

The comparison of a top-level Japanese tennis player's serve-performance evolution between two seasons

Bumpei Sato¹, Hiroki Yamaguchi², Shuhei Sato³ & Jin Eshita⁴

¹Meiji University, Japan. ²Doshisha University, Japan. ³Sendai University, Japan. ⁴Aoyamagakuin High School, Japan.

ABSTRACT

This study sought to determine the impact of changes in serve performance (relationship between speed, spin rate, reproducibility, and impact height) on world rankings for one top-level Japanese tennis player in 2017, when he became the All Japan Student Champion, and in 2022, when he represented Japan in the Davis Cup and won the ITF tournament (M25 Monastir: 10 Jan - 16 Jan 2022). This study clarifies the impact of changes in serve performance on world rankings in 2022. The results showed that, among the three types of serves (flat, slice, and kick), there were higher values for slice and kick in 2022 compared to 2017. Higher ball speed values were found for flat in 2022 and lower values for slice and kick in 2017. In 2022, all serve heights were higher, resulting in an increase in the flat success rate, which had the lowest reproducibility. These results suggest that longitudinal measurement and evaluation of the relationship between speed, spin rate, reproducibility, and impact height when serving is important for improving competitive performance.

Key words: serve performance, impact height, ball speed & number of revolutions, reproducibility.

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Corresponding author: Bumpei Sato. Email: bsato@meiji.ac.jp

INTRODUCTION

In tennis, the serve is the only skill that allows a player to initiate play at his or her own discretion (Chow et al., 2003; Fitzpatrick et al., 2019; Gillet et al., 2009; Kovacs & Ellenbecker, 2011; Roetert et al., 2009). It is an important skill that can determine the result of the match. Tennis serve performance has been found to be greatly influenced by the racket (frame material and string tension) and player competitive level (Sato & Funato, 2020) and body composition (Brody, 1987; Colomar et al., 2022; Trabert & Hook, 1984). It is customary for studies on servers to consider the type of serve (i.e., flat, slice, and kick) the player is attempting to perform. According to Sato (2021b), the flat serve is an offensive stroke with high speed and low rotation speed. The slice rotates in the lateral direction inducing the receiver to be pushed out of the court after bouncing. The kick, also known as a spin serve, has the characteristic of bouncing high because it is a top spin serve. The rotation of the ball causes a big change after bouncing, which may lead to an error in the opponent's receiving technique, so spin is an important factor in evaluating serve performance. Studies on tennis serves also tend to use speed guns and high-speed cameras to analyze ball speed (Chow et al., 2003; Elliott et al., 2003). However, it is known that the behavior produced by each of the three types of serve is different (Sakurai et al. 2013), and since the change in bounce direction that occurs after landing could be influenced by different behaviors among serve types, we should consider the types of serves the player is trying to perform. In evaluating serve performance, in addition to the

speed of the ball, ball spin rate is thought to be an important indicator, because the spin rate, which causes the trajectory of the ball to change, is the factor that induces errors in the opponent's prediction of how the ball will bounce and thus in his or her receiving skills.

In recent years, with the development of the TRACKMAN device to measure ball behavior, serve performance is now evaluated and analyzed comprehensively according to factors such as ball behavior (speed and spin rate), course, and reproducibility, and these data can be used by coaches for feedback (Murata & Takahashi, 2020; Sato et al., 2017; Murakami et al., 2016). Applying these experimental instruments, it was reported that high-quality serve can be evaluated and determined by analyzing the relationship between ball speed and spin rate (Sato, 2021b; Sato & Funato, 2020; Muramatsu et al., 2010; Muramatsu et al., 2015; Murakami et al., 2016). Sato and Funato (2020) attempted to quantify the relationship between players' competition level and serve performance in terms of serve speed and spin rate. They analyzed the data cross-sectionally by comparing the serve performance among male tennis players at three levels (i.e., professional, college student athlete, and junior athlete). They found differences in serve performance at the top level of each category, and performance could be evaluated by quantifying speed, spin rate, and the number of attempts required to make a successful serve. Expanding on this research and collecting data from wider levels, Sato (2021b), gathered serve performance data from Japanese

