The Teaching of Racquet Skills:
A Biomechanical Approach

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All racquet skills, such as hitting a topspin forehand drive in tennis, an overhead clear in badminton, or a backhand boast in squash have a theoretical mechanical base. Successful achievement of each of these skills is greatly affected by the technique which the player employs. The main objective of a teacher should be to help beginners develop "good technique". Who decides what is good technique? The **teacher/coach** who has an **understanding** of biomechanics can integrate the personal **characteristcs** of the player with the stroke mechanics of the **skill** and develop techniques which suit the individual.

The **individualised** model for performancemust be developed with consideration of four broad areas. Each of these will be considered with reference to the teaching of the multi-segment topspin forehand drive in tennis.

1. Past Experience of the Teacher

Experiences as a player **and/or** a coach should have led the teacher to the conclusion that a semi-western forehand grip should be adopted in preference to a continental grip when hitting a topspin drive.

2. The Individual Characteristics of the Performer

The physical characteristics of the player may dictate that a particular techniqueflair of this player must also be considered when deciding on the technique to be learned.

3. The Current Techniques used by Champion Players

High velocity forehand drives that clear the net with a margin for error and yet still land in the court are now an accepted part of modern tennis. Coaches must also decide when, or in fact if, they should teach the **multi-**

segment forehand used by many of the leading professionals to produce a high velocity stroke. In the multi-segment forehand the individual segments of the upper limb move relative to each other to produce a high racquet velocity. The alternative to this stroke is the forehand where the upper limb swings forward more as a single unit.

4. The Biomechanical Basis of the Multi-Segment Topspin Forehand

The theoretical requirements of the forehand are included to provide an understanding of how mechanics form the basis of the development of this stroke.

A. The Grip: ***A*** vertical or marginally closed racquet-face together with an upward racquet trajectory at impact are required if topspin is to be imparted to the ball (Groppel et al., 1983). This racquet orientation is best achieved, for a variety of bounce heights, by adopting a semi-western grip.

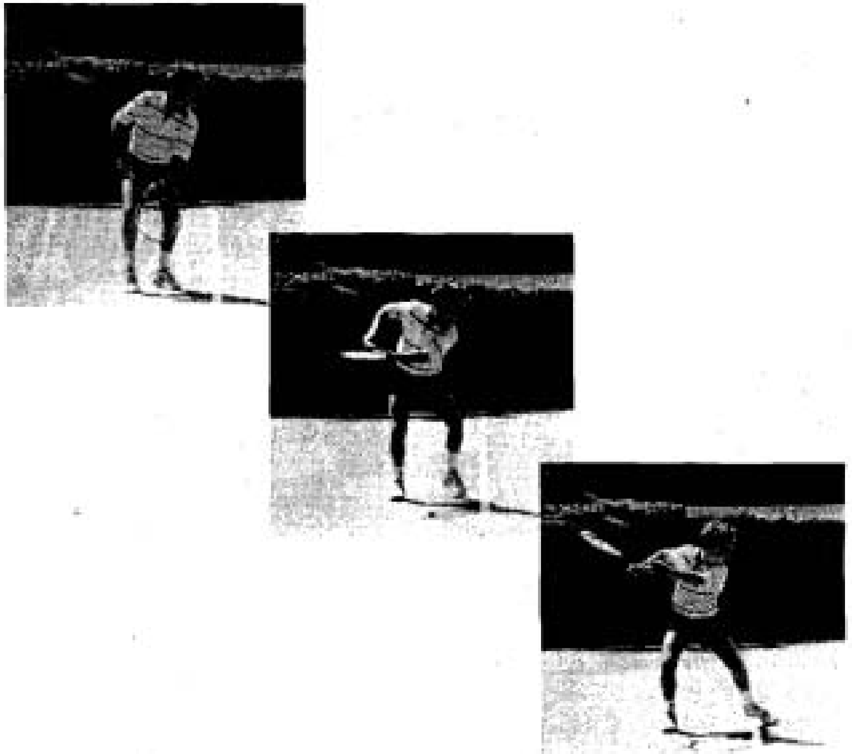
The level of grip tension affects both rebound velocity and the reaction impulse to ball impact. A tight grip increases the rebound velocity of the ball, particularly for off-centre impacts (Elliott, 1982). In teaching topspin stroke production off-centre impacts are a factor that must be considered by players of all proficiency levels (Groppel, 1975). Coaches should therefore advocate a firm grip as one of the factors that determine the effectiveness of this stroke (Elliott, 1982).

B. ***Preparatory Movements:*** Movement from the ready position to the ball initially requires the body to be accelerated towards the court with a velocity of approximately $0.5\ m\,s^{-1}$ (Elliott et al., 1989 - Figure 1). Deceleration of the body then applies stretch to the muscles which results in the subsequent storage of elastic energy, which may then at least partially, assist the lower limb drive in moving the player to the vicinity of the ball (Komi and Bosco, 1978).

