©Journal of Sports Science and Medicine (2015) **14,** 194-202
http://www.jssm.org

Review article

Performance Factors Related to the Different Tennis Backhand Groundstrokes: A Review

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Abstract
The backhand is one of the two basic groundstrokes in tennis and can be played both with one or two hands, with topspin or backspin. Despite its variety of derivatives, the scientific literature describing the backhand groundstroke production has not been reviewed as extensively as with the serve and the forehand. The purpose of this article is to review the research describing the mechanics of one and two-handed backhands, with a critical focus on its application to clinicians and coaches. One hundred and thirty four articles satisfied a key word search (tennis, backhand) in relevant databases and manual search, with only 61 of those articles considered directly relevant to our review. The consensus of this research supports major differences between both the one- and two-handed strokes, chiefly about their respective contributions of trunk rotation and the role of the non-dominant upper extremity. Two-handed backhand strokes rely more on trunk rotation for the generation of racquet velocity, while the one-handed backhands utilize segmental rotations of the upper limb to develop comparable racquet speeds. There remains considerable scope for future research to examine expertise, age and/or gender-related kinematic differences to strengthen the practitioner's understanding of the key mechanical considerations that may shape the development of proficient backhand strokes.

Key words: Coaching, skill development, groundstrokes, injury prevention.

Introduction

The backhand and the forehand are the two groundstrokes in tennis. Although the forehand may be considered the most important stroke behind the serve in the modern game (Brabenec, 2000), the evolution of the backhand (BH) represents one of the biggest changes in tennis over the past three decades. Indeed, where the one-handed backhand (1BH) was almost exclusively the backhand of choice before the 1980s, the two-handed backhand (2BH) has all but assumed that mantle in more recent times; often rivaling the forehand for importance among the professional game's best players (Reid, 2001). However, many high level players using a 2BH have also developed the ability to effectively hit slice 1BH, therein retaining tactical versatility (Saviano, 2002). Given this backdrop, and the need for coaches to understand and tailor their teaching to the mechanical nuance of the 1BH and 2BH strokes, it is interesting to note that the backhand has attracted less research attention than the serve and forehand.

With this in mind, Pubmed, Google Scholar and Science Direct were searched for two keywords: tennis and, backhand, which were in turn combined via Boolean operation "AND". Manual searches in reference lists of selected published papers were also performed. The articles were restricted to those written in English. Full publications and abstracts were screened, and all relevant studies were retrieved. Studies needed to satisfy the following criteria for inclusion in the review: (a) contain biomechanical or other descriptive (such as accuracy or frequency) data on one- or/and two- handed backhands or (b) among those studies related to tennis injuries, document technical considerations or observations related to the backhand. Ultimately, 50 references were selected from the 125 previously selected articles from the database searches as well as an additional eleven references retrieved from the manual search. Among them, 51 were research-based papers and a further 10 articles were based on expert opinion. The objective of this paper is to subsequently review these contributions to our understanding of backhand technique, with a critical focus on their implications for clinicians and coaches.

Backhand's place in the modern game

Backhand vs Forehand: In analyzing the distribution of the final strokes in a rally as a function of point outcome in elite level tennis players, Cam et al. (2013) revealed that forehands are associated with a greater number of points won, while more points are lost with backhands played as the final shot. Interestingly, players have generally been found to serve to an opponent's backhand more often when under pressure as it is considered the weaker side (Bailey and McGarrity, 2012). Across all forms of competitive play, including professional tennis, backhand strokes are less frequently played than forehand strokes (Johnson et al., 2006; Pellett and Lox, 1997; Ridhwan et al., 2010). This imbalance has also transcended the rally tests of young beginner players, where Farrow and Reid (2010) reported such players prefer to hit forehands rather than backhands. Indeed, the heightened relative strength demands to hit a backhand stroke (Giangarra et al., 1993) may help explain this observation with young players, while it would appear a tactical choice – potentially related to ease with which inside-out forehands but not backhands can be played (Kovacs and Ramos, 2011) – at the higher performance levels.

