A THREE-DIMENSIONAL KINEMATIC ANALYSIS OF THE STAND- AND JUMPSERVE IN FISTBALL

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The purposes of the study were a detailed 3D kinematic description of the stand and jump serve in fistball, a comparison of players of different performance levels regarding kinematic parameters and a kinematic comparison of the stand and the jump serve. 19 male fistball players – separated in 3 (stand) respectively 2 (jump) performance based groups – performed a long stand and jump serve. The movements were filmed with two digital cameras (60 Hz) and were analysed using SIMI Motion. The peak velocity of the hip, shoulder, elbow, wrist, fist and ball as well as body angles (shoulder axis, pelvis axis, body torsion and spread angle) and ball parameters were analysed. The results showed significant differences regarding all velocities and ball hitting heights between the groups, but only tendencies concerning the body angles. Thus, peak body segment velocities and - to a certain extent – peak body segment angles during stand and jump serve in fistball were found to be performance limiting factors.

KEY WORDS: fistball, kinematics, serve, segment velocities, segment angle

INTRODUCTION: Fistball certainly is a fringe sport, however, very popular in German-speaking countries and in South America. The game is quite similar to volleyball with some significant differences: (1) the ball (~365 g) may touch the ground once prior to the player's contacts, (2) the field is 20 x 50 m divided by a thin net mounted 2 m above the ground, (3) the serve is performed from the serve line ("3m-line") by a player whose team lost the previous point. The serve is one of the most powerful actions in fistball. On average 33% of the points are won by the serve (Almhofer, 2003). To the best of our knowledge only one study (Bayer, 1980) refers to a 2D kinematic analysis of the fistball serve, 3D kinematic analyses are not available at all. Thus, the goals of this study were (1) to describe the stand and jump serve in fistball kinematically in 3D, (2) to compare players of different performance levels in order to determine performance limiting factors and (3) to compare stand and jump serves regarding kinematic parameters.
The hypotheses were: (a) the peak segment velocities increase with the performance of the players, (b) the body angles differ with respect to the performance of the players, (c) the peak segment velocities are higher in jump serves than in stand serves, (d) body angles differ in jump and stand serves and (e) the coordinates of the fistball at impact differ with respect to the performance of the players.

METHODS: 19 male Austrian fistball players from various teams (including 4 national team players) participated in this study. The subjects were separated into 3 groups for the stand serve and into 2 groups for the jump serve based on their level of performance (Table 1). Long stand and jump serves of the subjects were filmed in a gym hall with two synchronised digital cameras (JVC, NTSC, 60 Hz, 1/500 s). The action space (3.0 m x 2.4 m x 2.0 m) was calibrated using 25 reference points and a standard DLT algorithm.

Table 1 Group statistics for stand and jump serve.

stand serve	age (yrs)	height (m)	mass (kg)
S1 (n=4) – top level	23.3 (±1.9)	1.89 (±0.04)	88.7 (±6.1)
S2 (n=8) – average level	24.6 (±7.6)	1.79 (±0.05)	77.9 (±8.2)
S3 (n=7) – low level	19.1 (±3.7)	1.77 (±0.05)	72.3 (10.3)
jump serve			
J1 (n=5) – top level	23.3 (±1.9)	1.89 (±0.04)	88.7 (±6.1)
J2 (n=4) – low level	24.6 (±7.6)	1.79 (±0.05)	77.9 (±8.2)

From the videos 22 body landmarks (toes, ankles, heels, knees, thighs, pelvis, shoulders, elbows, wrists, fists, and head), ball and the serve line were manually digitised and analysed with SIMI Motion 6.0. The following parameters were selected based on a pre-study: peak velocities of hip, shoulder, elbow, wrist and fist of the hitting arm side, shoulder axis, pelvis axis, body torsion, spread angle (angle between the two thighs), ball coordinates and ball velocity at impact. The differences between the groups were statistically calculated using ANOVA and t-test approaches (* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$).

RESULTS: Figure 1 presents the kinegrams of a stand serve including time axis with ball toss release (-0.75 s), stepping towards service line (-0.50 s), highest spread angle (-0.22 s), highest body tension (-0.15 s), acceleration of elbow, wrist and fist (-0.06 s), ball impact (0.00 s) and step in the serve area (3 m from net) with the swing leg. Figure 2 shows the time course of velocities of the subject performing the highest ball speed (30.5 m/s). The peaks of fist and wrist velocities occurred at the moment of impact (= 0.0 s) while the peak velocities of the elbow (13.2 m/s at -0.08 s), shoulder (6.0 m/s at -0.08 s) and hip (4.0 m/s at -0.15 s) were reached slightly earlier. In jump serves the velocity time courses were quite similar. The peak values, however, were about 3 m/s higher and the hip and shoulder moved consistently faster during the entire motion. The highest ball speed (34.2 m/s) was performed with a jump serve. In jump serves the in-run speed did not correlate with ball speed ($r^2 = 0.25$). The velocities of the elbow, wrist and fist highly correlated with the ball speed ($r^2 > 0.8$), both in stand and jump serves.

