

COMPARATIVE ANALYSIS OF THE TAKEOFF IN POLE VAULT AND LONG JUMP BASED ON TIME-CONTINUOUS DATA

Thomas Jaitner
University of Leipzig, Leipzig, Germany

A pattern recognition approach based on time-continuous kinematic data was applied to analyze movement patterns of the pole vault and the long jump during takeoff. Altogether, 24 trials of pole vaulters, long jumpers and decathletes were analyzed using a combination of cluster analysis and discriminant analysis methods. Concerning the jumping movement of the legs structural differences between pole vault and long jump patterns as well as individual movement behaviour were identified. The movements of the jumping leg played an important role for the different TO performances.

KEY WORDS: pole vault, long jump, movement patterns, multivariate analysis.

INTRODUCTION: Biomechanical analyses are an integral part of the technique training in high performance sports especially in sports disciplines as the track and field events. In many cases analyses are based on parameters (e.g. the angle and velocity of the center of gravity, c.g.) which describe the athlete's performance at given times or positions but lack information on how the movement has been processed in-between. More detailed knowledge about the movement processing is available if time-continuous data are analyzed. Based on a pattern recognition approach, analyses of the time courses of kinematic and dynamic variables have been useful recently to identify adaptations of ballistic sports movements following motor learning (Bauer & Schoellhorn, 1997) or to investigate structural differences between slightly varying movements, e.g. the long jump takeoff (TO) from various heights (Jaitner et al., 2001a) or between following phases during a singular running movement (Schoellhorn & Bauer, 1998). Further, the contribution of single variables on structural changes or differences of complex movement patterns could be determined (Jaitner et al., 2001b). The purpose of this investigation was to study the TO performance in pole vault and long jump based on time-continuous kinematic data. Biomechanical analyses of TO parameters indicate that pole vaulters should perform their TO similar to long jumpers because TO angles of the c.g. for pole vaulting are in the range from 15 to 20 degrees (Gros & Kunkel, 1988; Linthorne, 1994) and are therefore comparable with values measured for long jumping (18 to 23 degrees, Hay & Miller, 1986). For decathletes, TO angles greater than 23 degree have been reported. Considering these findings special interests were (1) to identify structural differences of movement patterns of pole vaulters, long jumpers and decathletes during TO and (2) to investigate to what extent differences in the complex patterns may be explained by single variables that describe partial motions of body segments.

METHODS: Twelve pole vault and 12 long jump trials were filmed at frame rates between 100 and 200 Hz using a 16 mm high speed film camera (LOCAM). Subjects were 6 pole vaulters (5.50–5.85 m), 6 long jumpers (7.89–8.49m) and 10 decathletes (pole vault: 4.30–5.00m/ long jump: 7.00–8.02m). Pole vault and long jump trials of the same athlete were available for 4 decathletes. 2D coordinates of 20 body marks were determined for each frame and the resultant time courses were smoothed with a recursive 2nd order Butterworth filter. TO angles calculated for the c.g. were in the range of the findings reported in literature. To describe the subject's movement during TO, time courses of angles and angular velocities of the main joints were calculated by the time courses of the body markers. In combination with the orientation angle of the trunk axis and its corresponding velocity, the description was considered physically complete. The distances between the time and amplitude normalized time courses were determined for all data sets according to Schoellhorn (1999). Distance matrices of various sets of variables were analyzed by cluster analysis using the single linkage algorithm. Based on the results of the cluster analysis a discriminant analysis was performed to determine the contribution of single variables on the classification of the complex patterns (Jaitner et al., 2001). The relative contribution of single

variables on the discriminant function was determined by the corresponding discriminant coefficients and structure coefficients.

RESULTS AND DISCUSSION: Considering all variables at the first step, the cluster analysis showed a clear distinction of all pole vault and long jump trials. This result was reasonable due to the different arm movements pole vaulters use to plant the pole.

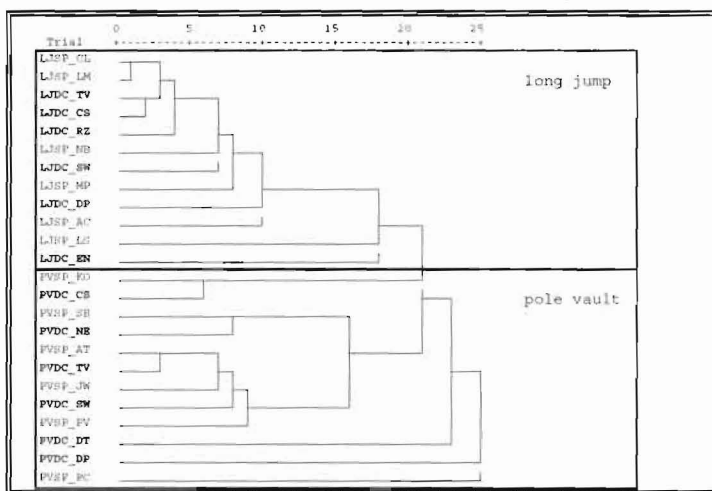


Figure 1. Dendrogram of the cluster analysis considering all kinematic variables. The first four letters of each trial's name identify the athletic discipline (LJ: long jump/ PV: pole vault) and the level of performance (SP: specialist/ DC: decathlete), e.g. PVDC_CS: pole vault trial of decathlete C.S.. All Decathletes' trials are marked with bold letters.

