# KINEMATICS OF UPPER LIMB AND TRUNK IN TENNIS PLAYERS USING SINGLE HANDED BACKHAND STROKES

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**INTRODUCTION:** The technique of the tennis single-handed backhand drive still has the function of defense, even it doesn't offer a good offensive function in the game. However, it is difficult for the tennis beginner to learn this technique very well. More than 90 percent of tennis elbow results from improper movements of the tennis single-handed backhand drive (Hang & Peng 1984; Ellenbecker, 1995). In order to increase ball velocity or control the path of the ball, a spinning ball is necessary. The shoulder, elbow and wrist joints are involved in the movement of rocketed acceleration at impact (Peterson, 1987). Understanding upper extremity joint movements during the tennis single-handed backhand drive will provide a correct swing pattern for tennis players to improve their skills and adjust the factors that produce injuries.

**METHODS:** In the kinematic model, the trunk, upper arm, forearm and hand were treated as a four-segment linkage system. For the spatial kinematic description, each segment was treated as a rigid body and each joint was assumed to be of the ball and socket type. Sixteen markers were unilaterally placed on selected anatomic landmarks to define the coordinate system of trunk, pelvis, upper arm, forearm and hand. The selected anatomic landmarks were processes xiphoideus, sternal notch, spinous process of the 7th cervical vertebra, acromin process, medical and lateral epicondyles of the elbow, radical and ulnar styloid processes, Knuckle and Knuckle V, anterior superior iliac pine, and posterior superior iliac pine. In addition, a triangular frame with three-marks was placed on the upper arm. The positions of the markers on the medial and lateral epicondyle during the tennis single-handed backhand drive were calibrated using the local vectors with respect to the triangular frame on the upper arm in an anatomically neutral posture. This was done in order to avoid errors resulting from skin movements.
The rotation matrix used to describe the orientations of objects could be formulated based on these coordinate systems. The orientation of a distal segment coordinate system relative to a proximal segment coordinate system was used to describe the joint movement by

$$R_j = R_p^{-1} \times R_d$$

Where $R_j$ is the rotation matrix of joint movement in the global coordinate system and $R_p$ and $R_d$ are the rotation matrices of the proximal and distal segments.

To systemically describe the joint movements, the joint reference position was defined as that joint position that exists when the body is in the anatomical posture. The rotation of joint movement was modified as:

$$R = R_j \times ({}_oR_j)^T$$

Where $R$ is the rotation matrix of the joint movement based on the anatomical posture and ${}_oR_j$ is the rotation matrix of the joint reference position.

Euler angles were used to describe the orientation of a distal segment coordinate system relative to a proximal segment coordinate system. The first rotation about the y axis represents the flexion/extension angle ($\alpha$). The second rotation about the x' axis represents the adduction/abduction angle ($\beta$). The third rotation about the z" axis represents segmental axial rotation ($\gamma$).

**Experiment:** Six Taiwan University tennis team members were recruited in this study. The ExpertVision system with six cameras (Motion analysis Corp., Santa Rosa, CA ) was used to collect the position of all reflective markers at 60 Hz while the subject performed tennis single-handed backhand drives. Ten trials were sampled for each subject. Each trial lasted for 5 seconds, with 3 minutes rest between trials. The positions of the markers were smoothed using a generalized cross-validation spline smoothing (GCVSPL) routine (Woltring, 1986) at a cutoff frequency of 6 $H_z$. A customized program in MATLAB language was written for the calculation of joint movements.

**RESULTS AND DISCUSSION:** The results of the joint movements of trunk, shoulder, elbow and wrist joints are shown in Figure 1. In the acceleration phase, the major movement of the trunk was left bending for balancing the body and enlarging the space of the forward swing. The major movement of the shoulder joint was abduction for speeding up the racket. The elbow began to extend from the initial acceleration and reached the maximum value immediately after impact. The wrist also extended and reached the maximum in the later acceleration before impact. Then the wrist movement changed to flexion and radial/ulnar deviation in order to control the direction of the racket for the proper impact. In the follow-through phase, the major movements of the trunk were right bending and right rotation. The major movements of the shoulder joint were flexion and abduction, and the major movement of the forearm was supination for controlling the rotation of ball. The elbow joint was kept near full extension position throughout the follow-through phase. After impact, the wrist continued its extension in order to control the direction of the ball in the follow-through phase. The results showed that the major movements of shoulder joint were abduction/adduction (73.6±11.5°), flexion/extension (45.7±20.2°), and internal/external rotation (46.3±13.7°). The major movement of the elbow was flexion/extension (35.3±14.4°). The major movements of wrist were flexion/extension (39.6±20.8°) and radial/ulnar deviation (46.8° ± 18.3°). At the end of acceleration phase, the elbow extension velocity, the velocity of shoulder external rotation and adduction rapidly increased to speed up the ball (Figure 2). At the same time, the wrist extension velocity rapidly changed to control the direction of the racket for precise impact.

**CONCLUSIONS:** In the acceleration phase, the trunk moves with the racket to increase angular momentum for the preparation of the impact. During this period, the movement of the shoulder is small. When the maximum angular velocities of the shoulder external rotation, elbow extension and wrist extension occur at the instant prior to impact, they then decrease promptly. In this way, the hyperextension of the wrist joint, the cause of tennis elbow, may be prevented. The results may provide the basic guidelines for tennis training and tennis evaluation.

