ASPECTS OF A THREE DIMENSIONAL MOTION ANALYSIS OF THE VOLLEYBALL SPIKE IN HIGH LEVEL COMPETITION

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The purpose of the study was a three dimensional motion analysis of the volleyball spike from position four during competition. Spikes were analysed at a tournament of the European league. Regarding the jump technique, only few athletes performed the discussed coordination pattern of the impulses within the body. It may be concluded that there exists reserves within the training process concerning the coordination in the take-off phase even in high level athletes.

Keywords: volleyball, spike, motion analysis, jumping technique, coordination

INTRODUCTION:

Based on the variety of movements, the analysis of the volleyball spike is a complex approach. Most of the studies that investigate the motion in volleyball were performed under laboratory conditions (e.g. Fantozzi et al. 2006; Tokuyama et al. 2005). There are only few studies under field conditions reported in the literature. Most of these measurements were performed during training process. A few articles only concern with motion analyses in important matches (Coleman et al. 1993; Tillman et al. 2004). The data acquisition of this study took place during an international competition. The purpose of this study was the analysis of the take off phase and coordination aspects during flight phase in spike jumps.

METHODS:

Spike movements performed by players of the national teams of Croatia, Estonia, Germany and the Netherlands were recorded during European league tournament. Since the favourite spike-position used by international top level teams is position four (Zimmermann, 2005) only diagonal spikes from this position have been considered. All subjects performed a step-close technique, identified by Coutts (1982). A second criterion was the flight angle of the ball after impact from 110° to 145° to the net. From the sum of all recorded spikes achieving those criteria, 10 spikes were chosen in a randomized order. No difference was made with respect to the national team.

Seven cameras were sited around the field, which were four digital High-Speed-Cameras (3x Basler, 1x Vosskühler) and three conventional video cameras (Panasonic). For the motion analysis only the digital cameras with a frame rate of 100 Hz were used. The conventional cameras were used for redundancy. The digital cameras were activated and triggered by "SIMI Motion-Capture" software. The frequency of the cameras was controlled by the software, too.

Calibration and coordinate system: A coordinate system was created to reconstruct the 3D-spatial coordinates of reference points representing the joints of the body. The origin was set at the bottom left corner of the calibration cube. This virtual cube was built by a stick of metal, fixed to a tripod. The stick had the length of the diagonal of a cube with edge length of two meters. It was fixed to the tripod in it's middle. The diagonal of the cube was calculated by: $d = \sqrt{3}a$. A reflecting marker was fixed at each end of the stick. Two additional markers were fixed in the middle of the distance "End of the stick - tripod fixation". By this construction another virtual cube with the edge length of 1m was constructed. The deformation of the stick by gravity was avoided by a special bending characteristic. The stick was turned four times with exactly 90° and fixed in this position while the cameras took pictures from all four positions. Afterwards the two convoluted cubes were constructed in the video pictures by the

software “SIMI-Motion”. By this procedure it was possible to define a scaled coordinate system based on these cubes.
A different position of the coordinate system was necessary, because the calibration cubes and the first coordinate system rely on each other. To analyse the motion with regard to the volleyball court, it was necessary to construct a second coordinate system representing the centreline, sideline and the left edge of the net. It may be more accurate and time-saving to calculate the exact data by a coordinate transformation than trying to place the calibration cube exactly. Hence, the coordinate system was placed intentionally in a different horizontal and vertical position. The second coordinate system was moved horizontally as well as vertically. The reference planes of the second coordinate system were calculated out of three known points. Plane one was set vertically to the sideline, plane two vertically to the centreline and plane three represented the floor. The new origin was located at the intersection of centreline, sideline and left edge of the net. Afterwards the 3D coordinates calculated by direct linear transformation (DLT) method had to be transferred to the new coordinate system. Using “Hesse’sche Normalform“ the distance of each point to the constructed levels was calculated. Due to this method it was possible to acquire the exact position of each body segment in the field.

