A BIOMECHANICAL ANALYSIS OF PIPE SPIKE MOTION FOR ELITE MALE VOLLEYBALL PLAYERS IN OFFICIAL GAMES

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The purpose of this study was to three-dimensionally analyze and compare the pipe spike motion for elite volleyball players and obtain insights into its techniques. The front and pipe spike motions of players of Japan, Brazil and Bulgaria were videotaped during four official games of the Volleyball World Cup 2007 with two high-speed video cameras to obtain three-dimensional coordinates of the body segments. The angles and angular velocities of the upper torso, shoulders, right elbow and wrist were three-dimensionally calculated. The results were summarized as follows. The CG horizontal velocity for the pipe spike was greater than that for the front spike for all players. In the pipe spike, all players shortened the time from the takeoff to the impact and the backswing time. After the takeoff, GG acutely twisted the trunk backward and maintained that position before twisting forward towards the impact in the pipe spike. GG had larger velocity of the left shoulder from the takeoff to the impact for the pipe spike than for the front spike.

KEY WORDS: volleyball, pipe spike motion, kinematics, three-dimensional motion analysis.

INTRODUCTION:

The spike motion is the most frequently used technique to obtain a point in volleyball. The players in the World Championship 2006 frequently used a quick back-row spike from the middle, which is called a pipe spike. The pipe spike has been incorporated into offensive combinations, increasing the level of games and making them more sophisticated, being nowadays considered to be one of the most effective attacking motions. Although previous researches (Coleman et al., 1993; Davila et al., 1994) have investigated front spike techniques of ordinary players, no study has been done on the pipe spike motion of elite players in official games. Therefore, the purpose of this study was to three-dimensionally analyze and compare the front and pipe spike motions for elite volleyball players who participated in the FIVB Volleyball World Cup 2007 and to obtain insights into both techniques.

METHODS:

Data Collection: The front and pipe spikes of five elite male players (1.96±0.05m, 90.2±6.3kg) from Brazil, Bulgaria and Japan were videotaped during four official games of the Volleyball World Cup 2007 with two high-speed video cameras (250Hz,1/2000s). The ball and 25 points of the body were digitized and coordinate data were three-dimensionally reconstructed using a DLT method (Ikegami, 1991). The coordinate data were smoothed with a Butterworth digital filter at optimum cut-off frequencies (5~12Hz) decided by a residual error method (Winter, 1975).

Data Analysis: The major variables computed were the vertical and horizontal CG velocity, height and velocity of the hitting hand at the impact, relative velocities of the segment endpoints and angular kinematics of the trunk and hitting arm.

RESULTS and DISCUSSION:

Table 1 presents selected kinematic parameters for the five players at the instant of the takeoff of the spike jump. The CG horizontal velocity for the pipe spike was greater than that for the front spike for all players. The takeoff angle for the pipe spike was smaller than that for the front spike. This indicates the players in the pipe spike jumped more forward than in the front spike. The jumping height tended to be higher in the front spike than the pipe spike. There were two types of players: The first one, GG, AD, and MK, had much faster CG horizontal velocity in the pipe spike than in the front one. The second one, YI, YK, used similar CG horizontal velocity in the pipe and front spikes.

Table 1 Kinematic parameters at the instant of the takeoff of the spike jump

Subject	Spike	CG horizontal vel.(m/s)	CG vertical vel.(m/s)	Takeoff angle(deg)	Jump height(m)
GG	front	0.96	3.96	76.5	0.80
	pipe	3.11	3.76	50.4	0.72
AD	front	1.62	3.74	66.6	0.71
	pipe	3.15	3.64	49.1	0.67
MK	front	0.95	3.93	76.5	0.79
	pipe	2.59	3.91	56.5	0.78
YI	front	2.09	3.96	62.3	0.80
	pipe	2.94	3.56	50.5	0.65
YK	front	2.00	3.77	62.1	0.73
	pipe	2.38	3.97	59.1	0.81