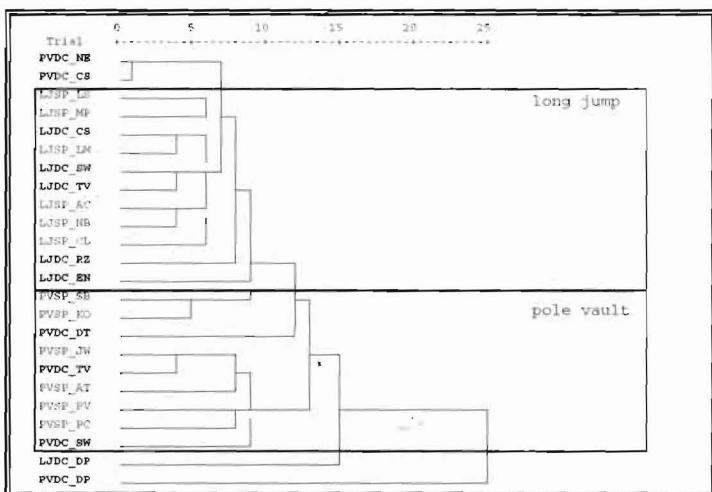


Figure 2. Cluster analysis of variables of the lower body.

In the second step, variables that described the movement of both legs during TO were analyzed (Figure 2). All long jump trials were clustered together with two pole vault trials performed by decathletes (CS, NE). The remaining pole vault trials were subsequently added. Pole vault and long jump trials of one decathlete (DP) were affiliated at the last stage of the clustering. Concerning the jumping movement of the legs, movement patterns of the

pole vault differed in most cases from patterns used for long jumping. Apparently, decathletes CS and NE performed their pole vault TO in a manner similar to the long jump TO. For decathlete DP, the different movement patterns of the pole vault and long jump TO might be explained by a deficient movement technique which resulted in rather low performances compared to other athletes. Discriminant analysis considering all variables of the lower body extracted two variables which classified 91.7% of the pole vault and long jump trials correctly. These variables were the angle of the hip (α_{HJ}) and the angular velocity of the knee (ω_{KJ}), both of the jumping leg. The relative contribution of the single variables on the discriminant function was determined by the corresponding discriminant coefficients and structure coefficients listed in Table 1. Variable α_{HJ} obtained higher values for both coefficients which indicated a higher contribution on the classification of pole vault and long jump trials.

Table 1. Standardized canonical coefficients and structure coefficients. Discriminant analysis using the stepwise procedure included two variables.

variable	standardized canonical discriminant coefficients	structure coefficients
α_{HJ}	.843	.655
ω_{KJ}	-.779	-.579

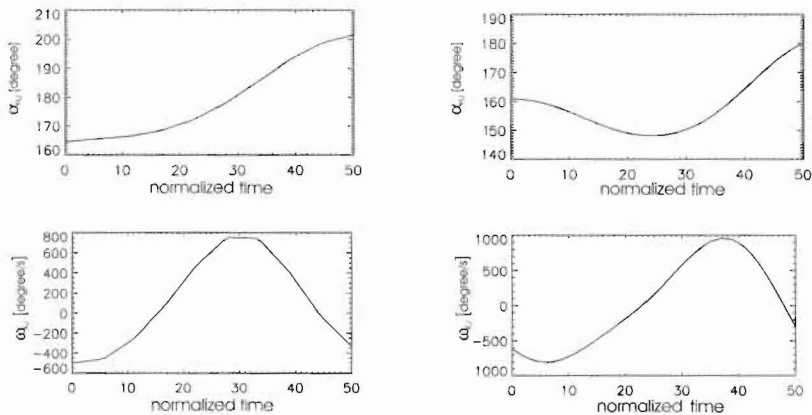


Figure 3. Time courses of the hip angle α_{HJ} (top) and angular velocity of the knee ω_{KJ} (bottom), both for the jumping leg. Curves of one pole vaulter (left) and one long jumper (right) are displayed.

The differences in the jumping leg's TO movements that associated with the statistical findings might be explained by the time courses of variable α_{HJ} and ω_{KJ} (Figure 3). Concerning the pole vaulters (left), the time courses of the hip angle (top) rose permanently. For the long jumpers time courses (right) these first decreased and then increased during the second part of the TO. This indicated that pole vaulters straightened their hip from the beginning of the TO, whereas long jumpers started with a bending movement in the hip. Angular velocities of the jumping leg's knee (bottom) showed for the pole vault a reduction of the negative velocities from the beginning of the TO, while for the long jump an initial increase of the negative values was observed. The time the maximal positive velocity was reached did not coincide over all trials. Therefore, it was suggested that pole vaulters intended to initially reduce the bending velocity of the knee in order to begin the straightening of the leg quickly. Long jumpers, on the other hand, first bent their knee with increasing velocity, before the bending velocity was reduced to zero and the straightening of the leg started. This movement might be due to the reduction of the high horizontal approach velocity and the development of vertical velocity during TO.

CONCLUSION: Overall, the applied pattern recognition method allows to identify structural differences of movement patterns between various jumping movements. It further seems possible to determine the contribution of the motion of body segments on the differences in the complex movement patterns. Therefore, this approach seems to be an appropriate and promising tool for the analysis of sports movements, which offers a wide range of application as the analysis of individual movement behavior or the diagnosis of deficits in movement techniques. Considering the pole vault and the long jump, the movement of the jumping leg plays an important role for the different takeoff performances. Concerning the pole vault of decathletes individual movement behavior was stated for single athletes, but in general movement patterns of decathletes showed no difference to patterns used by pole vaulters.

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