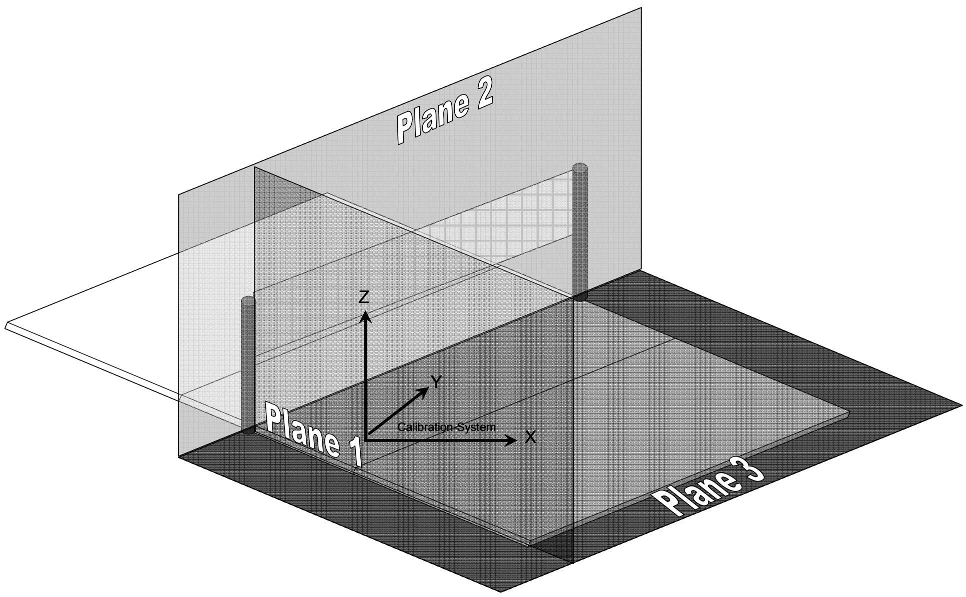

Figure1: Location of the reference systems

A verification of this method by calculating points with known 3D coordinates showed an accuracy of ±9 mm. This method was the basis to calculate motion specific parameters with reference to time. For example, the jump height was calculated by subtracting the height of the centre of gravity (CoG) in the last frame with ground contact from the maximum CoG-height. The CoG was calculated by using the HANAVAN-Model.
Statistical comparison of these data with data from Coleman et al. (1993) was made by using the Levene-Test and the t-test for mean values with SPSS 12.0 software.

RESULTS AND DISCUSSION:

Jump height is an important factor for success in volleyball spikes. Therefore, it was the aim of this study to analyse the jump height and the jumping technique. No significant difference in jump height was found comparing the results of this study and data from Coleman et al. (1993). Forthomme et al. (2005) found even lower mean jump height under training conditions in Belgian first division players. No significant difference could be shown, even in the vertical velocity at take-off. These results indicate stagnation in the performance of jump height in international volleyball.

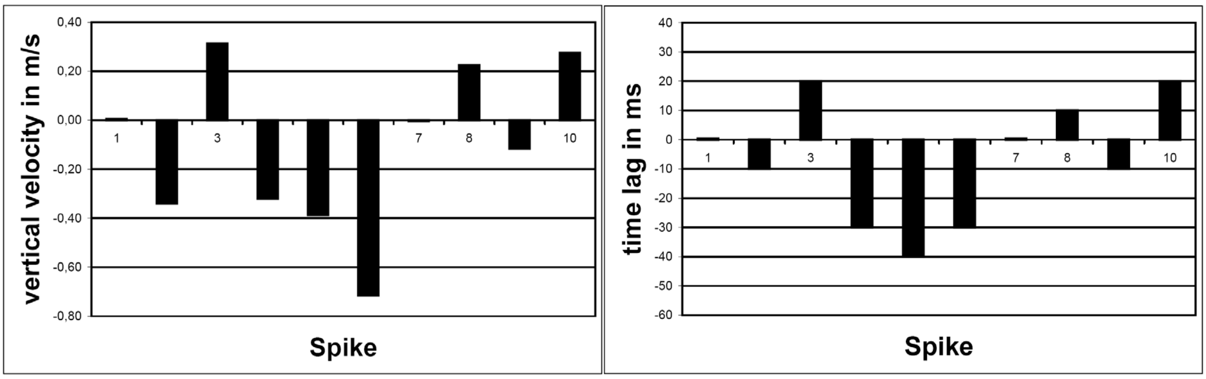

Figure 2: Vertical velocity of the CoG at the impact (left) and time-lag from maximum jump height to impact (right)

Considering the point of impact, it was shown that it was not produced exactly at the moment of the highest CoG. The amount of the averaged vertical divergence of the CoG is 5 (± 6) mm to the highest point of CoG. The amount of the mean time-lag is measured with 17 (± 13) ms to the highest point of CoG.

