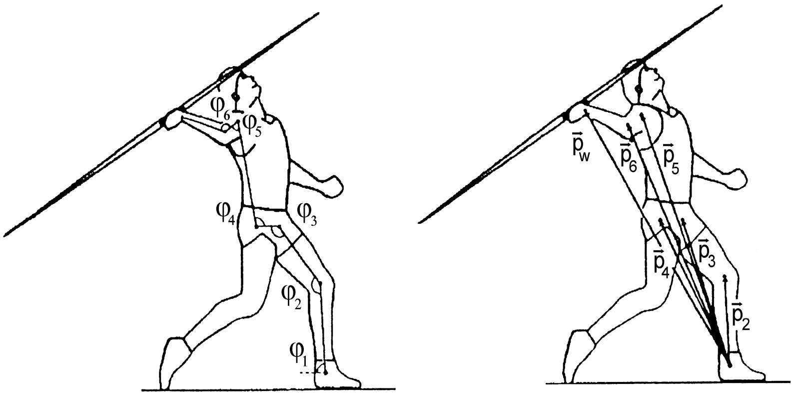


Fig. 1 3-D model of the javelin thrower's movement

- joints Pi of the model (P_1 – ankle, P_2 – knee, P_3 – left hip, P_4 – right hip; P_5 – shoulder, P_6 – elbow, P_W – wrist)
- Angular velocities ω_i of the rotation of the distal segment in relation to the proximal one

The velocity of the wrist $\boldsymbol{v_w}$ can be calculated as a function of the angular velocities ω_i and the vectors $\boldsymbol{p_i}$:

$$\vec{v}_W = \sum_{i=1}^{6} \omega_i * (\vec{p}_W - \vec{p}_i)$$

In order to analyze the time course of the variables of the above described model, the P-technique, where a number of *p* variables are correlated over a number of *m* moments, was applied as a method of multivariate time-series analysis.
As the result of this procedure, the movement pattern of each throw is represented by a factor matrix, where the factors represent variables with similar intensity-time courses. Subsequently the factor matrices were compared by an algorithm developed by Gebhardt (1967) which calculates a similarity coefficient for every pair of matrices. In this way a matrix of similarity coefficients was created that was then structured by a hierarchical cluster analysis. Finally, the S-factor analysis was applied to those variables which represent factors of different movement patterns (movement patterns which appear in different main branches of the dendrogram).

RESULTS: The hierarchical cluster analysis separated the movement patterns into two main clusters (Fig. 2). For one main cluster (3 throws) the release velocity was greater than and for the other (6 throws) less than 25 m/s. The throws with higher release velocity seem to have different movement patterns from those with less release velocity.

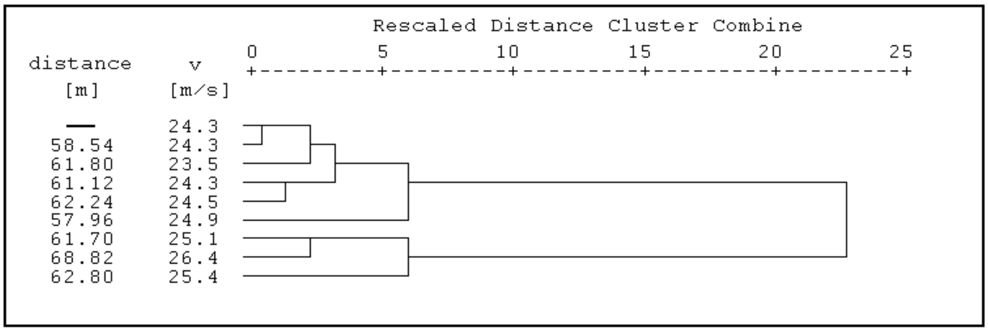


Fig. 2 Results of the cluster analysis

Tab.1 shows the factorial structure of three representative throws of each main cluster. For both movement patterns factor A is determined by the time course of the knee angle of the bracing leg. The second variable, which characterizes factor A, is the time course of the elbow angle for the throws with higher release velocity and the time course of the left hip angle for the throws with lower release velocity.
The variables with the highest factor loading for factor B are the course characteristics of the angles describing the trunk movement (throws with release velocity > 25 m/s) and the course characteristics of the angles describing the throwing arm movement (throws with release velocity < 25 m/s).