Ball velocity: The preferential use of the forehand may also be partly explained by evidence suggesting that forehands produce higher ball velocities for elite male

Received: 24 August 2014 / Accepted: 27 November / Published (online): 01 March 2015

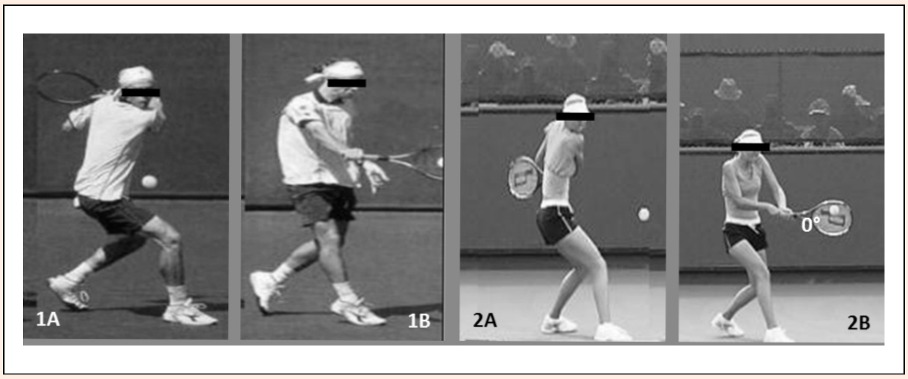

Figure 1. Examples of two key events in one-and two-handed backhands with the end of the backswing (1A and 2A) and the contact of the racquet with the ball (1B and 2B).

players (Fernandez-Fernandez et al., 2010; Landlinger et al., 2012; Pluim et al., 2006), for intermediate-level male players (Mavvidis et al., 2005), and elite female players (Kraemer et al., 1995; 2003).

Stroke accuracy: Inter-stroke differences in accuracy appear to relate to the protocol used. For example, in two studies where ball velocity was not considered, no differences in hitting accuracy were reported between forehand and backhand shots played crosscourt (CC) and down the line (DL) by elite tennis players during simulated tennis matchplay (Davey et al., 2002) or in a hitting accuracy tennis test (Strecker et al., 2011). Two studies reported hitting accuracy to be similarly independent of stroke, as well as gender (Lyons et al., 2013; Theodoros et al., 2008), but significantly influenced by skill level (Lyons et al., 2013). However, these findings that point to analogous accuracy between the groundstrokes contrast with the work of Mavvidis et al. (2010), who revealed that competitive young male and female players (13.6 ± 1.4 years) achieved a significantly higher accuracy with the forehand than with the backhand, as well as Perry et al. (2004) who reported that adolescent male and female competitive tennis players hit their backhands, but not forehands, with better accuracy and greater ball velocity directing the ball CC compared to DL. Finally, when generating near maximal ball velocities, Landlinger et al. (2012) has illustrated heightened accuracy for forehands compared with backhands (Landlinger, 2012). This latter empirical finding, albeit limited to shots played CC, is interesting in that it could be argued that these observed differences in accuracy are unsurprising if one shot is played (or practiced) more than the other. Given this inconclusive backdrop, further studies are clearly warranted to investigate the relationship between ball velocity, accuracy and stroke type among different playing levels.

Comparison between the one- and two-handed backhands

One of the most contemplated questions among tennis coaches is whether one of the two techniques is superior. From a scientific point of view, no study has provided a clear-cut answer. This can be explained, at least in part, by the difficulty associated with the same player mastering both techniques – logically owing to their quite disparate coordination. However, studies comparing elite and national level players performing either 1BH or 2BH observed comparable horizontal racquet velocities (Akutagawa and Kojima, 2005; Reid and Elliott, 2002), post-impact ball velocities (Fanchiang et al., 2013) and accuracy (Muhamad et al., 2011). These results suggest that both racquet or ball velocity and stroke accuracy should not prejudice any choice regarding which backhand to use; rather other factors need to be taken into account. Accordingly, the kinematic differences between each backhand stroke need to be appreciated, and then considered within the context of each individual player's kinanthropometry, coordination skill and style (Reid, 2001).

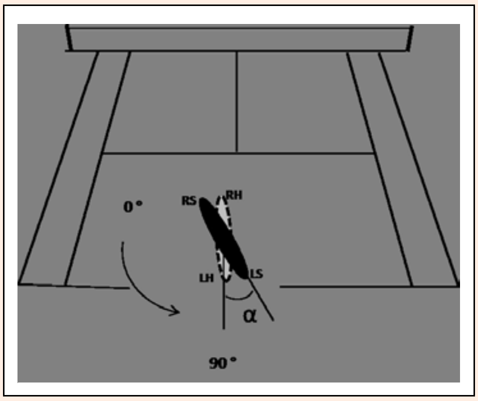

Figure 2. Spatial reference relative to the tennis court for a right handed player's hip alignment (RH, right hip,-LH, left hip), the shoulder alignment (RS, right shoulder –LS, left shoulder), and the separation angle (α) at the end of the backswing for a backhand.

