KINEMATIC ANALYSIS OF THE VOLLEYBALL BACK ROW JUMP SPIKE

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The purpose of this study was to identify and describe the kinematic characteristics of the volleyball one-foot and two-foot back row jump spikes. Eight elite male players participated in this study. Two Peak high-speed cameras (120Hz) were synchronised to record the spiking action. The results indicated that the one-foot spike had a greater approach, centre of mass (CM) velocity, a greater horizontal CM velocity at takeoff and a shorter spiking time than that of the two-foot spike. The swing leg of the one-foot jump spike also played an important role in contributing forward momentum to the jump during the support phase. This study provides information for coaches in teaching the volleyball one-foot and two-foot back row jump spike.

KEY WORDS: kinematics, biomechanics, volleyball, jump spike.

INTRODUCTION: The volleyball spike is one of the most important offensive weapons in the competition. Coleman et al. (1993) indicated that the volleyball jump spike can be divided into the following six phases: approach; plant; takeoff; flight; the hitting action; and landing and recovery. They studied ten male international volleyball players who spiked the ball in the front row at the 1991 World Student Games. They reported the mean vertical velocity of the CM at takeoff was 3.59m/s and the height of the jump was 0.62 m. Saunder (1980) studied the effects of approach speed on one and two-foot vertical jump performances. He found that vertical velocities of two-foot jump peaked 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. Vint and Hinrichs (1996) found the over all jump and reach heights were similar between one-foot and two-foot jumps. They suggested that a one-foot jump benefited from an increased takeoff height that was largely attributed to the elevation of the free swing leg. In offense, compared with front row spike, the back row spike has following advantages: 1. More offensive strategies can be used because all five players (except setter) can spike the ball; 2. The spiking ball from back row have more wide range passing the blockers; 3. The spiking ball behind the 3m line makes the blockers hard to judge the time to block the ball. Comparing the back row one-foot spike with the two-foot spike, the main advantage of one-foot jump spike is that more difficulties and confusions for the opponent's blockers by its quick and cross moving approach. The one-foot back row spike has a sharper approach running angle which make the blockers have to move the greater distance in order to block the ball (see Figure 2). In the last two decades, the spiking strategies have changed front row spiking to the full court spiking. It is important to understand the variables which contribute to the successful spiking action, such as approach velocity, ball velocity, jump height in order to improving the spiking performance. No research has been done on the biomechanical analysis of the back row jump spike. The purpose of this study was to describe the kinematic characteristics of the one-foot and two-foot back row jump spike performed by elite male volleyball players (See Figure 1).

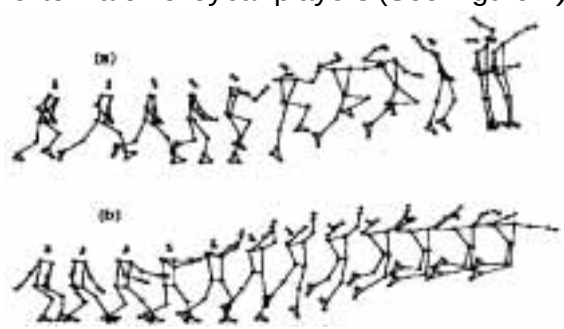

Figure 1 - Stick figures of the one-foot (a) and two-foot volleyball back row jump spike

METHODS: Eight male volleyball players from the National Taiwan Normal University volleyball team served as the subjects for this study. Four players were assigned to the one-foot spike and the other four players to two-foot spike groups by the coach based on their spiking ability. Their mean height, weight, and age were 1.86±0.05m, 78.5± 5.1kg, 22.5± 0.4 years, for the one-foot spike group and 1.87±0.05m, 79.8±3.9kg, 21.5±0.6 years for the two-foot spike group respectively. Informed consent was obtained from each subject prior to study. Two Peak Performance high-speed video cameras operating at 120Hz were synchronized to record the subjects performing the back row spiking action. A Peak calibration frame was set up in the spiking area and videotaped after the subjects performed the back row jump spike. Twenty-five control points were used for direct linear transformation (DLT) calibration. Table 1. Lists the calibration errors.