Figure 1: The Preparatory Phase

C. ***The Backswing:*** The greater the displacement of the racquet in the backswing phase of the stroke, the greater is the distance over which racquet velocity can be developed during the forward swing (Young, 1970). Advanced players use a looped backswing to increase racquet displacement and hence to achieve maximal racquet speed (Keating, in Braden and Bruns, 1977).

Players using the multi-segment forehand move the racquet through a different pattern to those players who use a single unit technique. The pivot of the back foot for a multi-segment forehand is followed by the backward movement of the elbow in synchrony with the turn of the shoulders, so that the racquet remains pointed at the oncoming ball (Figure 2). The racquet-head is then closed while the elbow is raised (Figure 3). The forearm and racquet then pivot about the elbow and shoulder and the racquet moves to a position above the elbow and shoulder (Figure 4: Elliott et al., 1989).



Figures 2 to 4: The backswing phase of multi-segment forehand

The study by Elliott et al. (1989) described the mean position attained by four elite players at the completion of the backswing for the multi-segment forehand. The shoulders rotated by approximately 1.75 radians (100deg) from an alignment initially parallel to the net, to a position beyond a perpendicular to the net (Figures 1 and 4). The upper limb was also more compact for this stroke when compared to descriptions in the literature for a single unit forehand, as angles of 0.8 rad (45 deg) for the shoulder joint, 2.1 rad (120 deg)for the elbow joint and posterior wrist joint angle of 2.55 rad (146 deg) clearly show. The racquet was not pointed at the back fence, as often stated in the literature, but rotated past this orientation by approximately 0.87 rad (50 deg). This racquet orientation is certainly made easier if a semi-western or western forehand grip is adopted.

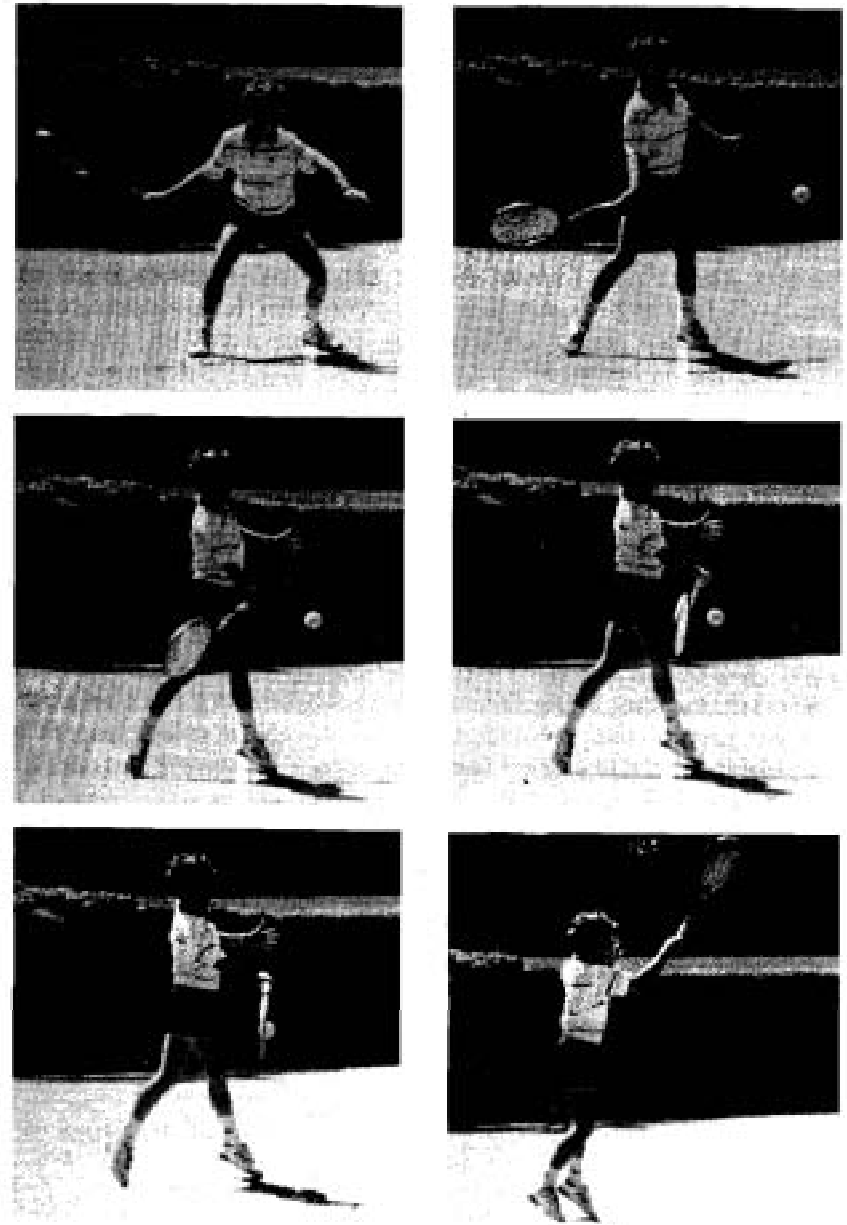
D. *The* Forward Swing and Impact: As the ball is in contact with the strings for only 4 to 6 ms no volitional movement is possible during the time the ball is in contact with the racquet (Brannigan and Adali, 1981). Whatever movement is required at impact to impart topspin to the ball must therefore happen prior to impact.

