ELITE OUTSIDE HITTERS IN VOLLEYBALL DO NOT MEET THEIR INDIVIDUAL POSSIBLE MAXIMUM IMPACT HEIGHT IN HIGH SPIKE JUMPS

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It is assumed that a high impact height is a relevant factor for success in volleyball spikes. The purpose of the study was to investigate whether outside hitters hit the ball at the highest possible impact height. Spikes from position IV were analysed at a tournament of the European League. The posture of the athletes was less extended in the trunk and upper limb with increasing jump height. Regarding the body posture at the moment of impact, there was no effect on the post impact ball speed. It is concluded that there could be enhancement with respect to the impact height as jump height increases even in elite athletes without reducing ball speed. This should be addressed within the training process.

Keywords: Volleyball, Spike, Motion analysis, Coordination

INTRODUCTION: Based on the complexity of the volleyball spike movement, an in depth analysis is difficult. It is easier to investigate such movements in a laboratory setting than during competition. This may be the reason why most of the studies were performed in laboratory conditions or during training when analysing volleyball spikes (e.g.: Tokuyama et al., 2005). Nevertheless, spike jumps in a competition are likely to differ from spike jumps in a laboratory setting. In the laboratory different environmental conditions can be found to influence the movement as they can be detected during competition. Therefore, findings from Forthomme et al. (2005) under laboratory conditions are reasonable showing a higher impact height and a higher post impact ball velocity of Belgian first league players than findings from Coleman et al.(1993) or Kuhlmann et al. (2008) both with international elite outside hitters during competition.
Because the optional target area increases with rising impact height, it is assumed that a higher impact height is a relevant factor for success in volleyball spikes (Neef & Heuchert, 1978). Hence, the aim of this study was to investigate, if outside hitters of different national teams reached their individual potential maximum impact height during spike jumps from position IV. This study was performed in order to close the gap of analysing volleyball spikes in a competitive setting. The data acquisition for this study took place during an international volleyball tournament.

METHODS: The database included spike movements performed by male outside hitters of the national teams of Croatia, Estonia, Germany and the Netherlands. The data were recorded during a European League tournament. Since the most important spike-position used by international top level teams is position IV (Kuhlmann et al., 2008), only spikes from this position were considered. Position IV is the position of the outside hitter at the left side of the court in front of the net. The pass was always played half high and without combination. Fast or unscheduled actions due to a bad pass were excluded. Therefore, only actions were accepted when the outside hitters always had enough time to prepare themselves for an optimal spike jump including the approach and the takeoff. All subjects performed a step-close technique, identified by Coutts (1982). The flight angle of the ball after impact had to be 110° to 145° to the net to improve the standardisation of the boundary conditions.

10 elite outside hitters of different national teams of the highest order were analysed. This is equivalent to approximately 10% of the outside hitters playing in national teams on highest international level. The sample had a mean body height of 198.8 ± 4.4cm and a mean body mass of 92.0 ± 5.3kg. From each player one spike jump was analysed. The study concurred in the exigencies of the ethics committee for human research and in current local laws and regulations. Due to the camera positions, no effect on the players or on the results occurred.

Four digital cameras were positioned around the volleyball court capturing the spikes with a frame rate of 100 Hz. The cameras were activated and triggered externally. The frame rate was also externally controlled. The accuracy of the frequency controlling was previously tested. No relevant irregularity in the frequency was reported.

The calibration of the measurement setup and the methodology of the data-processing was described by Kuhlmann et al. (2007) in detail. A verification of this method by calculating points with known 3D coordinates showed an accuracy of 9.9 ± 7.7 mm (x-direction), 4.7 ± 1.4 mm (y-direction), 8.3 ± 4.4 mm (z-direction).

All digitisers had to digitise the same standardised test videos before they were allowed to start the original digitising process for this study. Inter-digitiser reliability was investigated by calculating differences of angles and changes in segment length of selected angles and segments of these test-videos. Inter-digitiser reliability was calculated as 0.07 ± 0.06° for angles and 1.3 ± 0.9mm for changes in segment length in the mentioned test videos.

The centre of mass (COM) was calculated using the HANAVAN-Model. The values of impact height, COM-height and the difference in height between the COM and the impact height at the moment of impact (ΔCOM-height / impact height) were calculated from the 3D-coordinates, provided by the software SIMI-Motion. Jump height was calculated as the difference of COM-height at the last frame with ground contact and the highest COM in the flight phase. The extension of body angles or the elongation of the upper body position was calculated as the difference between the COM-height and the impact height.