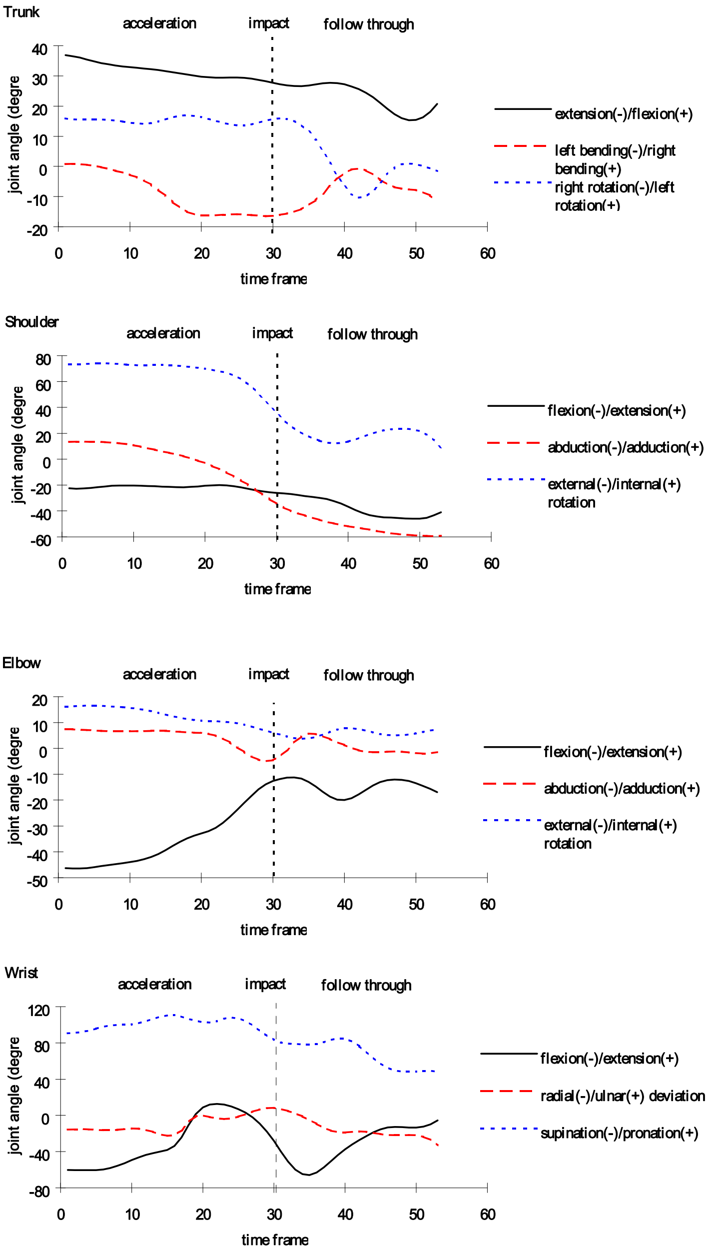


Figure 1: Joint movements of trunk, shoulder, elbow and wrist joints

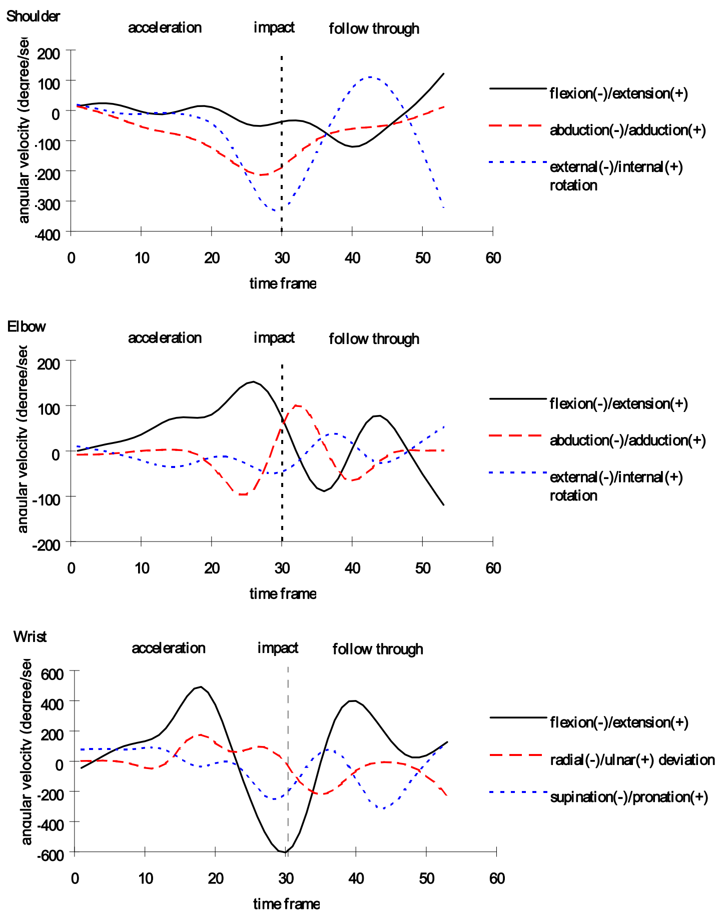


Figure 2: Joint angular velocity of shoulder, elbow and wrist joints

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