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A Scientific Approach for Diagnosing a Junior Tennis Player's Swing and Determining Optimum Racquet Parameters

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Abstract. A scientific approach for diagnosing a junior tennis player's swing has been developed. Eleven Junior USTA Tournament players participated in this study which involved hitting three tennis racquets with varying mass and string tension against balls served from a ball machine. Results from a lower mass racquet were compared against a standard mass racquet with both strung at standard tension. Also, for a standard mass racquet, results from lower tension were compared to those with standard tension. Each player's swing and approach to the ball were observed, along with the speed of the returned ball (as measured by a radar gun) as well as where it struck the court. The data were carefully analyzed to determine optimum racquet settings for each player as well as to diagnose any problems and make recommended improvements to their swings.

Keywords: tennis, swing, racquet, tension, mass

1. Introduction

Tennis studies conducted in both laboratory settings[1] and on court with advanced players[2] have shown that racquet mass and string tension affect a player's performance. These studies have confirmed the conventional wisdom that heavier racquets generate more power (ball speed) while lighter racquets generate less power. They have also demonstrated that racquets strung under higher tension generate less power but provide more accuracy. While laboratory settings emulate well the tennis swings of advanced players, this study examines the less consistent swing of developing junior tournament level players. This study seeks to embrace the differences from established norms to successfully diagnose deficiencies in the less experienced swing. At the conclusion of the study, each player was given a summary sheet of recommendations. For junior players, determining when to upgrade to a higher mass racquet is an important step. It represents a rite of passage to the next level, but if rushed it could lead to reduced performance. Knowing the appropriate racquet settings and what to improve in their swing will not only make tennis more enjoyable, but may also reduce the risk of injury.

2. The Experiment

2.1. Materials

Three Babolat AeroPro tennis racquets were used in this experiment, labeled Racquets A, B, and C as shown in Table 1. All were strung with Topspin CyberFlash main strings and Wilson Hollow Core cross strings. All racquet handles were a 4-3/8" grip size covered with the factory installed Babolat main grip and a Wilson Pro Overgrip. The same dampener was also used on all three racquets. In each case, the cross strings were 2 pounds lower tension than the main strings. This combination allowed for the strings to pop back into place after striking a ball. Note that Racquet A is the baseline for comparison. Racquet B has the same as Racquet A but a lighter tension. Racquet C has the same tension as Racquet A but a lower mass. For simplicity in this study, the racquets were referenced to the lower cross-string tensions (53 or 48).

Table 1. Racquet parameters used in experiment

	Racquet A	**Racquet B**	**Racquet C**
String Tension Main/Cross (lbs)	55/53	50/48	55/53
Unstrung Racquet Mass (grams)	300	300	260

A Silent Partner Ball machine was used to mimic a serve to the players. While there was some minor variation in ball speed, it was very repeatable since identical new USTA-approved Penn tennis balls were used. A Tracer Sports Radar Gun was used to measure the ball's return speed.

2.2. Experimental Setup

The ball machine was located at the center of the baseline on the target end of the tennis court. An orange pylon target was placed behind the center of the service line on the Deuce side (for right-handers) and the Ad side (for left-handers). The radar gun was held at the baseline on the same side as the targeted cone. Each player was instructed to return balls with medium-speed forehand topspin toward the crosscourt.

Recognizing that each participant played at a different level, the ball machine parameters were adjusted to each participant's preference before each trial began. Specifically, the speed of the ball, loft, and amount of spin were adjusted to the player's specifications. Players first swung Racquet A, then B, then C. For each new racquet, they were given two practice swings before the eight hits which were evaluated in the study. Recorded data included general observations regarding the participant's swing, the speed of the returned ball as measured by a radar gun, and the location on the court where the ball struck.

It is important to note that the speed measurement only accounted for the component of velocity toward the direction of the radar gun. If the ball was hit with any loft angle or wide, the full speed would be the measured value divided by the cosine of the angle away from the straight line connecting the ball to the radar gun. Therefore, in some cases the speed measured by the radar gun was less than the full speed of the ball, but properly hit balls were well characterized.

