Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 7), Art 199 pp. 1788 - 1794, July 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Analysis of ball speed and accuracy of groundstrokes on a clay court in young tennis players

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Published online: July 31, 2024
Accepted for publication : July 15, 2024
DOI:10.7752/jpes.2024.07199

Abstract
Accuracy and speed are critical factors that influence tennis performance. Various studies have examined speed, but less attention has been given to understanding the probabilistic structure of errors (i.e., accuracy). Tennis, a racquet sport requiring high physical fitness during competition, emphasizes the importance of both ball accuracy and speed for success. This is especially true for young male competitive tennis players. This study aimed to analyze the ball accuracy and ball speed of running groundstrokes on a clay court. Sixteen males at national-level junior tennis were assessed (age: 15.50 ± 0.63 years; height: 178.44 ± 8.08 cm; body weight: 67.25 ± 7.72 kg; body mass index: 21.12 ± 1.93 kg/m^2). All participants measured running groundstroke performances by hitting a ball to a target square and hitting it as fast as possible by using a ball machine that fed 10 balls at a velocity of 60 km/h, with a 2-minute break between trials. The running groundstroke variables measured included Running Forehand Down the Line (RFDL), Running Forehand Cross-Court (RFCC), Running Backhand Down the Line (RBDL), and Running Backhand Cross-Court (RBCC). The results found that the forehand technique was a more accurate skill than the backhand, with higher averages than other skills (RFCC; 1.81±0.544 RFDL; 0.37±0.500, RBDL; 0.25±0.447, RBCC; 0.62±0.719) p = 0.011. The forehand technique also showed a higher average speed, particularly in RFCC (p = 0.001). The Pearson correlation of forehand techniques in RFCC and RFDL was moderately related, r = .697, with statistical significance at $p \geq$ 0.05. These results suggest that the differences in groundstroke running each technique are different. Thus, coaches should adopt specific training programs focusing on ball accuracy and ball speed to enhance the performance of youth tennis players on clay courts.
Keywords: Racket sport, Technical analysis, Running groundstrokes, Court surfaces, Youth sports

Introduction

Tennis is a racquet sport that combines technical skills and physical fitness in competition, including successful speed and accuracy. In this regard, ball speed is usually considered one of the most important attributes of performance in tennis (Landlinger, Stöggl, Lindinger, Wagner, & Müller, 2012) because increased stroke speed reduces the time an opponent has to prepare to return the ball successfully. It appears that the evolution within the game has been characterized by a progressive increase in the ball speed during groundstrokes and serves (Cross & Pollard 2009), which may be a consequence of developing the physical, technical, and tactical preparation of tennis players. In addition, ball speed appears to be the main factor differentiating high-level tennis players from those of lower levels, regardless of the age of players (Ulbricht, Fernandez-Fernandez, Mendez-Villanueva, & Ferrauti, 2016). For these reasons, players generally try to maximize the ball speed of their groundstrokes and serves without sacrificing accuracy (Vaverka & Cernosek, 2013). Therefore, the importance of these variables for high performance among professional and young tennis players means it is necessary to distinguish the ball speed and accuracy of different strokes, how these variables evolve with increasing sport levels, and the factors that impact speed and accuracy (Landlinger et al., 2012; Ulbricht et al., 2016).

The athletes who win the Grand Slam Tournament might not always be the number one athlete, yet continue to be successful in competition. Court differentiations can influence game performance in professional tennis (Carboch et al., 2019). Therefore, tennis players need experience playing on a variety of surfaces. According to the International Tennis Federation (ITF) court surface classification, surface speed falls into 3 categories: Slow surfaces such as the French Open clay courts, medium surfaces such as the cement, acrylic, or synthetic courts (U.S. Open and Australian Open), and fast surfaces such as the Wimbledon grass courts (Gillet, Leroy, Thouvarecq, & Stein, 2009). Tennis players require technical and tactical proficiency, mental skills, and high physical performance levels. Elite tennis players need to implement both endurance and strength training to

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produce powerful strokes and handle the high intensities of play, including the rapid accelerations, decelerations, and changes of direction that occur over the length of a match (one or more hours) (Vaverka, Nykodym, Hendl, Zhanel, & Zahradnik, 2018).

