RELATIONSHIP BETWEEN BALL IMPACT LOCATION AND JOINT ANGLE CHANGES FOR ONE-HANDED TENNIS BACKHAND GROUNDSTROKES

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The purpose of this study was to investigate the effect of off-longitudinal axis and off-lateral axis ball-racket impact locations on racket and lower arm joint angle changes for one-handed tennis backhand groundstrokes. Three-dimensional racket and wrist angular kinematic data were recorded for fourteen university tennis players. Off-longitudinal axis ball-racket impact locations explained over 70% of the variation in racket rotation about the longitudinal axis and wrist flexion / extension angles during the period immediately following impact. Off-lateral axis ball-racket impact locations had a less clear cut influence on racket and lower arm rotations. This study has confirmed that off-longitudinal impacts below the longitudinal axis cause forced wrist flexion and established that there can be large differences in forced wrist flexion from individual to individual.

KEY WORDS: tennis, off-centre impacts, backhand

INTRODUCTION: One-handed backhand ground strokes in tennis have been widely investigated with a particular focus on the potential link to tennis elbow injuries. The location of ball-racket impact has a direct effect on the racket / arm motion during tennis strokes (King et al., 2012) with off-centre impacts frequently occurring (Elliott, 1982; Knudson, 1993). Furthermore, off-centre impacts away from the longitudinal axis of the racket result in less accurate rebounds (Knudson, 1993) and could contribute to elbow pain, especially in one-handed tennis backhands (Bernhang et al., 1974; Hennig et al., 1992; Giangarra et al., 1993). During an off-centre impact, the racket tends to rotate within the hand according to the ball-racket relative velocity and the distance of the impact location from the longitudinal axis of the racket (King et al., 2012). Knudson (1991) found that, together with the pre-impact force on the hand, the impact location accounted for 66% of the variability of the post impact loading on the hand for forehand strokes. Hennig et al. (1992) compared centre and off-centre impacts for backhand strokes and found an approximately threefold increase in arm loading during an off-centre impact.

King et al. (2012) used a torque-driven model to determine for one individual the effect of ball-impact location and grip tightness on the arm, racket and ball. This study showed the relationship between ball impact location and racket rotation immediately after ball impact with off-centre impacts below the longitudinal axis of the racket causing the wrist to flex up to 16° more with up to six times more wrist extension torque when compared to a centre impact simulation. The issue that has yet to be resolved is whether the effect of ball impact location is the same for different players. Consequently, the aim of this study was to examine the relationship between ball-racket impact location and racket / lower arm angular kinematics for one-handed tennis backhand groundstrokes performed by a range of performers of different abilities.

METHODS: Ten male and four female tennis players of university performance and university development standard (age 20.9 years ± 2.4 (mean ± SD), height 177.4 cm ± 8.9, and mass 72.4 kg ± 10) performed 30 one-handed flat backhand groundstrokes in an indoor laboratory environment. Babolat Team tennis balls were used and fired from a Lobster ball cannon at 80 mph (129 km/hr). No players stated they felt fatigued from the testing procedures. The testing procedures were explained to each participant and informed consent was obtained in accordance with the Loughborough University Ethical Advisory Committee.

Trials were recorded using a 17 camera Motion Analysis System operating at 480 Hz. Seven, 14 mm diameter, spherical reflective markers were attached to the racket arm along with four pieces of reflective tape (≈1 cm square) attached to each tennis ball. At the wrist a pair of markers was positioned near the styloid processes such that the midpoint of the pair of markers lay on the midline of the lower arm. At the elbow a pair of markers was positioned vertically above the medial and lateral elbow epicondyle bony landmarks (when the arm was horizontal and extended with the palm of the hand facing upwards) so that the midpoint of the pair of markers lay on the midlines of the upper arm and lower arm. At the shoulder a pair of markers was positioned (anterior and posterior to the shoulder) with the arm down so that the midpoint of these markers intersected the midline of the upper arm (King and Yeadon, 2012). In addition one marker was attached to the back of the hand. Reflective tape, 1 cm wide, was applied to the Wilson Pro Tour BLX 96 racket (Head size 96", length 27", weight 314 g [unstrung], string Pattern 18 x 20, tension 57 lbs) in five different locations, four on the stringbed frame creating a rectangle and one on the throat of the racket.

Successful trials where the ball made contact with the stringbed and the markers were tracked completely were analysed. For each participant this resulted in a minimum of 24 successful trials. For each trial the ball-racket impact location in the x (off-longitudinal axis) and z (off-lateral axis) directions on the racket were determined. In addition the 'peak change' in racket and arm angles over a 30 ms time frame after initial impact for the racket and arm relative to the racket and arm angles at the instant before impact were calculated. In particular; the racket rotation about the longitudinal and lateral axis of the racket, wrist flexion / extension angle and forearm pronation / supination angle were calculated. The relationship between ball-racket impact location and the changes in racket and arm angles due to the impact were assessed via linear regression.

