THE BACKSPIN BACKHAND DRIVE IN TENNIS TO BALLS OF VARYING HEIGHT

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INTRODUCTION

Modern tactics dictate that while the forehand drive is seldom hit with backspin, the backhand must be able to be hit with topspin or backspin depending on the height of bounce of the ball and/or tactical requirement of a particular rally. No studies have clearly identified the mechanical characteristics of the backspin backhand stroke, although data are available on topspin (Elliott et al., 1989), flat (Pecore, 1979; Young, 1970) and one versus two-handed backhand drives (Groppel and Ward, 1979). The purpose of this study was to compare the kinematic characteristics of the one-handed backspin backhand to balls of approximately hip and shoulder height.

METHODOLOGY

Three-dimensional (3D) high speed cinematography was used to compare backspin backhand techniques of 13 high performance players hitting low (mean height of 6 cm below standing hip height) and high (mean of 41 cm above the standing hip height) bouncing balls. The Direct Linear Transformation method was used for 3D space reconstruction from 2D images recorded by two laterally placed phase-locked cameras operating at 200 Hz. All subjects used their preferred grip (eastern backhand or continental) to hit two successful down-the-line shots (ball landed in a 2 m x 2 m area in the back corner of the court) to balls of approximately hip and shoulder heights.

The higher velocity backhand at each height was selected for analysis. The 2D images of both the reference structure (20 points) that encompassed the field of movement of the backhand strokes and subjects were digitized, and the unknown 3D coordinates of each subject's landmarks were determined using the procedures outlined in Marzan and Karara (1975). Each subject was painted with circular bands or black circles at: the center of the ankle joint (malleolar level), the knee joint, the mid-line of the thigh at the level of the greater trochanter, the acromion process of the right and left scapulars, the center of rotation of the right elbow and wrist, and the tip of the racket. After digitizing these points, the data were transferred to an IBM compatible computer where 3D joint angles and velocities were calculated. Coordinates from the sagittal and transverse planes were also used in the calculation of linear and angular kinematics, using procedures outlined by Wood (1977).

An automatic low-pass digital filtering procedure similar to the technique used by Wells and Winter (1980) was developed so that different anatomical land-marks and body segments could be smoothed at different frequencies (range 4 Hz to 12 Hz). Ball velocities pre- and post- impact were calculated over a 0.015 s period prior to and after impact. Racket displacement trajectories were measured with respect to the horizontal from a straight line of best fit of the tip of the racket over the periods from 0.02 s to 0.005 s prior to impact and from 0.005 s to 0.02 s after impact. Racket-face angle, the horizontal displacement between the front ankle and the impact position, and the vertical displacement between the position of the ball at impact and each player's standing hip height were measured directly from the film.

RESULTS and DISCUSSION

The backswing position for both strokes was characterized by the racket-arm wrapped around the body in conjunction with a large trunk rotation (approximately 130° for both strokes) such that the racket was above shoulder level. This large trunk rotation had been identified by Young (1970) as being a desirable trait if a high impact velocity was required. The 40° rotation in the transverse plane past where the trunk was perpendicular to the net was the same as the 130° rotation recorded for the topspin backhand (Elliott et al., 1989), but greater than the 90° of rotation often advocated by coaches.

Very little has been written on racket trajectories prior to impact, although coaches would seem to agree that the racket-face should be open (bevelled back with respect to the ball) and the racket moved forward and downwards. Braden and Bruns (1980) advocated that the racket-face should be perpendicular to the court or bevelled back by up to 10° when hitting a backspin drive. Groppel (1984), in an unpublished investigation of professional players, indicated that backspin was imparted by brushing the back of the ball in a downward manner with the racket-face slightly open. Computer simulation was used by Brody (1985) to assess the combinations of racket trajectory and racket-face angle that produced a successful stroke for backspin backhands hit at high velocity. He reported that if the racket-face was vertical and the trajectory from high-to-low, then the result produced was a backspin shot that would generally impact the net. An open racket-face was needed in combination with this trajectory to produce successful return.

There were differences recorded for the trajectory of the top of the racket for high and low impacts. A mean downward trajectory of 25° for the low impact was reduced to 15° for the higher impact. Players therefore approached the high bouncing ball with a flatter trajectory than occurred for the lower impact. These data support computer simulations presented by Brody (1985), who reported that a racket with a velocity of approximately 20 $m \cdot s^{-1}$ and a downward trajectory of 30° required a racket-face bevelled open by 10° (100° racket-face angle) to produce a ball trajectory of 2° above the horizontal.

Many coaching texts advocated that impact should occur in front of the leading foot for backhand strokes (Elliott and Kilderry, 1983). For the players in this study impact occurred approximately 12 cm forward of the front ankle for shots of varying heights. This mean impact position was closer to the body than the impact position recorded for a topspin backhand down-the-line drive (20 cm forward of front ankle: Elliott et al., 1989) and closer to the body than the impact position reported for a flat backhand drive (30 cm forward of front ankle: Holcomb, 1963).

Significant differences were recorded in the angle of the front knee at impact for backspin backhands hit at varying heights (low=155°: high=175°). These angles were both considerably larger than the 126° front knee angle recorded for a topspin backhand drive (Elliott et al., 1989). The slightly flexed front knee joint in the low backhand allows the racket to follow a high-to-low trajectory prior to impact. The almost fully extended front lower limb in the high impact obviously permitted the racket to follow a lesser high-to-low trajectory before impact.

