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

HORIUCHI Kentaro[1], AE Michiyoshi[2], NUMAZU Naoki[2] and KAWABATA Mayo[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 and compare the serving motions of the fast hitters who can hit a fast serve and normal Japanese male college players in matches. The variables used in this study were ball speed, racket speed, joint and segment angles of the shoulder, the torso and the lower limbs. Ball speed and racket speed for the fast hitters were significantly greater than that of the normal players. There was a significant difference between two groups in the angles of the shoulder and the knee joint. The results indicate that it is necessary for normal players to maintain the shoulder more horizontally abducted, and not to lean the shank forward too much during the backswing.

KEYWORDS: tennis, 3D motion analysis, averaged motion, improvement in technique

INTRODUCTION: A tennis player who can hit a fast serve has an advantage in a match (Adachi, 1999; Brody, 2003). Therefore, the serve technique to hit a fast serve is one of the most essential techniques in tennis. There have been numerous studies on techniques to hit a fast serve (Sprigings et al., 1994; Murata et al., 2015), which have mostly dealt with experimental trials in laboratory setting, while only a limited number of studies (Fleisig et al., 2003; Michikami, 2014) have investigated the serving motion in matches.
The serve has long been a weak-point for Japanese male tennis players. Match statistics at competition level says that Japanese male college players had a significantly higher percentage of success on first serves than world-class players, but a significantly lower percentage of points' won on it (Hayashi et al., 2016). For female players, the percentage of points' won from the first serve had a larger impact on the total number of points' won than the percentage of the success of the first serve (Murata, 2018). Japanese male college players need to hit faster serve in matches. For the improvement in their serve techniques to hit a fast serve, it is helpful to investigate and understand their serve techniques in real matches. It would be useful to analyse and compare the serving motions of players at different competition levels for finding out critical points. However, there have been few studies on the serving motion in male college players at different competition levels. Therefore, the purpose of this study was to analyse the serving motions of the fast hitters who can hit a fast serve to compare with the normal Japanese male college players in matches. The hypothesis of this study would be that the racket speed of fast hitters is greater than that of the normal ones. The critical movements will be the shoulder horizontal adduction/abduction.

METHODS: The serving motion of twenty-eight Japanese male college players (height, 1.73 ± 0.05 m; weight, 66.5 ± 5.2 kg; right-handed players, 24 and left-handed players 4), who participated in an official or simulated matches was videotaped with two high-speed cameras (AX-700, SONY) and synchronized by the event method. The camera speed was set at 120 frames/s and the exposure time was from 1/1000 to 1/2000 second, depending on conditions. Based on class of competition, the male college players were divided into two groups (fast hitters, n = 9, top 16 in All Japan Inter-Collegiate Tennis Championships; normal players, n = 19, from regional qualifiers to national championship level). The trial with the highest ball speed and hit from the Deuce-side to the centre was selected for each subject.
Twenty-three points on the body, five points on the racket, and a ball centre were manually digitised by an experienced digitiser using Frame-DIAS VI (DKH, Co., Japan). Three-dimensional coordinate data of these points were reconstructed with the three-dimensional

DLT method. Left-handed players were treated as right-handed players by transforming their coordinates. The right-handed coordinate system was defined: 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 0.02 m in the X, Y and Z directions.
The three-dimensional coordinates data 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 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 the three-point numerical differentiation equation. Joint and segment angles of shoulder horizontal adduction/abduction, adduction/abduction and internal/external rotation of the hitting arm (Kobayashi et al., 2012) and the torso lateral lean and forward/backward lean and the lower limbs of the knee joint, shank and thigh were calculated using the smoothed data. The time-series data of the joint angles were normalized to 100% from the instant the ball leaves hand (Toss-up) to the instant of the ball impact (IMP). The backswing phase was defined as the period from Toss-up to 65%, and the forward swing phase as the period from 65% to IMP.
An unpaired t-test was used to examine differences in ball speed, racket speed and angles between two groups. The significance level was set at 5%.