Tennis match play is characterized by repeated high-intensity running (i.e., accelerations, decelerations, and changes of direction) and hitting (i.e., strokes with different speeds, spins, and angles) during a period that is not entirely predictable (i.e., an average of 90 min, but sometimes as long as 5 h for elite adult players) (Fernandez-Fernandez et al., 2011; Hoppe et al., 2014). The work-to-rest ratio is from 1:2 to 1:5 (Kovacs, 2006) throughout a competition, during which there is very high intensity and intermittent exercise. The total match time and total distance covered were 81.2 ± 14.6 minutes, and 3362 ± 869 meters, respectively (Hoppe et al., 2014). For men's singles, the time taken for each point is approximately 5.2 seconds, and approximately 7.1 seconds for women's singles. For a Grand Slam competition, the average duration of each point is 6.3 ± 1.8 seconds. On a clay court, the average duration of each point is 7.2 seconds, and the break time is 15.5 seconds (O'Donoghue & Ingram, 2001). Of course, the intensity of a particular competition greatly affects the ability and performance of athletes, especially the decrease in efficiency of speed and accuracy in hitting.

Applying sports technology to analyze tennis skills and games by specialized personnel to develop athletes' potential needs to be completed appropriately and regularly (Cui et al., 2017). The study of Fitzpatrick, Stone, Choppin, & Kelley (2019) reveals that certain characteristics are important to an athlete's ability to compete on clay and grass courts. It was found that getting each point by the winning group of athletes in a rally took longer and more time than a grass court. From the literature review, research by Tonejc, Horvatin-Fučkar, and Filipčič (2008) studied the relationship between the speed and accuracy of tennis players by comparing a group of professional players and a group of highly experienced athletes. Professional players were found to be able to hit balls more powerfully, accurately, and with more control to an opponent's side of the court than experienced athletes. Likewise, the winning group was found to be better than the losing group. A study by Kovalchik and Reid (2017) performed a statistical analysis to regress the differences between junior and professional competitions. It was found that, in general, professional tennis players' shots were more powerful and more accurate than youth players and had a 50% more competitive load, while female youth players had a 50% more competitive load than female professional players.

There is also a study by Landlinger et al. (2012) that assessed the differences in ball speed and accuracy of tennis groundstrokes between elite and high-performance players. The study found that the accuracy of groundstroke among elite athletes was higher than that of experienced athletes. Interestingly, in the analysis of valid shots, both groups increased their backhand accuracy when playing down the line. This gives the impression that participants felt more comfortable in this situation, particularly since speeds were similar to cross-court as well as the ball speed results. Forehand cross-court shots were played significantly more accurately than backhand cross-court shots. During competition, tennis players have to change direction with increasing acceleration and decreasing acceleration. The running average distance to hit the ball is 3 meters per time, 8-15 meters per point, and 1,300 -3,600 meters per competition (Fernandez-Fernandez et al., 2011).

Although many studies have focused on serving shots by young tennis players, running groundstrokes can be more difficult when playing on a clay court. Players must rely on both speed and accuracy with their shots to gain an advantage in the competition, and youth players may not consider the proper directional control, accuracy, or speed of the ball. To analyze the efficiency of hitting tennis balls on clay courts at the youth level, studying the accuracy of hitting on clay courts, especially at the youth level, is an interesting topic. Therefore, this study was interested in the analysis of ball accuracy for running groundstrokes on a clay court (Forehand and Backhand in direction Down the Line and Cross-Court) for national-level junior tennis, which would provide important information for developing specific techniques for youth tennis players on clay courts.

Material & methods

This study was an analysis of the ball accuracy and ball speed of running groundstrokes on a clay court by measuring the stroke performances of hitting the ball to a target square and hitting it fast by using a ball machine (BM) fed with 10 balls (Lobster Elite 2, Australia) for the test. Kinovea software version 0.8.15 (Klaus, Bradshaw, Young, O'Brien, & Zois, 2017) was used to calculate speed ball for hitting various running groundstrokes, including Running Forehand Down the Line (RFDL), Running Forehand Cross-Court (RFCC), Running Backhand Down the Line (RBDL), and Running Backhand Cross-Court (RBCC). This study was approved by the ethics board for Human Research at the Strategic Wisdom and Research Institute, Srinakharinwirot University (SWUEC-G 275/2565) based on the Declaration of Helsinki.

