BIOMECHANICAL ANALYSIS AND EVALUATION OF THE POWER SERVE OF FEMALE TENNIS PLAYERS

Hui Liu, Liangbiao Li and Xing Fang[1]
Beijing University of Physical Education, Beijing, People's Republic of China
[1]National Research Institute of Sports Science, Beijing, People's Republic of China

The purpose of this study was to obtain and analyze the kinetic characteristics of the power serve in tennis and to judge whether or not the subjects' skills were reasonable. This in turn would provide a theoretical reference of the theory and training of the tennis power serve. Three-dimensional (3-D) videography was used to record the tennis service action of eight female tennis players. The analysis suggested that the theory of "whiplash movement" can be applied in the analysis of this performance. Quality and effectiveness of racket-swing action are decided directly by increased velocity and timing in successive segments from lower to upper. Some indexes were provided to evaluate the actions of the tennis power serve. Some suggestions were made to players for improvement in their performance.

KEY WORDS: tennis, power serve, technique analysis

INTRODUCTION: The tennis serve is a concentrated skill in which the player has full control over his performance. It is considered to be one of the most important strokes in the game of tennis. Many players use the power serve as the ultimate weapon in their matches. However, it is also a difficult stroke to master, as every segment of the body must be coordinated with each other appropriately. Many researchers and coaches have carried out biomechanical studies on the tennis serve technique. However, most of these studies have been limited to merely reporting the data and describing the pattern of technique of elite players. With the help of biomechanical method and theory, it is hoped to reveal the kinematic characteristics and theory of tennis serve techniques, to determine whether the subjects have reasonable technique, and to provide some suggestions for improvement.

SUBJECTS: Eight young female tennis players with a mean age 19 years were used as subjects. They were the most accomplished players of their age group. Three subjects were on the national team and two of them were champions of a match at India in 1998.

METHOD: Two phase-locked PEAK video recorders were operated at 120fps (exposure time 1/2000s) to record each subject hitting at least three successful power serves. Video records of the serve were obtained as they served on a plastic tennis court outdoors. The area was arranged as shown in Figure 1.

Analysis and treatment of data. The serve with the highest velocity was selected for analysis. An Aijie Video Analysis System was used to digitize the video records of both reference structure (25 points) and each subject (23 point). The ball and marks on the racket were also digitized (the pattern of marks shown in Figure 2). The DLT method for 3-D space reconstruction from 2-D image was used. All digitized coordinates were digitally filtered using a low-pass digital filter with a 10Hz cutoff.

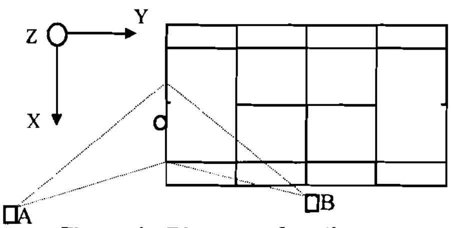

Figure 1 - Diagram of testing setup.

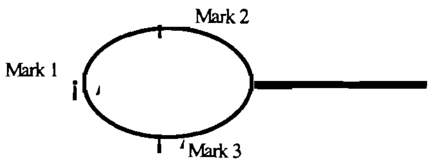

Figure 2 - Three Points at racquet.

RESULTS: The mean initial velocity of toss was 5.94ms^{-1}, therefore the mean peak ball toss height was 3.35m off the ground, which was 0.94m higher than impact position (table 1). This displacement meant that the ball had a downward mean velocity of 4.23ms^{-1} at the moment of impact.

