ATTACK HEIGHT AND JUMP HEIGHT FOR MEN'S VOLLEYBALL PLAYERS

ChengTu Hsieh and Zachary Lamm

California State University, Chico, Chico, CA, USA

The purpose of this current study was to investigate the factors that associate with the ball contact height for men's volleyball players and the difference between good and poor volleyball players. Ten male collegiate volleyball players (club teams) were recruited (BH: 1.82 ± 0.09m; BW: 80.13 ± 13.22kg). Each subject performed 3 successful trials of volleyball attack performance by hitting the ball above the net and inside the boundary. 3D motion analysis (3 digital cameras) was used to obtain kinematic data of the performance. Results indicated that ball contact height was significantly associated with takeoff and reach height. When all heights were normalized to body height, player's body positions at instant of takeoff and ball contact are important to ball contact height.

KEY WORDS: ball contact height, kinematics, volleyball attack.

INTRODUCTION: The attack is an important technique in volleyball which can determine the outcome of a match for men's volleyball (Rodriguez-Ruiz, Quiroga, Miralles, Sarmiento, de Saá, & García-Manso, 2011; Ziv & Lidor, 2010). Studies have identified that to execute this complex technique well requires many different components in different phases of the performance (Abendroth-Smith & Kras, 1999; Vint & Hinrichs, 2004). Although the factors that result in a successful volleyball attack have yet to be fully examined due to its complexity, it has been suggested that ball contact height, ball speed, and ball control are fundamental for the success of this performance (Vint & Hinrichs, 2004). For a hitter to have proper ball control ability, ball contact height can provide a wide range of attack angles which result in higher success rates of an attack. (Abendroth-Smith & Kras, 1999). The studies conducted in the past have focused on the factor relating to jump height of center of mass (CoM); however, this does not explain overall ball contact height. There is only a handful of studies which examined the relationship between jump height and ball contact height (Matušov, Zapletalová, Duchoslav, & Hagara, 2013; Vint & Hinrichs, 2004).
Ball contact height consists of takeoff height, flight height, reach height, and loss height (Vint & Hinrichs, 2004). In the same study, reach height was identified to have a significant relationship ($r = 0.70$) with ball contact height and accounted for 39.40% of overall ball contact height for elite female volleyball players. Takeoff height accounted for 47.34% of overall ball contact height but had no significant association with ball contact height. More interestingly, jump height (from takeoff to ball contact) was not related to overall ball contact height and only accounted 14% of overall ball contact height. This ability of jumping has been considered as essential element for volleyball attack performance. It seems some other contributors may be more meaningful than jump height for skilled volleyball players. Since there are very limited studies on the factors that contribute to ball contact height in men's volleyball players, the purpose of this current study was to identify the contributors for ball contact height and ball speed of male volleyball players. Additionally, the participants of this current study were separated into two groups based on their normalized ball contact height to further examine differences of these contributors.

METHODS: Ten active male collegiate volleyball players between the ages of 18-22 (Body Height: 1.82 ± 0.09m; Body Weight: 80.13 ± 13.22kg) were recruited from the local university. The subjects are all members of the club team with an average of seven years of experience in practicing and competing in volleyball. Subjects' positions on the team were either outside or middle attacker. No previous injuries were reported. All policies and procedures for the

use of human subjects were followed and approved by the university's Institutional Review Board. Data from two subjects were disregarded due to a calibration issue.
Each subject was required to complete a warm-up routine of their own choosing and practice their spike jumps in front of the cameras. An experienced coach tossed the ball for all subjects in each trial. All subjects performed multiple volleyball attacks until five good trials were achieved. A good trial consisted of a good toss as well as the subject hitting the ball within the boundary. Three good trials from each subject were selected for further analysis (24 trials total).
Three-dimensional coordinated data were obtained with three digital video cameras (60Hz) in conjunction with a motion analysis system (Vicon Motus: 9.2) and synchronized by using Remote Audio Synchronization Unit. A model using 19 points that composed 14 segments was used. Anthropometric parameters from deLeva (1996) were adapted for CoM calculation. All the trials were cropped from the 10th frame before the onset of the approach to the 10th frame after initial ball contact. The coordinate data were filtered using quantic spline processing (Woltring, 1986; Winter, 1990).
To determine the components of ball contact height, the deterministic model was adapted from Vint and Hinrichs (1996). Ball contact height was the vertical distance between the floor and the ball at the instant of contact. Takeoff height was defined as the vertical distance from the CoM to the floor at the instant of takeoff. Flight height was obtained from the vertical distance of CoM between the instant of takeoff and ball contact. Reach height was the vertical distance between CoM and the ball at the instant of contact. Zero order correlation was performed to determine the association among all the variables with the overall ball contact height. The statistical significance level was set at 0.05. Overall ball contact height was normalized to performer's body height to further determine good and poor players by separating eight players into two groups (top 4 and bottom 4). All the height components were normalized to body height for further comparisons. Independent t-tests were applied to examine the difference of all components between top and bottom 4 players. Effect size was also calculated due to small number of subjects (Cohen, 1988).

RESULTS: Table 1 represents the means and standard deviations of all the components of overall ball contact height. Table 2 and Figure 1 show the normalized heights (to body height) between players. Table 3 shows the correlation matrix of the height components, ball speed, and physical parameters of the subjects. The overall ball contact height was significantly associated with takeoff height (r = 0.80, p < .01), reach height (r = 0.78, p < .01), body height (r = 0.58, p < .01), and bodyweight (r = -0.54, p < .01). When all the height components were normalized to body height, the significant differences between good and poor men's volleyball players were found at takeoff height, reach height, and ball contact height.

