BIOMECHANICAL SIMILARITIES AND DIFFERENCES OF A. AGASSI'S FIRST AND SECOND SERVES

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INTRODUCTION

The purpose of this study was to perform a three-dimensional analysis of the instrumentally recorded elements of Andre Agassi's (1992 Wimbledon and Davis Cup champion) serving technique during competition. Kinematic parameters of his first and second serves were compared.

METHODOLOGY

Data were collected during the match between A. Agassi vs. B. Gilbert (November 24, 1992). A video based analysis system was used to analyze the data provided by two SVHS (60 Hz) back and right side view camcorders. Three dimensional Direct Linear Transformation was performed using a preliminary filmed $8m^3$ calibration object. A right hand coordinate system was considered. Two view sequences of 85 frames for each serve were digitized containing eighteen body, one ball, and four racquet points.

Four successful first and four successful second serves into the deuce court were selected for the analysis. Spatial kinematic characteristics of the defined points and segments were analyzed.

RESULTS AND DISCUSSION

The comparison of the basic (generalized) biomechanical characteristics for the both serves is depicted in the Table 1.

Table 1. Kinematic parameters of the first and second serves.

Kinematic Parameters	Component	Units	First Serve	Second Serve
Ball Speed at Impact	Absolute	m/s	45.8± 2.2	37.9± 2.4
Directional angle from the center line	Horizontal	°	17± 3	10± 4
Ball Position at impact relative to the Center of Gravity (CG)	Forward	m	.23± .02	.02± .03
	Left Lateral	m	.12± .04	.36± .04
Height of the impact	Vertical	m	2.68± .02	2.76± .02
CG Maximal Speed	Absolute	m/s	1.89± .11	1.74± .09
CG Displacement at the moment of impact	Vertical	m	.41± .01	.40± .02
	Forward	m	.79± .02	.59± .02
	Left Lateral	m	.11± .01	.04± .01

As might be seen in the Table 1, the first and second serves have a number of differences. The first serves were hit with a higher velocity (on average 21% more than the second serves) and directed closer to the left far corner of the service box, opening more service area and placing the opponent at a disadvantage. The second serves were

directed closer to the center line using a pronounced topspin. The topspin serve could be characterized as relatively reliable, and also by serving closer to the center line a less aggressive return can be expected.

The kinematics of the body's Center of Gravity (CG) in the preparation phase reflects direction, velocity and rotation of the ball. In both cases the direction of horizontal velocity of CG at the moment of impact, coincided with the continuing direction of the ball flight, with variations within ± 1.5°. Components of the CG velocity are presented in the Figure 1.

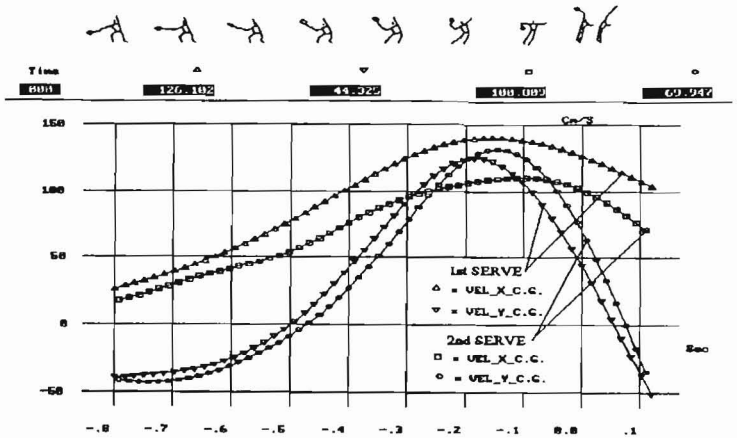


Figure 1. Vertical and horizontal (forward) components of the velocity of the C G (time 0.0 is the moment of impact).