Table 1 **Ball Movement Prior to Impact**

	Ball velocity when release(m/s)	Height of toss(m)	Height of impact(m)	Distance dropped(m)
$\overline{X}$ (n=8)	5.94	3.35	2.41	0.94
S	0.47	0.32	0.65	0.31
MAX	6.24	3.39	2.79	1.55
MIN	5.22	2.92	2.31	0.61

Some calculations were made about knee joint flexion-extension action during "backswing phase". The correlation of the range of knee flexion and the maximum vertical velocity of hip joint action was not significant (r=0.262). However, a correlation coefficient of 0.728(p<0.05) was obtained between mean angular velocity of knee extension and the maximum vertical velocity of hip joint action. There is a significant negative correlation between the minimal angle of knee bend and the distance of downward racket movement (r=-0.762,p<0.05). Furthermore, the correlation between range of knee movement and velocity of ball, and between the angular velocity of knee extension and velocity of ball was somewhat (0.773 and 0.609 respectively).

Table 2 is a record of the linear vertical velocities of the racket top at the time when the hip was at its maximum vertical velocity. As the lower limb extended and drove the hip upward, the racket moved down the back with a mean negative velocity of 3.79ms^{-1}.

Table 2 **Vertical Velocity of Top of Racket at the Time when the Hip was at its Maximum Vertical Velocity (ms^{-1})**

	Hip	Racket
$\overline{X}$ (n=8)	2.18	-3.79
S	0.56	1.79
MAX	3.04	0.05
MIN	1.60	-6.92

The maximum resultant velocities of segment end points (Table 3) revealed a resultant velocity increase in the successive segments from the hip joint to the head of the racket as the time of impact approached. This summation process produced a maximum velocity of the racket that was higher than any other segment. However, the maximum velocity of the racket of 33.14ms^{-1} was recorded not at impact but at 0.009s prior to impact. The velocity of racket at impact was 31.57ms^{-1}. Elliot and Marsh's study (1986) stated that female subjects reached a maximum velocity of racket 0.04±0.01s prior to impact. This result suggests that the impact action is not simply contact with the ball when racket reaches its largest velocity.

Table 3 **Maximum Resultant Liner Velocity of Segment and Racket Endpoint Prior to Impact**

	Hip		Shoulder		Elbow		Wrist		Racket	
	V	*t*	*V*	*t*	*V*	*t*	*V*	*t*	*V*	*t*
$\overline{X}$ (n=8)	2.28	0.133	5.31	0.102	7.79	0.090	9.58	0.054	33.14	0.009
S	0.57	0.053	2.03	0.025	2.03	0.016	2.38	0.020	1.53	0.003
MAX	3.14	0.192	10.01	0.142	9.36	0.108	11.93	0.100	35.26	0.017
MIN	1.62	0.025	6.38	0.067	6.38	0.067	4.45	0.042	31.31	0.008

DISCUSSION: Impact occurred 0.94m below the peak height of the toss, which was greater than the mean of 0.53m reported by Elliot (1986). Figure 3 shows the racket velocity of the action of two players: player A who had the highest ball toss and player B, who had the lowest ball toss. The figure shows that the racket of player A had a reduced velocity after "backscratch position"*, while player B's velocity continued to increase.

In theory, the reduced of velocity will disrupt the rhythm of the serve. Furthermore, it also can

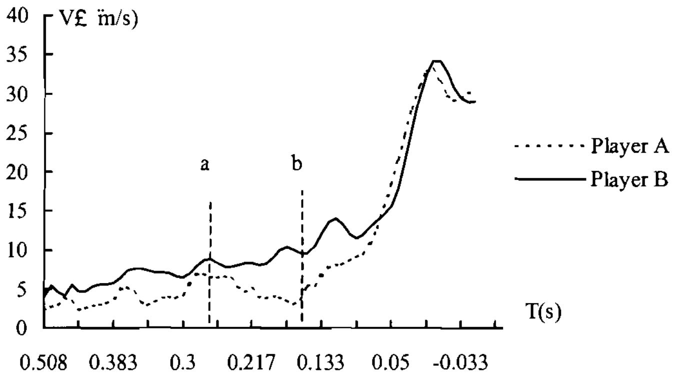

Figure 3 - Racket velocity of two players with different ball toss height.

consume the potential energy of muscle stored during "backscratch action". On the other hand, the ball toss reaching a height of 0.94m above impact means the ball will be moving at approximately 4.23ms^{-1} at impact, and is therefore more difficult to hit than if stationary at the peak of the toss.

