THE EFFECT OF GRIP POSITION ON UPPER LIMB ANGULAR KINEMATICS DURING TENNIS TOPSPIN DOUBLE-HANDED BACKHAND STROKES

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The purpose of this study was to compare the effect of grip on upper limb angular kinematics of sub-elite tennis players during a topspin double-handed backhand while aiming crosscourt. Sixteen sub-elite right-handed tennis players performed double-handed backhand trials using two different non-dominant grips (eastern & continental). Upper limb trajectory data was captured using the Vicon motion capture system (250 Hz). Greater peak angular velocity was observed in the eastern grip at the dominant shoulder (flexion, extension, abduction, adduction) and non-dominant shoulder (extension), elbow (pronation) and wrist (flexion, ulna and radial deviation). Subsequently peak linear velocities for the racket head (horizontal), and upper limb resultant joint centres were greater in the eastern condition. Collectively, these data suggest that using the eastern grip in the non-dominant limb is more optimal for developing racket head speed, and may provide coaches relevant information for athlete development in double-handed backhands.

KEYWORDS: kinematic chain, wrist, angular velocity, grip, tennis

INTRODUCTION: In tennis, the ability to execute effective groundstrokes is crucial. Second to the serve, forehands and backhands contribute to the majority of completed strokes throughout a professional tennis match (Johnson & McHugh, 2006). High racket head speed, which is primarily developed by shoulder internal rotation angular velocity in serves (54.2%; Elliott, Marshall, & Noffal, 1995), and subsequent ball speed are key characteristics in professional tennis as it limits preparation time for opponents to return the ball. In backhands, the double-handed system has emerged as the preferred technique in modern tennis, particularly the continental (bottom/dominant hand; towards butt of handle) and eastern forehand grip (top/non-dominant hand; towards racket head) which are currently used on the professional circuit (Eng & Hagler, 2014). A recent analysis demonstrated that the continental grip (at peak backswing [PBS] and impact) was performed with increased non-dominant elbow (PBS: 51.8 ± 25.6°; impact: 46.8 ± 20.1°) and wrist (impact only: −43.0 ± 16.7°) extension compared with the eastern grip (elbow; PBS: 68.8 ± 24.0°; impact; elbow: 60.9 ± 20.3°, wrist: −34.7 ± 16.0°; Busuttil, Reid, Connolly, Dascombe, & Middleton, 2020). A more extended elbow joint in double-handed backhands, also said for the serve, possibly increases the effort required to produce racket head speed as this may reduce internal rotation at the shoulder joint (Elliott et al., 1995). Although the serve (Elliott et al., 1995) and forehand (Takahashi, Elliott, & Noffal, 1996) have been variously analysed, a detailed biomechanical understanding of the effect of non-dominant grip position on upper limb angular kinematics during double-handed backhands is yet to be determined.

The purpose of this study was to compare upper limb angular kinematics of sub-elite adolescent tennis players using two non-dominant hand grip variations (eastern and continental) during a crosscourt topspin double-handed backhand. It was hypothesised that the use of the eastern grip would be performed with greater peak non-dominant shoulder adduction angular velocity and greater peak horizontal racket head linear velocity compared with the continental grip.

METHODS: Sixteen right-handed sub-elite adolescent tennis players participated in the study. Their preferred grip position was the eastern forehand and continental grip for the non-dominant and dominant limb, respectively. All testing was completed on an indoor court (National Tennis Centre, Melbourne, Australia). Participants were injury free at the time of testing and used their personal rackets. Participants were positioned two metres medially from the left singles backhand corner of the baseline, which allowed the participants to step into the incoming ball. Participants were then instructed to hit a series of topspin double-handed backhand strokes aiming for a crosscourt target zone (target size: 2.5 m x 2.5 m) adjacent to the baseline and left singles backhand corner. They performed these strokes using their preferred non-dominant grip (eastern) first and once five successful attempts were achieved, the participants then repeated the protocol using their non-preferred grip (continental). Participants were instructed to perform all strokes with the same technique typical of match-play with no instruction given regarding stance. Balls were fed to participants using a Spinfire Pro 2 ball machine (Fry Developments Pty Ltd, Melbourne, Australia) along the left singles line at a speed of 20 m/s.

