11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

FACTORS EFFECTING LOADING AT THE ELBOW IN TENNIS

Mark A. King[1]*, Behzat B. Kentel[2] and Sean R. Mitchell[3]

[1*] School of Sport Exercise and Health Sciences, Loughborough University, Ashby Rd, UK, M.A.King@lboro.ac.uk and http://www.lboro.ac.uk/departments/ssehs/staff/dr-mark-king-.html
[2] Middle East Technical University, Northern Cyprus Campus, Guzelyurt, Mersin 10, Turkey, kbehzat@metu.edu.tr and http://ncc.metu.edu.tr/cv/170/Behzat%20Bahad%C4%B1r_KENTEL.html
[3] School of Mechanical and Manufacturing Engineering, Loughborough University, S.R.Mitchell@lboro.ac.uk and http://www.lboro.ac.uk/departments/mechman/staff/sean-mitchell.html

Key Words: *Tennis, one-handed backhand, simulation, modelling.*

The one-handed tennis backhand groundstroke has been associated with being a substantial contributing factor to 'tennis elbow' injury due to adverse loading conditions. The aim of this study was to investigate the effect of several variables of the equipment and the player on the wrist and elbow loadings during one-handed tennis backhand groundstrokes. A subject-specific, 9-segment, torque-driven, 3D computer simulation model for one-handed tennis backhand groundstrokes was used that had previously been evaluated (Figure 1, [1]).

Figure 1. Nine segment computer simulation model [1].

The stringbed was represented by nine point masses connected to each other and the racket frame with 24 elastic springs [2]. The ball-racket impact was modeled as a normal force and a frictional force at the location of any of the point masses on the stringbed [2]. There were twelve rotational degrees of freedom: three at the shoulder, two at the elbow, two at the wrist, three at the grip and two between the racket handle and the racket head [1]. Seven pairs of torque generators were used to control the movement of the arm via activation profiles in the model. Three pairs of equal and opposite torques between the hand and the racket handle were used to represent the gripping torque around the principal axes of the tennis racket [1]. Subject-specific parameters for the racket, ball and one elite subject were determined from experiments [1, 2]. A previously obtained matching simulation where the ball contacted the centre of the racket head [1, 2] was used as the starting point for all simulations in this study.

The matching simulation was perturbed using single simulations with fixed activation profiles and the effect on the loading at the wrist and elbow were observed along with the changes in kinematics. In particular ball impact location, racket mass, racket moment of inertia, racket frame flexibility and soft tissue movement were perturbed.

Perturbing the ball-racket impact location had a large effect on the wrist, elbow and racket kinematics. The racket rotated about 30° more in each direction around its longitudinal axis depending on the impact location at the upper or lower part of the racket. When the impact was on the lower part of the racket the wrist flexed and elbow supinated approximately 16° and 20° more, respectively compared with a centre impact. For an impact at the upper part of the racket, the wrist extended and elbow pronated approximately 10° and 12° more, respectively. The wrist and elbow joint forces increased by up to 28% for an impact on the longitudinal axis of the racket near the tip. The major effect of the impact location was observed on the wrist flexion/extension torque. An impact at the upper part of the racket caused seven times more flexor torque whereas an impact at the lower part caused a six times more extensor torque in magnitude due to eccentric loading.

When the mass of the racket was doubled, the wrist flexor torque increased for a centre impact, however, for an off-centre impact the wrist extensor torque and wrist and elbow joint forces decreased by up to 8%. In addition, if the moment of inertia of the racket was doubled as well as the mass, the wrist extensor torque decreased by up to 27%. When only the moment of inertia of the racket around the longitudinal axis was doubled, the decrease in the wrist extensor torque was 16% but no substantial change in the joint forces was observed. The racket frame flexibility and soft tissue movement in the arm had a negligible influence on the wrist and elbow kinematics and kinetics.

In conclusion, this study suggests that the off-centre impacts at the lower part of the racket may be a substantial contributing factor for ‘tennis elbow’ and changes to racket parameters make only a small difference to the effect of off-centre impacts. In the future, the model can be used for further investigations on the technique of the backhand stroke for different players and demographic groups.

REFERENCES

[1] B.B. Kentel, M.A. King and S.R. Mitchell, Evaluation of a subject-specific, torque-driven computer simulation model of one-handed tennis backhand groundstrokes. J. App. Biom., Vol. **27**, pp. 345-354, 2011.

[2] J.A. Glynn, M.A. King and S.R. Mitchell, A computer simulation model of tennis racket/ball impacts. Sports Eng., Vol. **13**, pp. 65-72, 2011.