top tennis players at various levels (including male and female professional players, student athletes, junior athletes, and wheelchair athletes) and measured the differences in serve performance (serve speed, spin rate, and reproducibility). The statistical analysis showed that players at higher competition levels tended to have a higher score for speed and spin rate in each type of serve (i.e., the male professional players' performance index was located in the upper right of the approximate curve obtained from the analysis). They also found that, for most players, the serve speed differed by serve type, ranked from fastest to slowest: flat, slice, and then kick. A rather different trend was seen for spin rate, which was highest for kick, slice, and lowest for flat). They also found that a negative correlation (or trade-off) between serve speed and spin rate for all three serve types. The results of their study were congruent with previous studies, such as Muramatsu et al. (2015). However, the significance of the study of Sato (2021b) was that they implemented an experimental data collection method. The data analyzed in Muramatsu et al. (2015) was a partial extract of the actual match and did not consider strategic bargaining in the match. In an actual game, the 1st serve is not always hit with a fast ball because players bargain with the opponent. In some cases, the 2nd serve, which requires a high success rate, is not hit with a rotating system. With regard to these issues, their studies were not strictly controlled. Judging from these previous studies, Sato (2021b) was a significant study that provided new evidence on the relationship of players' competitive level, the serve speed, and the spin rate. From the different studies, Sato (2021b) organized the "Serve Performance Evaluation Table," which quantitatively measures serve speed, spin rate, and success probability rate based on these findings.

Other than ball speed and spin rate, the impact height of the serve is also a major factor in improving serve performance, and there is a correlation between impact height and serve performance (Vaverka & Cernosek, 2013). Vaverka and Cernosek (2007) found that when the impact height increased by 10 cm from 2.7 m, which is the minimum to hit the service line with a straight ball, the landing point moved 25–30 cm from the service line toward the net for each 10 cm. Japanese tennis players (in ATP Tour Inc. 2021) tend, on average, to be shorter than the world's top tennis players. According to the ATP Tour website, concerning the height of the world's top 10 and Japan's top 10 ranked players in 2021, the average height of the top Japanese players tended to be about 11cm shorter than that of the world's top players. In this regard, a conscious approach to raising the impact point higher than now seems to be an essential task since this improvement would lead to a higher success rate and improved quality of the serve, which in turn would support Japanese players to take advantage of the game.

What was interesting about prior studies was that serve performance was compared multidimensionally (speed, spin rate, and reproducibility) between different competition levels to gain rich information about estimated serve performance for researchers, coaches, and the players themselves. Having an index of this kind will be beneficial because they can draw inferences about serve performance and learn from an objective data source. Although such cross-sectional studies are beneficial in that they provide a better understanding of players' performance level and serve performance, they did not measure serve performance at different stages in the players' career. Limited studies on the relationship between serve performance and players' competitive performance have continuously measured, analyzed, and evaluated tennis players longitudinally at two different career stages.

In this study, the serve performance (relationship between speed, spin rate, reproducibility, and impact height) of a top-level Japanese tennis player A (hereafter, Subject A) was assessed at two time points: (a) in 2017, when he became the All Japan Student Champion, and (b) in 2022, when he became a professional tennis player, represented Japan in the Davis Cup, and won the ITF Tournament. This study sought to clarify the impact of serve performance changes on performance level. Such data, together with those of Sato and Funato (2020) and Sato (2021b), provide additional knowledge, with both cross-sectional and longitudinal data, about players' competitive level and serve performance.

METHODS AND PROCEDURES

Subjects

The subject was a current Davis Cup player representing Japan, Subject A. Subject A's physical characteristics and changes in ranking are shown in Table 1. Subject A adopted the foot-up type (FU) stance technique for the lower limbs.

Table 1

The change in subject's physical characteristics and ranking.

Year	2017	2022
Age (yrs)	20	25
Body height (cm)	182.2	182.4
Body Mass (kg)	76.7	79.5
JTA Ranking*	34	12
ATP Ranking**	893	397

*JTA Ranking: Domestic ranking of the Japan Tennis Association (at the time of measurement). **ATP Ranking: International ranking of the Association of Tennis Professionals (at the time of measurement).

