BODY ANGLES IN VOLLEYBALL SPIKE INVESTIGATED BY MODELING METHODS

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Joint angles in the movement of volleyball spikes were investigated in this study. The database was provided by three dimensional motion analysis of the volleyball spike recorded during international competitions. The investigated movements occurred in different game situations and different sets, but individual coordination techniques could be identified for the movement. By modelling methods it was possible to analyze the time histories of shoulder angles around all three axes.

Keywords: VOLLEYBALL, SPIKE, MODELING, MOTION ANALYSIS

INTRODUCTION:

In order to understand how specific movements are performed, it is important to describe the specific movement under consideration with high accuracy. Assets and drawbacks of these movements can only be understood, if it is possible to describe movements with close-to-reality and artifact-poor time histories for the inner co-ordinates.
By modelling it is possible to gain further information about movement. For example it is possible to forecast effects of changes in coordination techniques. Another advantage is the quantification of motion details using inverse kinematics. Therefore, joint angles can be analyzed more accurately in a competition setting without using marker sets.
The aim of this study was to perform inverse kinematics for a volleyball spike under competitive conditions and to investigate the shoulder angles by modelling methods.

METHODS:

Spike movements carried out by male elite players of the national teams of Croatia, Estonia, Germany and the Netherlands were recorded during European League competition. Since the favourite spike-position by international top level teams is position four (Zimmermann, 2005) only spikes from this position built the database for this study. For motion analysis, four digital cameras (3x Basler, 1x Vosskühler) with a frame rate of 100 Hz were used. This setup was calibrated by 16 landmarks with known coordinates. The direct linear transformation method was used to calculate the spatial coordinates. Therefore, the software “SIMI Motion-Capture” was utilized to carry out motion analysis.
Boundary conditions for the analysis were: diagonal performed spikes from position four, flight angle of the ball after impact from 110° to 145° to the net, and the step close technique (Coutts, 1982). Out of all recorded movements, two players were chosen for this study who carried out two valid spikes each. The data were collected under field conditions during international matches. Therefore, it was impossible to use any kind of marker sets. Hence, the digitizing process had to be done manually.

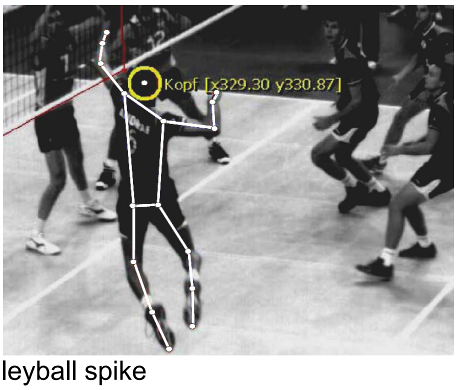

Figure 1: Video analysis of a volleyball spike

17 body points were digitized per frame. 12 points representing the major joints were used – i.e. ankle, knee, hip, hand, elbow and shoulder. In addition 5 points representing the head, foot tips, and carpals were identified. It was not possible to calculate the different movement angles within the shoulder and hip joints, without having the opportunity to identify more points per segment accurately.
The solution was to execute inverse kinematics. The multi body system (MBS) man model DYNAMICUS implemented in the software tool *alaska* 5.1.4. was used to quantify the time histories of these joint angles. 13 joints were considered and the total degree of freedom for this model was 22. Using the Dynamic Tracking method (Roemer et al., 2001), model-fixed points were defined corresponding to the digitized body points of the subject. In these points the man model was connected viscoelastically to the reference points. This leads to dynamic adjustments of the man model with the moving reference point cloud. Due to the linear elasticity used to connect the markers, this approach is equivalent to linear filtering. Thus, the movement of the real volleyball spiker was transferred to the man model and the time histories of all major joints were quantified.

Figure 2: Man model in marker cloud

Time histories for the spatial coordinates and all joint angles of the man model DYNAMICUS were calculated as well as the velocities and accelerations.

RESULTS AND DISCUSSION:

A verification of the digitized points by calculating other points with known 3D coordinates showed an accuracy of ± 9 mm. Additionally the right knee joint angle was used to identify the accuracy for the simulated movement. This joint angle was explicit defined by motion analysis and modelling methods respectively.

Table 1: Statistical values of knee angles

Statistical Value	Angle [°]		Angular Velocity [°/s]	
	Simulation	Measurement	Simulation	Measurement
Maximum	175.8	173.9	1195.2	1234.8
Minimum	58.4	57.8	-787.7	-796.9
Correlation coefficient	0.99		0.98	
Ratio of deviation	0.04		0.03	

The correlation coefficients showed a high correlation between the results of the simulation and the motion analysis. The ratio of deviation refers to the numerical integral of the time histories of the data. The values lead to the outcome that the movement was reproduced accurately by dynamic tracking with respect to the knee angle.
Referring to time histories of the distances of each reference point and body marker, respectively, mean values over all body markers showed an accuracy of two centimetres. Points with large displacements were located at hand and hip.

