A THREE-DIMENSIONAL ANALYSIS OF THE VOLLEYBALL ONE-FOOT JUMP SPIKE

Chen-Fu Huang, Gin-Chang Liu, Tai-Yen Sheu,
National Taiwan Normal University, Taipei, Taiwan

INTRODUCTION: Since volleyball became an official event starting with the 1964 Tokyo Olympic Games, the techniques and strategies of the game have changed dramatically. The improvements of the player's height, strength, and jump abilities have made the offense more powerful. Since Chinese female volleyball players developed the one-foot jump spike technique in the 1980s, we found that it is getting a higher percentage of successful spikes and has made this skill a powerful offensive weapon on volleyball courts all over the world.
Coleman et al. (1993) indicated that the volleyball jump spike can be divided into the following six phases: approach; plant; takeoff; flight; hitting action; and landing and recovery. They studied ten male international volleyball players at the 1991 World Student Games. They reported that the mean vertical velocity of the center of mass at takeoff was 3.59(0.05) m/s and the height of the jump was 0.62(0.02) m. Saunder (1980) studied the effects of approach speed on one and two-foot vertical jump performances. Three volleyball players and three basketball players served as the subjects. He found that the vertical velocities of the two-foot jump reached a peak when the approach speeds were up to 50~60 % of maximum sprint speed and the vertical velocities of one-foot jumps were up to 60~70 % of maximum sprint speed to reach the peak. Vint and Hinrichs (1996) found the overall jump and reach heights were similar between one-foot and two-foot jumps. He suggested that one-foot jumps benefited from an increased takeoff height that was largely attributed to the elevation of the free swing leg. In general, studies related to the biomechanical analysis of the volleyball jump spike mainly focus on male subjects performing the two-foot jump spike. No research has been done on the biomechanical analysis of the female one-foot jump spike.
The purpose of this study was to describe the biomechanical characteristics of the one-foot jump performance by the female players.

METHODS: Four elite female players from the Chinese Taipei National Volleyball Team of the 1997 World Student Games were selected as subjects. Their mean height, weight, and age (and their variances) were 1.78(0.03) m, 63.53(0.11) kg, and 21.5(0.58) years, respectively. Informed consent was obtained from each subject prior to study. They have been using the one-foot jump spike technique during past competitions. Two Peak Performance high speed video cameras operating at 120 Hz were synchronized to record the action employed by the subjects in performing the one-foot jump spike. A peak calibration frame was set up in the spiking area and videotaped before and after the subjects performed the one-foot jump spike. Nineteen control points were used for DLT calibration. Table 1 lists the calibration errors.

Table 1. Calibration errors

	X	Y	X	Position
Average mean square error (m)	0.005	0.007	0.008	0.012
Average volume error (%)	0.220	0.372	0.517	0.357

Following a brief warm up and stretching period, an assistant passed the ball to the setter, who backset the ball for the subject to spike the ball into the valid area (Figure 1). Each subject was asked to perform three successful one-foot jump spike trials. Twenty-one body landmarks (head, ears, shoulders, elbows, wrists, fingers, hips, knees, ankles, heels, and toes) were digitized with the Peak Performance motion measurement system. Digitizing began approximately five video fields before the last heel strike of the approach and ended five video fields after the ball contact.

The Butterworth 4th order zero lag digital filter with the optimal filtering option (Peak5, 1994) was used to filter the data. The second central different differentiation method was used to determine velocities. The segment center of masses, and body center of mass were estimated by using the Dempster data that were provided by Winter (1990).

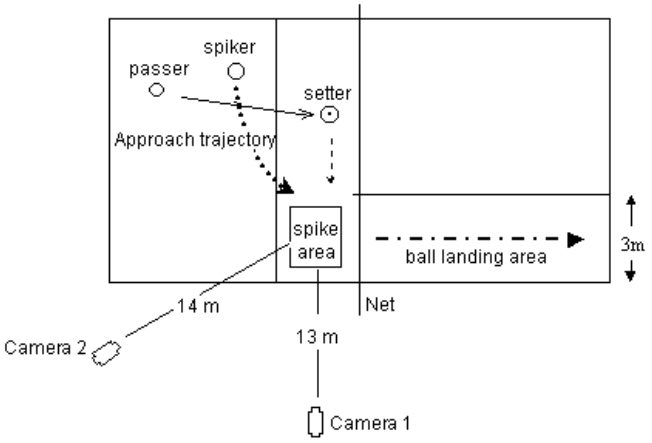

Figure1. Experimental setup of volleyball one-foot jump spike

RESULTS AND DISCUSSION: The results are presented in four sections: approach and takeoff, flight, and ball impact of one-foot jump spiking action. Figure 2 showed the vertical displacement of the center of mass (CM) of one subject performing the one-foot jump spike.

Table 2 listed the variables of the one-foot jump spike during approach and takeoff, the approach body angle was defined by the connection of the two hips and two shoulders projecting on the horizontal plane. The two-foot jump spike usually had an approach body angle less than 10 degrees, and the approach net angle close to 45 degrees (Adrian & Cooper, 1995). The greater approach body angle and a smaller approach net angle of the one-foot jump spike shown in Table 2 indicate that it will have the advantage of viewing the opponent blocking action and also maximize the hitting area.

