KINEMATICS ANALYSIS ON THE FOREHAND STROKE OF ATP TENNIS PLAYER KAREN KHACHANOV

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Three-dimensional video analysis was used to examine the forehand stroke technique of the ATP tennis player, Karen Khachanov. The study provides a reference for all tennis learners to improve their forehand stroke. In preparation, Khachanov's center of gravity was lowered, and his body control was steady. In the swing, his racquet arm was fully extended, to increase the swing radius. His right leg was the support point for the swing stage. Notable in the swing stage motion was his driving leg action and full hip rotation, the whole hitting action typical of a whipping movement. The follow-through was natural, coordinated, and smooth.

KEYWORDS: kinematics, tennis forehand, leg action, hip rotation

INTRODUCTION: This paper used three-dimensional video analysis method to examine the forehand stroke of the ATP tennis player, Karen Khachanov. Kinematic data obtained in competition was the basis of the kinematics analysis and description of the forehand movement model.

METHOD: Three-dimensional video analysis: Two JVC-GC-PX10AC high-speed cameras (50 fps) were used in the International ATP250 Chengdu Open 2016 to record forehand strokes. The axis of the two cameras was about 50° apart. The selected video was the last forehand stroke in the 2nd point of the first games first set in which he won the point. The selected video was analysed using the 3-D Signal TEC V2.0C analysis system. The Dempster manikin with 16 links, 21 joint parameters, was used in body motion analysis, adding the racket as a segment for the study. A low-pass filter was used for smoothing point data. Kinematic variables were determined at critical points in the stroke; end of preparation, end of backswing, swing stage, contact with the ball, and end of follow through

RESULTS: Analysis of the backswing stage: At the end of preparation, the center of gravity (CG) height was 0.92m, compared to his normal CG height, 1.20 m, lower by 0.28m. Lower limb joints were flexed to lower the CG. At that time, the left and right hip joint angles were 123.6°, 121.6°. The left and right knee joint angles were 125.3°, 108.9°, and the left and right ankle joint angles were 98.5°, 101.6°. The hip, knees and angles were bent, body control was steady, and compared to his left knee joint angle, the bent angle of his left knee joint was larger, according to the data. All these indicate that at the time of after preparation, the player already knew the ball coming from his competitor would point to his own forehand position. Therefore, his body adjusted in a short time, and stayed in a relative lower CG to finish all following movements better. His right shoulder joint angle and elbow joint angle were 30.3°, 124.4°, and the racket-forearm angle was 106.3°, which means the racket wrist joint was naturally bent at that time.

Table 1. Parameters about the end of preparation

Center of gravity (m)	Right shoulder (°)	Right elbow (°)	Racket forearm (°)	Hips (°)		Knees (°)		Ankles (°)	
				Left	Right	Left	Right	Left	Right
0.92	30.3	94.4	106.3	123.6	121.6	125.3	108.9	98.5	101.6

Table 2. Parameters about the end of backswing

Center of gravity (m)	Right shoulder (°)	Right elbow (°)	Racket forearm (°)	Hips (°)		Knees (°)		Ankles (°)	
				Left	Right	Left	Right	Left	Right

0.87	79.4	149.5	136.8	144.8	131.5	132.6	112.1	88.7	81.5

At the end of backswing, the right shoulder joint angle and right elbow joint angle were 79.4°, 149.5°, and the racket-forearm angle was 136.8°. Related research (Yang and Zhou, 2015) pointed out: The angle of right shoulder and elbow shows the player's hitting-arm stretch state at the end of backswing, compared to the trunk; At this moment, the right shoulder and the right elbow joint's angle of Andy Murray were 46.5°, 136.53°. That means at this moment, hitting-arm of the joints stretched fully and lead to the larger swing radius. At the end of backswing, Khachanov chose the semi-open stance, and his left and right hip joint angles were 144.8°, 131.5°; the left and right knee joint angles were 132.6°, 112.1°, and the left and right ankle joint angles were 88.7°, 81.5°, the set of data shows that Khachanov used his right leg as the main supporting function at this moment. The height of Khachanov's CG was 0.87m, compared with the after preparation time's CG, which was 0.92 m; the CG lower by 0.05 m. The main reason was Khachanov deliberately to keep the CG focus on the right leg. Wang (2014) showed that the strength of forehand stroke comes from the ground, the right knee fast forceful extension to promote the formation of angular momentum, knee angular momentum deliver to the hip, shoulder, elbow, wrist and then get through racket head to form a complete power chain system. In the process, nevertheless, the premise of right knee fast forceful extension was that the CG near to the right leg. Therefore, through the kinematic parameters of the lower limbs show that Khachanov's whole body CG was close to the right leg, which means established the advantageous condition for the next stage of hitting the ball.