Tab.1 Factorial structure of throws representing the movement pattern of the two main clusters

Cluster A ($v_o > 25$ m/s)			***Cluster B*** ($v_o < 25$ m/s)	
		Factor A		
Variables	***loadings***		***variables***	***loadings***
φ08	.92 - .99		φ08	.82 - .98
φ13	.93 - .95		φ10	.91 - .98
		Factor B		
Variables	***loadings***		***variables***	***loadings***
φ09	.92 - .98		φ11	.94 - .98
φ10	.93 - .97		φ13	.89 - .95

As the time course of the knee angle of the bracing leg (*φ08*) defines factor A of both movement patterns (with release velocities greater and lower than 25 m/s), the S-factor analysis was applied in order to review if the time courses are identical. The results of this factor analysis shown in Tab.2 prove different time courses of the knee angle of the bracing leg for throws with release velocities higher and lower than 25m/s.
According to these results (shown in tab.1 and the figures 3 and 4) the differences between the two main movement patterns can be characterized as follows:

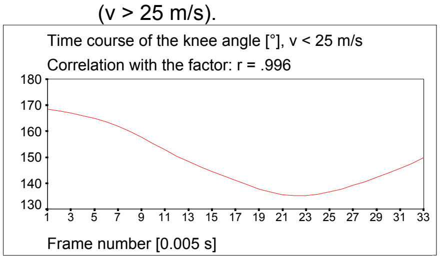
- The time course of the knee angle (*φ08*) defines factor A of both movement patterns.

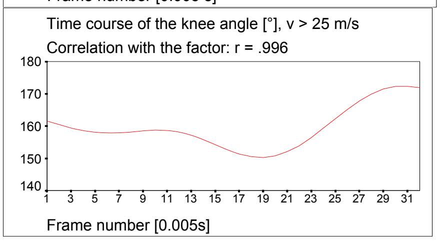
- throwing arm.
- The variables with the highest factor loading for factor B are the course characteristics of the angles describing the trunk movement (for the throws with release velocity > 25 m/s) and the course characteristics of the angles describing the throwing arm movement (for the throws with release velocity < 25 m/s)

CONCLUSIONS: For top level female javelin throwers, different intra-individual movement patterns can be identified and correlated with performance levels. The

Fig. 3 Time course of the knee angle (v < 25 m/s).

Fig. 4 Time course of the knee angle (v > 25 m/s).





The S-factor analysis, however, reveals that the time courses of the knee angle of the bracing leg ($\varphi 08$) are different for the two types of movement patterns. At the beginning of the release phase (planting of the bracing leg) the knee angle is nearly the same for both movement patterns ($160^o < \varphi 08 < 170^o$). The throws with lower release velocity (v < 25 m/s) are characterized by a decrease of the knee angle which has its minimum at about 135^o, whereas the throws with higher release velocity (v > 25 m/s) have the knee angle nearly constant for about half of the release phase, which provides adequate conditions for the reduction of the trunk's velocity and an optimal impulse transmission to the C:\menzel\IFS_Bisp\SAV_Daten\isbs2.chtContents

most important differences between these movement patterns are the course characteristics of the knee angle (bracing leg) and the angles which define the trunk movement. Technical training should be organized according to individual movement patterns. Further studies analyzing the inter-individual differences of movement patterns of athletes with the same performance level should be made in order to investigate compensatory mechanism.

REFERENCES:

Bauer, H. U., Schöllhorn, W. (1997). Self-Organizing Maps for the Analysis of Complex Movement Patterns. *Neural Processing Letters* **5**, 193-199.

Gebhardt, F. (1967). Über die Ähnlichkeit von Faktormatrizen. *Psychol. Beiträge* **10**, 591-599.

Menzel, H.-J. (1990). Biomechanical Analyses of the Javelin Throw of Top Class Athletes. In G.-P. Brüggemann, J. K. Rühl (Eds*.), Techniques in Athletics - Conference Proceedings 2* (pp. 662-668). Köln: Sport und Buch Strauß.