A total of 54 reflective markers (12 mm in diameter) were attached to the shoulders and upper limbs of each participant using a combination of rigid clusters and single markers (Wells, Donnelly, Elliott, Middleton, & Alderson, 2018; Busuttil, et al., 2020). An additional six light rubber markers (12 mm in diameter) were placed on each participant's racket. Marker trajectory data were collected using a 12-camera Vicon Vantage motion capture system (Vicon Motion Systems Ltd., Oxford, UK; 250 Hz). Subject-specific static calibration was established in the anatomical position which then followed with capture of dynamic trials. Individual marker coordinates were reconstructed using Nexus software (Vicon Motion Systems Ltd., Oxford, UK, V 2.7.0) with marker trajectories filled using spline, pattern or rigid 'gap filling' functions. Joint angles were calculated using a nine-segment linked upper limb kinematic model with the racket modelled as an additional segment (Wells et al., 2018; Busuttil et al., 2020). Variables of interest included post-impact ball velocity (m/s) which was measured using the Hawk-eye ball tracking system (Hawk-Eye Innovations, 2007), racket head linear velocity (horizontal, vertical; m/s) and upper limb joint angular velocities (˚/s; shoulder [flexion/extension, adduction/abduction and internal/external rotation], elbow [flexion/extension and pronation/supination] and [wrist flexion/extension and ulnar/radial deviation]) at the instance of peak magnitude during the forward swing and at ball impact. Resultant linear velocity (m/s) of joint centres (shoulder, elbow and wrist) were also calculated. Three successful backhand attempts from each condition (total of 6 trials) were used for analysis using Jamovi (v 1.1.8.0, Jamovi project). A series of paired-samples t-tests were calculated to detect statistical significance between conditions with an alpha level of .05.

RESULTS: Post-impact ball velocity ($p < .001$) was greater in the Eastern grip (29.1 ± 2.4 m/s) compared with the Continental grip (26.8 ± 2.3 m/s). Peak horizontal racket head linear velocity was significantly higher ($p = .006$) in the Eastern condition (25.8 ± 2.7 m/s) when compared with the Continental condition (23.4 ± 2.0 m/s) but did not differ at impact (Eastern: 17.7 ± 1.9 m/s; Continental: 16.5 ± 2.1 m/s; $p = .142$). Peak vertical racket head velocity was similar between conditions (Eastern: 10.3 ± 2.9 m/s; Continental: 9.6 ± 3.4 m/s; $p = .487$) but was significantly higher ($p = .003$) in the Eastern grip (8.4 ± 2.9 m/s) when compared with the Continental grip (7.0 ± 3.1 m/s) at impact. In the non-dominant limb, peak joint angular velocities were higher in the Eastern condition compared with the Continental condition across several variables at the wrist, elbow and shoulder ($p < .05$; Table 1). In the dominant limb, only shoulder joint peak angular velocities were higher in the Eastern condition compared with the Continental condition ($p < .05$) with all other variables being non-significant ($p > .05$; Table 1). Only non-dominant shoulder extension angular velocity remained significant at impact (Eastern: 281.0 ± 129.4˚/s; Continental: 179.3 ± 92.1 ˚/s; $p < .001$). Peak resultant joint centre linear velocities of the dominant limb were higher in the Eastern condition compared with the Continental condition across each joint (Eastern: wrist: 8.0 ± 1.2 m/s, elbow: 4.5 ± 0.6 m/s, shoulder: 3.1 ± 0.5 m/s; Continental: wrist: 6.9 ± 1.2 m/s, elbow: 3.8 ± 0.5 m/s, shoulder: 2.6 ± 0.5 m/s; $p \leq .001$). At impact, dominant limb resultant joint centre linear velocities in the Eastern condition were greater at the wrist (Eastern 5.2 ± 0.5 m/s; Continental: 4.7 ± 0.7 m/s; p = .001) and elbow (Eastern 2.1 ± 0.6 m/s; Continental: 1.7 ± 0.6 m/s; p = .005) but not for the shoulder (Eastern 1.7 ± 0.4 m/s; Continental 1.5 ± 0.6 m/s; p = .096). In the non-dominant limb, only elbow and wrist peak resultant joint centre linear velocity was greater in the Eastern condition (elbow: 6.9 ± 0.8 m/s, wrist: 8.8 ± 1.2 m/s) compared with the Continental condition (elbow: 5.5 ± 0.8 m/s, wrist: 8.1 ± 1.0 m/s; p < .001). All other non-dominant limb variables for resultant linear velocity at peak magnitudes and impact did not result in significant differences (p > .05).

Table 1. Dominant and non-dominant upper limb peak angular velocities (Mean ± SD) during crosscourt strokes across grip types.