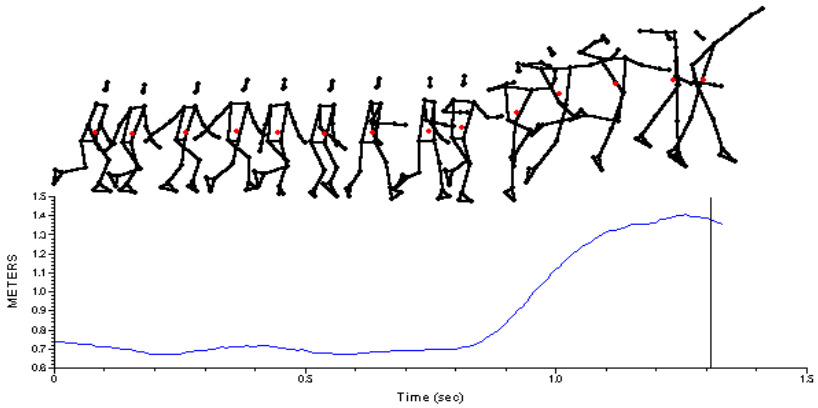

Figure 2. Vertical displacement of the CM during the spike action.

The values of the vertical velocity of CM at takeoff (2.69 m/s) and the jumped height (37.42 cm) were smaller than the male two-foot jump spike (3.59 m/s & 62 cm) reported by Coleman et al. (1993).

Table 2. Variables of the one-foot jump spike during approach and takeoff.

N=4	Mean	SD	Max	Min
Peak horizontal velocity (m/s)	4.30	0.61	4.98	3.50
Approach body angle (deg)	62.96	6.04	68.95	56.79
Approach net angle (deg)	27.02	1.47	28.38	25.60
Takeoff time (sec)	0.198	0.005	0.2	0.191
Vertical velocity of CM at takeoff (m/s)	2.69	035	3.06	2.30
Height jumped (cm)	37.42	9.63	47.75	26.89

The ball velocity (Table 3) of the female one-foot jump spike was smaller than the male two-foot jump spike (27 m/s) (Coleman et al. 1993) The ball was hit in front of the body. The data provided useful information for further comparison.

Table 3. Variables of one-foot jump spike during ball impact

	Mean	SD	Max	Min
Ball velocity (m/s)	20.19	1.99	22.92	18.5
Ball angle (deg)	23.93	2.06	26.48	21.63
Arm angle with vertical axis at impact	24.2	9.62	33.4	12.8

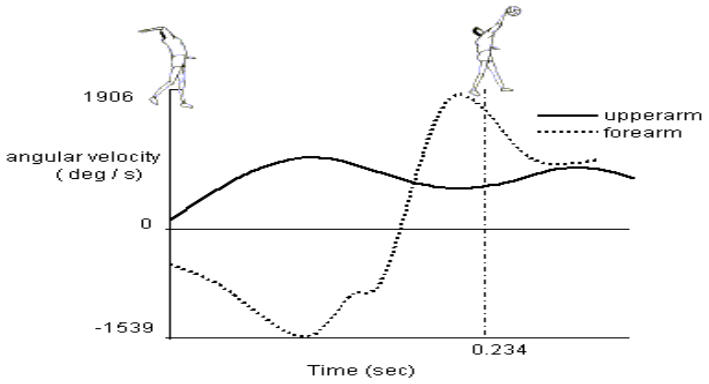

Figure 3. Angular velocities of the upper arm and forearm during the spike action.

Figure 3 showed the angular velocities of the upper arm and forearm of one subject performing the spiking action. The motion indicated the kinetic chain process. When the upper arm accelerated forward, the forearm ”lagged behind” due to inertia, and the acceleration was negative. When the upper arm’s angular velocity reached the peak value, the forearm angular acceleration became positive, and when the angular velocity of the upper arm reached the maximum, the forearm angular velocity reached the peak value.

CONCLUSIONS: The purpose of this study was to describe the biomechanical characteristics of the one-foot jump spike performed by elite female players. It was noted that female one-foot jump spikers had a smaller ball velocity and lower jumped height than male two-foot jump spikers. In addition, the female one-foot jump spikers had a greater approach body angle and a smaller approach net angle than the male two-foot jump spikers; they also had a wider view and maximize the hitting area during the spike action.

REFERENCES:

Adrian, M. J., Cooper, J. M. (1995). Biomechanics of Human Movement. Iowa: Brown & Beuchmark.

Coleman, S., Benham, A., Northcott, S.(1993). A Three-Dimensional Cinematographical Analysis of the Volleyball Spike. *Journal of Sports Sciences* **11**, 259-302.

PEAK5. (1994). User's Reference Manual Version 5.2.1. Englewood, CO: Peak Performance Technologies Inc.

Saunder, H. L. (1980). A Cinematographical Study of the Relationship between Speed of Movement and Available Force. Unpublished Doctoral Dissertation. College Station, TX: Texas A & M University.

Vint, P. F., Hinrich, R. N.(1996). Differences between One-Foot and Two-Foot Vertical Jump Performances. *Journal of Applied Biomechanics* **12**, 338-358.

Winter, D. A.(1990). Biomechanics and Motor Control of Human Movement. 2nd ed. New York: Wiley.