JOINT TORQUE AND POWER OF THE ARM AND TORSO IN TENNIS FOREHAND GROUND STROKE FOR WORLD-TOP FEMALE PLAYERS

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INTRODUCTION

Forehand ground stroke is a most frequently used technique in tennis games, and also one of the most difficult stroke techniques (Braden, 1998). The number of biomechanical analyses on forehand ground strokes has increased (Blieverricht, 1968; Elliott et al., 1989; Elliott et al., 1997). However, we have still little information of three-dimensional kinetics of the upper limb during the forehand ground stroke, and no quantitative data taken from top players. It is useful for an effective method of instruction of the stroke technique and the improvement in the player's forehand ground stroke technique to investigate the forehand ground stroke mechanics of top players.

The purpose of this study was to investigate three-dimensional kinetics of the arm and torso during forehand ground strokes of the world-top female tennis players in official games.

METHODS

Forehand ground strokes of world-top female players were videotaped with two high-speed VTR cameras operating at 200Hz during official games. Area covered was deuce court, 5.485m (from center mark to the doubles sideline)×4m (±2m from the baseline)×2.47m (height). World-top female players selected for analysis were S. Graf, A. Huber, K. Date, A. Flazier, N. Sawamatsu, A. Sugiyama, N. Kijimuta. They all were right-handed. Six forehand ground strokes hitting ball to the cross-court direction were chosen in each player. Three-dimensional coordinates of the body segment endpoints, the racket and ball were obtained by using a DLT method. The three-dimensional coordinates were smoothed with Butterworth digital filter, and were used to calculate the joint angular velocities, the joint torques and the joint torque powers of the arm and torso.

The joint torques were computed on a link segment model consisted of racket, the forearm, upper arm and torso. The joint angular velocity and the joint torque were converted to the segment coordinate system fixed to each segment and torso. The joint torque power was calculated as the product of joint angular velocity and joint torque.

RESULTS AND DISCUSSION

Fig. 1 shows the patterns of joint torques (left column) and joint torque powers (right column) of the wrist, elbow, shoulder and torso for S. Graf during the forward swing phase, from maximum backward rotation of the torso to impact. Fig. 2 shows the patterns of joint angular velocities of the shoulder (left figure) and torso (right figure). Data in forehand ground stroke were normalized by the time of the forward swing phase and averaged on six forehand ground strokes.

The palmar flexion and radial flexion torques at the wrist joint and the flexion and pronation torques at the elbow joint were generated and reached the peaks about 25% time before the impact. The varus torque at
the elbow joint and the internal rotation torque at the shoulder joint were generated during the forward swing phase and reached the peaks about 40% time before the impact. However, the shoulder adduction and extension torques showed the maximum just before the impact. In the torso, the remarkably great extension torque was generated during the second half of the forward swing phase. The peak of the torso extension torque was the largest (ca. 210Nm), followed by the left flexion torques (ca. -100Nm). The peaks of joint torques appeared from the torso to the distal joint during the forward swing phase. These results support a proximal - distal kinetic chain principle, and indicate that the torso plays an important role in forehand ground stroke as a torque generator to increase the mechanical energy of the segments.

Although the palmar flexion torque was seen before the impact, the wrist joint torque and joint torque power were very small at the impact. The extension/flexion and pronation/supination torques at the elbow joint were also small at impact. Minute torques of the wrist and elbow joints at the impact can be interpreted as a result that both agonists and antagonists of these joints might generate equal torques in magnitude to fix the wrist joint at the impact or to adjust the racket movement, since EMG studies showed the simultaneous activities of the muscles about the wrist and elbow joints at the impact.

In the shoulder joint, the internal rotation torque power and the internal rotation velocity were very large during the second half of the forward swing phase. Furthermore, the adduction and extension torques rapidly increased just before the impact. These results indicate that the internal rotation torque was useful to accelerate the forearm and the racket toward the impact during the forward swing phase, and the adduction and extension torques just before the impact were used to keep the racket close to body.

In the torso, the positive joint torque power produced by the left rotation torque during the forward swing phase contributed to rotate the torso counterclockwise toward the hitting direction. The large extension torque but small extension velocity of the torso indicate that the torso extension torque may be generated to keep the torso in an appropriate position during the second half of the forward swing phase where the reaction force will be applied to the hip by the stride leg. This suggests that the muscle strength in the hip extensors is one of factors to improve forehand ground stroke technique.

REFERENCES
Fig. 1  Changes in joint torque and torque power of the wrist, elbow shoulder and torso during the forward swing phase for S. Graf

Fig. 2  Changes in joint angular velocity at the shoulder and torso during the forward swing phase for S. Graf