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An EXPERIMENTAL STUDY on the KINEMATICS of a SKILLED SERVICE in PLAYING TENNIS

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ABSTRACT

This paper studies the effective parameters of a skilled service in playing tennis and determines their relationship with skill deals. Effective service in tennis plays an important role in gaining more desirable result and the most important factor of success in getting scores depends on the player's skills in serving an effective service. The characteristics of a good service are the high speed of the ball and the precision of landing the ball. The several parameters affecting on these two characteristic in the service, are studied in this paper. Therefore, the Kinematic parameters of 8 Iranian professional tennis athletes of first division tennis league and also 8 non-professional Iranian athletes who exercise about 3 sessions a week were extracted. After land marking these athletes, by use of two high-frequency cameras, pictures were recorded when the tennis players were serving the services.

The investigation on the results of these tests is performed by three dimensional motion analyses. The pictures are analyzed with the WinAnalyze software. Therefore, in this paper, the most important effective parameters in serving a successful service are detected.

Keywords: Kinematics, Tennis, Service, motion analysis, three dimensional analyses.

INTRODUCTION

Tennis is a wide-aged popular exercise. Tennis players are continually being challenged to increase their serve velocity in an attempt to dominate their opponent. Thus it is required to produce a high speed at the end of the distal segment of the racquet in the kinematic chain so that the racquet head can generate a maximum speed of the ball [1]. To build up racquet speed, coordinated movements in the trunk rotation, upper arm flexion, abduction and internal rotation, as well as hand palmar and ulnar flexion are required [2].

To improve the understanding of high velocity serve, Elliot and colleagues conducted a series of biomechanical studies using skilled amateur tennis players [3]. A kinematic chain was quantified in a way to be able to characterize the increase of the maximum linear velocity of the proximal to distal segments, in the sequence from the knee to the racquet. Joint angles at the instant of the ball impact were also reported and investigated in this study and Angular velocities of segment were measured in the subsequent study [4]. At the instant of ball impact, the velocity of ball was mostly attributed to the shoulder internal rotation and the wrist flexion. Furthermore, Feltner (et. al) studied the effect of the sequencing of angular velocity for the various segments on generating the highest speed of the ball [5].

These series of studies provided a good foundation of understanding on first-serve biomechanics used by skilled players. Three-dimensional (3D) kinematic analyses of the service technique of high performance tennis players have provided the athlete and coach with a practical information on the key mechanical characteristics of this action [3,4].

The purpose of this paper is to study the effective parameters of a skilled service in playing tennis and determines their relationship with the skill deals. The result of this study can be helpful for the competitive players and their coaches to understand the mechanics needed to generate high serve velocity.

METHODS AND PROCEDURE

Two subjected groups participated in this test were a group of eight Iranian professional male tennis athletes of first division tennis league and a group of eight non-professional Iranian athletes who exercise about three sessions a week. The selected athletes in both groups are chosen by having approximately equal bmi [1].

Mass and height for the first group ($p< 0.05$) was (76.5+- 10 kg, 1.82+- 0.08 m) and for the second group was (76.2+- 8 kg, 1.78+- 0.09 m).

Forty eight service motions (three serve for each subject) were videotaped with two electronically synchronized high-speed video cameras. These two cameras were positioned approximately 4 m far from the service area with side and front views. These views were adjusted to capture the entire serving motion, while the visibility of the used cameras is 4mx3.5m. Video data were collected at a rate of 250 Hz.

To control the memory usage of the calculation system, for investigating the total movement the rate was chosen to be 250 Hz and not the maximum of 1000 Hz. In investigating the small portion of the movement the higher rates could be used. For each camera, the shutter rate was set at 0.002 s and the aperture was adjusted according to condition. . (A digital high speed camera, Kodak motion coder SR: 1000, dynamic analysis system, Pte-ltd).

Ball velocity was recorded just as the ball left the tennis racquet. A $2.040^{m}\times1.040^{m}\times1.040^{m}$ 28 control points calibration frame was videotaped after each test with a measurement tolerance of 0.005m. The position of the frame encompassed the space occupied by the players during the serve (from initial ball toss to impact).

Since kinematic parameters were measured from the ball toss to just after the ball impact, and not during the follow-through phase, the period of the recorded data was long enough to contain the portion of the tennis serve that was digitized.

All videotapes were first qualitatively analyzed to determine that the data from 16 players had the required quality for quantitative analysis. For each of these subjects, the three successful serves with the greatest ball velocity were manually digitized with the motion analysis system: WINanalyze (V 1.4, 3D Mikromak, Gmbh Germany) [6].

A 20-point spatial model was created, comprising the centre's of the left and right mid-toes, ankles, knees, hips, shoulders, elbows, wrists, and the subject's head, hand racquet grip, and four points around the racquet head (medial, lateral, proximal, and distal) (figure1). Each of these 20 points were digitized in every video field (250 Hz), starting at five frames prior to the motion of the ball leaving the hand and ending five frames subsequent to the racquet impacting the ball.

