ANALYSIS OF THE SERVING MOTION OF MALE COLLEGE TENNIS PLAYERS IN SIMULATED MATCHES

HORIUCHI Kentaro[1], AE Michiyoshi[2], NUMAZU Naoki[2], ARII Sayaka[1] and HARIGAI Rieko[1]

Graduate School of Health and Sport Science, Nippon Sport Science University, Tokyo, Japan[1]
Faculty of Coaching Science, Nippon Sport Science University, Tokyo, Japan[2]

The purpose of this study was to analyse the serving motion of nineteen male college tennis players in simulated matches, and to identify critical points to improve technique by comparing to that of world-class players reported by Fleisig et al. (2003) and Michikami (2014). The variables used in this study were ball speed, racket speed, joint angles and angular velocities of the upper and lower limbs. Ball speed and racket speed for the male college players were significantly lower than that of the world-class players. The peak right shoulder internal rotation and left knee extension angular velocities were lower in the male college players compared to the world-class players. To improve ball speed when serving, the critical points identified would be increased shoulder internal rotation and knee extension angular velocities.

KEYWORDS: college player, serving technique, racket speed, 3D motion analysis.

INTRODUCTION: The serve is considered to be the only closed skill in tennis, and a player can hit a ball with any speed, placement, and spin he or she intends. Adachi (1999) and Brody (2003) reported that a player with a high ball speed in the serve during matches have a higher possibility to win the game. Therefore, serve technique to hit a fastball is one of the most crucial techniques in tennis. There are numerous biomechanical studies for hitting a fast serve (Sprigings et al., 1994; Murata et al., 2015), which have used experimental trials in a laboratory setting, while only a few studies (Fleisig et al., 2003; Choppin et al., 2011; Michikami, 2014; Maquirriain et al., 2016) have investigated the serving motion in real matches.
Hayashi et al. (2016) compared statistical data on serving in matches between world-class players and Japanese male college players and found that the rate of point' won from first serves of Japanese male college players was significantly lower than that of world-class players, pointing out that their ball speed should be increased even if the probability of the first serve reduced. To improve serve techniques of Japanese male college players to hit a fastball in matches, it is important to investigate, observe and understand their serve techniques in real matches, or as close as possible, as in the integrated model of qualitative movement diagnosis (Knudson, 2013) and the improvement loop (Ae et al., 2007). However, few studies have been conducted on serve techniques of male college players in matches, who are in the second or third level of the technique. Investigating differences in the motion between skilled players and male college players may help to obtain information on effective coaching methods for improvement in serve techniques of male college players. The purpose of this study was to analyse the serving motion of male college tennis players in simulated matches, and to identify critical points for improvement in their technique by comparing to that of world-class players reported by Fleisig et al. (2003) and Michikami (2014). It was hypothesised that shoulder internal rotation angular velocity and racket speed would be lower in the male college players compared to the world-class players. The comparison of the serving motion will help to identify critical points in the technical training of the serve.

METHODS: The serving motion of 19 Japanese male college players (height, 1.73 ± 0.05 m; weight, 66.1 ± 5.5 kg) in simulated matches (one-set match) was videotaped with two high-speed cameras (AX-700, SONY), and synchronized by the event method. The camera speed was 120 frames/s and the exposure time was set from 1/1000 to 1/2000 second.