Table 2: Mean values and std. deviation for distances of selected reference points

	Shoulder_R [cm]	Shoulder_L [cm]	Elbow_R [cm]	Hand_R [cm]	Hip_R [cm]
$\bar{x}$	1.1	1.2	1.8	3.9	3.4
S.D.	0.7	0.7	0.9	1.4	1.5

Changes in segment length were found in the motion analysis data due to difficulties to identify hidden points exactly. For simulation of the movement, no changing of segment length was allowed. Using these boundary conditions, the recorded movements were reproduced by simulation. Based on the above mentioned results, it was concluded that the measured movement was reproduced with high accuracy. This provided the basis for calculating the triaxial movement within the shoulder joint.
The following results show the time histories of shoulder angles of four different volleyball spikes. Only the spike arm was analysed. Two movements were performed by a German player and the two others by a Dutch player. The ball impact was at frame 93.

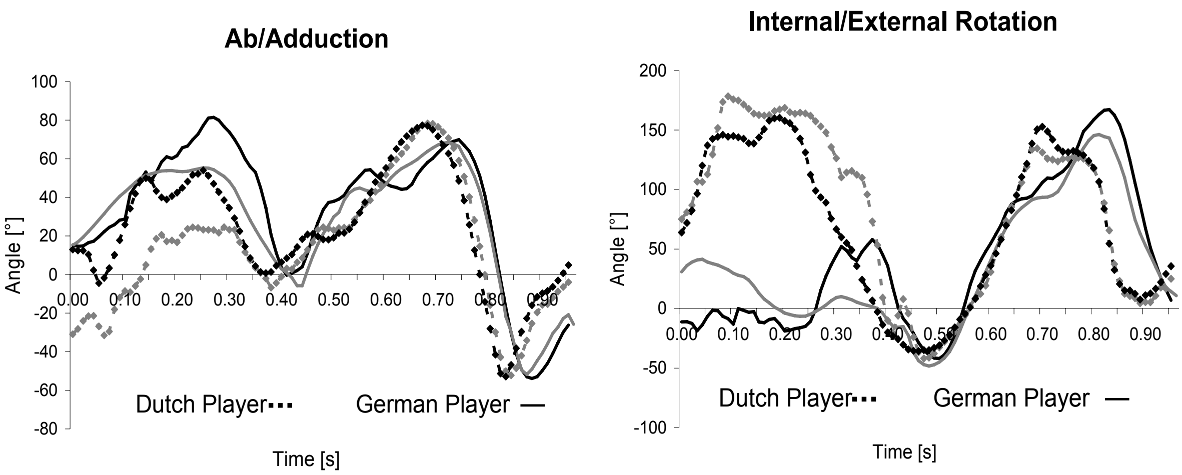

Figure 3: Abduction, adduction and rotational angles of the shoulder

These results show individually different strategies of coordination. The location of ball impact was above the side line with a distance to the net of 1.2 m to 2 m.
The Dutch player increased the abduction angle earlier than the German. Also the external rotation increased earlier and, in contrast to the other player, decreased before ball contact. The range of motion for the rotational movement of about 201° for the German and 182° for the Dutch player agrees with findings of Dun et al. 2007 for baseball pitchers and Forthomme et al. 1982 for volleyball players.

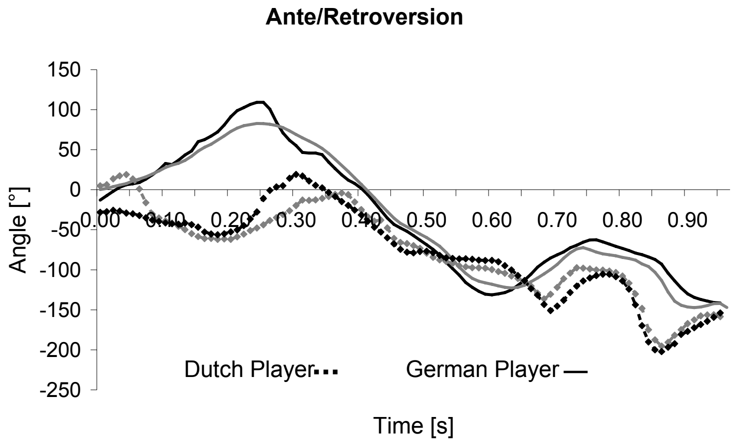

Figure 4: Anteversion and retroversion angles of the shoulder

In addition the Dutch player showed higher anteversion angles, which decreased before ball contact unlike the increasing anteversion angles of the German player. These results were found for both players in two randomly chosen volleyball spikes performed in international competitions.

CONCLUSION: The aim of this study was to perform inverse kinematics for a volleyball spike under competitive conditions and to investigate the shoulder angles by modelling method. The recorded movements were simulated with high accuracy using motion analysis methods without any marker sets. Based on these simulations the shoulder angles around the three shoulder axes were calculated for two players. The investigated movements occurred in different game situations and different sets, but individual coordination techniques could be identified for this movement. Thus it can be concluded that using this model it is possible to quantify time histories of shoulder angles in volleyball spikes under competitive conditions. Further studies will be carried out to analyse more subjects and more body angles relating to additional parameters like spike height and ball velocity.

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