The Kinematics Analysis of Wu Yibing's Tennis Forehand Technique

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Abstract. Objective: Search for the forehand swing stroke technical characteristics and kinematics rules of the outstanding young men's tennis players in the world. It provides some theoretical basis of Tennis forehand technique for tennis coaches and athletes. Research object: The world's elite teenage male tennis player Wu Yibing. Research methods: Using two JVC GC-PX10AC high-speed cameras (50 frames per second), the scene of the 2017 international tennis federation youth masters competition was filmed in the field. And the video recorded in the field was analyzed with a 3-D Signal TEC V2.0C software. Conclusions: (A) In the stage of the backswing: Wu Yibing's shoulder and hip angle has been obviously reversed. He uses his elbow to guide the tennis racket to lead the whole movement smoothly and form an “arc”. Wu Yibing's right wrist, elbow and shoulder keep a certain linear velocity, increasing the racket acceleration time and space. And the process of the traditional forward swing acceleration is extended to the backward stage.(B)In the stage of hitting the ball: Wu Yibing's shoulder and hip angle has been obviously reversed. To gain more control to counteract the impact of the ball, his right shoulder joint remains a small angle to reduce the radius. In tennis racket contact ball moment, the right shoulder joint and right hip joint linear velocity were 0.94m/s and 1.06m/s respectively. The right wrist and elbow joint linear velocity achieve a high standard of 11.81m/s and 5.56m/s respectively. (C)In the stage of the follow up: Wu Yibing's body center of gravity is not moving forward and the body's center of gravity is slightly undulating. However, his body's moving to the left is obvious. His right shoulder angle changes a little and the elbow lifts a little, but the right elbow is in the substantial rotation around the torso to the left. To increase the friction of the racket to the ball, there is a reacceleration of Wu Yibing's right elbow after the racket touches the ball. And his right elbow is rapidly spinning with a twist of the wrist. So he can play a powerful upper spin ball.

Objects and Methods of Research

Research Objects
Wu Yibing: born in 1999, Chinese men's tennis players, now ITF teenagers, ranked first in the world.

Research Methods

3D Camera Analysis Method. Two JVC GC-PX10AC high-speed cameras (50 frames per second) were used to record Wu Yibing's forehand stroke technique in the field of the 2017 international tennis federation youth masters competition. In this paper, the forehand stroke technique is defined as the forehand stroke of the athletes trying to gain advantages through returning the ball speed and depth. The 3-D Signal TEC V3.2HDC analytical system developed by Beijing Sen Miao Xin has been used to analyze the video of the forehand stroke technique. When analyzing, we select the Songjing human body model of Japan (16 links, 22 joint point parameters). Because of the need of research, two test points (tennis racket, tennis) are added when parsing. At the same time, the data is analyzed step by step, and the data are smoothed by low - pass digital filtering method. The truncation frequency is 8 Hz. Therefore, the kinematics parameters such as joint angle and linear velocity of the motion technique are obtained.

The Division of the Action Phase. According to the points of the tennis forehand stroke technique and the frequency of the camera, Wu Yibing's forehand stroke action is divided into three stages. From the end of preparation moment to end of backswing stage moment (In the stage of the backswing), from the end of backswing stage moment to hitting the ball moment (In the stage of
hitting the ball). from the racket touching the ball moment to the end of the swing (the stage of in follow up ).

Results, Analysis and Discussion

Analysis of Kinematic Parameters at the Stage of the Backswing

Wu Yibing’s right hand grip is a half western grip and semi-open position. From the end of preparation moment to end of backswing stage moment. Wu Yibing mainly presents the movement of the swing the back of the body. The rotation amplitude of the shoulder and hip angle was 42°. The related muscles of the waist, abdomen, chest and shoulder are fully prestretched in order to reserve more elastic potential energy. At the end of backswing stage moment, Wu Yibing’s body center of gravity is lower near the right side of the body and the right leg plays a major supporting role. His right knee joint angle is 142° and the right hip joint angle is 98°. He used his elbow to guide the tennis racket to lead the whole movement smoothly and form a “arc”. Right shoulder angle is 71°, right elbow angle is 138°. The structure provides a very good attitude towards the ball. To create conditions for the stage of hitting the ball. In the stage of the backswing time is 0.25s. At the end of backswing stage moment, the right hand wrist linear velocity is 3.72m/s, the right elbow joint linear velocity is 1.04m/s and the right shoulder linear velocity is 1m/s. Through the analysis, we find at the end stage of backswing and at the initial stage of hitting the ball, Wu Yibing’s right wrist, elbow and shoulder maintain a small linear velocity. As shown in Figure 1, it actually increases the racket acceleration time and space and the process of the traditional forward swing acceleration is extended to the backward stage. In the late stage, the slow motion of body movements have two functions, one is to regulate the accuracy of hitting, and the other is to keep the arm muscles in a relaxed state. So that the muscle has a good reflexes after the last beat and forward.