The setup of the court is show in Figure 2. Masking tape was also used to mark portions of the court identifying whether an "Out" ball was more wide or long. Note that the masking tape is applied at a 45 degree angle to the center line. This demarcates whether a ball landed either wider or deeper compared to an "In" ball. Locations where balls struck the court were separated into seven categories as follows:

- **In:** Balls landing in bounds in the targeted crosscourt location
- **Net:** Balls landing short and not clearing the net
- **Wide Left:** Balls landing left of the targeted crosscourt location
- **Wide Right:** Balls landing right of the targeted crosscourt location
- **Long:** Balls landing deep past the baseline but inside the masking tape and court centerline
- **Long Left:** Balls landing deep *and* Left of the masking tape for right-handers, Left of the centerline for left-handers
- **Long Right:** Balls landing deep *and* Right of the centerline for right-handers, Right of the masking tape for left-handers

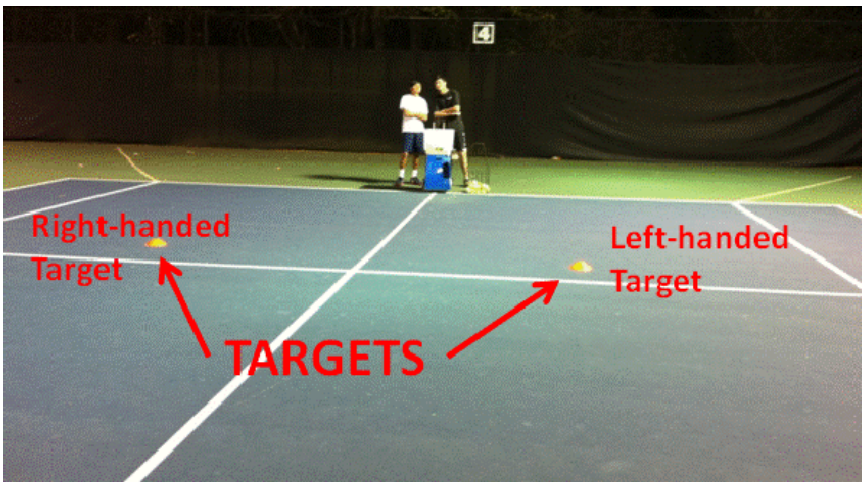

Fig. 2: Setup of the court showing ball machine and target location in a view seen by a right-handed player

2.3. Data Analysis

For each participant and racquet type, the recorded ball speeds measured by the radar gun were tabulated. The means and standard deviations of each participant's ball speeds were computed to determine the "best fit" to a Gaussian distribution.

Other important parameters that were recorded included an observation of the participant's swing as well as the ball landing location on the court. To correctly interpret the data it was required to apply an understanding of tennis along with the mathematical statistics.

Some general trends were learned during data analysis. For example, a player who hit a lighter racquet with more average speed probably did not have the strength to swing a heavier racquet. Also, right-handers who hit a large number of balls "Wide Right" were meeting the ball too late, often because they did not taken a full enough backswing to generate sufficient racquet head speed. Lower standard deviations in ball speed indicated more consistency in the swing while larger standard deviations indicated less control.

As stated in the Introduction, the effects of racquet mass and string tension for experienced players are well established. Junior players are still developing their swings and are not yet at full strength. This study embraces the differences from established trends to help diagnose problems with the less developed player. All available data were placed in a table and carefully analysed, with the key deviating trends used to draw conclusions shown in boldface type. This was used as a coaching tool by giving respective players their tabular results to provide insight into what areas they can work to improve their swing. For example, in explaining to a player the need for taking a fuller backswing, it was instructional to show them actual data regarding how it affected their ball speed and accuracy with different racquets.