It can be seen from the graphs that the horizontal component in the first serve has greater magnitude and reaches its maximum earlier before impact than in the second serve. However, the vertical component of CG's velocity of the second serve is 12% higher than that of the first and again, velocity maximum is closer to the moment of impact than in the first serve. The greater vertical velocity in the second serve is provided by the greater velocity of left knee extension (Figure 2). The pronounced CG's forward action in the first serve, and vertical action in the second serve is seen. The ball positioning, relative to the CG at the moment of impact for the first serve was, 0.23 ± 0.02 m forward and 0.12 ± 0.04 m laterally. The second serve had no significant forward shift between the ball and CG, however, it had significant lateral shift (0.36 ± 0.04 m) to the left of the CG. Having equal magnitudes of the CG's vertical displacement, the CG's absolute height at the second serve was 1.28 ± 0.04 m, which is an average of 7.8 cm higher than that of the first serve. The longitudinal displacement for the first serve was significantly larger (0.79 m vs. 0.59 m). The observed differences in the above parameters are reflected the height of the ball at impact (1st serve - 2.68 m, 2nd serve - 2.76 m).

The stick figure diagram is used to visualize the kinematic structure of these serves (Figures 3 and 4). The orientation of the racquet swing plane is significantly different. The plane of the first serve is more perpendicular while the plane of the second demonstrates a noticeable slope to the court surface. Also the second serve is oriented more parallel to the baseline than the first serve. At the same time the lengths of the racquet trajectories for both serves are identical.

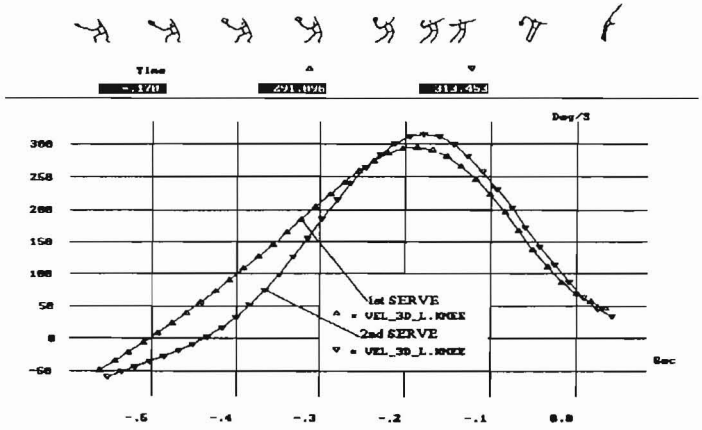
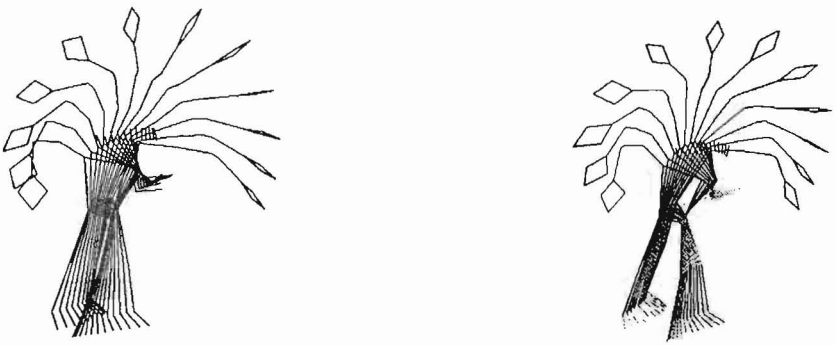


Figure 2. Angular velocity of left knee extension (time 0.0 is the moment of impact).



First Serve Second Serve

Figure 3. Right side view of the serves.

First Serve Second Serve

Figure 4. Front view of the serves.

A closer look at the fine structure of locomotions that the right leg movement is different. In the first flat serve, the pelvis has a powerful swing rotation (Figure 5), therefore the right hip has greater longitudinal displacement (see Figure 3). In the second topspin serve there is greater lateral body flexion thus exaggerated thigh adduction acts as counterbalance (see Figure 4).