In the low backspin backhand, impact occurred closer to the body (upper arm adduction angle with trunk=55°) compared to the higher backhand (mean=60°). This greater angle obviously occurred to position the racket higher for the shoulder height impact when compared to the impact in line with the hip. The low impact shoulder joint angle was almost identical to that recorded by Elliott and associates (1989) for a topspin backhand drive (52°).

Elbow joint angles for both heights (170°) showed that while the upper limb was relatively straight at impact it certainly was not fully extended. This was also the case with the topspin drive where mean elbow angle of 164° was recorded (Elliott et al., 1989). It is important where players use the elbow joint to generate racket velocity that the elbow joint is not fully extended as this will often increase the load on this general region and thus increase the potential for injury. At impact, the movement at this joint was minimal showing that a stable joint was a characteristic of both impact heights. That is, while the upper limb is almost fully extended at impact it is not "locked," a technique that may place undue stress on the elbow region.

The mean wrist angles at impact (160°) were the same for balls of varying heights. The hand was, therefore, not a natural extension of the forearm at impact. This was also found to be the case in the topspin backhand drive.

A larger shoulder alignment in the transverse plane was evident for the higher impact (110°) than was recorded for the lower stroke (90°). The shoulders, therefore, rotate more from the backswing position for the lower impact so they are perpendicular to the net at impact. In the higher stroke, less rotation occurred and impact was characterized by a shoulder alignment of 20° beyond a perpendicular to the net.

The trunk was also leaning more in the sagittal plane (in the direction of the hit) for the low impact (60°) than was recorded for the high impact (70°). This lean in the direction of the net clearly showed that weight was predominantly on the front limb at impact irrespective of the height of impact.

Rotation of the trunk and forward movement of the body increased racket-shoulder velocity such that similar peak velocities were recorded for both strokes (approximately 0.13 s prior to impact). At impact the racket-shoulder was moving toward the net with a higher velocity for the low impact than for the high impact. However, the minimal velocities for both impacts (approximately 1 $m \cdot s^{-1}$) showed that the trunk was stable at impact for both strokes.

In both high and low backhands the upper arm rotated forward across the body in the period prior to impact. A peak elbow velocity (end of the upper arm) was recorded approximately 0.09 s before impact. The velocity of the elbow was the same (3 $m \cdot s^{-1}$) at impact for both strokes. Trunk rotation and upper arm movement therefore accounted for approximately 15% of the racket velocity at impact.

The elbow joint extended during the forward swing to create an almost fully extended hitting limb (≈ 170°) at impact. Peak elbow joint angular velocity occurred 0.05 s prior to impact which produced a mean peak velocity at the end of the forearm (the wrist) for both strokes of approximately 9 $m \cdot s^{-1}$. This mean velocity was reduced by impact to 7.5 $m \cdot s^{-1}$ for the low and 8.0 $m \cdot s^{-1}$ for the high bouncing balls. Elbow extension was therefore an important velocity generating aspect of both strokes accounting for approximately 25% of the racket velocity at impact. These movements at the shoulder and elbow joint support the technique advocated by Groppel (1984) who had identified forward rotation of the upper arm followed by extension of the forearm as key movements during the backhand forward swing.

Movement about the wrist joint and long axis of the upper limb followed extension of the elbow for both strokes. A summation effect had, therefore, taken place with each joint playing a role in generating the racket velocity at impact. A major difference in the movement of the racket in the two strokes is the role of rotation of the upper arm (outward rotation) and forearm (supination), particularly in the high backhand. While only minor levels of forearm supination occurred in the forward swing for a low backhand, much of the racket-head velocity at impact can be attributed to the outward rotation of the upper arm and forearm supination in the high backhand. Braden and Bruns (1980) had identified forearm supination as the means by which the racket-face was rotated from a position almost parallel with the court to where it was bevelled open by up to 10° at impact. The increased level of upper arm and forearm movement for the high backhand, while not seen in all subjects, was a characteristic of most subjects, and all subjects who had played on the professional circuit. Final racket velocities of 20 $m \cdot s^{-1}$ (low) and 19 $m \cdot s^{-1}$ (high) were then recorded at impact. The impact velocities, which were similar to those recorded for a topspin backhand (Elliott et al., 1989) produced post-impact ball velocities that were less than in the topspin stroke primarily because the racket-face angle at impact was "open" in the backspin stroke and perpendicular to the court in the topspin stroke. The impact velocities in this study were only marginally reduced from peak mean racket tip velocities of 21 $m \cdot s^{-1}$ (low) and 20 $m \cdot s^{-1}$ (high) recorded 0.01 s prior to impact.

The racket tip velocity was approximately 50% of its pre-impact velocity during the early part ofhe follow through. In the period immediately after impact the shoulder alignment was relatively constant and did not immediately "open" as suggested by some coaches. During the follow through the elbow joint was stable emphasizing the need for this joint to retain its impact orientation, while the wrist angle increased such that the hand was more in line with the forearm. The racket trajectory of approximately 40° downward was the same for both strokes immediately after impact although it was obviously at a different level with respect to the body.

CONCLUSIONS

Many aspects of the stroke mechanics of the high and low backspin backhand are different. Sport scientists must, therefore, inform coaches of these differences so that correct teaching procedures can be established that will maximize player development.

ACKNOWLEDGMENT

The author thanks the National Sports Research Program, of the Australian Sports Commissionor supporting this study.

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