![Figure 1. Right elbow and right shoulder, right hand wrist line velocity curve.](attachment:figure1.png)

Analysis of Kinematic Parameters at the Stage of Hitting the Ball

Wu Yibing's racket swings the ball with a time of 0.46s and the time of the hitting stage is 0.21s, The shoulder hip angle turns 54°. It can explain that his body has a fast and large scale of rotation. Before the racket swings the ball, the torso is in a certain stretch and a larger elastic potential energy, which plays an important role in the subsequent batting. The moment Wu Yibing's racket swang the ball, his right shoulder angle, right hip angle and elbow joint angle were 61°, 108°and 150° respectively. From the curve of the angle change of the right shoulder joint in Figure 2, we can find that Wu Yibing's right shoulder joint is always keeping a smaller angle, so as to reduce the radius to get more control to counteract the impact produced by the reaction of the ball. Through
three dimensional video analysis, it is found that Wu Yibing hit the ball late and the batting point was slightly closer to the body, causing a slight backward movement of the body's center of gravity. The moment Wu Yibing's racket swung the ball, the low linear velocity of the right shoulder joint and the right hip joint were 0.94m/s and 1.06m/s respectively. But his right wrist and elbow joint linear velocity has reached a very high standard for 11.81m/s and 5.56m/s respectively. However, playing a powerful topspin needs the right elbow spin quickly to pull the wrist. Therefore, when the racket touches the ball, the racket head can still reach 22.38m/s.

**Analysis of Kinematic Parameters at the Stage of the Follow Up**

From Figure 3: the movement of the body center of gravity in a multiple stick diagram, it can be found Wu Yibing hit the ball late and the batting point was slightly closer to the body, causing a slight backward movement of the body's center of gravity. So In the stage of the follow up Wu Yibing's body center of gravity is not moving forward, the body's center of gravity is slightly undulating. However, his body's moving to the left is obvious. At the moment Wu Yibing's racket touch the ball, his right shoulder angle and elbow angle were 58° and 145° respectively. The maximum angle of the right shoulder joint and the minimum angle of the elbow joint were 78° and 40° respectively in the follow-up stage. It can explain his right shoulder angle changes very little and the elbow lifts a little, But the right elbow is in the substantial rotation around the torso to the left. It conform to that principle of swinging with wave motion and long distance. The moment the racket touches the ball at 0.46s, It can be found through Figure 4 and Figure 5: after Wu Yibing's racket touching the ball within 0.1s after right elbow speeding up again, his right elbow joints quickly turn 83°. To increase the friction of the racket to the ball, the right elbow is rapidly spinning with a twist of the wrist. It's why he can play a powerful upper spin ball. At this stage, Wu Yibing balanced the whole body better, and the torso and each link maintained good rotation speed and buffer effect.

![Figure 2. Curve of angle change of right shoulder joint.](image)

![Figure 3. Multiple stick diagram (The movement of the body center of gravity).](image)
Research Conclusions

Wu Yibing's technical features are summarized as follows:

(a) At the stage of the backswing: Wu Yibing's shoulder and hip angle has been obviously reversed. He used his elbow to guide the tennis racket to lead the whole movement smoothly and form an “arc”. At the end of the backswing stage moment, the right hand wrist linear velocity is 3.72m/s, the right elbow joint linear velocity is 1.04m/s and the right shoulder linear velocity is 1m/s. Wu Yibing's right wrist, elbow and shoulder keep a straight linear velocity, increasing the racket acceleration time and space, will accelerate the process of front swing extends forward to back stage.

(b) At the stage of hitting the ball: Wu Yibing's shoulder and hip angle has been obviously reversed. To gain more control to counteract the impact of the ball, his right shoulder joint remains a small angle to reduce the radius. In tennis racket contact ball moment, the right shoulder joint and right hip joint linear velocity were 0.94m/s and 1.06m/s respectively. The right wrist and elbow joint linear velocity achieve a high standard of 11.81m/s and 5.56m/s respectively.

(c) At the stage of the follow up: Wu Yibing's body center of gravity is not moving forward and the body's center of gravity is slightly undulating. However, his body's moving to the left is obvious. His right shoulder angle changes a little and the elbow lifts a little, but the right elbow is in the substantial rotation around the torso to the left. To increase the friction of the racket to the ball,
there is a reacceleration of Wu Yibing's right elbow after the racket touches the ball. And his right elbow is rapidly spinning with a twist of the wrist. So he can play a powerful upper spin ball.

Reference