Definition of stroke

The backhand stroke is divided into three common phases (Ryu et al., 1988). The preparation phase begins from the displacement of the racquet backward and ends at the moment of reversing the direction (Figures 1A/2A); the acceleration can be considered from the start of the racquet forward displacement to the ball contact (Figures 1B/2B); the follow through phase begins from the contact point and finishes at the end of the racquet forward movement.

Definition of trunk angles

Only one spatial model has been used to compare the results of literature, (Figure 2). The shoulder alignment angle defines an angle between the left shoulder – right shoulder and the baseline, projected down onto the surface of the court. The hip alignment angle is similarly defined. When either the hips or shoulders are aligned parallel to the baseline, a 0° angle is noted. When they rotate such that they were perpendicular to the baseline, a 90° angle is recorded. The angular difference between the shoulder alignment and hip alignment (trunk twist) is defined as the separation angle (Elliott, 2003), and is shown in figure 3. A positive separation angle indicates a greater shoulder alignment rotation angle relative to the hip alignment angle, while a negative value indicates a greater hip alignment rotation angle relative to the shoulder alignment rotation angle.

Segmental coordination

The power of a tennis stroke is characterized by the velocity of the racquet-head at impact, which in turn develops through the aggregated segmental rotation and energy flow from the feet, legs, trunk, arm to the hand/racquet; otherwise referred to as the kinetic chain (Kibler et al., 2004). Researchers, in effectively taking the role of the legs for granted, have variously represented the 1BH as a five-stage multisegment stroke involving trunk rotations (hip and shoulder alignments), together with rotation about the shoulder (upper arm), elbow and wrist (Elliott et al., 1989; Groppel, 1978; Reid and Elliott, 2002; Wang et al., 1998). Similarly, the 2BH has been described as a five-stage multisegment stroke, where elbow joint motion helps contribute to racquet speed and positioning, or a four-stage multisegment stroke during which the elbows remain relatively extended throughout the forward swing to impact (Reid and Elliot, 2002). Recently, Stepien et al. (2011) challenged these models as too simplistic, suggesting that the 1BH was more appropriately considered an open kinetic chain action with seven degrees of freedom and the 2BH, a closed kinetic chain action with eight degrees of freedom. However, as interesting as this model is for researchers, in the opinion of the authors, these additional degrees of freedom present an interpretive challenge for coaches and thus become more difficult to transfer to the field.

From a functional point of view, racquet velocity is the product of the relative rotational movements of (a) seven angular velocity components involved with preparation (shoulder internal rotation, shoulder extension and shoulder adduction; elbow flexion and pronation; wrist flexion and ulnar deviation) and power generation (shoulder external rotation, shoulder flexion and shoulder abduction; elbow extension and supination; wrist extension and radial deviation) (Figure 3), and (b) the velocity of the centre of the shoulder joint that is the result of the angular velocity of the trunk and the velocities the two hip joints centres, which are determined by the various rotational velocities in the lower extremities (Mester, 2006).

Logically, as both upper extremities are connected to the racquet in the 2BH, this leads to differences in the angular displacements of the different segments during the three phases of the two strokes.

Backswing

Shoulder and hip alignment

Reid and Elliott (2002) have demonstrated that both shoulder and hip alignment angles related to the baseline at the end of the backswing were larger in 1BH than in 2BH, but also that the shoulder alignment angle was larger than the hip alignment angle for both BH. (Table 1 and Figure 1A/2A).

The degree of the shoulder and hip alignment rotation angles at the end of completion of the backswing appears to be affected by several factors such as stroke direction, height of impact, post impact ball velocity and gender. Indeed, Reid and Elliott (2002) reported that the shoulder alignment angle was larger when playing DL than when playing CC for both BH, but that the hip alignment angle was larger only for the 2BH. Elliott and Christmas (1995) observed a larger shoulder alignment