RESULTS AND DISCUSION: Off-longitudinal axis ball-racket impact locations had a significant and consistent effect on the racket rotation about the longitudinal axis and the wrist flexion / extension angle for all participants. In contrast the racket rotation about a lateral axis and the pronation / supination of the forearm in response to off-longitudinal axis impacts had a weaker association with some participants having significant relationships. Furthermore off-lateral axis impacts had an inconsistent effect on the racket and arm rotations after impact.

The strongest relationships were between off-longitudinal axis impacts, racket rotation about the longitudinal axis and wrist flexion / extension. In both cases on average over 70% of the variation was explained by the off-longitudinal impact location with 'similar' relationships for each participant found (Figure 1). This is in agreement with a theoretical study by King et al. (2012) where off-longitudinal axis impacts caused substantial changes in both racket rotation about the longitudinal axis and wrist flexion / extension angles.

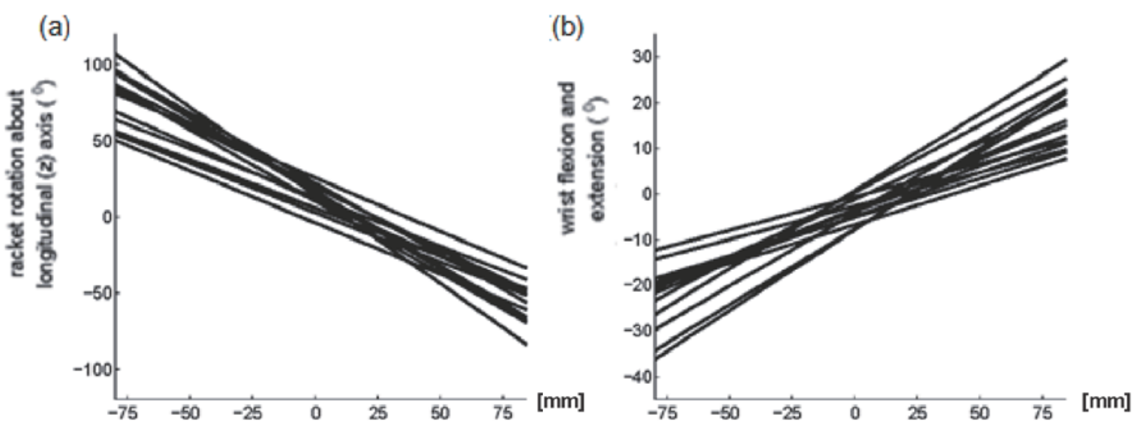

Figure 1: The relationship between off-longitudinal axis impact locations and (a) racket rotation about the longitudinal axis, (b) wrist flexion / extension for all participants.

For all participants, impact locations below the longitudinal axis resulted in the wrist being forced into a more flexed position after ball-racket impact. As a consequence the wrist extensors are forced to stretch eccentrically. Although impacts below the longitudinal axis caused forced wrist flexion for all fourteen participants, there was variation in the amount of forced wrist flexion (Figure 1b). For an impact 68 mm below the longitudinal axis, the range of changes in the wrist flexion angle was 11º - 32º. In this study it was not possible to specifically establish the cause for a three-fold variation in forced wrist flexion angle change but it is likely to be due to a combination of technique and grip tightness. It is probable that the participants with larger amounts of forced wrist flexion will be at a greater risk of getting tennis elbow. Future research should examine this relationship in more detail to see if there is an amount of forced wrist flexion that puts participants at high risk of getting tennis elbow. Furthermore understanding the specific relationship between technique, grip tightness and off-centre impacts is crucial if the current high levels of tennis elbow are to be reduced in the future. Once this relationship is established it may be possible to encourage techniques with younger players that leave them less susceptible to developing tennis elbow.

The effect of off-lateral axis impacts on the racket and arm motions were weak with there being very little evidence for a consistent effect. This may well be because the effect of an off-longitudinal impact is so dominant on the resulting movements. This is in agreement with the study by King et al. (2012) where different off-lateral axis impacts had proportionally small effects on racket rotation and wrist flexion / extension angles compared to off-longitudinal axis impacts.

CONCLUSION:

Off-longitudinal axis ball-racket impacts have a substantial effect on the kinematics of the racket and the wrist flexion angle while off-lateral axis impacts have much less effect. Furthermore this study has confirmed that off-longitudinal axis impacts below the longitudinal axis cause forced wrist flexion and established that there can be large differences in the amount of forced wrist flexion from individual to individual. Further work should focus on what causes these individual differences with the aim to reduce the effect of off-centre impacts, minimise the risk of developing tennis elbow and improving the accuracy of shots.

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