Table 1 **Calibration errors**

	X	Y	Z	Position
Average mean square error (m)	0.005	0.004	0.007	0.009
Average volume error (%)	0.22	0.237	0.409	0.280

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 2). Each subject was asked to perform three successful one-foot or two-foot back row jump spike trials. The post impact ball for all three trials were digitised to calculate the ball velocity. The trial which had the greatest post impact ball velocity was selected for the statistical analysis. Twenty-one body landmarks (head, ears, shoulders, elbows, wrists, fingers, hips, knees, ankles, heels, and toes) were digitised with the Peak Motus system. The cubic spline function with the optimal filtering option (Peak, 1998) was used to filter the data. The second central differentiation method was used to determine velocities. The segment centre of masses, and body centre of mass (CM) were estimated by using the Dempster data that were provided by Winter (1990). The independent variable was the groups of the back row one-foot and two-foot jump spike. The spike time was defined by the time from the takeoff to the ball impact. The jump height was defined as the height from the vertical displacement of CM at takeoff to the highest point. The relative momentum approach was used to determine the contributions of the arms and legs to the change in forward momentum of the body during the support phase of the one-foot and two-(one) back row jump spike (Vint and Hinrichs, 1996). An independent t-test was used to test the variables between the two groups.

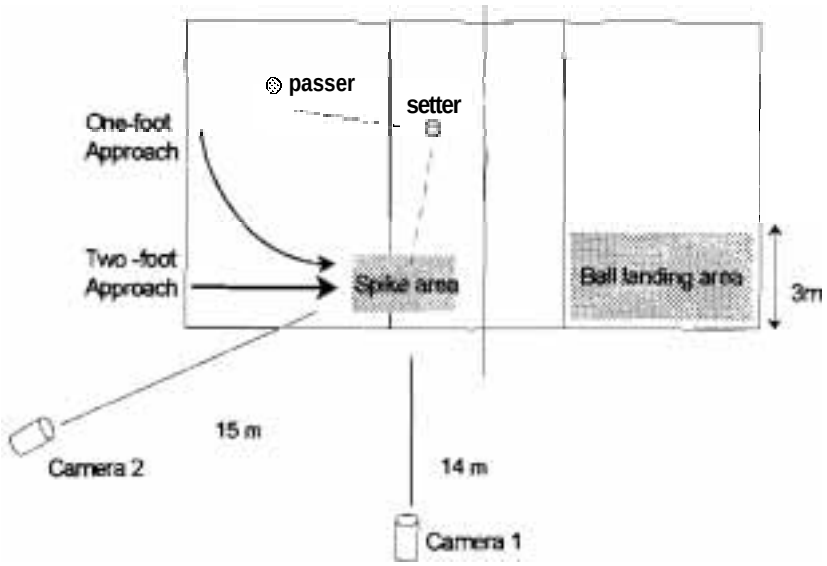

Figure 2 - Experimental setup of volleyball back row jump spike

RESULTS AND DISCUSSION: Table 2 listed the variables of the one-foot and two-foot back row jump spike. When the significant difference was found, the effect size was also reported. The one-foot jump spike had significantly greater values on the maximum CM approach velocity and horizontal velocity of CM at takeoff than the two-foot jump spike. The one-foot jump spike also had a shorter spike time than that of the two-foot jump spike. The greater maximum CM approach running velocity and higher horizontal velocity of CM at takeoff and a shorter spike time of the one-foot back row jump spike indicated a shorter time for the blockers to move to the right spot to block the ball. Especially, in order to control the fast offensive strategy, the one-foot back row jump spike would have more advantage than two-foot back row jump spike. Although the jump height was not significant ($p = .058$), the 10 cm difference has a large effect size (1.29) which indicated the back row two-foot jump spike may have a greater jump height than the back row one-foot jump spike. The mean vertical velocities of centre of mass (CM) at takeoff for the one-foot and two-foot back row jump spike were 3.55 m/s and 3.79 m/s respectively. These values are similar to that reported by Samson and Roy (1976) of 3.5 m/s and Coleman et al. (1993) of 3.59 m/s. The initial ball velocities of the one-foot and two-foot back row jump spike are also similar to that reported by Coleman et al. (1993) of 27 m/s who used international players as the subjects. Coleman et al. reported a mean jump height of 62 cm for their subject using the front row two-foot jump spike. The data suggested that the back row jump spike had similar ball velocity and jump height to the front row jump spike. However, due to the wide range the ball will pass the net and difficulty timing of the jumping to block the ball, the back row jump spike has the advantage over the front row spike.

