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KINEMATIC ANALYSIS OF ELITE MALE TENNIS PLAYER'S STEP MOVEMENT FOR RETURN OF SERVICE

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A three-dimensional camera analytic method was used to make kinematic analysis on three players' step movement for return of service in finals and semi-finals of the ATP Champions Tour. The movements were broke down to three stages (preparation stage, skip step stage, stroke stage) for analyzing the kinetic parameters. Then the kinematic characteristics of elite tennis player's step movement for return of service were derived, to serve as reference for skill training and tennis matches. It was found that: in the preparation stage, Sampres, Aynaoui and Moya have an average horizontal angle between the feet of 12.1deg., 2.2deg., 45.6deg.respectively. In the stroke stage, the travel distances of Sampras and Moya were found to be greatly differed (0.892m and 0.667m respectively), and move faster (2.23m/s and 1.96m/s respectively).

KEY WORDS: men; step movement; kinematics; tennis

INTRODUCTION: In modern tennis, the return of serve is of great importance in the game. The serving side is in a more advantageous position, so the receiving side has to be able to break the opponent's serving game to come out top. One of the ways to gain initiative in the opponent's service game is to improve the quality of return of service. The key factor to win in the return of service is the fast, flexible and exact step movement. Therefore, the study of step movement for return of service in tennis shows great significance.

Great athletes have technical characteristics conform to bio-kinetic principles. Therefore, analysis of great athletes' movement technicalities is of significance in finding structural technical characteristics. Through studies of relevant materials, it is found that the current emphasis in training in both domestic and international scenes is on general techniques related to returns of serve and training, less on analysis of the movement of the feet during the game, for example, stroke analysis during serve and return of serve, analysis of movements and manoeuvres. "The initial movement in a tennis game is like step adjustments in long jumps "(Yaying Zhao, 2011). "The position a player in when receiving a serve and the adjustment made in response to the way the opponent serve, is of significant importance." (Bao Qin, 2005 SEP). "Sluggishness in movement would hinder the exertion of technical capabilities" (Xu Wang & Biao Zhao, 2012 Jul.). A three-dimensional video analysis during the 2011 Chengdu ATP Tour final and semi-final games of three athletes was conducted, and sporting behaviors of great athletes were studied, providing a useful reference for tennis training.

METHODS: Two JVC9800 cameras (50fps) were used to make three-dimensional fixed-point shooting (see positions of cameras in Fig. 1) on the player's returns of service in Chengdu ATP Tour, and the camera footage of three returns of service of each player were selected, from the champion Pete Sampras, the second placed Younes El Aynaoui and the third placed Carlos Moya. The selection standard is as follows: a. the position for return of service being in the same area; b. one service is received; c. the action to receiving the service is sliced backhand; d. the return of service being successful. Hitachi 3-D Signal TEC V2.0C (three-dimensional camera analytic system) software was used to analyze the return of service. The arrangement of coordinate system is found in Fig. 2. The mannequin of Japanese Matsui Hideharu was chosen (16 joints, 21 arthroses). Due to the fact that the footages were recorded in 50Hz, the instances when the ball hit the racket were not captured. In the post-processing stage, interpolation was done to produce a footage of 100Hz. Low-pass filtering smoothing treatment was used to optimize on the raw data, with a

truncation frequency of 8 Hz. After interpolation and filtering, the data sample between the two consecutive frames one before and one after hitting the ball were referred to as the sample at the instance when the ball was hit.

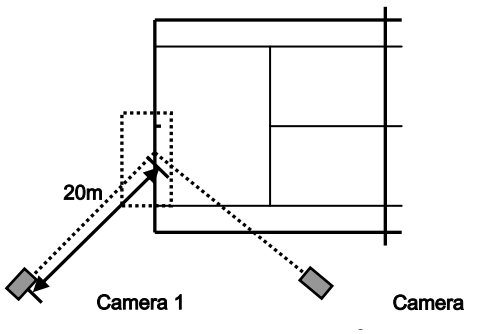

Fig.1 Sketch map of camera

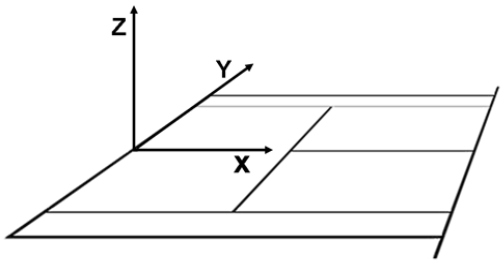

Fig.2 Sketch map of coordinate system

RESULTS AND DISCUSSION: Step movement for return of service in tennis is a general term for various actions adopted by player to control body, and change position, direction and speed. The actions are divided into three stages, so as to analyze the main kinematic parameters.

Analysis of preparation stage: The preparation stage refers to the period from the time that player chooses suitable stance and prepares well to receive a service to the time that the player takes one foot off from ground when beginning to move the step.