RESULTS: Figure 1 shows the averaged motion of the serve and the impact parameters of the fast hitters (n = 9) and the normal players (n = 19). The ball speed and racket speed for the fast hitters were significantly greater than those of the normal players ($p < 0.01$). A close observation of Figure 1 revealed that the normal players showed an earlier elevation of the hitting upper arm at 10%time, a higher elbow position at 60%time and a smaller external rotation of the shoulder joint at 90%time. For the torso, the normal players leaned more leftward from 0 to 60%time. For the lower-limb joints, the normal players flexed the knee joint more deeply with greater forward lean of shanks.

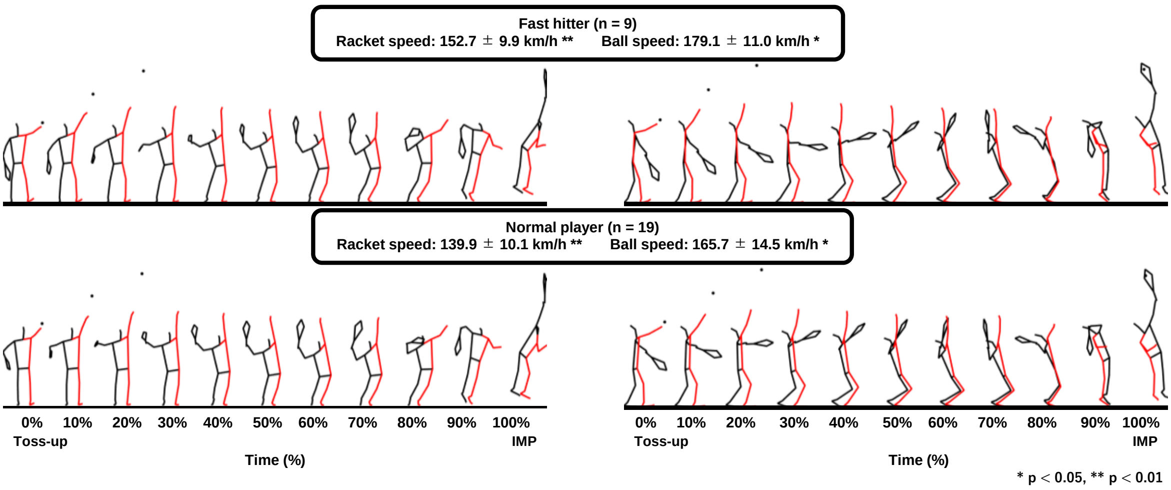

Figure 1 The averaged motions and the impact parameters of the fast hitters (n = 9) and the normal players (n = 19) from lateral view and backward view.

Figure 2 shows the shoulder joint angles of the two groups. Small circles denote significant differences between two groups. There was a significant difference in the shoulder horizontal adduction/abduction angle between two groups during 36-60%time and 97-100%time (p = 0.001 to 0.045), with the fast hitters having greater shoulder horizontal abduction during 0-65%time and maintaining a horizontal adduction angle of zero degrees at impact, while the normal players remained a horizontal adduction position from the toss-up. There was a significant difference in the shoulder adduction angle between the two groups during 86-95%time (p = 0.001 to 0.041). The fast hitters showed a smaller abduction angle during 0-65%time and the normal players largely abducted in the 86-95%time. There was a significant difference in the angle of the shoulder internal/external rotation between the two groups during 93-100%time (p = 0.001 to 0.04).