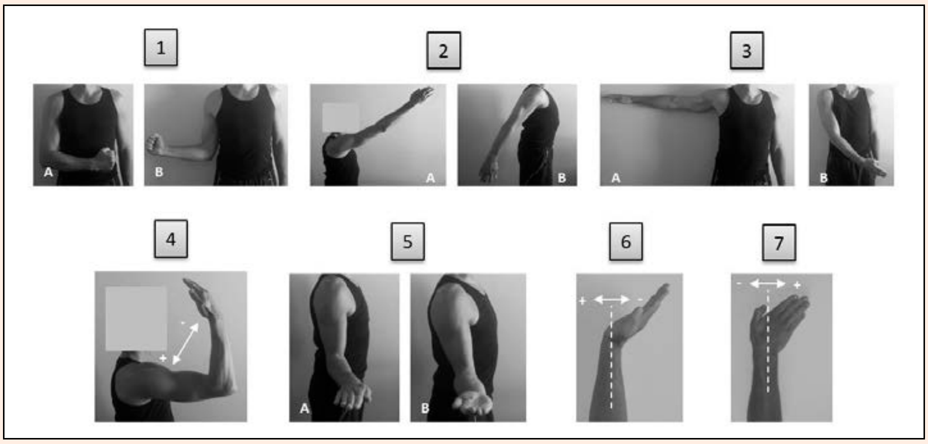

Figure 3. Pictorial definitions of seven joint angles used to detect upper-limb motions during tennis backhand strokes. (1) shoulder internal (A)/external (B) rotation, (2) shoulder flexion (A)/extension (B), (3) shoulder abduction (A)/adduction (B), (4) elbow flexion (+)/extension (-), (5) elbow pronation (A)/supination (B), (6) wrist flexion (+)/extension (-), and (7) wrist ulnar (+)/ radial (-) deviation.

Table 1. **Mean (±Standard deviation) for hips and shoulder angle values during one-(1BH) and two-handed (2BH) backhand strokes at the completion of the backswing (preparation phase).**

Authors	sample	Stroke direction and type	Shoulders rotation (°)		Hips rotation (°)	
			1 BH	2 BH	1 BH	2 BH
Reid & Elliott (2002)	18 male collegiate players	CC On-C	117.2 (7.0)	79.5 (11.5)	90.1 (15.8)	58.0 (8.8)
		DL On-C	120.9 (6.8)	87.2 (9.5)	88.5 (9.4)	68.8 (10.8)
Elliott et al. (1989)	7 male state ranked players and 1 female internally ranked player	CC topspin On-C	123.0		NR	
		DL topspin On-C	129.1		NR	
Elliot & Christmas (1995)	13 male high performance players	DL backspin On-C	≈ 130		NR	
Akutagawa & Kojima (2005)	14 male collegiate players	DL (laboratory condition)	NR		111.6 (9.3)	117.7 (9.3)

CC = cross-court; DL= down the line; NR = not reported; On-C = On-court.

angle for a shoulder height impact compared with a hip height impact during a backspin 1BH. Finally, during the 1BH, the results of Fanchiang et al. (2013) showed a significant positive relationship between post-impact ball velocity and hip and shoulder alignment rotation angles for both genders ($p < 0.05$). They also showed a tendency of female players to utilize about 10% more hip and shoulder alignment rotation angles than male players in generating their racquet velocity. One can suggest that these differences between genders are related to comparatively less strength and then a need to a longer acceleration drive for the female players. The results of Ellenbecker and Roetert (2004) support this assertion, demonstrating that tennis female players' isokinetic trunk rotation strength was almost 20% lower than that of the male players on the backhand side. Moreover, Kibele et al. (2009) also found that maximal trunk rotation angle was the most significant kinematic parameter correlated to post-impact ball velocity for young players aged between 10 and 12 years with different skill levels ($r = 0.7$)

Although the results of the studies cited above are interesting to better understand the differences between both BH at the end of the backswing, their comparison should be made with caution due to different methodologies used. Some studies used a ball machine to project the ball (Elliott et al., 1989; Elliott and Christmas, 1995; Kibele et al., 2009; Reid and Elliott, 2002), while others used a long inclined flute devised to reduce variation of the contact points between the racquet and the ball (Akutagawa and Kojima, 2005; Fanchiang et al., 2013). In addition, the difference in time when maximal hip alignment rotation is measured could explain the larger value observed by Akutagawa and Kojima (2005). That is, they measured the maximal hip alignment rotation before the beginning of its forward rotation, while other studies measured it at the beginning of the racquet forward movement, when hips might have started to rotate forward before the completion of the backswing (Akutagawa and Kojima, 2005) because the upper body rotation followed the pelvis rotation (Kawasaki et al., 2005).

This shoulder and hip alignment characteristics influence the racquet position at the end of the backswing in the same way, namely an augmented displacement in 1BH compared with 2BH (Reid and Elliott, 2002).