2.4. Results

Of the eleven participants, three sample cases were evaluated in detail to illustrate the data interpretation process. Key features in the data set are shown in bold face print for each of these participants. The recommendation of racquet type and improvement of swing for each of these players is also given.

Participant 1: Female, 14, 8th grade, 3 years experience, Player preference: Racquet A (Accuracy)

Swing observations: Participant 1 demonstrated a consistent and smooth swing with all three racquets. She seemed to have no trouble finding the sweet spot among all of them. With the heavier racquets (A&B) her swing appeared a little slower.

RACQUET ID	Babolat AeroPro	Tension (lbs)	SPEED (mph) Avg	Std Dev	IN	OUT *SHORT*	OUT *LONG Left*	OUT *LONG Middle*	OUT *LONG Right*	OUT *WIDE Left*	OUT *WIDE Right*
A	Drive	53	37.38	4.44	5	1	0	1	0	0	**1**
B	Drive	48	38.25	5.04	4	0	0	1	0	0	**3**
C	Lite	53	**43.00**	5.35	5	1	0	2	0	0	0

Data Analysis: Based on the recorded data, Racquet C seems to be her most effective weapon. She tied in accuracy with Racquet A by hitting 5 of 8 balls in the desired area, but averaged more than 5.5 mph extra speed using Racquet C. The extra ball speed is attributed to a faster racquet head speed achievable with the lower mass Racquet C. This more than compensated for the extra transfer of energy delivered by the heavier Racquet A. All 4 of the 6 balls which were "Out Wide" went to the right and were hit with the heavier racquets, reinforcing the observation that she did not bring the racquet around quickly enough.

Recommendations: Her preference among the three racquets was Racquet A because it "was more accurate and felt better." This accuracy is demonstrated in the data since Racquet A had a smaller standard deviation of ball speed. For practice sessions, her choice of Racquet A is advised for a better workout provided its weight does not lead to injury. However, under match conditions, the extra 5.5 mph delivered by Racquet C, which pushed none of the balls "Wide Right," makes it the superior choice. In a long match, the lighter racquet may also prove easier to wield.

Participant 2: Male, 15, 10th grade, 4 years experience, Player preference: Racquet B (Power and Control)

Swing observations: Participant 2 is tall in height with accompanying long reach. He took a relatively short backswing, but with the leverage from his long arms was able to accelerate through the ball to generate high ball speed which is also needed for spin. This can be viewed as catching the ball on the racquet then directing its face toward the desired direction, while pulling upward to apply the desired topspin.

RACQUET ID	Babolat AeroPro	Tension (lbs)	SPEED (mph) Avg	Std Dev	IN	OUT *SHORT*	OUT *LONG Left*	OUT *LONG Middle*	OUT *LONG Right*	OUT *WIDE Left*	OUT *WIDE Right*
A	Drive	53	57.00	4.90	3	3	0	1	0	0	1
B	Drive	48	**63.63**	5.73	**7**	1	0	0	0	0	0
C	Lite	53	58.38	6.59	5	0	0	0	0	2	1

Data Analysis: Based on the style of his swing, the lower tension of Racquet B proved to be the most effective. This racquet provided a trampoline effect, allowing the ball to sling outward with more velocity. Racquet A, with its higher tension was not effective for his style of swing since it limited the amount of contact time with the ball, requiring more impact speed generated from a longer backswing. The larger sweet spot and sling effect with Racquet B contributed to an extra 6 mph compared to Racquet A, along with better accuracy with 7 of 8 balls landing "In." The lower speed of Racquet A probably contributed to 3 of the 8 balls falling short into the net. Participant 2 is a strong player and Racquet C proved too light with 2 balls going wide left, indicating early racquet arrival due to over-swinging.

Recommendations: He preferred Racquet B and the data supported this as being the best choice due to his strength (over Racquet C) and swing style (over Racquet A). To improve his game, a smoother and longer backswing is recommended and as this develops the use of a higher tension racquet may be in order.