Table 2 Variables of the one-foot and two foot back row jump spike

	One-foot spike (N=4)		Two-foot spike (N=4)		Effect
	Mean	S.D	Mean	S.D	size
$V_{X\,max}$ of CM (m/s)	5.31	0.09	4.28	0.33 *	1.72
$V_{X\,takeoff}$ of CM (m/s)	3.23	0.42	2.21	0.33'	1.18
$V_{Y\,takeoff}$ Of CM (m/s)	3.55	0.39	3.79	0.43	
Spike time (ms)	342	14	403	8'	4.62
Jump height (cm)	49.5	6.6	59.5	5.4	
Hand V at impact (m/s)	19.75	1.42	19.55	1.65	

Elbow angular V at impact (rad/s)	25.9	4.8	23.7	5.7
Initial ball V (m/s)	27.6	3.3	26.7	1.2
CM horizontal displacement during flight phase (m)	1.13	0.2	0.87	0.26

* p< .05

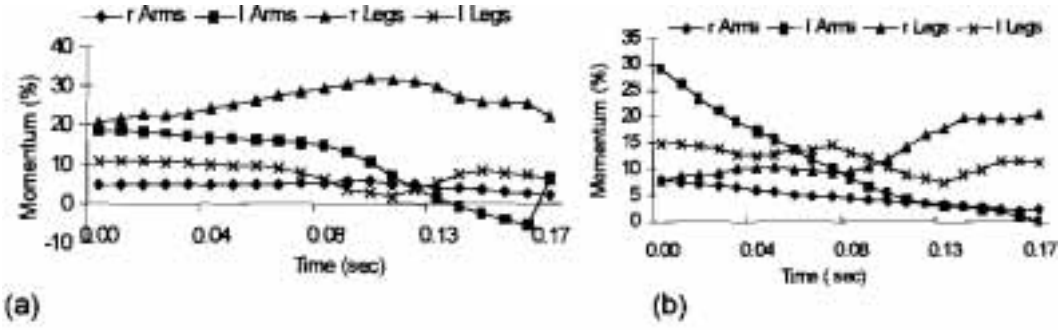

Figure 3 - Percentages of the forward momentum of the arms and legs during the support phase of the one-foot (a) and two-foot (b) back row jump spike

Figure 3a and figure 3b showed the upper and lower extremities' contributions of the forward momentum during the support phase of the one-foot and two-foot back row jump spike. For the one-foot jump spike, the swing leg (right leg) had the highest contributions (more than 20%) during the support phase. However, for two–foot jump spike, the left arms had greater contributions at the beginning of the support phase and the right legs showed higher contributions toward the end of the support phase. The results indicated that the swing leg played an important role during the support phase of the one-foot jump spike.

CONCLUSIONS: This study described the kinematic characteristics of the male volleyball one-foot and two-foot back row jump spike. It was noted that the one-foot jump spike had a greater approach CM velocity and a shorter spiking time than that of the two-foot jump spike. The swing leg of one-foot jump spike contributed more than 20% of the forward momentum of the jump during the support phase. However, the two-foot back row jump spike seem had a greater jump height than that of the one-foot jump spike. In training, it is harder to master the back row one-foot jump skill (due to the sharper approach path and one-foot takeoff) and for offensive strategy reason, the team will use all kinds of spiking skills during the competition. The advantage of the back row spike suggested that the coaches should also coach the players both the one-foot and two-foot back row jump spike skills in order to make the offense more powerful.

REFERENCES:

Coleman, S., Benham, A., & Northcott, S. (1993). A three-dimensional cinematographical analysis of the volleyball spike. Journal of *Sports* Sciences, 11,259-302.

PEAK Motus (1998). *PeakStart* Manual. Englewood Peak Performance Technologies Inc.

Samson. J. and Roy, B. (1976). Biomechanical analysis of the volleyball spike. In Biomechanics *V-B*(edited by P. Komi), pp.332-336. Baltimore, MD. :University Park Press.

Saunder, H. L. (1980), A *sinematographical* study of the relationship *between* speed of movement and available force. Unpublished doctoral dissertation, Texas A & M University, College Station.

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.