Participants

Sixteen male junior tennis players (age: 15.50±0.63 years; height: 178.44±8.08 cm; body weight: 67.25±7.72 kg; body mass index: 21.12±1.93 kg/m^2) from the Thailand national team participated in the study. They are the top players for national-level junior tennis in Thailand. The inclusion criteria for participants comprised having experience of at least 3 years, with continuous training throughout the period, and participating in Thailand's youth tennis championship competitions. All participants were free of injury, including joint or muscle pain, and provided written informed consent before participating in the study.

Procedures and Protocol

All participants were tested at an indoor tennis facility on a clay course with a constant temperature between 22-25 °C. For 48 hours before the testing, the subjects did not undertake moderate to high-intensity activities, including resistance exercise, and avoided drinks containing caffeine for 24 hours. Between each test, there would be a rest period of at least 48 hours to wash out so that their physical conditions would be fully ready for the test.

The test protocol for ball accuracy to hit the running groundstrokes consisted of 10 shots per skill by using an automatic ball machine (Lobster Elite 2, Australia) set to a ball speed of 60 km/h, then a 2-minute break for each skill. The subjects were required to hit a ball into a zone target consisting of a large target area (3x4.5 m), and the accuracy of the number of strokes that hit the ball inside the large target area, called the accuracy zone (0.7x0.7 m), was observed on the designated side (Landlinger et al., 2012). To evaluate the players' efficiency in hitting the ball, all were set out to measure the total number of balls hit, which were divided into an accuracy zone (AZ) (for hitting a small area of 0.7x0.7 m), none-accuracy zone (NAZ) (for hitting a large area of 3x4.5 m but not into the accuracy zone), and error zone (EZ) (for balls that do not hit as specified and do not cross the net). Two cameras with high resolution were utilized (Sony Handycam (HDR PJ670) resolution: 1920 x 1080/60p) to record and analyze ball speed using Kinovea version 0.8.15 (Klaus et al., 2017). All shown in illustration Figure 1. Analysis with the Kinovea program was carried out by people with expertise and experience in tennis as well as at least 2 years of experience using the analysis program. Analysis of each data set was conducted 2 times.

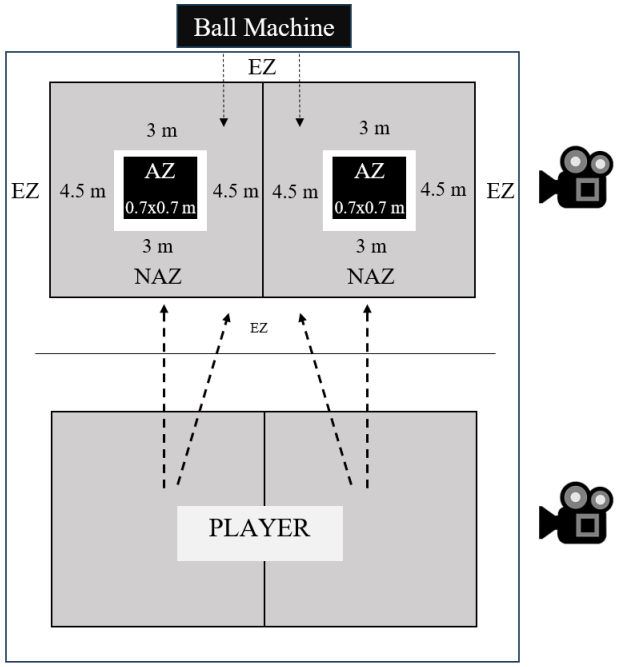

Figure 1 Illustration of the experimental location in the tennis court, adapted from (Landlinger et al., 2012)

Statistical Analysis

This study used Two-way ANOVA with repeated measures to analyze the interaction between x-zone target techniques and analyze the influences between groups as well as within groups. Ball speed was analyzed using One-way ANOVA with repeated measures. The relationship between each ball-hitting technique was analyzed using Pearson's method. Statistical significance was set at the $p < 0.05$ level.

Results

From the results, the difference between techniques was shown to affect the accuracy of shots. Using the forehand technique is a more accurate technique than the backhand, with higher averages than other skills (RFCC; 1.81±0.544 RFDL; 0.37±0.500, RBDL; 0.25±0.447, RBCC; 0.62±0.719) $p = 0.011$), as shown in Table 1. The speed of hitting the ball using the forehand technique indicates an average speed (RFCC; ($p = 0.001$), as shown in Table 2.