Participant 3: Female, 16, 11th grade, 1 year experience, Player preference: Racquet B (Feel)

Swing observations: She approached the ball well and swung each of the racquets smoothly.

RACQUET ID	Babolat AeroPro	Tension (lbs)	SPEED (mph) Avg	Std Dev	IN	OUT *SHORT*	OUT *LONG Left*	OUT *LONG Middle*	OUT *LONG Right*	OUT *WIDE Left*	OUT *WIDE Right*
A	Drive	53	**40.13**	4.12	3	3	0	1	0	0	**1**
B	Drive	48	**40.63**	4.66	**5**	0	0	0	0	1	**2**
C	Lite	53	35.25	5.04	6	0	0	0	0	0	**2**

Data Analysis: Participant 3 swung the two regular mass Racquets (A and B) to generate about the same average ball speed (40 mph) which was about 5 mph hour greater than Racquet C (only 35 mph). She clearly had the strength to swing the heavier racquet. Of the two, she preferred Racquet B which she hit much more accurately than Racquet A. The larger "sweet spot" of Racquet B seemed to be helpful. Combining the data among all racquets, 5 of the 6 balls that went "Wide" landed on the "Right" side. This suggests that sometimes her racquet is meeting the ball too late and reinforces the observation that she does not take a full back swing.

Recommendations: For the best combination of accuracy and power, Racquet B is recommended. To improve her performance, it is suggested that she take an earlier and fuller backswing. She can also concentrate more on hitting the ball with the center of the racquet. Finding the "sweet spot" will increase her power. As she perfects her swing, a higher tension racquet may help with her return ball placement, but for her just one year experience she is demonstrating excellent skills.

2.5. Conclusions

Taking an engineering approach to diagnosing a developing junior player's tennis swing was successful. This approach helped to identify areas for improvement and to verify deficiencies already observed in their swings. Evaluating average ball speed, accuracy based on hitting the targeted area, and location of missed shots also helped in selecting the appropriate racquet for each player. This approach is not intended to replace, but rather enhance a coach's evaluation of a player's swing. Providing the players with tabulated results and data analysis can help explain to them the direct impact of focusing on the recommended areas of improvement.

One of the most important findings of this study was that almost all of the students who were recommended the heavier racquet were also recommended lower string tension. This tension (50 lbs. main strings 48 lbs. cross strings) was much lower than the 55-65 lbs. that Babolat suggests for the AeroPro Drive. While it was expected that the lower tension racquet produced more power, it may be somewhat surprising that it also provided more accuracy. However, for the developing player, the larger sweet spot of the lower tension racquet tended to increase the number of "In" shots. Also, players with a shorter backswing but stronger follow-through hit more accurately with lower tension racquets. This indicates that the racquet head needs to be at full speed for higher strung racquets since there is a shorter impact time compared to lower

strung racquets. Since many developing junior players choose the recommend higher string tension, this research suggests that some should be coached into trying a lower tension until their skills improve to the point where they regularly hit the sweet spot and develop a full backswing. In some cases, lower than recommended string tension may also be appropriate lighter racquets, although this combination of racquet parameters was not evaluated here.

To make this technical approach more efficient a few upgrades are suggested to the process. First, video cameras could be included to observe the player's swing. Rather than relying on the instructor's notes, video footage could be reviewed to help confirm trends observed and may also be shared with the player when describing areas of improvement. Also, more racquet choices and more swings per racquet can be offered to provide a larger sample population for the computed statistics. Specifically, for the less strong player, multiple tensions of the lighter racquet would be appropriate. The installation of an automatic radar gun would also be helpful in reducing the number of people required to conduct the experiments. Finally, it would be useful to repeat the study with players after one month to assess how much they have improved in their recommended areas.

There is no reason this same diagnostic approach could not be extended to beginning and intermediate adults. For these stronger players, heavier racquets with three different string tensions could be used to help diagnose their swing as well as to choose optimum tension.

3. Acknowledgements

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4. References

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