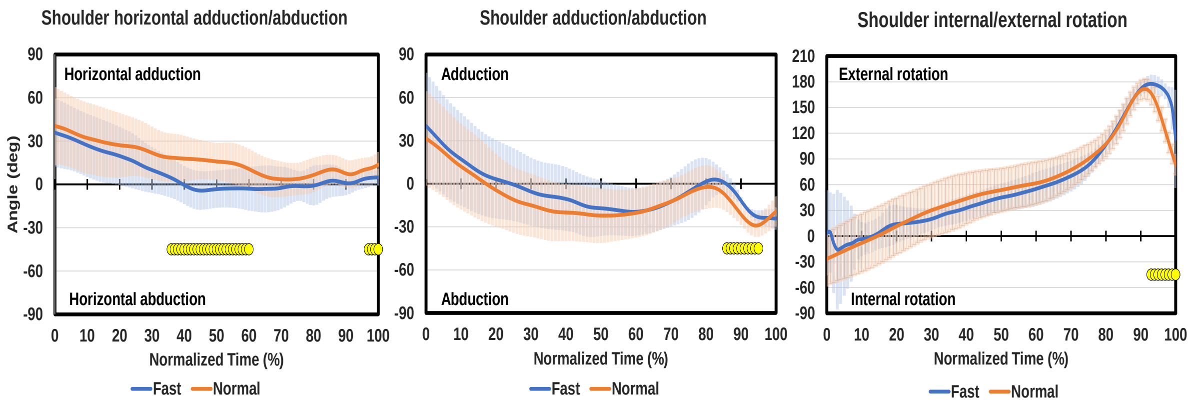

Figure 2 The averaged patterns of changes in the shoulder angles for the two groups.

Figure 3 shows the left knee joint angle and the lower limb segment angle of the two groups. Circles (knee and shank) and diamond (thigh) denote as in Figure 2. There was a significant difference in the knee joint angle between the two groups during 50-68%time and 90-97%time (p = 0.009 to 0.041). The normal players flexed more greatly but less extended of the knee joint than the fast hitters. There was a significant difference in the angle of the shank between two groups during 35-70%time (p = 0.009 to 0.044), and in the thigh during 90-100%time (p = 0.002 to 0.043). The angular displacement of the thigh was similar in both groups up to about 85%time, but the normal players leaned the thigh more rightward during 90-100%time and the normal players largely leaned the shank more rightward than the fast hitters during 0-70%time.

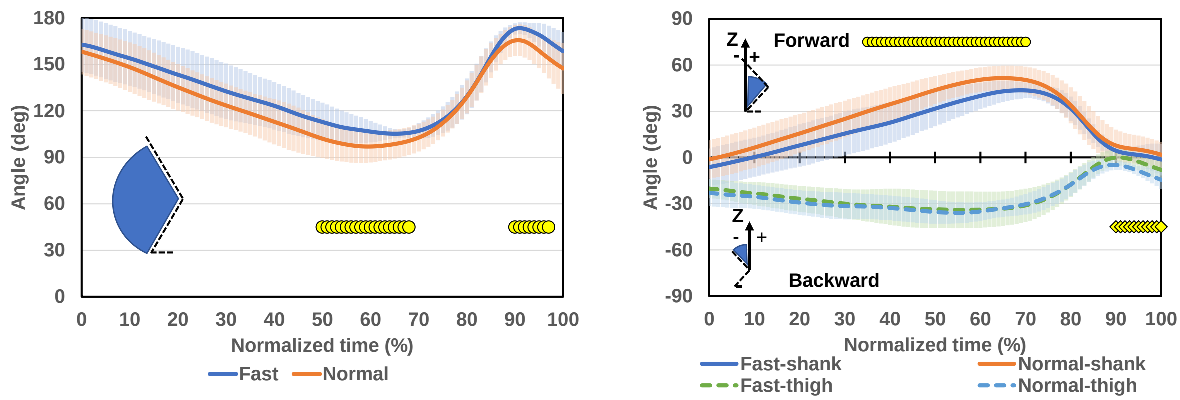

Figure 3 The averaged patterns of changes in the left knee joint and the segment of the lower limbs on the XZ-plane for the two groups.

DISCUSSION: The racket speed of the normal players was 8.4% lower and the ball speed was 7.5% lower than the fast hitters. This clearly indicates that the normal players need to increase the racket speed to hit faster serves.

For the shoulder joint, the normal players showed smaller external rotation than the fast hitters, which might indicate a critical point for the normal players. The previous studies pointed out the importance of internal rotation of the shoulder joint (Sprigings, et al., 1994; Murata et al., 2015). Murata et al. (2015) reported that for proper external rotation and racket speed, the elbow joint should be in 90° extension and the adduction/abduction angle of the shoulder joint should be about 0°. Therefore, the external rotation of the shoulder joint in the normal players should be improved by maintaining the adduction/abduction angle around 0° at 80%time and avoiding a large shoulder abduction after 80%time.