Analysis of the forward-swing stage: At the moment of touching the ball, the height of Khachanov's CG was 0.94 m, the right shoulder joint, right elbow joint and racket-forearm angle were 62.3°, 107.1° and 105.4°. Through these data and combined with the video record we can see that: in this stroke, Khachanov's control of the starting point was appropriate, which was an important prerequisite for this stroke to complete the winning points. At the same time, the data show that Khachanov's the left and right hip angle were 157.8°, 166.8°; the left and right knee angle were 165.0°, 154.6°, the left and right ankle angle were 124.2°, 115.0°. Khachanov's two knees are still in the buckling state, the height of the CG was still lower than the standing position; observed from the Y-X plane, the projection point of the CG in the left foot horizontal position, showed that Khachanov had a significant leg kick his leg and hip rotatation, and the action means the CG was rapidly moved.

Table 3. Parameters about the moment of contact the ball

Center of gravity (m)	Right shoulder (°)	Right elbow (°)	Racket forearm (°)	Hips (°)		Knees (°)		Ankles (°)	
				Left	Right	Left	Right	Left	Right
0.94	62.3	107.1	105.4	157.8	166.8	165.0	154.6	124.2	115.0

Table 4. Parameters about the swing stage （m/s）

Center of gravity	Right knee	Right hip	Right shoulder	Right elbow	Right wrist	Racket head
0.86	1.32	1.47	2.68	5.46	11.21	22.61

Data shows that at the moment of touching the ball, Khachanov's right knee speed was 1.32 m/s, the right hip speed was 1.47 m/s, which also demonstrated that he thrust the hips and rotated his whole body significantly in the process of Swing stage. Furthermore, Table 4 also showed: his right shoulder joint, right elbow joint, right wrist joint and racket head speed were respectfully 2.68 m/s, 5.46m/s, 11.21 m/s and 22.61 m/s . From that, the proximal end of the link to the speed of the speed increases at the moment of touching the ball, the head speed was 22.61 m/s, the technical action keep in line with the principle of whipping.

Analysis of the follow-through stage: At the end of the follow through action, the right shoulder, right elbow angle were 84.5°, 106.8°, which means his shoulder and elbow were bent naturally. Shoulder-hip angle was 76.3°, indicated that Khachanov made full use of the rotational torque generated by his twisted torso, to assist the shoulder action, and increase the role of this racket on the ball time, and then increase the power of distance. The left and right knee angles were 139.2°

and 115.0°, the left and right ankle angles were 113.5° and 119.5°, and the CG was 0.97 m. By observing the original video, with the end of the follow through action, Khachanov's lower limbs have completed the buffer action, then enter the next stroke action.

Table 5. Parameters about the end of the follow-through

Center of gravity (m)	Right shoulder (°)	Right elbow (°)	Racket forearm (°)	Hips (°)		Knees (°)		Ankles (°)	
				Left	Right	Left	Right	Left	Right
0.97	84.5	106.8	76.3	167.7	177.2	139.2	115.0	113.5	119.5

DISCUSSION: The back-swing stage: At the end of the preparation, Khachanov's hips, knees, ankles joints were bent and bent to similar size, body control was more stable; compared to the height of normal anatomical body, his CG height was lowered 0.28 m, with body CG kept a low position, ready for the back position. At the end of the backswing stage, Khachanov's right shoulder, right elbow joint angle were 79.4°, 149.5°, racket-forearm angle was 136.8°, that means the articulation of the joint arm was more fully and the waving radius was larger; From his hips, knees, ankles angle can be seen, that right lower limb flexion was more obvious, the right leg forming the main support role for the next stage of the leg to establish the basis for his rotated hips.

The forward-swing stage: At the moment of contact the ball, Khachanov's CG height was 0.94 m, the right shoulder joint, right elbow joint and the knee arm angle were 62.3°, 107.1° and 105.4°, respectively. through the data with the video recording, we can see that during the stroke process, Khachanov controlled the starting point; he rotated his hips adequately; the right shoulder, the right elbow, the right wrist joint and the head speed respectively, 2.68 m/s, 5.46 m/s, 11.21 m/s and 22.61 m/s, the proximal end to the distal end of the speed increases, in line with the principle of whipping.

The follow-through stage: At the end of the follow-through, Khachanov's lower limb joints were still bent, the CG height was 0.97 m, the body control is smooth; the shoulder hip angle was 76.3°, making full use of the torso torque generated. The shoulder action is, at the same time, increasing the role of racket on the ball time, and increaing the work distance of racket on ball. The forehand stroke of Khachanov was a high quality hitting action.

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