Table 4 Angular Parameter of Knee Extension during "Backswing phase"

	Time of extension (s)	Angular displacement (°)	Mean angular velocity (rad/s)
Group A $\bar{x}$(n=2)	0.40±0.05	88.54±4.72	6.52±0.32
Group B $\bar{x}$(n=3)	0.213±0.04	46.96±6.68	6.44±0.50
Group C $\bar{x}$(n=3)	0.28±0.09	41.55±10.88	4.34±0.35

Table 4 shows that the subjects can be classified into three groups according to their knee joint extension movement during "backswing phase". Group A has largest angular displacement and mean angular velocity. Group C shows the lowest angular displacement and velocity. Since there are significant correlations between the mean angular velocity of knee extension and the maximum vertical velocity of the hip action, it can be concluded that the group C has the poorest leg drive action, and group A has the best leg drive movement.

The top of the racket has velocity of -3.79ms^{-1} when the hip reaches its maximum vertical velocity. This result was much lower than –7.5ms^{-1} reported by Elliot (1986). In Elliot's study, the subjects were classified by three professional coaches, as having a good leg drive. This comparison suggested that the subjects of the present study had poor leg drive action.

Generally, players may benefit by increasing their knee flexion as their strength of lower limb permits. Statistics confirm that range and velocity of lower limb extension influence the velocity of the ball. However, the proper amount of knee flexion actually depends on the strength and coordination of players.

* "backscratch position" is the position when the elbow reaches its largest flexion.

Figure 4 This shows the resultant velocities for one player, and it is evident that segment end point velocities increase from the hip, to the shoulder, to the elbow, to the wrist, and finally to the racket. It suggests that tennis serve action is a typical whiplash movement. The momentum transferred from lower to upper by the segments revealed acceleration and deceleration in the same sequence. Finally, the racket obtains the largest velocity. Therefore, the quality and the effectiveness of racket swing action were determined directly by increased velocity and timing of successive segment action from lower to upper.

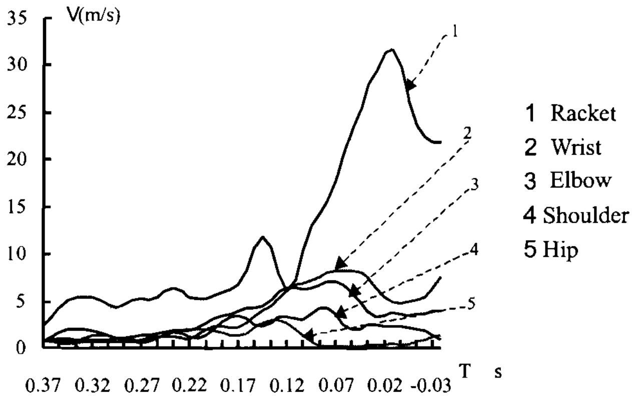

Figure 4 - Resultant linear velocities of segments.

CONCLUSION: It has been shown that the range and velocity of lower limb extension have a direct influence on the velocity of the ball. Players may benefit by increasing their knee flexion as their strength of lower limb permit. Tossing the ball too high can interrupt the successive serve movement break while waiting for the falling ball. The tennis serve action replicates a typical whiplash movement with no movement break. The quality and the effectiveness of racket swing action are decided directly by increased velocity and timing of successive segment from lower to upper.

REFERENCES:

Elliott, B., & Marsh, T. (1986). A Three Dimensional Cinematographic Analysis of The Tennis Serve. *International Journal of Sport Biomechanics*, **2**, 260-271.

Plagenhoef. (1979). Tennis Racquet Testing related To Tennis Elbow. *Symposium On Racquet Sport,* 291.

Duane Knudson. Dave Luedtke & John Faribault. (1994). *How To Analyze The Tennis Serve.* Strategies, June.

Groppel, J. (1992). *High Tech Tennis* (2nd ed.). Champaign, IL: Leisure Press.