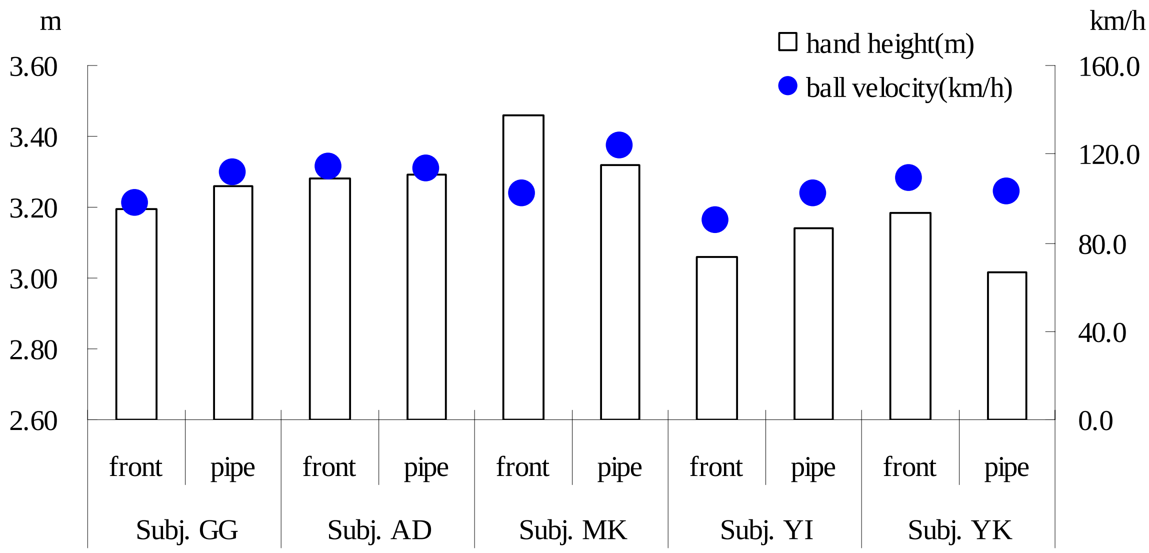

Figure 1 The height of the hand at ball impact and the ball velocity

Figure 1 presents the height of the hand at the ball impact and the ball velocity. For Subjects GG, MK, and YI, the ball velocity in the pipe spikes was larger than that in the front spikes. For Subject AD, the ball velocity was almost same, while for YK, the ball velocity and hand height were larger in the front than in the pipe spike.

Figure 2 shows the back-forward lean, lateral lean and twist angles of the trunk during the airborne motion for Subjects GG and YK as typical examples. The vertical gray line denotes the instant of maximal backswing, dividing the airborne motion in backswing phase and forward swing phase. In the pipe spike, both players shortened the time from the takeoff to the impact and the backswing time. After the takeoff, GG acutely twisted the trunk backward, kept that position, and twisted forward until the impact in the pipe spike. Such a motion may be advantageous because it enables the player to adjust the timing for hitting the ball more easily, since the setting for a pipe spike is known to be faster than that for a front spike. Differently from all other players, YK displayed smaller trunk twist for the pipe spike, larger trunk twist for the front spike, and leaned the trunk to the left for both motions. In the front spike, YK's ball velocity was larger that in the pipe spike, indicating that ball velocity may have increased with maximal backward trunk twist angle, so it is likely that this motion is essential. Coleman et al. (1993) reported significant correlation between the maximum right humerus angular velocity and the velocity of the ball in the front spike. In our study, a large backward twist angle of the trunk, followed by large forward twist angular velocity was found for front spikes with high ball velocity (e.g. YK's front spike), so it is possible that the angular velocity of the right humerus was also large in our subjects.

