UPPER LIMB KINETICS BETWEEN TWO DIFFERENT STANCES IN A TENNIS FOREHAND DRIVE: A PRELIMINARY STUDY

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The purpose of this study was to compare the joint moments of force of the upper limb between one forehand drive performed in quasi-static stance (QSS) (with both feet on the ground at the impact) and one forehand performed with a dynamic frontal weight transfer stance (DS) (with both feet off the ground at the impact). One high-performance tennis player was recorded with an optical system with a frequency of 240Hz during both techniques. Three forehands in QSS and three in DS were selected for analysis. Results demonstrated that the forehand performed with DS could present higher moments of force, especially in the shoulder joint abdu/addu (QSS:45.5 vs DS:52.8 Nm), moreover, the DS presented higher racket velocity compared with the QSS forehand drive (DS: 32.7(0.4) vs QSS:31.5(0.4) m/s). The results of this study could present an important information for tennis coaches as for their players in order to understand which forehand technique creates higher joint loads, and, therefore adapt the practice for each situation.

KEYWORDS: upper limb, kinetics, forehand, racket velocity.

INTRODUCTION: Biomechanics research in the tennis forehand drive has focused mostly in kinematics studies such as the key factors between different level of expertise (Landlinger, Lindinger, Stöggl, Wagner, & Müller, 2010b), differences between flat and topspin forehand (Genevois, Reid, Creveaux, & Rogowski, 2020) and also differences in the forehand kinematics as post-impact ball speed increased (Seeley, Funk, Denning, Hager, & Hopkins, 2011). Moreover, it was demonstrated that the most important rotations of the upper limb to the racket head velocity in the forehand drive were the horizontal flexion/abduction and internal rotation of the upper arm (Elliott, Takahashi, & Noffal, 1997). On another hand, with regard to the kinetic studies focusing the upper limb in the forehand drive the studies are scarce, nevertheless, Bahamonde & Knudson (2003) showed the kinetics of the upper limbs between the close and open stance demonstrated that the square stance produced higher torques resulting in higher loadings at the upper limb joints. Most of the studies addressing the tennis forehand have no reference to the stance used by the players (Landlinger, Lindinger, Stöggl, Wagner, & Müller, 2010a; Landlinger et al., 2010b; Seeley et al., 2011). The studies that defined the stance used by the participants refereed mainly the close and the open stance (Bahamonde & Knudson, 2003; Genevois et al., 2020). However, in modern tennis there are many variations used by top players in the stance adopted in relation to the ball. A particularly interesting variation when players hit the ball is that they can hit the ball with their feet off the ground (DS), transferring all their body weight to the ball. This technique used by the players should have implications in their performance as well as on the mechanical load placed upon the upper limb joints. Thus, a better understanding of these differences could give an important insight to tennis coaches and physiotherapists for injury prevention. To the best of our knowledge, no study has compared these different forehand drive stances to understand what differentiates quasi-static stance (QSS) when the player hits the ball with their feet on the ground with a more DS with frontal weight transfer when the players contact the ball with their feet off the ground. Thus, the aim of this work was to compare the joint kinetics of the shoulder, elbow and wrist, and the raquet velocity between the tennis forehand drive performed in a QSS and a DS with frontal weight transfer.

METHODS:

One male expert tennis player (age: 21 years old; height: 175 cm; mass: 65 kg), provided written informed consent to participate in this study, which was approved by the Institution's Ethics Committee. The participant was free from injuries, practiced regularly 10h hours per week and competed at national competitions. Before testing, the participant had 15 min for an individual warm-up and to become familiar with the test environment. Before data collection, the experimental procedure was explained. The participant used his own tennis racket and he was instructed to hit the ball as in a real situation during both stances. Three forehand drives performed with the feet on the ground at ball impact and three with the feet off the ground at impact were performed against a hanging cotton cloth of 3X2 m to cushion the ball. An experienced tennis coach provided the ball feed into a bounce area with 3 seconds between each stroke. Upper body kinematics were recorded at 240Hz with an optical system (OS) with fifteen infrared high-speed cameras (Oqus 300, Qualisys AB, Sweden) and one video camera (Oqus 210c) to identify the ball contact with the racket, using the Qualisys Track Manager (version 2.17, Qualisys AB, Gothenburg, Sweden) software. Kinematic data were collected with 15 reflective markers with a 25 mm diameter placed on the following anatomical landmarks: C7, T8, suprasternal notch, xiphoid process, lateral and medial epicondyle of the humerus, acromioclavicular joint, lateral point of the radial styloid, medial point on ulnar styloid, base of the second and fifth metacarpal proximal phalanges, anterior and posterior superior iliac spines, (Wu et al., 2005). Additionally, four rigid light weight clusters with four non-colinear tracking markers were placed laterally on the upper-arm, forearm and hand. Four additional tracking markers were placed on the tennis racket of each participant (racket tip, shaft, at 3 and 9 o'clock positions, Figure 1) (Landlinger et al., 2010b). The 3D marker trajectories during the standing and forehand drive trials were identified in Qualisys Track Manager software and exported to c3d format, and filtered in Visual 3D using a 4th order low-pass Butterworth filter with a cut off frequency of 15 Hz (Martin, Bideau, Ropars, Delamarche, & Kulpa, 2014). Using the markers coordinates during the standing trial, a biomechanical model was built with 5 segments (thorax, upper-arm, forearm, hand and racket) and joint angles of shoulder, elbow, wrist, separation angle (difference between shoulders and pelvis in transverse plane were computed using an ML-AP-Axial Cardan sequence (Grood & Suntay, 1983).The segments' POSE was computed from the trajectories of the tracking markers using a segment optimization (Spoor & Veldpaus, 1980). All joint angles were time normalized to 101 data points representing the period between the first movement of the racket shaft in the direction of the shot (Figure 1) until the impact. The Netwton-Euler inverse dynamic approach (Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2014) was used to calculate the joint loads (moments of force) in Visual 3D software (Visual 3D Professional V5.01.21, C-motion, Germantown, MD). The dominant arm was modelled as a five-link kinetic chain composed of racket, hand, forearm, upper arm and trunk. The inertial parameters of the segments were computed based on Hanavan (1964), while segment masses were determined according to Dempster (1955). The moments of inertia of the racket about its medial-lateral, the long axis and the anterior-posterior axis were determined as in Elliott, Fleisig, Nicholls, & Escamilia (2003). To better interpret the findings we defined: negative shoulder joint moments indicate external rotation, adduction and horizontal adduction; negative elbow joint moments indicate supination, valgus and extension; negative wrist joint moments indicate extension and radial deviation.