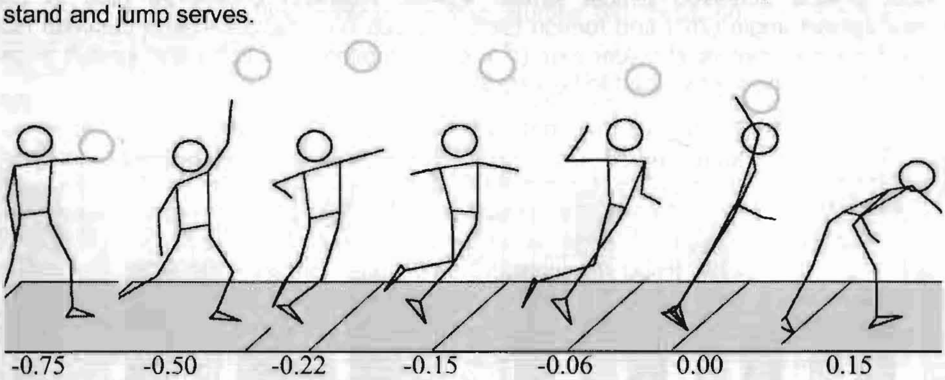

Figure 1 Kinegrams of a stand serve.

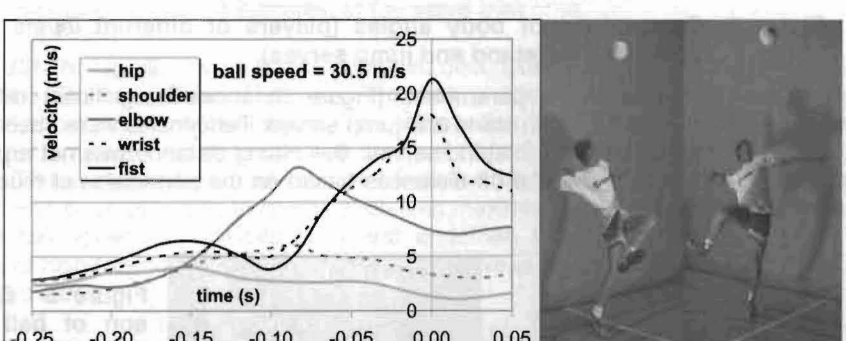

Figure 2 Time course of velocities during stand serve and camera views of a subject at t = -0.18 s.

The comparison of the stand serve groups yielded significant differences regarding all peak end-point velocities of the hitting arm and the ball (Figure 3). Elite players consistently achieved higher velocities than players on a lower level. The differences between peak shoulder and peak elbow velocity (~200 %) as well as between peak fist and peak ball velocity (50%) were remarkable. The comparison of the jump serve groups showed significant differences only regarding elbow, wrist, fist and ball velocities.

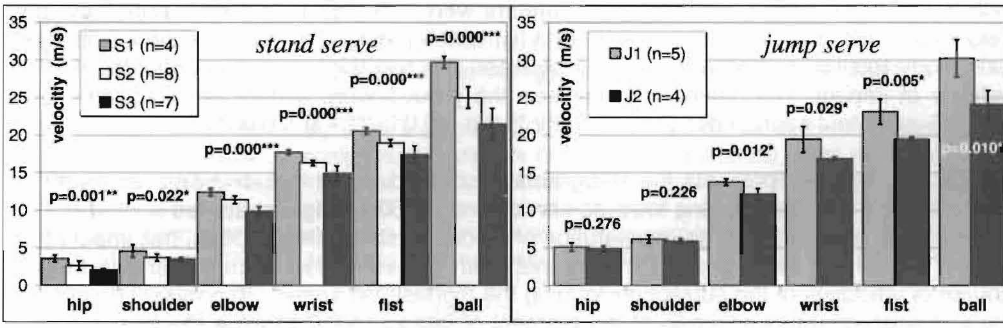

Figure 3 Comparison of the peak velocities (players of different levels of performance, hitting arm, stand and jump serve).

No significant differences between the groups were found regarding body angles, both in stand and jump serves. Tendencies were observed that in stand serves players with higher skill levels achieved greater angles of the shoulder axis, torsion and spread angle. In jump serve both groups achieved almost similar values. Attention should be paid to the parameters spread angle (75°) and torsion (56°) in group S1. The correlation between ball velocity and the parameters shoulder axis (r^2 = 0.18), torsion (r^2 = 0.13) and spread angle (r^2= 0.19) in stand serves was found to be very low.