To calculate post impact ball speed (PIBS) a vector was calculated out of the 3D-coordinates of the ball two frames and 8 frames after the ball contact. The length of this vector represented the mileage of the ball. Due to the camera frequency the used time period is known and velocity was calculated out of mileage and the dedicated time.

Pearson's correlation coefficient was calculated to detect coherence between those parameters. Statistical evaluation of the data was conducted using SPSS 16.0.

RESULTS: The values of impact height, COM-height and the difference in height between the COM and the impact height at the moment of impact are presented in Table 1. The mean jump height of the sample was 63.17 ± 6.2 cm.

Table 1: Parameters representing the efficiency of impact height with respect to jump height

Subject	Impact height in cm	COM-height at impact in cm	ΔCOM-height / impact height in cm
1	323.6	208.0	115.6
2	313.1	202.2	110.9
3	305.5	196.7	108.8
4	317.7	206.7	111.0
5	310.0	191.1	118.9
6	307.6	188.5	119.1
7	317.4	176.2	141.3
8	317.5	212.4	105.1
9	312.7	201.3	111.5
10	314.9	207.3	107.5
$\bar{x}$	314.0	199.0	115.0
S.D.	5.4	11.1	10.3

Pearson's correlation coefficients were calculated between those different parameters. The parameters and the appendant coefficients are shown in Table 2.

Table 2: Pearson's correlation coefficients of the analysed parameters

Parameters	Pearson's correlation coefficient
COM height / Impact height	0.37
COM height / Jump height	-0.19
Jump height / Impact height	0.45
COM-height at impact / Impact height	0.38
COM-height at impact / ΔCOM-height - Impact height	**-0.87**
COM height / ΔCOM-height - Impact height	0.20
ΔCOM-height - Impact height / Post impact ball speed	0.43

As shown in Table 2 a high correlation coefficient can be calculated only between COM-height at impact and ΔCOM-height / impact height. The higher the COM-height at impact the lower is ΔCOM-height / impact height.

DISCUSSION: Impact height is an important factor for success in volleyball spikes. Increasing impact height automatically increases the target area on the opponent's court (Neef & Heuchert, 1978). Therefore, the chance of a successful spike increases. It was the aim of this study to analyse the impact height and whether the individual maximum possible impact height of the athletes could be reached. A detector for the individual maximum impact height is the difference between the COM-height at the moment of impact and the impact height as a value for body angle extension. The larger this difference, the more extended are the body angles at the moment of impact. The athlete is able to hit the ball in a higher position when body angles are more extended. As a result, the athlete gets closer to the individual maximum impact height.

According to the results of the correlation analysis, it cannot be stated that taller attackers will automatically hit the ball higher or jump higher than smaller outside hitters under standardised conditions. Also the COM-height at the moment of impact showed just a small correlation coefficient to impact height (Table 2).

The difference in height between the COM height at the moment of impact and the impact height showed a high negative correlation (r = -0.87) to the COM height at the moment of impact. As a consequence, outside hitters with less jump height hit the ball with more extended body angles than those with a higher jump height. This leads to the assumption,

that high jumping attackers may increase their impact height even more by extending their upper body.

The parameter ∆COM-height / Impact height showed no correlation to body height and post impact ball speed. This parameter seems to be independent from body height. Therefore, it can be assumed, that more elongation of the trunk and upper limbs will not reduce the post impact ball speed, but will increase the target area.

Outside hitters might use different elongated postures and changes in movement techniques for tactical reasons. Regarding to the discussed importance of a high impact height (Neef & Heuchert, 1978), it could be useful to modulate the coordination pattern in higher jumps for reaching higher impact heights. Therefore, it is essential that the outside hitters are able to "read" the set with high precision and coordinate their jumping movement according to it.

CONCLUSION: Elite outside hitters of different volleyball national teams did not meet their individual maximum impact height in volleyball spikes from position IV for higher jump heights. The posture of the upper part of the body was more extended within spike jumps showing lower COM-height than in jumps with a higher COM-height. Because of the small coherency between elongated posture and post impact ball speed it is assumed that a different posture will not reduce the ball speed. Hence, no negative effect from an elongated posture in higher jumps is anticipated. The individual impact height could be increased easily in higher spike jumps. This study provides important insight about the hitting technique from elite outside-hitters, which may be used to improve their performance during competition.

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