Table 1: Centre of Gravity Data

Subject	1	2	3	4	5	6	7	8	9	10	$\bar{x}$	S.E.
Jump height in cm	69,3	61,7	62,4	69,7	63,8	62,8	64,0	61,9	66,0	55,8	63,7	4,0
Vertical velocity at take-off in m/s	3,6	3,5	3,6	3,7	3,4	3,5	3,8	3,5	3,9	3,4	3,6	0,2
Difference from max. jump height to impact height in cm	0,0	0,3	0,5	2,0	0,4	1,3	0,0	0,4	0,1	0,3	0,5	0,6
Amount of time-lag max height to impact in ms	|0|	|-10|	|20|	|-30|	|-40|	|-30|	|0|	|10|	|-10|	|20|	17,0	13

Angular velocity: To analyse the jumping technique, the time-lags of the maximum angular velocities of selected joints of the lower limb to the take-off were calculated. It was shown by Bobbert & van Ingen Schenau (1988) that body segments contribute in a fixed sequence from proximal to distal to improve the optimal jump height. The maximum angular velocities are performed in the same order (Coleman et al. 1993). This movement pattern was only found in four subjects (Fig.3 left). The other subjects performed maximum angular velocities at the same time (two subjects) or were completely off the described movement pattern (Fig.3 right). These results are in a line with results from Selbie and Caldwell (1996) who showed that the onset time order of the angles can differ in a wide range with good results in jump height. Future studies have to show if individual performance can be improved by training coordination in the take off phase during spike jumps.

In addition, the moment of blocking the movement by the upper extremities was determined. Eight of ten subjects did not block the arms in the last phase of ground contact but when airborne. Therefore, the effect of impulse transfer could not be used. When shifting the moment of arm movement blocking to the last moment with ground contact, it might be possible to increase the vertical velocity at take-off and therefore, to increase jump height. On the other hand it has to be attended that the rotation of the trunk can be alleviated by a later arm block. It is possible to maintain or regain balance by this kind of arm movement (Ashby & Heegaard, 2002).

It is necessary to coordinate the arm swing precisely. The lower reversal point has to pass along with the lower reversal point of the CoG. Otherwise, there would be a negative effect between these two impulses. The time-lag was calculated with 9 (± 11) ms. Obviously, there is no room for improvement in the discussed parameters (timing of arm motion resp. impact timing).

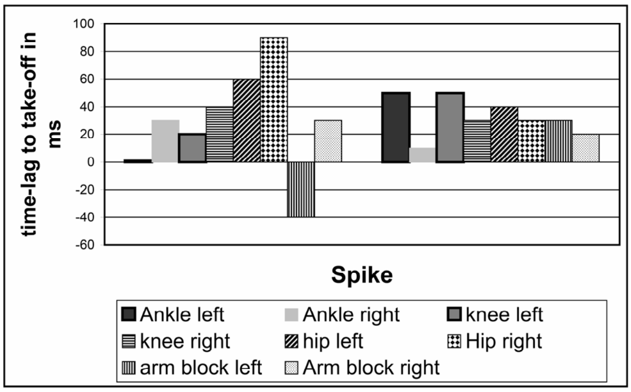

Figure 3: Coordination of maximum angular velocities and arm block.

CONCLUSION:

The timing point of impact was analysed to be in an optimum range. Only few of the subjects performed a good sequence of impulses. To achieve a higher jump height it seems to be useful to emphasize the training of jumping techniques even with high level athletes. It may be possible to perform a faster vertical velocity at take-off by training jumping coordination. A faster vertical velocity is associated with a better jump height which could have good effects on the success in competition. Future studies have to investigate the improvements resulting out of this training process and if individual jump performance can be improved by varying coordination in the take off phase.

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