DIRECTION OF SPIN AXIS AND SPIN RATE OF THE BALL IN TENNIS SERVICE

Shinji Sakurai [1,2], Tsutomu Jinji [1], Machar Reid[2], Cesar Cuitenho[2], and Bruce Elliott [2]
[1]School of Health and Sports Sciences, Chukyo University, Japan
[2]School of Human Movement and Exercise Sciences; The University of Western Australia
e-mail: ssakurai@sass.chukyo-u.ac.jp

INTRODUCTION

The serve is widely regarded as the most important stroke in tennis. It also represents the game's only closed skill. In an effort to assert immediate control over a rally, players aim to serve with high speed and varying spin. In turn, three types of serves, namely; flat, slice and kick serves are commonly used. However, where ball speed has attracted considerable researcher interest, comparatively few reports have detailed rates and directions of ball spin in the tennis serve. Ball spin is a key to serving success as it affects the ball's trajectory in the air and its bounce from the ground. The purpose of this study is to therefore describe the three-dimensional (3D) ball kinematics, including spin axis directions and spin rates of the flat, slice, and kick serves as executed by high-performance male tennis players.

METHODS

Seven full-time, right-handed, professionally ITF ranked (n=5) and unranked (n=2) male players participated in the study. Each player hit three successful maximum effort flat, slice, and kick serves to a 1x1 meter target area bordering the 'T' of the first service box. Balls were marked with three hemisphere shaped reflective markers made of foam (diameter: 1cm, total mass of three markers: 1g, Figure 1).

Figure 1: Reflective markers on ball and racket

A 12-camera 500Hz, Vicon MX motion analysis system (Oxford Metrics Inc.) recorded the 3D marker trajectories, and thus reconstructed the motion of the ball for three meters in serve direction from the ball impact (Figure 2).
A local coordinate system of the ball was established from the three markers so that the ball's angular velocity vector in the global coordinate system was obtained. The direction of ball spin and spin rate were expressed by three coordinate values and the absolute values of the angular velocity vector, respectively.

RESULTS AND DISCUSSION

Average values for 3D ball kinematics for flat, slice and kick serves are shown in Table 1 and Figure 3. No 'flat serves' were hit without spin. However, slice (2300rpm) and kick (3400rpm) serves were characterized by spin rates 1.9 times and 2.7 times higher than flat serves (1240rpm). A clear trade-off existed between the development of ball spin rate and ball speed. The α angle (between ball spin axis and ball velocity vector) was almost perpendicular, regardless of the serve type. Elevation angles (φ), represented as angles between the spin axis and the horizontal plane, were 82°, 68°, and 52° for flat, slice, and kick serves, respectively (Figure 3).

Table 1: Summary of 3D Ball Kinematics (mean ± (SD))

	Vx (m/s)	Spin Rate (rad/s)	α (deg)
flat	51	130	87
(n=20)	(3)	(51)	(11)
slice	46	241	87
(n=13)	(3)	(43)	(5)
kick	40	356	88
(n=14)	(3)	(58)	(2)

Vx : x component of initial ball velocity
Spin Rate: 100rad/s = 960rpm
α: angle between spin axis and ball trajectory

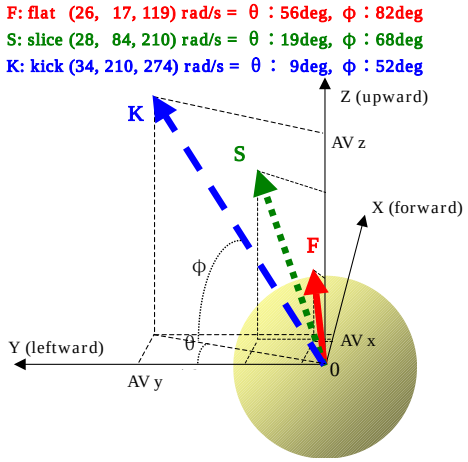

Figure 3: Average angular velocity vector (AVx, AVy, AVz) of ball spin for each type of tennis serve

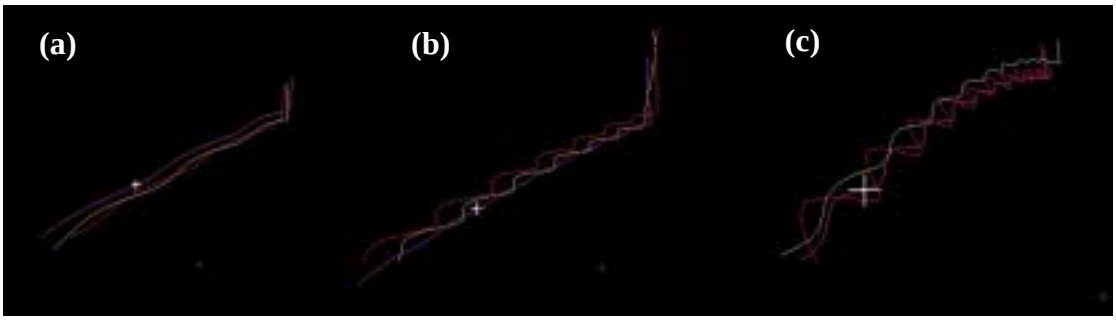

Figure 2: Examples of the three marker trajectories on the tennis ball during the flat (a), slice (b), and kick (c) serves