The Pearson correlation coefficient of forehand techniques for RFCC and RFDL have a moderate positive correlation of $r = .697$ (shown in Figure 2), with statistical significance at $p < 0.05$, as shown in Table 3.

Table 1 Two-way ANOVA with repeated measure of hitting skills and accuracy

	RFDL	RFCC	RBDL	RBCC	Between Group (P-value)
Accuracy (AZ)	0.37±0.500	1.81±0.544#	0.25±0.447	0.62±0.719	0.011^
Non accuracy (NAZ)	7.62±2.217*	7.12±0.619*	7.50±1.592*	7.50±1.89737*	0.352
Error (EZ)	2.00±2.366	1.06±0.772	2.25±1.528*	1.87±1.928*	0.239
Within Group (P-value)	0.007^	0.001^	0.001^	0.001^	

Note. * *Significant when compared within group, # Significant when compared between group, and ^Significant from Two-way ANOVA with repeated measure analysis, All set p < 0.05.*

Table 2 One-way ANOVA with repeated measured speed ball of hitting running groundstrokes

	RFDL	RFCC	RBDL	RBCC	Between Group (P-value)
Speed	49.335±6.178#	45.680±9.467#	30.996±2.782	33.678±2.700^	0.001*

Note. * *Significant from One-way ANOVA with repeated measure analysis, # Significant when compared RBDL and RBCC, and ^ Significant when compared with RBDL, All set p < 0.05.*

Table 3 The Pearson correlation of speed ball each technique

Technique	RFDL	RFCC	RBDL	RBCC
RFDL	1	.697*	-.124	-.445
RFCC		1	-.058	-.158
RBDL			1	.228
RBCC				1

Note. * *Significant p < 0.05.*

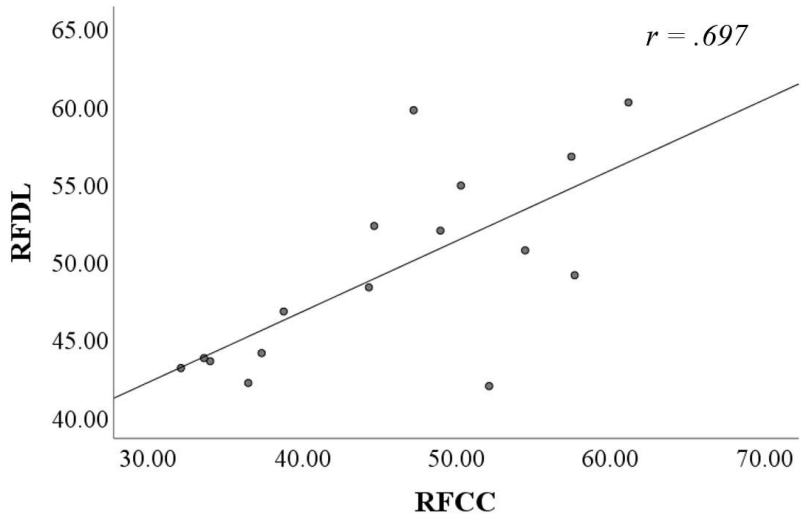

Figure 2 *The Pearson correlation between RFDL (Running Forehand Down the Line with RFCC (Running Forehand Cross-Court)*

Discussion

The use of skills and techniques, especially speed and accuracy, differs among athletes at various levels (Kolman et al., 2019). The skills commonly used by youth tennis players are forehand and backhand, with similar proportions (Thongthanapat & Khamros, 2024). However, it seems that the score obtained from hitting a Forehand Winner Point is higher than the score obtained from hitting a Backhand Winner Point (Janák, Pačes, & Zháněl, 2018; Reid, Morgan, & Whiteside, 2016). Therefore, there is reason to support the notion that tennis athletes will have more confidence in hitting the ball at high speeds with the ability to bounce the ball higher in the diagonal direction than in the parallel direction. In each training session, most coaches will focus on these abilities as basic offensive and defensive skills. For hitting the ball to bounce on the ground, the focus will be on hitting the ball with topspin to get the ball to move high across the net. The ball falls deep at the end of the court and bounces high. As a result, it will be more difficult for an opponent to hit the ball back than a flat ball (Cyril Genevois, Reid, Creveaux, & Rogowski, 2020). Accuracy in controlling the ball with the front hand to land in the target area is higher than with the backhand. Because forehand ball striking skills use the main and large muscles related to each other, it is a simple and uncomplicated way to learn the mechanics of movement. Every tennis athlete can use the force from hitting the ball to bounce more forcefully on the ground with the forehand than with the backhand. Also, hitting the ball into the cross-court often uncovers a higher frequency for both forehand and backhand skills than Down the Line because the travel distance of the ball is longer, thus reducing unforced hit errors (Fernandez-Fernandez, Kinner, & Ferrauti, 2010; Landlinger et al., 2012).