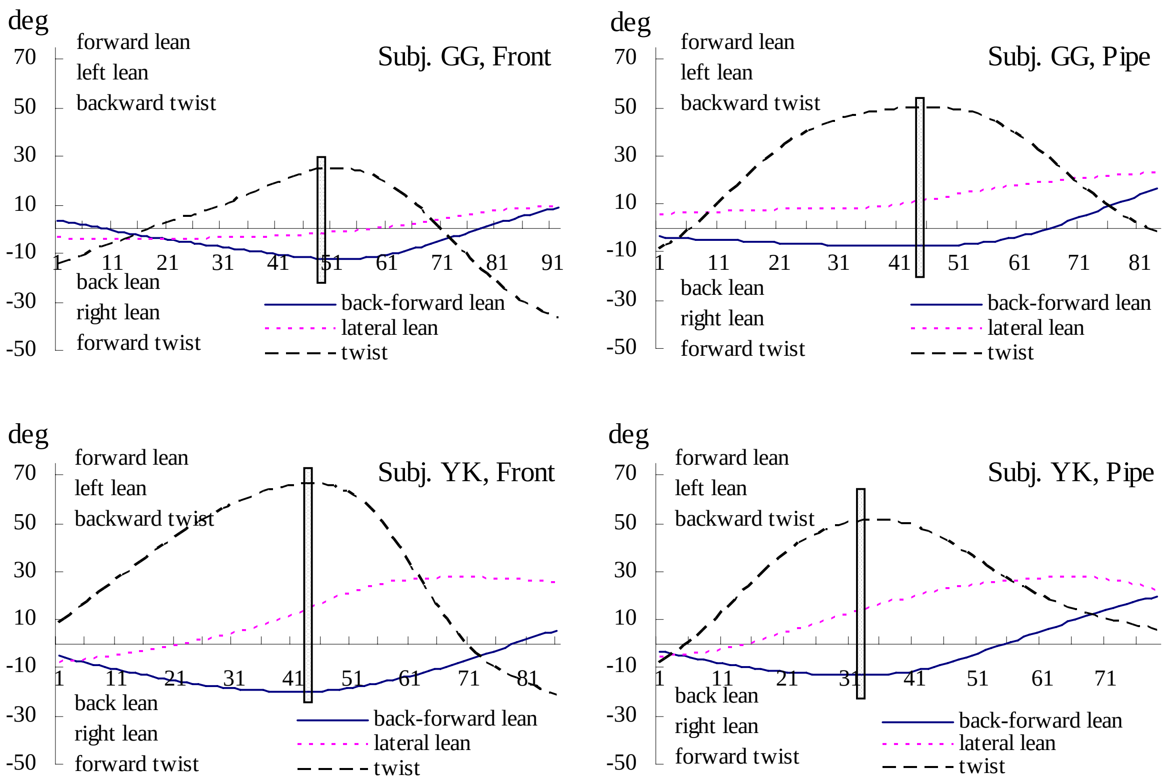

Figure 2　Changes in the trunk angle during the airbone phase

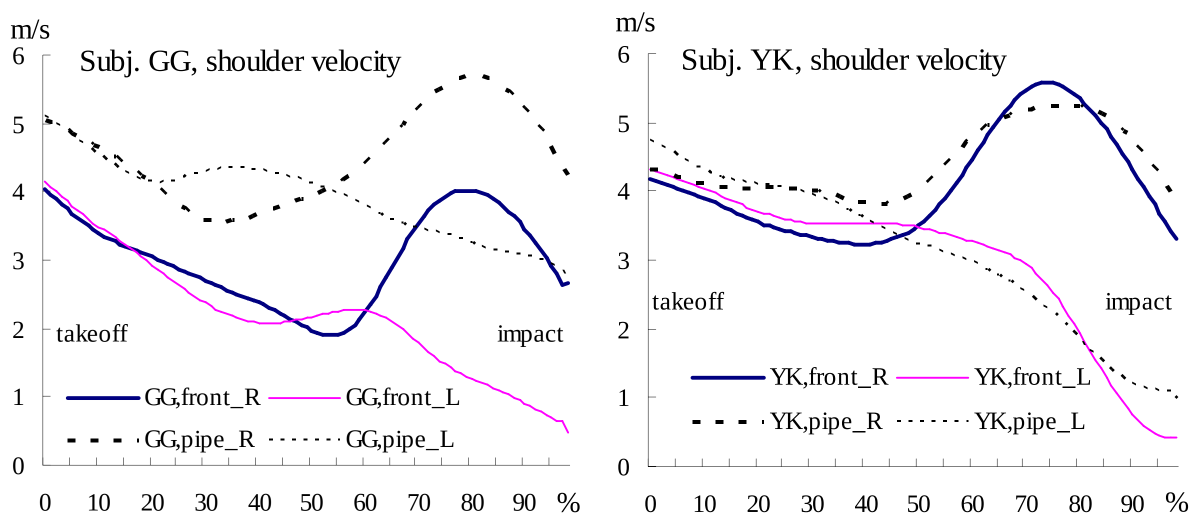

Figure 3 Changes in the right and left shoulders velocity during the airbone phase

Figure 3 shows the velocity of the right and left shoulders during the airborne phase for Subjects GG and YK. The time was normalized to 100%. The velocity of the left shoulder from the takeoff to the impact was larger for the pipe spike than the front spike for Subject GG. This suggests that GG threw the left shoulder first as a technique of anticipating the

trunk backward swing in the pipe spike. Other players did not perform similar motion, which partially explains why the forward trunk twist velocity was greater in GG than in the others.
In the pipe spike, this large backward twist angle also occurs. This may increase the total swing time, facilitating the opposing team to set up the block. Jumping throwing the left shoulder first in the pipe spike (e.g. GG) may facilitate the trunk twist motion in the air, preventing excessive increase in the total swing time. Also, since the moment of inertia of the trunk is greater about the transverse and frontal axes than the longitudinal one, it is likely that leaning the trunk forward or laterally may require more energy than twisting it. This may be one of reasons why a trunk twist is more effective than a trunk lean to generate large velocity of the right shoulder. Therefore, we recommend that the left shoulder be set forward at the takeoff as a preparation for the following forward swing of the trunk, which should be preferably done by twisting it.

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