Figure 1: Participant performing the forehand with balance stance with their feet on the ground at the impact and with frontal weight transfer with their feet off the ground at the impact, from the beginning of the acceleration phase until the impact. Racket with four tracking markers.

RESULTS: Table 1 displays the means and standard deviation of the peak joint moments of the upper arm during the acceleration phase of the forehand drive performed in a quasi-static stance (with both feet on the ground at the impact) and with a dynamic stance (with both feet in the air at the impact) and the racket tip velocity at impact in both techniques. The shoulder joint presented the largest peak moment of forces, followed by the elbow and the wrist. The dynamic stance showed higher joint moments of forces in all three joints of the upper limb. A higher racket tip velocity was observed during the dynamic stance forehand technique.

Table 1: Mean and standard deviation of peak joint moment forces (Nm) performed during the acceleration phase of the forehand in BS forehand and in WTS forehand.

Variables	QSS	DS
	Mean(SD)	Mean(SD)
Shoulder		
Int(+)/Ext(-) rotation	-41.4 (6.9)	-48.6 (11.1)
Horizontal abdu(+)/addu(-)	43.7 (6.9)	54.0 (7.2)
Abdu(+)/addu(-)	45.4 (5.2)	52.8 (1.2)
Elbow		
Pronation(+)/supination(-)	-17.2 (1.5)	-17.4 (1.1)
Varus(+)/Valgus(-)	-14.7 (2.2)	-16.4 (2.8)
Flexion(-)/Extension(+)	-9.0 (0.6)	-10.7 (2.5)
Wrist		
Flexion(+)/extension(-)	6.4 (0.6)	6.7 (0.1)
Ulnar(+)/radial(-) deviation	2.2 (0.1)	2.0 (0.2)
Racket tip velocity (m/s)	31.5 (0.4)	32.7 (0.4)

DISCUSSION:

The purpose of this study was to compare the kinetics of the upper limb between two different forehand drives, one in a quasi-static stance and one in dynamic stance and to identify if the dynamic stance presented a higher racket velocity. Our preliminary results show that the dynamic stance presented higher racket velocity compared with the quasi-static forehand drive 32,7 (0.4) vs 31,5 (0.4) m/s). The upper limb kinetics in the DS forehand also presented higher peak joint moments of force for all the three joints of the upper limb. These differences were higher for the three axes of the shoulder, while for the elbow and wrist the differences were lower. These results suggest that coaches should take careful when introducing a dynamic stance forehand due to the higher loads presented in this technique. Our results are preliminary and involve only one experienced player, nevertheless the shoulder peak joint torques obtained were similar to the ones in a previous study that compared the close and open stance forehand (Bahamonde & Knudson, 2003), as well as the internal/external rotation shoulder moment of force in the square stance performed by teaching professionals and higher when compared with the results obtained by intermediate players from the same study. Our results presented inferior peak joint moments, in comparison with the ones from the same study, for the horizontal abduction of the shoulder. These differences could be explained by individual differences in the forehand technique. Moreover, our study was developed inside the laboratory which could have some influence in the performance of the participant. On the other hand, in the abduction of the shoulder we have observed higher values compared to the ones obtained by Bahamonde & Knudson (2003), which can be explained by a considerable abduction at the beginning of the acceleration phase from the participant of our study. Conversely, and despite a different technique, Creveaux et al., (2013) showed higher joint moments in shoulder during the tennis serve, during the upward acceleration in all three axis of rotation. The higher peak joint moments of force of the shoulder are in line with Elliott et al., (1997) that considered that the higher contributions to the racket head velocity were related to the flexion/abduction of the upper arm and the internal rotation of the upper arm regardless of the grip used by the players. The shoulder joint presented the large peak moment of forces values, followed by the elbow and the wrist, the same pattern was shown during the tennis serve (Martin et al., 2014). The elbow peak joint moments were higher for the pronation/supination, inferior for varus/valgus and inferior for flexion/extension of the elbow compared with teaching professionals and inferior to intermediate tennis players (Bahamonde & Knudson, 2003).The wrist peak moments were similar to teaching professionals in square stance and inferior to intermediate players (Bahamonde & Knudson, 2003). The racket velocity were similar to elite tennis players when played in the cross court and down the line direction (Landlinger et al., 2010b) although this latter study was developed in a tennis court.

CONCLUSION: This study compared the peak joint torque between a forehand drive in a quasi-static stance and a dynamic stance with weight transfer. Our results suggest that the players create higher loads when they hit the ball with their feet off the ground and the racket velocity seems to be a little higher. These results could present a valuable information for coaches and players in order to make better decisions concerning the practice and to select the better technique in different game situations. Moreover, coaches should ensure that players are physically prepared (to withstand the higher loads) and that their forehand drive is stabilized before they introduce the dynamic stance technique.

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