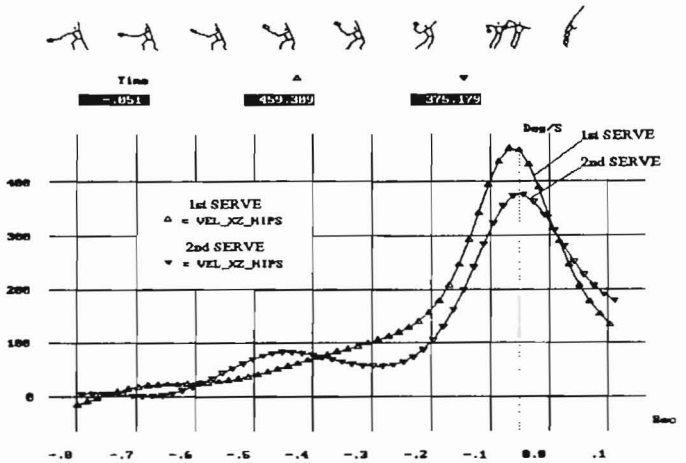


Figure 5. Angular velocity of hip rotation (time 0.0 is the moment of impact).

It also can be noticed that the changes in the height of the left shoulder at the final stage of the serve have opposite tendencies. In the first serve the height drops down and in the second serve the shoulder is rising up. Additionally, in the first serve the left shoulder has greater lateral displacement. These tendencies reveal pronounced trunk flexion and shoulder torsion in the first serve, and pronounced action of the trunk lateral flexors in the second serve.

No significant differences were found in right elbow extension during the first and the second serves. In both cases maximum elbow angular velocities (1185 ± 110°/s) occur at the same moment of time prior to impact (Figure 6). The phenomenon of the consistent motion of the right arm in both serves reveals that changes in body movements between first and second serves are mainly provided by leg and trunk muscles.

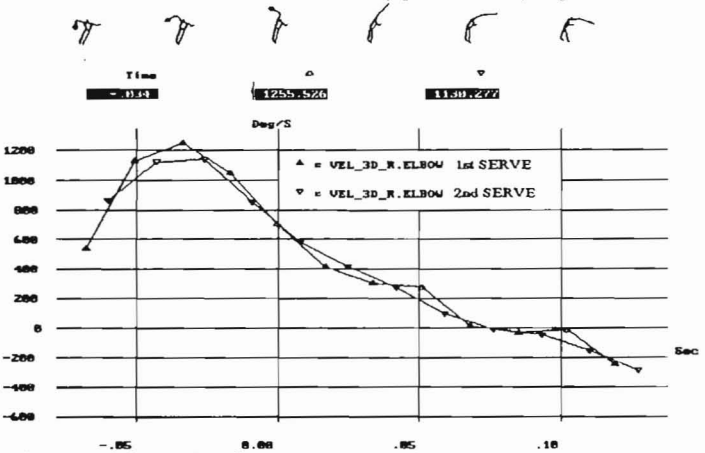


Figure 6. Velocity of the right elbow extension (time 0.0 is the moment of impact).

CONCLUSIONS

Comparison of the techniques employed in the two serves leads to the conclusion that fundamental distinction lies in the differences in movement of the CG and relative positioning of the ball at impact.

It was found that there are practically no differences of the right arm movement between first and second serve. The changes of motion pattern from the first to the second serve are mostly provided by torso and leg muscles which are larger and more stable than the arm muscles. Keeping the relative motion of the racquet holding arm constant increases reliability of the second serve.

The A. Agassi's "First Serve Formula" might be summarized as follows: active right knee extension, energetic pelvis and shoulder rotation and trunk flexion provide pronounced forward body motion, placing the point of the ball impact relatively high and forward from CG. This opens a good position for the aggressive and powerful serve.

The A. Agassi's "Second Serve Formula" is: dominant extension of the left knee with less influence by the hip and shoulder rotation, but with more notable lateral trunk action and shoulder tilting which provides the body's upward motion. That motion and placing the point of the ball contact over the left shoulder without forward shift supplies the ball with spin rotation.