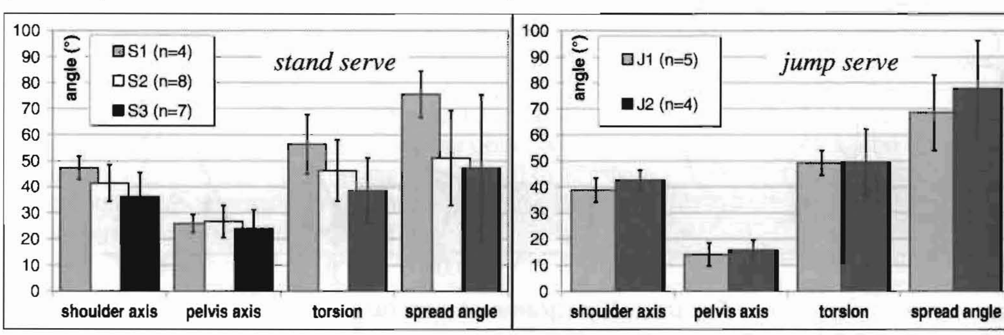

Figure 4 Comparison of body angles (players of different levels of performance; stand and jump serves).

A comparison of ball coordinate parameters (Figure 5) showed significant differences concerning ball hitting height, both in stand and jump serves. Tendencies were observed with respect to the ball impact distance in stand serves. Ball hitting distance was not analysed in jump serves due to the different take-off distances based on the permission of touching the serve area (3 m to the net).

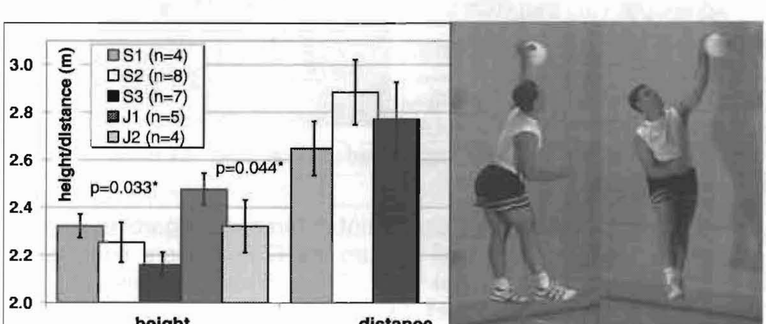

Figure 5 Comparison of ball impact height and distance to the net and camera views of a subject performing a jump serve.

The comparison of stand and jump serve showed significant differences in all peak velocities and ball speed. It is remarkable that the subjects who performed both stand and jump serve did not add their horizontal jump speed to their stand serve's peak velocities to achieve their jump serve's peak velocities. Differences between the two serving techniques were found for the pelvis angle and the ball hitting height.

DISCUSSION: The time courses of the end-point velocities of the hitting arm were quite similar to other throwing sports as javelin throwing and handball. All analysed peak velocities increased with the performance level of the group. High ball velocity at impact is one of the most important factors for performing an effective serve. Lower ball speed extends the duration of the ball defending actions for the opponent defender (running distances up to 10 m).
The difference in fist and ball speed can be explained by the physical term of the "elastic stroke". Here the hitting mass plays an important role. While highly skilled players can use up to 1.65 kg as effective mass, lower skilled players only use about 0.60 kg. In contrast to handball, where the ball is accelerated by the throwing arm during the entire throwing motion, in fistball the ball is only accelerated by the impact causing higher ball speeds. The analysed peak body angles did not correlate with ball speed and seem to be no performance limiting factor. It might be that time courses of the body angles as well as the angular velocity and angular acceleration are more important in this context. Further studies will focus on these aspects more specifically.
Player with better skills hit the ball in a higher position so the risk of ball-net contact (= fault) is reduced. The body height highly correlates with hitting height, so it is advantageous for fistball attacker to be tall (Group statistics, Tab. 1).
The main differences between stand and jump serves were observed for end-point velocities, pelvis axis and ball hitting height. Consequently, the jump serve is advantageous for achieving higher ball speeds and reducing net faults. The difference in pelvis axis can be explained with Newton's third law (actio – reactio). The player cannot touch the ground during the impact in jump serves. So the reacting force of gaining an inclination of the shoulder cannot be transferred to the ground (Figure 6).
The most severe limitation of the study was the sampling frequency of 60 Hz impeding an exact description of the serve over time.

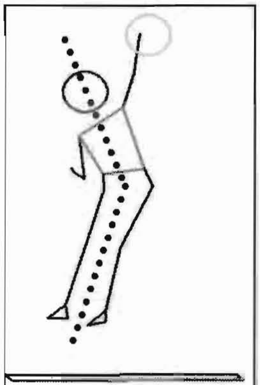

Figure 6 jump serve at time of ball hit.

CONCLUSION: Up till now an exact kinematic description has only been made by trainers without scientific background. The presented study yields 3D kinematic data and 3D-views of the stand and the jump fistball serve. This information is of particular importance for both, athletes and trainers in order to optimise the level of performance and to improve the training process. The analysed data yield important facts for the training process: (1) maximising the segment end-point velocities in combination with maximising the 'effective mass' to enhance maximal ball speed, (2) specific back and abdomen muscle training to prevent injuries because of high torsion angles and (3) the jump serve is a powerful alternative for achieving high speed serves.

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