Table 1
Mean and SD of all the components of overall ball contact height.

n = 8 24 trials	Ball Contact Height	Takeoff Height	Flight Height	Loss Height	Reach Height
Absolute	2.83 ± 0.22 m	1.37 ± 0.13 m	0.40 ± 0.12 m	0.05 ± 0.01	1.06 ± 0.13 m
Relative	100 ± 0%	48.57 ± 3.08%	14.05 ± 4.31%	1.86 ± 3.89%	37.39 ± 3.45%

Table 2
Mean and SD of all the normalized height components between top and bottom performers

n = 8 24 trials	Ball Contact Height	Takeoff Height	Flight Height	Loss Height	Reach Height
Good	1.67 ± 0.1*	0.81 ± 0.07*	0.22 ± 0.05	0.02 ± 0.03	0.63 ± 0.05*
Poor	1.45 ± 0.07*	0.70 ± 0.2*	0.20 ± 0.07	0.04 ± 0.07	0.55 ± 0.08*
Effect Size	0.79	0.34	0.16	-0.18	0.51

Note: * represents the significant differences were found between top and bottom 4 players.

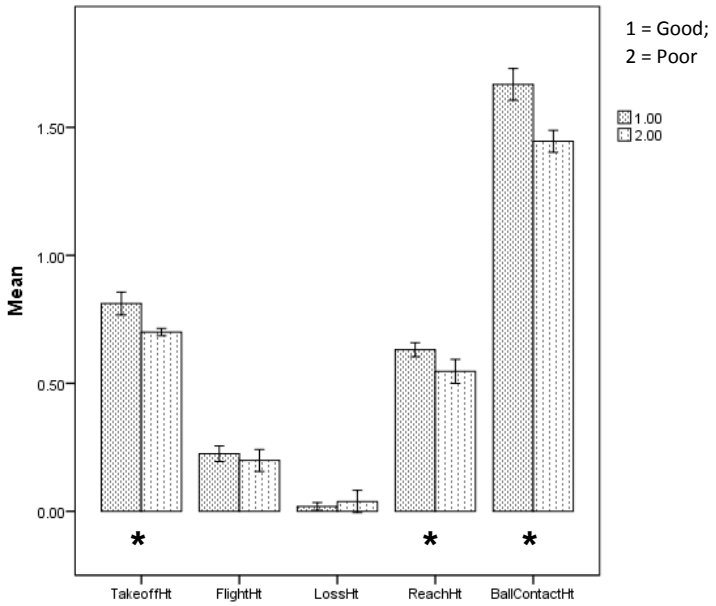

Figure1. The difference of normalized height components between good and poor volleyball players. * represents the significant difference with *p* less than adjusted alpha level.

Table 3
Associations among the height components, ball speed, and physical parameters

n = 8 (24 trials)	Y1	X1	X2	X3	X4	X5	X6
Ball Contact Height (Y1)	1						
Takeoff Height (X1)	.803**	1					
Flight Height (X2)	.277	-.152	1				
Loss Height (X3)	-.117	.085	-.710**	1			
Reach Height (X4)	.782**	.592**	-.197	.309	1		
Body Height (X5)	.581**	.459*	.145	.018	.476**	1	
Body Weight (X6)	-.544**	-.471*	-.514**	.426*	-.081	.399*	1

Note: ** represents *p* < 0.01; * represents *p* < 0.05.

DISCUSSION: During a volleyball game, the height of ball contact can provide the advantage of wider attack angle to overcome the net height and blockers' hands which leads to a greater success rate of the hit with more options of target areas. Therefore, jumping ability has been considered as a crucial criterion for volleyball performance such as attack jump, jump serve, and block. However, the findings of this current study indicated that jump/flight height was not as crucial as other factors such as takeoff, reach, and body heights when ball contact height, in fact, is the outcome of the performance. Flight height for male volleyball players had no association with and only accounted for 14% of the total overall ball contact height which was similar to Vint and Hionrichs's findings (2004) of 13% for elite female volleyball players.

In the current study, about 85% of the overall ball contact height accounted by takeoff and reach heights together which was similar to the previous study (Vint & Hinrichs, 2004). In addition, strong association was found between ball contact height and reach height which can be important for performance enhancement. Moreover, when all components of overall ball contact height was normalized to body height, there were significant differences in takeoff, reach, and ball contact heights between good and poor male volleyball players. This indicated that when body height is not a factor between individuals, the technique of body position at the instant of takeoff and ball contact is important. Therefore, to gain this

advantage at takeoff, volleyball players need to swing their arms upward farther with all the lower extremities extended more to obtain a higher CoM at the instant of takeoff. A further investigation of factors that influences the takeoff height between performers is needed since the difference between good and poor players was about 11% of their body height.
Reach height was identified as another contributor for overall ball contact height. There was also a significant difference of reach height between good and poor players when it was normalized to body height (about 8%). This indicated that a volleyball player whose shoulder is more abducted, elbow is more extended, and with lower CoM at the instant of ball contact can result in greater reach height (Vint & Hinrich, 2004). Likewise, this could also be due to the relative location of the ball and the body in the air. For a given ball set by a setter, the adjustment of approach from the beginning could influence the outcome of the reach height which factors in the takeoff location relative to the ball location.

CONCLUSION: The present study confirmed the findings from Vint and Hinrichs (2004) that reach and takeoff heights are the highest contributors to the overall ball contact height. Additionally, overall ball contact height was associated with takeoff, reach, body heights, and body weight. There were significant difference of normalized takeoff, reach, and ball contact heights between "good" and "poor" male volleyball players. This indicates that the technique to have proper body posture at the instant of takeoff and ball contact is crucial for volleyball attack performance.

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