Twenty-three points on the body, five points on the racket, and a ball center were manually digitised by an experienced digitiser using Frame-DIAS V (DKH, Co., Japan). Three-dimensional coordinate data of these points were reconstructed with the three-dimensional DLT method. The right-handed coordinate system was set with; the direction toward the net (the hitting direction) as the Y-axis, the X-axis perpendicular to the Y-axis, and the vertical direction as the Z-axis. The mean calibration errors were 0.01 to 0.02 m in the X direction, 0.01 to 0.02 m in the Y direction and 0.01 m in the Z direction.
The three-dimensional coordinates were smoothed using a Butterworth digital filter at the optimum cut-off frequencies from 8 to 15 Hz determined by the residual method (Winter, 1990). However, the coordinate data of the racket head and the ball in several frames just before and after impact were not smoothed and were used to calculate the racket speed immediately before impact and ball speed immediately after impact, by a three-point numerical differentiation equation. The trial with the peak ball speed for each subject was selected. Joint angles of elbow extension/flexion, shoulder horizontal adduction/abduction, shoulder internal/external rotation of the hitting arm, inclination and rotation angles of the torso (Kobayashi et al., 2012), and the angular velocities of these joint and torso angles were calculated using the smoothed data. The timeseries data of the joint angles and angular velocities were normalized to 100% from the instant of the lowest center of gravity (CGmin) to the instant of impact (IMP).
We compared kinematic data of the subjects with those of the world-class players who participated in the AIG Japan Open Tennis Championships in 2002 (n = 13; Michikami, 2014) and the world-class players who participated in the Olympic Games in Sydney, Australia in 2000 (n = 20 (8 male, 12 female); Fleisig et al., 2003).
An unpaired t-test was used to test differences in ball speed and racket speed between the male college players and the world-class players (Michikami, 2014). The significance level was set at 5%.

RESULTS: Figure 1 shows the serving motion of a world-class player (Michikami, 2014) from maximum knee flexion to impact (IMP), and the averaged motion (Ae et al., 2007) for the male college players (n = 19) from CGmin to impact. Additionally, the averaged upper trunk angles of the male college players are presented (Figure 1). A close observation of Figure 1 revealed that the upper trunk forward rotation at IMP for the male college players was smaller than that of the world-class players. However, since no numerical data of the trunk rotation for the world-class players were reported, the finding should be further verified.

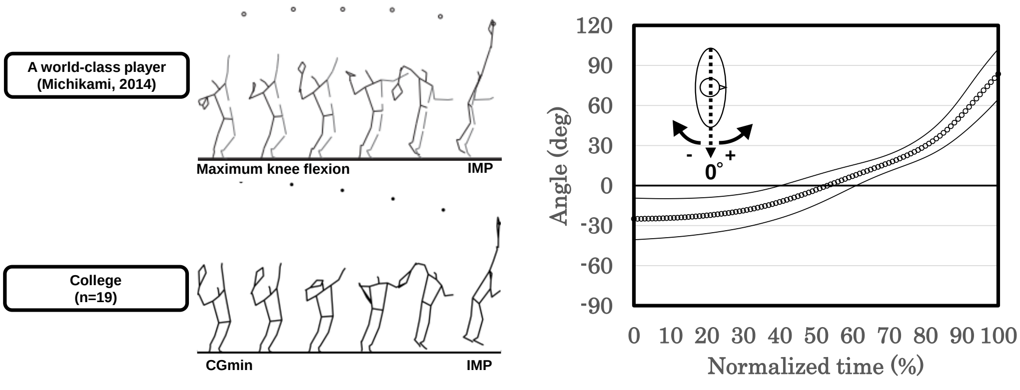

Figure 1: Serving motion of a world-class player (Michikami, 2014), the averaged motion of the male college players, and the averaged upper trunk angles of the male college players (n = 19).

Table 1 and 2 show impact parameters and peak angular velocities of the male college players and the world-class players (Michikami, 2014; Fleisig et al., 2003). Ball speed and racket speed for the male college players were significantly lower than those of the world-class players ($p < 0.001$; Table 1; Michikami, 2014).

The peak right shoulder internal rotation angular velocity was 43% lower in the male college players than in the world-class players (Table 2; Fleisig et al., 2003). The peak left knee extension angular velocity was 33% lower in the male college players in the world-class players. Since there was no significant difference in the left knee between male and female (Fleisig et al., 2003), the combined data were used.

Table 1: Impact parameters of male college players and world-class players (Michikami, 2014).

	Racket speed(km/h)	Ball speed(km/h)
Male college (n = 19)	134.6±10.3	164.5±14.0
World-class (n = 13) (Michikami, 2014)	172.3±9.9	202.0±11.6
Significant difference	***	***

* : p<0.05 *** : p<0.001

Table 2: The peak shoulder and knee joint angular velocities of male college players and world-class players (Fleisig et al., 2003).