Acceleration phase

Lower limb and hip kinetics: The role of the lower extremities in the two backhands further illustrates their varying coordinative strategies. Although hip rotation is the first segmental rotation for both BH techniques (Reid and Elliott, 2002; Kawasaki et al., 2005; Stepien et al., 2011), Akutagawa and Kojima (2005) observed a significant difference in hip joint moments between the two techniques between the start of the forward rotation of the pelvis and the start of racquet's forward movement. A large hip joint adduction moment was created by the front leg in the 1BH, whereas, a large hip joint extension moment was created by the back leg in the 2BH. Noteworthy is that the back leg's hip extension moment and the angular displacement of the pelvis during the 2BH are comparable with those observed by Iino and Kojima (2001) during a forehand stroke, thus suggesting certain analogy between the roles of the lower extremities in trunk rotation in 2BH and forehand strokes. This then supports the observation of Yandell (1998) that the function of the lower limbs in the 2BH is similar to that used to hit a forehand on the opposite side of the body.

Angular displacement: Most of studies have demonstrated significant differences in angular kinematics between 1BH and 2BH during the acceleration phase (Table 2 and Figure 1B/2B). The hip and shoulder alignment rotation angles are relatively more pronounced during the acceleration phase of the 2BH. Moreover, 1BH strokes show a significantly smaller axial rotation angle of the shoulder against the pelvis (separation angle) and that of the pelvis against the feet during the acceleration phase (Kawasaki et al., 2005). Fanchiang et al. (2013) observed that the 2BH required significantly more (12%) shoulder rotation than the 1BH during the acceleration phase. This can be explained by the fact that during a 2BH played at waist height, the shoulder alignment rotates beyond the hip alignment, which is not the case during a 1BH played at the same height. This is confirmed by the results of Stepien et al. (2011) who reported a positive separation angle (by subtracting the shoulder alignment angle from the hip alignment angle at the moment of contact) for the 1BH and a negative one for the 2BH (+9.2 ± 7.2° vs. -6.4 ± 4.3°, respectively). Concerning the range through which the hips rotate during the acceleration phase, Fanchiang et al. (2013) reported males to use significantly less hip rotation than females in the 1BH stroke, but more hip rotation than female players when hitting maximal

Table 2. Mean (±Standard deviation) for hips and shoulder angular rotation values during one-(1BH) and two-handed (2BH) backhand strokes from the initiation of forward swing to ball contact (acceleration phase).

Authors	Sample	Stroke direction	Shoulders rotation (°)		Hips rotation (°)	
			1 BH	2 BH	1 BH	2 BH
Stepien et al. (2011)	9 male experienced coaches	DL	30.1 (10.6)	71.1 (13.8)##	19.0 (6.9)	47.4 (10.3)##
Akutagawa & Kojima (2005)	14 male Colleg Players	DL	NR		31.4 (8.3)	54.4 (9.0)#
Fanchiang et al. (2013)	5 male Colleg Players	DL	51.0 (16.0)	85.0 (12.0)#	26.0 (22.0)	59.0 (12.0)#
Fanchiang et al. (2013)	5 female Colleg Players	DL	59.0 (27.0)	85.0 (13.0)#	33.0 (24.0)	43.0 (14.0)#
Reid & Elliott (2002)	18 male Colleg Players	CC	≈ 51.4*	≈ 65.3 *	≈ 35.9 *	≈ 36.1*
		DL	≈ 50.3 *	≈ 64 *	≈ 30.1*	≈ 36.6*

Colleg = collegiate; CC = cross-court; DL= down the line (laboratory condition); NR=not reported. * = values from average differences between data noted at the end of the backswing and at impact.

velocity 2BH strokes. These authors noted also that the trunk twist was larger in the 2BH compared with the 1BH for both genders (29.4 vs. 20.1°, respectively), and larger still for the females compared with male players (40 vs. 26.3°, respectively).

Thus it is evident that the 1BH and 2BH involve different strategies to develop horizontal racquet velocity at impact. Indeed, 2BH strokes rely comparatively more on trunk rotation whereas the 1BH does the same with the rotations of the upper limb joints of the hitting arm (Kawasaki et al., 2005). Conceptually and in general terms, comparable linear racquet velocities at impact are achieved by either increasing the radius of rotation of the racquet swing in the 1BH, and by increasing angular velocities because of a shorter hitting radius in the 2BH technique.

Comparison of momentum across strokes: The more pronounced use of trunk rotation during the acceleration phase of the 2BH leads to a larger angular momentum for the trunk and racquet compared with the upper extremity joints (Wang et al., 2010). This is confirmed by the mean angular velocity of the pelvis during the forward swing phase in the 2BH which was significantly larger than in the 1BH (538.5 ± 194.8 vs. 280.7 ± 108.8 deg·s^{-1}), respectively) (Akutagawa et al., 2005).