For the speed of hitting the ball, the research study found that the average speed of hitting the ball using the skill of running and hitting the ball on the surface of the hand was higher than using the skill of running and hitting a ball that bounced on the surface of the hand. This is consistent with the study by Bower and Cross (2008), who found that professional tennis players were able to add higher angular velocity than amateur tennis players. This can also be explained by biomechanical principles, in which tennis players can transfer force from the ground to the racket and transfer it to the tennis ball. If the athlete can transfer force through the joints, from the lower to the upper joints, correctly and in a consistent relationship, the speed of the ball increases (Denning, Funk, Hager, Hopkins, & Seeley, 2011). The coefficient of friction on the tennis court surface also affects the speed of the tennis ball, with ground tennis courts having a higher value for coefficient of friction than other court surfaces. This results in a high and relatively soft bounce (O'Donoghue & Ingram, 2001). Consequently, athletes tend to use counter-attacking games more than competing on hard surfaces. Athletes who want points from the game will try to adjust their game plan to find opportunities to play in front of the net, using volleyball skills or overhead balls, as well as methods to increase or decrease the speed of the ball at times to gain an advantage over opposing players. In this study, the opposite was found more often in the winning group than in the losing group. This is consistent with past studies that found different surfaces affect the performance of professional tennis players (Kovalchik & Reid, 2017; Carboch, Sklenarik, Šiman, & Blau, 2019; Christos et al., 2024), which can be observed from a flat hit that can create a high hitting speed and is different from other types of hitting (Maksym, 2019). Among youth tennis players, improving shot speed and accuracy improves the ability of young athletes to become elite athletes (Kolman et al., 2023). However, the training of athletes from the youth to elite levels involves additional complicating factors, especially playing on different courts.

There is a moderate relationship between running and hitting a ball that bounces on the forehand surface (RFDL, RFCC). Among youth athletes, skill is needed for hitting the ball and bouncing the forehand inside-out instead of hitting the ball and bouncing off the backhand (Delgado-García et al., 2019). Because athletes want to reduce the number of errors and lost points from their shots as much as possible, they favor the skill of hitting the ball with the forehand. However, it is understood that errors can be found in hitting a ball that bounces on the ground all over the face, hands, and back of hands (Yamamoto, Shinya, & Kudo, 2019). Therefore, coaches should apply this information to their training so that athletes can play in a variety of ways appropriate to the surface of the tennis court and the strategies laid out. This is because, in some situations, athletes have to make split-second decisions in terms of selecting a particular skill to hit the ball according to the situation at that time. If the ball has both speed and accuracy, then the athlete will be successful in competition (Landlinger, Lindinger, Stöggl, Wagner, & Müller, 2010).

Conclusion

Differences in technique significantly affect the accuracy of male tennis players with experience at the international youth level. Players seem to be more adept at hitting cross-court than down the line. The highest hitting speed is higher with the forehand technique than with the backhand technique. The most important goal in the process of teaching tennis should be increasing ball speed as a priority compared to accuracy. Based on the results, coaches should design methods for practicing more comprehensive techniques needed for hitting balls on a clay court to reduce the athletes' weaknesses and develop their abilities, thus making the athletes' hits even better. A limitation of this study was real-time analysis. Future studies should analyze real-time games to reveal more complexity in competitive analysis.

Acknowledgement

The authors would like to thank the Department of Sports Science, Faculty of Physical Education, Sports and Health, Srinakharinwirot University for support the sports science equipment for this research.

Conflicts of interest

The authors declared this research no have conflict of interest publications.

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