Procedure

Before the experiment, the subject had sufficient time to hit three types of serves (flat, slice, and kick) as a warm-up. We asked the subject to use the racket to which he was accustomed for experimental trials. The ball used for the experiment was a Dunlop Fort (International Tennis Federation ITF Certified Ball/ Japan Tennis Association JTF Certified Ball, Pressure Rise Tennis Ball, manufactured by Dunlop). The subject was required to hit flat and kick serves toward the center (T zone), and the slice serve to the wide direction with maximum effort, and the ten fastest serves for each type were analyzed. Each serve was considered a successful trial if it landed in the target area (2 m long × 1 m wide). Reproducibility (serve probability) was measured from the start of the trial until each of the serves successfully landed in the targeted area five times.

Measurement material

We used a TRACKMAN Tennis Rader (TRACKMAN Inc), a measuring device that can track and measure Doppler radar from the launching to the landing of the ball, to measure the ball speed and the spin rate of the serve. The accuracy of TRACKMAN was examined by Sato et al. (2017), who compared the ball speed and spin rate calculated from TRACKMAN and Vicon, and the results showing a high correlation for both speed and spin rate (speed, $r = 0.9969$; spin rate, $r = 0.9788$). During measurement, the center of the TRACKMAN was placed on the extension of the center mark, 5.26 m behind the baseline and 2.65 m in height, so that the

range of the doppler radar emitted could sufficiently cover the sideline of the court.

Methods used for the analysis

Ball speed and spin rate calculated from TRACKMAN were analyzed statistically using Spearman's rank correlation coefficient. We measured how the values of the speed, spin rate, and impact height of the subject's serve performance changed from 2017 to 2022 by calculating the rate of change of those values.

Ethical considerations

This study was approved by the Meiji University Ethics Review Committee (Approval No. 557). The subject was provided with written and verbal information regarding the purpose and contents of the study. It explained that the results would not be used for anything other than the purpose of this study and that participation in the experiment was voluntary. In addition, an explanation that there would be no disadvantage for not participating in this study was also included. Finally, the subject could cancel participation even during the measurement.

RESULTS AND DISCUSSION

Ball speed and spin rate

Prior research has shown that there is a trade-off relationship between ball speed and spin rate, with higher speeds resulting in lower spin rates (Sakurai et al., 2013). Muramatsu et al. (2015) also found that the higher the level of competition,

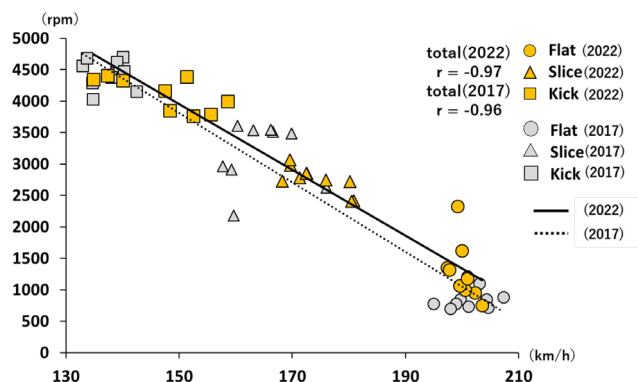


Figure 1. The Relationship Between Ball Speed and Spin Rate (2017 vs 2022).

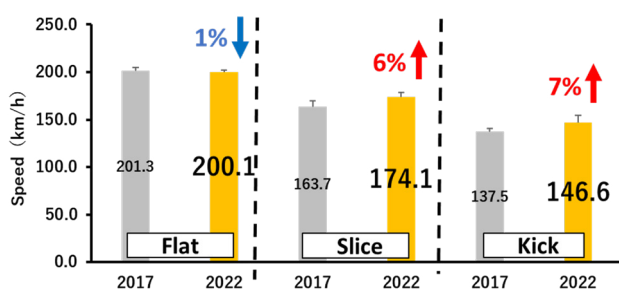


Figure 2. The Speed (km/h) of the Serves (2017 vs 2022)