In contrast, Wang et al. (2005) observed that the linear momentum of the trunk is more pronounced in the 1BH. The authors argued that forward, leftward, and upward trunk movements are essential for generating the necessary linear momentum of the racquet, and that stabilization of the trunk is also considered to be very effective for the sequential transfer of the high force and the energy through the trunk. However, further studies are warranted to investigate the obvious question of when does this stabilization happen and how it is different to what is observed in the 2BH. In their critique of the 1BH slice, Elliott and Christmas (1995) observed a similar phenom, where trunk rotation and upper arm movement accounted for approximately 15% of the racquet velocity at impact but with a stable trunk at impact irrespective of the height of ball contact (shoulders or hips height). They also observed that the shoulder alignment was relatively constant during the early part of the follow through, which could contribute to the trunk stability.

From a coaching point of view, Wang et al. (2010) demonstrated that the three dimension components of trunk linear movement not only do not contribute to power generation during the 2BH stroke, but they may even increase body instability and waste energy during the stroke. Indeed, the comparison of expertise in their study showed that the intermediate group created significantly higher linear momentum about all three axes of the trunk than the advanced group, yet failed to generate higher hitting speeds. The subsequent suggestion was that advanced players reduced trunk linear movement to create a more stable axis of rotation about which the other segments could rotate.

Upper limb rotations: Significant differences in angular segment positions at impact have been observed at the elbow, with the dominant arm being more flexed and the wrist more extended in the 2BH (Reid and Elliott, 2002). Stepien et al. (2011) argued that the dominant side plays the role of stabilizing the non-dominant extremity during the 2BH stroke. The role of the non-dominant side as an important contributor to horizontal racquet velocity generation at impact is offered some support with the linear velocities of hip, shoulder, elbow and wrist of the non-dominant side being reported as higher than those of same joints on the dominant side of players (Stepien et al., 2011). Further, higher elbow flexor/extensor electromyographic ratios were observed in the non-dominant arm of skilled double-handed backhand players – not dissimilar to those observed in the dominant arm of skilled single-handed forehand, during the acceleration phase (Huang et al., 2005). Thus, it's unsurprising that Eng and Hagler (2014) have observed that male and female players ranked in the professional top 100 and using the 2BH, adopted eastern forehand grips with their non-dominant hands. Moreover, Stepien (2012) noted different muscle activations during the acceleration phase of 1BH and 2BH played with similar racquet velocities. Indeed, the normalized activities of the anterior and posterior deltoid, pectoralis major, brachioradialis, and biceps brachii and triceps brachii muscles during 2BH were higher in both limbs than in 1BH, with the lone exception being the triceps brachial muscle. As the triceps brachial muscle is responsible for elbow joint extension, this may explain the previously reported different elbow joint angular positions of the dominant arms observed at impact between both BHs. Elbow extension leads to a relatively straight but not fully extended upper limb at impact for both backspin (≈ 170°) and topspin (≈ 164°) 1BH (Elliott et al., 1989; Elliott and Christmas, 1995; Reid and Elliott, 2002). In this way, the upper limb is not "locked" so as to avoid undue stress on the elbow region. Wang et al. (1998) reported a 35.3 ± 14.4° of elbow joint extension during the acceleration phase of topspin 1BH with the maximum angular velocity occurring at the instant prior to impact. Finally, Elliott and Christmas (1995) estimated that the elbow joint extension accounts for approximately 25% of the racquet velocity at impact during a backspin 1BH, while ball speed has been shown to share a negative association with rebound angle in the same shot (Chiang et al, 2005).

With regard to the tactical use of different ball spins, coaches should understand that for players using 2BH, the 1BH backspin requires a different co-ordination pattern while more subtle adaptations are needed by those using 1BH. Indeed, King et al. (2011) observed that for similar ball–racket impact conditions, there were comparable angle–time relationships at the wrist and elbow joints but with the major kinematic differences evident at the shoulder between 1BH topspin and backspin strokes. The major movements of the shoulder joint in the topspin 1BH are flexion and abduction (King et al., 2011; Wang et al., 1998), while extension and abduction apply to the slice 1BH (Elliott and Christmass, 1995; King et al., 2011). The work of Elliott and Christmas (1995) implies, by extension, that despite these different joint actions, similar racquet velocities at impact are produced for a backspin 1BH and topspin 1BH (Elliott et al., 1989). Finally, the role of external rotation and abduction in the dominant arm during the 1BH is evidenced through the greater activity of the supraspinatus, infraspinatus, and the middle deltoid muscles during the acceleration phase of flat 1BH (Ryu et al., 1988). All of these elements suggest that players using 2BH should learn the backspin 1BH early in the stroke development process. In this way, coaches can focus on promoting the use of the continental grip with their players' dominant hands (the right hand for right-handers) as it provides more flexibility for a variety of shots, especially the one-handed backspin backhand stroke (Crespo and Milley, 1998).