The start of the forward swing was characterised by the racquet moving to a position below the intended point of impact (Figure 5). Extension of the knee and hip joints raised the hitting-shoulder which assisted the low-to-high trajectory of the racquet (Figures 6 to 9). Braden and Bruns (1977), Elliott and Kilderry (1983) and Groppel (1984) identified the following critical factors for the production of topspin:

1. an upward racquet trajectory from below the point of impact to above this point during the forward swing and follow-through;
2. a vertical or near vertical racquet-face at impact.

Elliott et al. (1989) showed that the racquet tip moved on an upward path of 0.30 rad (17 deg) for the multi-segment forehand which was in agreement with the angle of 0.30 rad proposed by Braden and Bruns (1977). This upward trajectory was increased dramatically to 0.83 rad (48 deg) from 0.005 s pre-impact through to 0.005s post impact, an angle similar to that reported by Groppel et al. (1983) and Brody (1985). These data then suggested that players first aligned the racquet and ball and then, once impact was assured, increased the trajectory to impart an off-centre force to the ball.

The study by Elliott et al. (1989) also described the forward swing and impact locations for the multi-segment forehand. The shoulders rotated through 1.66 rad (95 deg) from the backswing position so that at impact



Figures 5 to 10: The forward swing phase the alignment was 0.12 rad (7 deg) behind a line drawn parallel to the net (Figure 9). The arm remained a comfortable distance from the trunk during the forward swing so that at impact a shoulder angle of 0.83 rad (48 deg) was recorded. The elbow joint initially extended during the early forward swing and then flexed over the 0.04 s prior to impact to form an angle of 2.44 rad (140 deg) at impact. Players, who use a multi-segment forehand were in fact flexing the elbow joint at impact.

The wrist joint angle decreased during the early forward swing as the racquet "trailed" the forward moving upper limb (Figures 5 and 6). Small wrist joint angular velocities were recorded in the 0.08 s prior to impact showing that players who used this technique flexed the wrist to increase racquet velocity over this period. A 2.76 rad (158 deg) wrist angle at impact showed, however, that the hand was still hyperextended at impact. Maximum racquet velocity was recorded 0.01s prior to impact.

E. The Follow-Through: The racquet retained approximately 80% of its velocity after impact (Elliott et al., 1989). During this period after impact, the body segments decelerate gradually to reduce the possibility of injury.

A teacher/coach can integrate these biomechanical factors with other learning experiences to create an individual performance model for each player. The establishment of this technique model is however, only the first stage in the teaching of this stroke. *An* analysis of stroke technique in conjunction with the implementation of efficient teaching principles is then essential if optimal learning is to occur.

REFERENCES

Braden, V. and Bruns, B. (1477). *Vic Braden's* Tennis for the Future, Boston: Little, Brown Co.

Brannigan, M. and Adali, S. (1981). Mathematical modelling and simulation of a tennis racquet, Medicine and Science in Sport and Exercise, **13(1):** 44-53.

Brody, H. (1985). Science Made Practical for the Tennis Teacher, USPTR Instructional Series, Vol. VI.

Elliott, B.C. (1982). Tennis: The influence of grip firmness on reaction impulse and rebound velocity, Medicine and Science in Sport and Exercise, **14(5):** 348-352.

Elliott, B. and **Kilderry,** R. (1983). The Art and Science of Tennis, New York: Saunders Pub.

Elliott, B.C., Marsh, A. and Overheu, P. (1989). A biomechanical comparison of the multi-segment and single unit topspin forehand drives in tennis. Accepted for publication International Journal of Sports Biomechanics.

Groppel, J. (1975). A kinematic analysis of topspin and backspin techniques in the tennis forehand drive, unpublished masters theses, University of Illinois.

Groppel, J., **Dillman,** C. and Lardner, T. (1983). Derivation and validation of equations of motion to predict ball spin upon tennis impact. Journal of Sports Sciences, **1:** 111-120.

Groppel, J.L. (1984). Tennis for Advanced Players and Those Who *Would* Like to Be, Champaign: Human Kinetics Pub.

Komi, P.V. and Bosco, C. (1978). Utilisation of stored elastic energy in leg extensor and muscles by men and women, Medicine and Science in Sport and Exercise, **10(4):** 261-269.

Young, G. (1970). *An* analysis of selected mechanical factors and accuracy in tennis strokes as related to ball velocity and skill level, *unpublished* doctoral dissertation, Temple University.