[1] Body Mass Index

Figur1- A frame captured during the serving.

The pictures were analyzed with the WinAnalyze motion analysis software. WinAnalyze is specifically programmed to calculate kinematic and kinetic parameters. In this program resultant force and torque levels at the elbow and shoulder joints are calculated using inverse dynamics. Because of the dynamic effect of impact on the racquet, kinetic analysis is limited to data just before ball impact and the drag effect of each segment through the air is neglected.

This software can do automatic tracking; means in each frame recognize the markers and trace them in subsequent frames. Though, it can give the coordinate of each point in every second. Also, if the lines between these points are defined for the program, it can calculate the angle and angular velocity of these lines (figure 2).

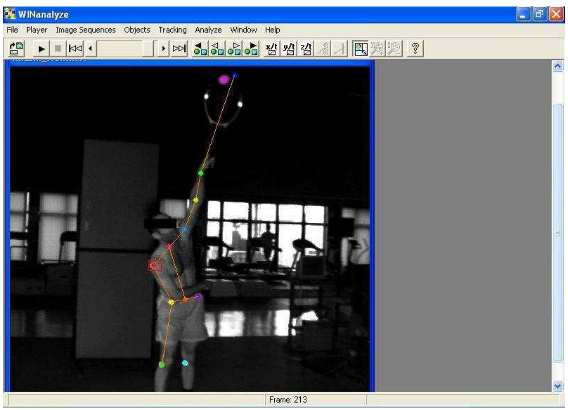

Figure2- The software tracking the markers and the lines.

Thus, Angles were calculated for each trail at three key events: 1. when the flexed lead knee began to extend and move the player upward; 2. when the shoulder was in maximum external rotation; 3. when the racquet impacted the ball. Maximum angular velocities were also calculated.

RESULTS AND DISCUSSIONS

Body mass, height, and service velocity for the mean of the best three trials are shown in Table 1. Serving speeds for the first group players were 141.3(19.9) km/hr (mean (standard deviation)) and for the second group players were 118.3(14.6) Km/hr. The maximal ball speed in non-professional Iranian athletes was significantly smaller than professional tennis athlete ($p=0.01$). The differences between these two groups occurred mainly in the upper trunk and wrist movements**.**

	1st group Mean (SD)	2nd group (Mean (SD)
Anthropometric and ball velocity data		
Height (cm)	182(8)	178(9)
Mass (kg)	76.5(10)	76.2(8.0)
Velocity of the ball(km hr-1)	141.3(19.9)	118.3(14.6)

Table 1- Mean (standard deviation) values of service data

In order to compare the exact details of the serving movement of two groups, we investigate the kinematics of the services. As the ball moves out of lead hand, the player flexes both knees. Then, the player extends both knees to move his body upward and this movement then combines with trunk rotations, and then the rotation of the racquet and the arm occurs. Maximum angular velocity of lead knee extension occurred before ball impact. The angular velocities of each of these movements can be seen in table 2.

Maximum Angular Velocity		
	1st group Mean (SD)	2nd group Mean (SD)
Knee extension (° /s)	700(300)	580(310)
Trunk angle decrease (° /s)	220(40)	190(30)
Pelvis rotation (° /s)	400(90)	420(70)
Upper torso rotation (° /s)	800(100)	680(130)
Shoulder internal rotation (° /s)	2100(500)	1800(420)
Elbow flexion (° /s)	1100(300)	980(270)

Table 2- High velocity kinematics of services

It's considerable that the high speed of the athlete in serving also can be a necessity in having a perfect service. The angular velocities of the segments in the first group are mostly higher than the other group.

At the instant of ball impact, maximum external rotation occurs. In this instant the shoulder was abducted, horizontally adducted, and externally rotated. The elbow was flexed, and the wrist was extended the angle of each of these movement could be seen in table 3. The differences between professional group and non professional players are not considerable, but comparing with elite players [7] they have obviously different values.

Angle of the segments in the instant of Ball Impact		
	1st group Mean (SD)	2nd group Mean (SD)
Shoulder abduction (°)	120(11)	116(12)
Shoulder horizontal adduction (°)	10(5)	10(8)
Elbow flexion (°)	17(4)	19(7)
Wrist extension (°)	12(8)	17(10)
Trunk angle above horizontal (°)	58(7)	53(8)
knee flexion (°)	24(14)	21(19)

Table 3- Segment's angle at the instant of ball impact

To produce an effective high velocity serve, coaches can use the values presented in this paper to define a range of proficiency level for a specific movement, in assessing selected techniques used by players. For example, players should strive to attain a shoulder horizontal adduction of approximately 10° in last instance of phase of the serve, if the racquet is to be positioned correctly for the forward swing and the muscles of internal rotation are to be stretched. Future research on tennis players of various skill levels is needed to investigate the relationship among variations in serve kinematics, joint kinetics, and ball velocity.

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