Timing of the acceleration phase: Studies have shown that average maximal linear velocities of segment end points increase from the hip to wrist for both backspin (Elliott and Christmas, 1995) and topspin 1BH and 2BH strokes (Stepien et al., 2011; Wang et al., 2010) and that their relative order of occurrence is similar. However, their timing relative to impact occurs earlier during the 1BH than in the 2BH. The 2BH is also characterized by end point velocities of the segments on the non-dominant side reaching their peak just before or at the moment of ball/racquet contact (Stepien et al., 2011). These results are in line with those of Reid and Elliott (2002), who observed that mean maximum pre-impact horizontal accelerations of the racquet tip to have occurred significantly earlier in the 1BH when compared with the 2BH stroke, as well as the findings of Akutagawa and Kojima (2005) who reported shorter 2BH mean swing times compared to 1BH (0.5 ± 0.1 and 0.4 ± 0.1 s respectively). From a tactical point of view, the shorter forward swing of the 2BH and the delayed horizontal acceleration may provide opponents with less time to detect any kinematic change associated with the intended direction and trajectory of the shot (Reid and Elliott, 2002).

Impact

Techniques and stroke direction have been shown to affect the ball / racquet contact positions in the sagittal plane. Relative to the mid-point of players' hips, impact of the 1BH is significantly further forward than during the 2BH, but also further forward for a BH played CC compared with the DL (Reid and Elliott, 2002). Important to note here though is that the mid-point of players' hips vary between the two strokes, meaning that the disparity in impact locations may be less pronounced if referenced differently. By comparing the results of Elliott et al. (1989) with those of Elliott and Christmas (1995), we can also observe a variation in the impact position of slice and topspin 1BH strokes, with the latter impacted further forward. This could be explained, in part, by the different grips preferentially used to perform both strokes. Indeed, an eastern or western grip is mainly advocated for topspin strokes that are impacted forward of the front foot compared with a continental grip that is advocated for a backspin stroke.

Follow-through

The follow-through enables the development of peak racquet speed at impact, while permitting the arm to slow under control to reduce peak loading (Elliott et al., 2009). The middle deltoid, supraspinatus, infraspinatus and biceps brachii muscles are most active in this phase during a flat 1BH, with the biceps brachii muscular activity representing an effort to control extension at the elbow (Ryu et al, 1988).

Although important, the kinematics of this phase are poorly understood, and further studies are warranted both from a performance and injury prevention perspective. Indeed, the different muscular eccentric contractions involved in the follow-through to decelerate the racquet and the body could be present a risk of injury occurrence in case of insufficient eccentric strength (Kovacs et al., 2008).

Implications for injury

A proper technique is needed both for performance and injury prevention. As mentioned above, 2BH strokes rely comparatively more on trunk rotation, whereas the 1BH does the same with the rotations of the upper limb joints of the hitting arm, which leads to different injury profiles.

Improper movements of the 1BH drive account for approximately 90 percent of tennis elbow injuries (Ellenbecker, 1995; Hang and Peng 1984; Renstrom, 2002). Indeed, a greater incidence of tennis elbow has been observed when the 1BH is executed with a flexed wrist instead of a wrist moving further into extension at impact to counteract the force applied by the ball at the instant of ball–racquet impact, (Blackwell and Cole, 1994). Moreover, Wei et al. (2006) reported that more shock impact transmission from the racquet to the elbow joint occurs with large wrist flexor and extensor EMG activities during the follow-through phase of the 1BH, effectively underlining the importance of a firm grip. Kelley et al. (1994) observed that the injured players had significantly greater activity for the wrist extensors and pronator teres muscles during ball impact and early follow-through, almost certainly caused by sub-optimal mechanics including a "leading elbow", wrist extension over the impact phase and an open racquet face at impact, as well as ball contact on the lower half of the string bed. Consequently off-center impacts below the longitudinal axis of the racquet may be a substantial contributing factor for tennis elbow injuries with a tight grip aggravating the effect due to high eccentric wrist extension torques and forced wrist flexion (King et al., 2012). Finally, the determination of appropriate grip size for individual players may help to mitigate injury risk, as grip size has been reported to relate to loading of the wrist extensor tendon (Rossi et al, 2014).