Table 1
Comparison of player's step characteristics in the preparation stage

Player	Horizontal angle between both feet (deg.)	Distance between both feet (m)	Period for preparation stage (s)
Sampras	12.1	0.465	0.62
Aynaoui	2.2	0.874	0.54
Moya	45.6	0.583	0.60

It can be concluded from Table 1 that, in this stage, the average horizontal angles between both feet of Sampras, El Aynaoui and Moya are 12.1 deg., 2.2 deg. and 45.6 deg., respectively, and the distances between both feet are 0.465m, 0.874m and 0.583m, respectively. It shows that Sampras and El Aynaoui have the approximately same stance, with both feet nearly in parallel, while Moya has the slightly larger angle between both feet. Distance between both feet is affected by height of player. The distance for Sampras is relatively smaller. The stance for return of service is considered best if it allows quick start, which has small influence on return of service.

Analysis of skip step stage: The skip step stage is the period from the time that player takes one foot off from ground to the time that the player lands with both feet after skip step before the stroke.

Table 2
Comparison of player's step characteristics in the skip step stage

Player	Maximum jumping height in skip step (m)	Distance between both feet after skip step (m)	Horizontal moving distance of left foot(m)	Horizontal moving distance of right foot(m)	Moving period (s)	Average moving speed of the left foot(m/s)	Average moving speed of the right foot(m/s)
Sampras	0.101	0.832	0.501	0.237	0.44	1.139	0.539
Aynaoui	0.175	1.001	0.400	0.382	0.30	1.333	1.273
Moya	0.091	0.746	0.437	0.314	0.89	0.491	0.353

There information shows that the height of skip step shall not be more than 0.15m, and the distance between anterior soles of both feet shall be slightly wider than shoulder width when landing on the ground. It can be concluded from Table 2 that, in this stage, the maximum jumping heights of Sampras, El Aynaoui and Moya are 0.101m, 0.175m and 0.091m, respectively, and the distances between both feet are 0.832m, 1.001m and 0.746m, respectively. The jumping heights of Sampras and Moya are reasonable, but El Aynaoui's jumping height is slightly higher, which influences the quality of service.

After the skip step, the horizontal moving distances of left foot for Sampras, El Aynaoui and Moya are 0.501m, 0.400m and 0.437m, respectively. All the distances for the three persons are longer than the horizontal moving distances of right foot, especially Sampras. The average moving speeds of left foot are 1.139 m/s, 1.333 m/s and 0.491 m/s, respectively. El Aynaoui's moving period is the shortest (0.30s).

Analysis of stroke stage: Stroke stage is the period from both feet of player being landed on the ground after the skip step is over to one foot of player being landed after the stroke.

Table 3
Comparison of step characteristics of players in the stroke stage

Player	Stance	Horizontal movement distance of left foot (m)	Moving period (s)	Average moving speed of the human body (m/s)	Step amount of moving
Sampras	Open	0.892	0.40	2.23	1
Aynaoui	Open	0.141	0.38	0.37	2
Moya	Open	0.667	0.34	1.96	1

Table 3 shows that: the moving distances of left foot of Sampras and Moya are greater (0.892m and 0.667m respectively); when the elapsed time is equal, the moving speed of their feet is faster, and the centre of body quickly followed and they could hit the ball in one step while El Aynaoui needs two steps. This shows that a player needs to prepare well the following adjustment action, so that he/she can prepare in advance to ensure center of gravity of body and the movement of step is accurate. The distance from the body to the ball should be appropriate, and this is easier to swing the racket to hit the tennis ball effectively. The player can improve the effect of return of service only by doing so. The moving speed of Sampras and Moya are also faster, being 2.23m/s and 1.96m/s respectively.

CONCLUSION: There are no special requirements on the body posture when doing stance in the preparation stage, as long as the stroke posture can be formed rapidly. The average horizontal angles between the two feet of Sampras, El Aynaoui and Moya are 12.1 deg., 2.2 deg. and 45.6 deg. respectively, and the distances between the two feet are 0.465m, 0.874m and 0.583m respectively.

In the skip step stage, the maximum jumping heights of Sampras, El Aynaoui and Moya are 0.101m, 0.175m and 0.091m respectively, the horizontal moving distances of their left feet are 0.501m, 0.400m and 0.437m respectively, and the average moving speeds of their left feet are 1.139 m/s, 1.333 m/s and 0.491 m/s respectively. The skip step jumping heights of Sampras and Moya are reasonable while El Aynaoui is a little higher which will affect the effect of his return of service.

In the stroke stage, the moving distances of left feet of Sampras and Moya are greater (0.892m and 0.667m respectively) and the moving speeds of Sampras and Moya are faster, being 2.23m/s and 1.96m/s respectively.

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