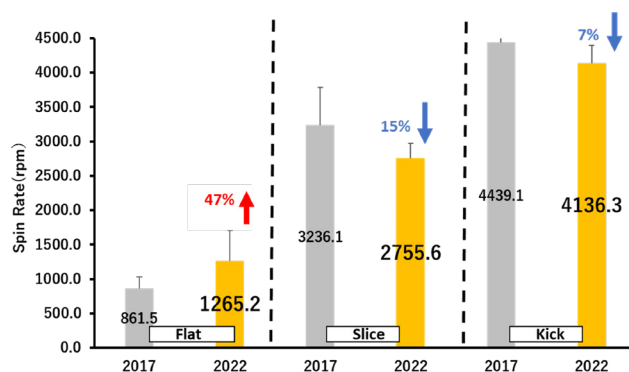


Figure 3. The Spin Rate (rpm) of the Serves (2017 vs 2022).

the higher the serve speed (x-axis) and the spin rate (y-axis), which were located in the upper right of the curve of the regression line. Some studies have stated that the same ball speed shows a tendency for a greater spin rate and the same spin rate shows a tendency for higher speed (Murakami et al., 2016; Muramatsu et al., 2015; Sato & Funato, 2020). However, focusing on the values of Subject A's flat serve in 2017 and 2022, we found a significant increase in spin rate (47%), while only a slight decrease in speed (1%), which indicates that speed and spin rate do not necessarily follow a trade-off relationship, which commonly occurs when evaluating serves (fig. 2, 3). This positive development may be one indicator showing higher performance for Subject A's serves (and for the flat serve in particular) in 2022 compared with 2017. The increase in spin rate for the flat serves, the so-called fastball type, affects the behavior of the ball both in the air and after it lands in the service area, making it more difficult for the opponent to hit the ball back and contributing to the server proceeding in the game favorably. Given that the approximate line in 2022 went up to the upper right location compared with that from 2017, it can be presumed that this indicates an improvement in the quality of Subject A's serves, in line with Muramatsu et al. (2015) (fig. 1). In addition, when this value was assessed using the serve rubric (3-point scale) created by Sato (2021a, b), we can assume that the improvement from a score of 2 to a score of 3 has made it possible for the subject of this study to take advantage of the game having a higher quality of serve.

Reproducibility and impact height

The relationship between ball speed, spin rate, and reproducibility is an important indicator for assessing competition level (Sato & Funato, 2020; Sato, 2021b). When looking at Subject A's impact height in 2022, we found that it was higher than in 2017 (an average increase of 5.6%) (fig. 4). In addition, in the flat serve, where the trade-off between speed and reproducibility (Chow et al., 2003) generally indicates a tendency toward lower reproducibility, the reproducibility improved from 10 serves required for a successful attempt for the serve task in 2017 to 6 serves in 2022. Vaverka and Cernosek (2013) found a correlation between impact height and serve performance, and Brody et al. (1987) stated that a higher impact height increases the opponent's margin of error. In fact, the success probability of the first serve (which is said to often be hit in a fastball type) by the two players ranked first (J.I.: Body height; 2.08m) and second (R.O.: Body height; 2.11m) in the Serve Rating calculated by the ATP Tour in 2022 was 68.8% for J.I. and 65.9% for R.O. (ATP Tour, 2022),

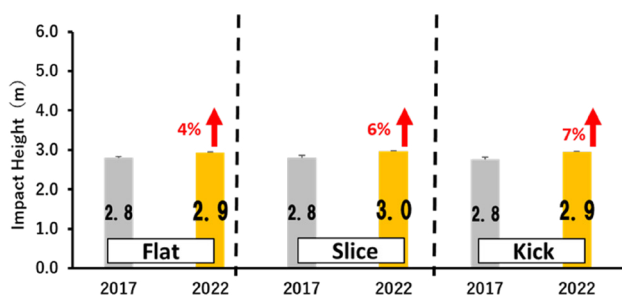


Figure 4. The Impact Height of the Serves (m) (2017 vs 2022).

with an average of 2.3 to 2.4 double faults per match (i.e., an extremely low probability rate). The estimated impact height is said to be about 150% of the height of the player (Whiteside et al., 2013), and because the impact height of J.I., the world's No. 1 server, is estimated to be 3.16 m, the margin of error is extremely high.