	Dominant limb		**Non-dominant limb**	
Peak angular velocity (˚/s)	**Eastern**	**Continental**	**Eastern**	**Continental**
Wrist flexion**^**	752 ± 318	650 ± 194	567 ± 244	400 ± 178
Wrist extension	-766 ± 300	-678 ± 191	-274 ± 126	-203 ± 114
Wrist ulnar deviation**^**	347 ± 186	335 ± 197	465 ± 169	366 ± 156
Wrist radial deviation**^**	-256 ± 186	-262 ± 143	-256 ± 174	-197 ± 143
Elbow flexion	445 ± 130	437 ± 121	314 ± 145	330 ± 135
Elbow extension	-101 ± 117	-98 ± 105	-287 ± 163	-253 ± 156
Elbow pronation**^**	403 ± 169	379 ± 116	415 ± 138	341 ± 129
Elbow supination	-317 ± 161	-286 ± 216	-400 ± 145	-334 ± 134
Shoulder flexion*****	321 ± 107	256 ± 89	358 ± 120	277 ± 197
Shoulder extension***^**	-283 ± 119	-219 ± 98	-354 ± 118	-225 ± 104
Shoulder adduction*****	534 ± 136	411 ± 87	514 ± 152	420 ± 200
Shoulder abduction*****	-527 ± 141	-405 ± 100	-102 ± 78	-137 ± 207
Shoulder internal rotation	5 ± 3	3 ± 1	8 ± 4	7 ± 3
Shoulder external rotation	-4 ± 2	-3 ± 2	-3 ± 3	-2 ± 1

Significant differences which are indicated by * and ^ for the dominant and non-dominant limb respectively between the eastern and continental grip; p < .05.

DISCUSSION: The current study is the first to explore the effect of grip position on upper limb angular kinematics during a tennis double-handed backhand. Our initial hypothesis was supported as greater peak angular velocity in non-dominant shoulder adduction, and greater peak horizontal racket head linear velocity were observed in the eastern grip compared with the continental grip. The greatest differences were evident for peak magnitudes, where dominant shoulder angular velocity for flexion, extension, adduction & abduction, and non-dominant angular velocity for multiple variables at the shoulder, elbow and wrist were greater in the eastern grip compared with the continental grip. A recent investigation has demonstrated that the use of the continental grip at the non-dominant hand resulted in a more extended non-dominant elbow joint at peak backswing and impact for crosscourt double-handed backhands (Busuttil et al., 2020). The more extended elbow increases the moment of inertia of the non-dominant upper limb, which then requires greater torque at each joint to produce similar joint angular velocity in the continental condition compared with the eastern condition. This subsequentially results in reduced racket head speed as observed in the continental condition of the present study. Internal and external rotation of both the dominant and non-dominant shoulders resulted in relatively small peak angular velocities compared with the remaining shoulder joint rotations (Table 1). This suggests that athletes do not rely on shoulder internal/external rotation to develop racket head speed in the double-handed backhand. Previous analyses in high-performance adults have emphasised the importance of shoulder internal rotation in tennis forehands for topspin (Takahashi et al., 1996) and racket head speed in serves (Elliott et al., 1995) which may suggest that the importance of trunk rotation is greater for generating racket head speed in double-handed backhands. Although trunk rotation was not assessed in the current study, this difference possibly reflects physical developmental differences between the current participants (sub-elite adolescents) and previous cohort of high-performance adults. The greater peak angular velocities observed in the eastern condition for the non-dominant wrist may have also been a result of grip force applied by the non-dominant hand. Maintaining a forceful grip possibly allows for preservation of a concentric contraction of wrist flexors (non-dominant limb) during impact, thereby creating a more stable racket face. This minimises eccentric overload of the associated musculature which is a hypothesised mechanism for overuse injuries (Pull & Ranson, 2007). Although impact location and grip tightness were not assessed in the present study, impacts below the racket's longitudinal axis can result in forced wrist flexion up to 16°, with up to six times more wrist extension torque when compared with a central impact in singled-handed backhands (King, Kentel, & Mitchell, 2012). It can be proposed that the non-dominant limb of the double-handed backhand would respond in a similar manner, resulting in forced wrist extension. It is probable that off-centre impacts occurred in the continental condition as the grip is untrained compared with the eastern condition. This may then affect coordination between upper limb segment joint rotations, possibly reducing angular velocity at the elbow and wrist and subsequent racket head speed. The greater peak resultant linear velocity of each dominant limb, and non-dominant elbow and wrist joint centre in the eastern condition may have been a result of an increased distance for the upper limbs to travel and therefore more time to generate joint centre linear velocity. The forward acceleration of the distal segment act as a function of the proximal segment's angular velocity (Putnam, 1993). Therefore, the angular velocity at the shoulder joint, being the most proximal joint centre of the upper limb kinetic chain would influence the velocity of the elbow joint centre, and consequently the wrist.

CONCLUSION: This study demonstrated that a change in non-dominant hand grip position during a double-handed backhand stroke resulted in multiple kinematic differences across the dominant and non-dominant limb. The hypothesis was supported as non-dominant peak shoulder adduction angular velocity, and horizontal racket head linear velocity was greater in the eastern grip. The eastern grip produced greater angular velocity at the non-dominant and dominant shoulder, and non-dominant elbow and wrist, subsequently resulting in greater peak horizontal racket head speed. Collectively this suggests that the eastern grip is more optimal for developing racket head speed to execute effective high-speed strokes. This information may benefit coaches to optimise technical development of athletes choosing between grip types and quantify the effect of grip position on upper limb angular kinematics.

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