

A REVIEW OF TENNIS SERVE BIOMECHANICS

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INTRODUCTION

Tennis is a sports played by millions of Americans. The tennis serve is perhaps the most important facet of the game, as a successful serve greatly increases the chance of overall success. Additionally, the serve is a skill that often results in various athletic injuries. Due to the aforementioned factors, there is an extensive body of scientific literature describing the biomechanics of the tennis serve. The purpose of this abstract is to briefly review five scientific studies that have considered the biomechanics of the tennis serve. The abstract will consider: 1) serve kinematics, 2) serve kinetics, 3) serve electromyography, and 4) the production of linear ball speed. To facilitate biomechanical analyses of the tennis serve, Morris et al. (1989) divided the serve into six separate phases: 1) wind-up, 2) early cocking, 3) late cocking, 4) acceleration, 5) early follow-through, and 6) late follow-through. These divisions have aided biomechanists in comparing data collected during various tennis serve studies.

KINEMATICS

Kinematics of the tennis serve have been described quite extensively. Among others, Fleisig et al. (2003), and Marshall and Elliot (1993) quantified tennis serve kinematics. Fleisig et al. (2003) observed serve kinematics during the singles competition at the 2000

Olympic games. Fleisig et al. (2003) classified the end of cocking and onset of acceleration as the most crucial instant of the serve. At this time, the elbow was flexed to 104° and the upper arm had rotated to an astounding 172° of external rotation. Also importantly, at this time the knee was approaching full extension. This knee flexion contributes to maximal racquet head rotational velocities. Maximal rotational velocity values for certain body segments are presented in Table 1. Additionally, Fleisig et al. (2003) explained that higher internal humeral rotation velocities, exhibited by the male sample, were the primary reason for greater mean ball velocities produced by the male sample.

Table 1. Maximal segmental angular velocities ($^\circ/s$) during the acceleration phase of the tennis serve, as reported by Fleisig et al. (2003).

| Segment | Velocity ($^\circ/s$) |
|----------------------------|-------------------------|
| Trunk Tilt | 280 |
| Upper Torso Rotation | 870 |
| Pelvis Rotation | 440 |
| Elbow Extension | 1510 |
| Wrist Flexion | 1950 |
| Shoulder Internal Rotation | |
| Male | 2420 |
| Female | 1371 |

KINETICS

Joint kinetics have also been documented during the tennis serve. In a sample of Olympic athletes, Elliot et al. (2003) reported shoulder and elbow joint

torques during the onset of acceleration and the ball-racquet impact. Several of the more impressive kinetic values reported by Elliot et al. (2003) are presented in Table 2.

Table 2. Shoulder and elbow torques (Nm) and shoulder forces (N) during the tennis serve, at the onset of acceleration, as reported by Elliot et al. (2003).

| Torque/Force, Joint | Male | Female |
|------------------------------------|-------------|---------------|
| Internal Rotation Torque, Shoulder | 64.9 | 37.5 |
| Compressive Force, Shoulder | 608.3 | 363.7 |
| Varus, Elbow | 67.6 | 41.3 |

ELECTROMYOGRAPHY

Muscle activity during the tennis serve for three anterior and four posterior shoulder muscles was quantified by Seeley et al. (2004). It was reported that all of the observed muscles were active during each serve phase. During the earlier phases of the tennis serve (early and late cocking), the pectoralis major was most active, indicating an eccentric contraction prior to the acceleration phase. During the latter phases of the serve (acceleration and follow-through), the posterior muscles (middle trapezius, infraspinatus, and posterior deltoid) were most active. This activity revealed an eccentric action on the part of the posterior shoulder musculature, in order to decelerate the rotating humerus.

BALL SPEED

Linear ball speed is likely the most important predictor for a successful tennis serve; this speed is affected by various body segments. Marshall and Elliot (1993) reported that the major contributors to linear ball speed were, in order of most important to least important, humeral internal rotation,

wrist flexion, upper arm horizontal flexion and abduction, and linear motion of the shoulder. Marshall and Elliot (1993) reported that the aforementioned humeral internal rotation accounted for more than 50% of the linear ball speed, while wrist flexion accounted for approximately 30%. Thus, it appears that in order to achieve increased linear ball speeds, the competitive tennis player should focus on muscle groups that facilitate increased internal humeral rotation and wrist flexion. Additionally, although shoulder and wrist musculature contribute to increased ball speed, Elliot et al. (2003) emphasized the importance of significant lower-extremity contributions to linear ball speed.

SUMMARY

The tennis serve is a commonly performed athletic skill and has received some attention in the scientific biomechanical literature. Serve kinematics, kinetics, electromyography, and ball speed have all been observed. It appears that during the tennis serve, the greatest forces and moments are applied at the shoulder joint. Also, the lower-extremities are important to the successful performance of the tennis serve.

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