	Right shoulder internal rotation (deg/s)	Left knee extension (deg/s)
Male college (n = 19)	1389±194	534±100
World-class (Fleisig et al., 2003)	2420±590 (n = 8)	800±400 (n = 20)
Difference in %	43%	33%

Figure 2 shows the averaged pattern of angles of the right shoulder horizontal abduction/adduction for the male college players (left). The change in the right shoulder horizontal abduction/adduction for the male college players was small, and no apparent horizontal abduction was observed. On the other hand, horizontal abduction (about -15 degrees) followed by horizontal adduction (about 10 degrees) was observed in the world-class players from maximum knee flexion to IMP (right; Michikami, 2014).

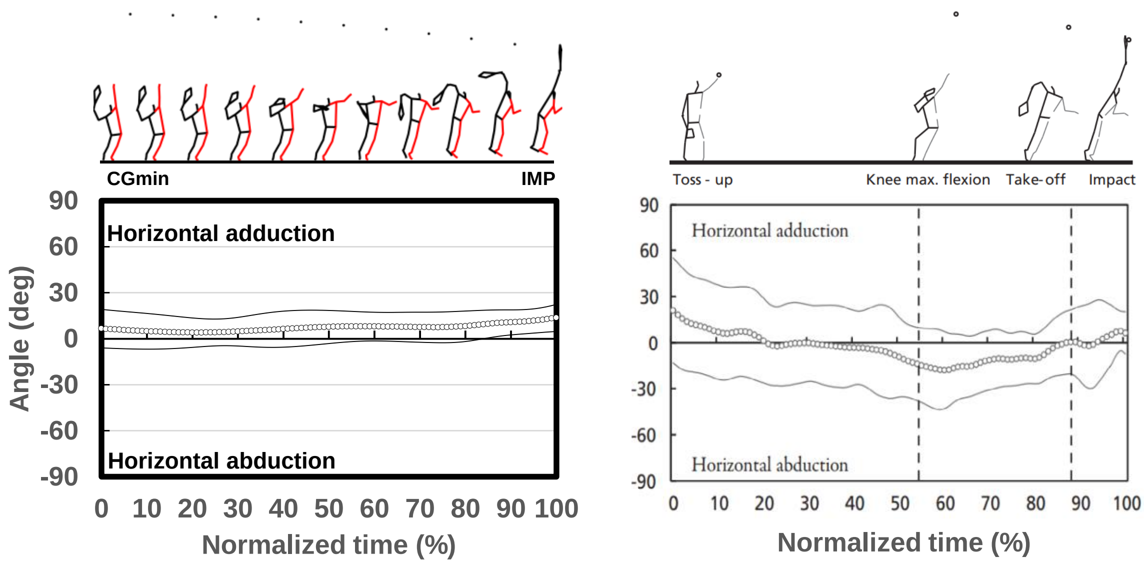

Figure 2: The right shoulder horizontal abduction/adduction angles of male college players (n = 19) and world-class players (n = 13; Michikami, 2014).

DISCUSSION: The racket and ball speeds of the male college players were 18% and 15% lower, respectively, than those of the world-class players (Michikami, 2014). This result indicates that the male college players would need to increase their racket speed to serve a fastball and that racket speed would be a critical point to improve fastball serves.

Sprigings et al. (1994) showed that shoulder joint internal rotation angular velocity greatly contributed to the racket speed. Since the mechanical work by the left knee joint extension torque contributed to gaining high racket speed (Murata and Fujii, 2014), another critical point for the male college players would be faster knee extension.

Trunk rotation and right shoulder horizontal abduction/adduction would relate to the distance for the acceleration of the racket. Therefore, the male college players should learn the effective use of shoulder horizontal abduction and trunk forward rotation toward IMP.

CONCLUSION: The ball speed and the racket speed of the male college players were significantly lower than those of the world-class players. To increase ball speed during serves, technique changes to increase shoulder joint internal rotation angular velocity and knee extension angular velocity are recommended. Future researcher should investigate the motion of shoulder joint horizontal abduction/adduction and trunk rotation.

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