It can be inferred that an increase in body weight (+2.8 kg) brought about an improvement in overall physical performance, although there was no increase in height between the two measurement points. The leg drive during the loading phase (hereafter referred to as leg drive) resulted in a large ground reaction force (GRF; Elliott & Wood, 1983). This large GRF may have enhanced the movement linking knee flexion to jumping, resulting in a higher impact height compared to 2017. Subject A's use of FU in the lower limb stance technique is another important technique for improving serve performance among Japanese players (Konishi et al., 1997), who are generally relatively short in stature. It has been suggested that FU tends to increase vertical GRF during the loading phase and may increase impact height (Elliott & Wood, 1983). This would be one essential process to include when the change in impact height is used as an evaluation indicator following Sato (2021b) and Sato and Funato (2020), and could be a reason for Subject A's improved competition level (i.e., world ranking). Increased impact height is a major factor (Bartlett et al., 1995) in producing higher ball speed and higher serve performance. How the player uses the chain of mechanical energy to hit the ball with the racket is a major factor for the speed and spin rate of the serve. As mentioned, the minimum impact height for a straight ball to land on the service line is 2.7 m (Brody, 1987; Chow et al., 2003; Trabert & Hook, 1984), and increasing the impact height by 10 cm moves the point of impact 25–30 cm closer to the net from the service line (Vaverka & Cernosek, 2007). For Japanese tennis players, the approach to impact height is a critical issue for performance improvement. The average height of the world's top-level tennis players (ATP Ranking 1–10) is significantly higher than that of the top-level Japanese tennis players (JTA Ranking 1–10) (ATP Tour, 2021). According to Whiteside et al. (2013), the estimated 2017 and 2022 impact height for Subject A can be estimated as 2.73 m. Adding the increase in impact height (5.6%) obtained in this study, the impact height would have been raised to approximately 2.87 m. These results suggest that Subject A consciously focused on the relationship between the net and impact height, which may be a factor for the higher probability of successful attempts (Bartlett et al., 1995), mainly by strengthening the lower limb muscle groups and improving loading technique, thus leading to a higher vertical GRF than in 2017. The increase in impact height may have increased the margin of error and contributed to the improvement in the reproducibility of flat serve values (2017: 10 balls vs. 2022: 6 balls).

CONCLUSION

Longitudinal measurement and quantification of serve performance in tennis players will reveal how serve performance improvements affect competitive performance (i.e., ranking). This study sought to clarify the impact of changes in serve performance on world rankings by comparing and examining the speed, spin rate, reproducibility, and impact height of a Japanese top-level tennis player in 2017 and 2022. There are four key findings. First, higher values were found for slice and kick in 2022 compared to 2017. Second, higher values were observed for speed in 2022 for flat and lower values for slice and kick compared to 2017. Third, higher values for impact height in all three serve types were observed in 2022 compared to 2017. Fourth, high reproducibility (based on the number of attempts required for success) in the flat serve, together with an increase in speed and spin rate, was observed in 2022, although this type of serve is highly influenced by the trade-off relationship between speed and spin rate. These results suggest that longitudinal measurement and evaluation of serve performance (speed, spin rate, repeatability, and impact height) is important for improving competitive performance.

LIMITATIONS AND FUTURE ISSUES

This study examined the relationship between serve performance and world ranking by focusing on the serve performance of a Japanese top-level tennis player (Subject A) in 2017 and 2022 in terms of four variables: speed, spin rate, reproducibility, and impact height. In addition to the measurements used in this study, future studies could also analyze movement, body composition (muscle length, thickness, body fat percentage, etc.), and the energy flow generated by the upper and lower limbs to contribute to further improvement of athletic performance.

CONFLICT OF INTEREST AND FUNDING

The authors declare that they do not have any conflict of interest and that they did not receive any funding to conduct the research.

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