The world-class players (Michikami, 2014) showed greater shoulder horizontal abduction than that of the present fast hitters at 40-60%time. Murata et al. (2015) reported that the shoulder horizontal adduction torque in the forward swing was important for the shoulder external rotation. The eccentric contraction of the primary muscle groups for the serving motion such as the pectoralis major would be helpful to exert larger horizontal adduction torque. Therefore, the shoulder horizontal adduction/abduction would be considered to be critical for the male college players.
For the lower limb, the difference in knee joint angle observed in this study was caused by the inclination of the shank during 0-70%time. During the knee flexion phase from 60 to 70%time, large forward lean of the shank and deep knee flexion shown by the normal players as in Figure 1 may have caused insufficient knee extension before take-off; in referred to Elliott suggestion (2003) that an appropriate knee flexion would be 110 ± 10° . In other words, the knee flexion of the normal players was too deep to extend enough to transfer the knee extension force to the upper body. Murata (2014) pointed out that the importance of mechanical energy from left knee extension for increasing racket speed.

CONCLUSION: Based on the findings obtained in this study, the implications for normal players to improve their racket speed would be; (1) The right shoulder abduction angle should be as close to 0° as possible after 80%time to enhance the right shoulder external rotation. (2) The right shoulder should be abducted horizontally during 40-60%time. (3) Avoid excessive forward lean of the shanks and too deep knee flexion. An appropriate angle of the knee maximum flexion would be recommended as 100-120° .

REFERENCES

Adachi, N. (1999). The analysis of tennis matches about world top class tennis player according to the serve. *Bull. Mukogawa Women' University, Humanities and Social Science,* 47: 57-63. http://doi.org/10.14993/00000234 (in Japanese)

Brody, H. (2003) Serving strategy. *ITF Coaching and Sport Science Review,* 31: 2-3.

Elliott, B., Reid, M. and Crespo, M (2003) Biomechanics of advanced Tennis. *The International Tennis Federation.* pp.158-161.

Hayashi, J., Hosokawa, S., Ohara, K., Yoshiyama, K., Kato, T., Nishijima, Y. (2016). Serve statistics comparison between different groups of players in Men's singles tennis -aiming to improve service game tactics for male Kansai college players-. *Japanese Journal of Tennis Science*., 24: 11-19. (in Japanese)

Kobayashi, Y., Ae, M., Miyazaki, A. & Fujii, N. (2012). Biomechanical characteristics of the overarm throwing motion of skilled elementary school children in comparison with standard motion model. *Japan J. Phys. Educ. Health*. *Sport Sci*, 57: 613-629. https://doi.org/10.5432/jjpehss.12032 (in Japanese)

Michikami, S. (2014). Kinematic analysis of the tennis first serves of world-top male tennis players in official games. *The Hikone Ronso,* 399: 114-131. https://doi.org/10.20693/jspeconf.54.0_380 (in Japanese)

Murata, M. and Fujii, N. (2014). Biomechanical Analysis for Control of Ball Spin in a Tennis Serve, Focusing on the Lower Limbs and Trunk. *Journal of biomechanism.,* 22: 155-166. https://doi.org/10.3951/biomechanisms.22.155 (in Japanese)

Murata, M., Fujii, N. and Suzuki, Y. (2015). Mechanical energy flow of the racquet holding arm in the tennis serve, focusing on the energy form. *Japan J. Phys. Educ. Hlth. Sport Sci.* 60: 177-195. https://doi.org/10.5432/jjpehss.14081 (in Japanese)

Murata, M. (2018). Trends in the top 100 players' serves in the 2018 Women's Tennis Association tournaments. *Journal of sports performance.* 10: 354-363. (in Japanese)

Sprigings, E., Marshall, R., Elliott, B. and Jennings, L. (1994). A three-dimensional kinematic method for determining the effectiveness of arm segment rotations in producing racquet-head speed. *Journal of Biomechanics.,* 27 (3): 245-254. https://doi.org/10.1016/0021-9290(94)90001-9

Winter, D. A. (1990). Biomechanics and motor control of human movement (4^{th} ed.). *John Wiley & Sons, Inc.*