Interestingly, Wu et al. (2001) demonstrated the importance of a sufficiently long backswing in a 1BH stroke to reduce the load on the upper extremity. In their study, 1BHs that hit with a short backswing had significantly shorter contact duration and a greater peak resultant impact force than those with a long backswing (8 ± 3 ms vs. 16 ± 4 ms, and 330.0 ± 140.7 vs. 180.8 ± 49.1 N, respectively) irrespective of skill level. Thus, when teaching the 1BH stroke, a correct transfer of the momentum from proximal (trunk) to distal (hand) segments should be emphasized, from both performance and injury prevention perspectives.

Iwamoto et al. (2013) demonstrated that the direction of the front foot relative to the net when playing a simulated 2BH with a closed stance influences the risk of ankle inversion sprain and heightens the stress on the knee. Conscious of these perils, Ellenbecker (2006) has suggested that a placement of the front foot approximately about a 45 degree angle relative to the baseline helps to facilitate additional body rotation and decrease the stress on the hip, knee, and ankle joints of the front leg. With regard to the loads imposed on the spinal joints, Kawasaki et al. (2005) these results suggest that they are larger in 2BH than in 1BH.

Implications for stroke development

Among the factors that could explain the preferential choice of the 2BH in the learning process, one could cite the greater strength required to perform the 1BH compared with the 2BH (Giangarra et al., 1993), but also the greater segment co-ordination that is indicative of the 1BH (Groppel, 1984). Before the equipment scaling development (tennis ball modification, court and racquet size), children learned with adult racquets and coaches mainly taught the 2BH allowing their young competition players to be more performant. Currently, children learn in conditions more suited to their morphological characteristics and/or their playing level. This can have a positive effect as shown through the recent work of Farrow and Reid (2010) that showed young beginner tennis players to develop superior BH proficiency (1- and 2BH) through scaled environmental conditions. When it comes to beginning level adult players, a recent study observed no significant differences during a tennis ability test after four weeks of tennis training between those players using one- or two-handed backhands (Erman et al., 2013). However, a factor favoring the choice of the 2BH over the 1BH, for the adult recreational player, is also a general agreement that players performing 1BH groundstrokes are more susceptible to “tennis elbow” injury due to adverse loading conditions (Blackwell and Cole, 1994; Giangarra et al., 1993; Roetert et al., 1995).

From a tactical point of view, the game style of players also needs to be considered when choosing between the 1- or 2BH. For example, the 2BH is the stroke of choice of most baseline players, while all-court players appear more likely to adopt a 1BH owing to the ease of transition in to hitting a slice approach shots and backhand volleys, among other potential advantages.

Future research directions

If the scientific litterature reveals dissimilar patterns of driving the racquet in both BHs, it is also clear that there remains considerable scope for future research to examine the inter-relationships between backhand mechanics. For example, it would be instructive to investigate the kinematics of both techniques (1BH and 2BH) performed by players of different skill levels and genders to more fully understand their coordinative differences. Moreover, it would be of interest to investigate the influence of the technique used (1- or 2BH) on the performance and the kinematics of a backspin 1BH. Finally, with injury prevention in mind, the inter-relationships between backhand stroke performance, kinematics/kinetics and the anthropometry of players may provide useful insights for coaches and clinicians alike.

Conclusion

Whether played with a single hand or in its two-handed form, the appropriateness of a player’s backhand selection is key. Whatever the choice, the mechanical efficiency of an individual’s strokes often determine the level of success experienced by the recreational, competitive, and elite tennis player. If the two-handed backhand has often been privileged in the young player development, the equipment scaling allows now coaches to teach the one-handed backhand with a proper technique, thus improving performance but also decreasing the risk of tennis-elbow injury.

The aims of this article were to provide an insight about differences between backhand techniques in order to help coaches in their teaching process. However, further studies are clearly needed to fully understand the key coordinative differences across male and female players of varying skill levels using both backhand techniques.

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Key points

- One-and two-handed backhands require different motor coordination
- Two-handed backhand strokes rely more on trunk rotation for racquet velocity generation, whereas one-handed backhand strokes rely more on segmental rotations of the upper limb
- Players using a two-handed backhand should learn early a slice one-handed backhand because of the different co-ordination pattern involved
- Equipment scaling is a great tool for coaches to learn early proper one-handed backhand strokes
- Future research related to the interaction between backhand technique, gender and skill level is needed

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