INFLUENCE OF A PROLONGED TENNIS MATCH PLAY ON TENNIS SERVE BIOMECHANICS

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The aim of this study was to quantify biomechanical changes that occur in the serve throughout a prolonged tennis match. Serves of tennis players were recorded with a motion capture system before (T0) during (T90), and after (T180) a 3-hour match. Before and after each match, EMG data of upper limb muscles were analyzed to determine the presence of muscular fatigue. RPE and ball velocity and biomechanical variables were analyzed. Decreases in ball velocity; maximal angular velocities and increase in RPE were observed. The majority of the upper limb joint kinetics decreases between T0 and T180. No change in timing of maximal angular velocities was observed. A prolonged tennis match induces fatigue in upper limb muscles, which decreases performance and modifies serve biomechanics.

KEY WORDS: fatigue, kinetics, kinematics, upper limb.

INTRODUCTION: The typical average tennis match duration is between 1 and 2 hours but in some cases this duration can be prolonged (from 3 to 6 hours). Throughout an extreme five set tennis match, players can hit more than 1000 groundstrokes and 400 serves leading to muscular fatigue, which is considered both as a cause of performance impairment and an injury risk factor (Hornery et al., 2007). However, the influence of muscular fatigue on serve ball velocity during tennis is unclear. Indeed, Girard et al. (2012) showed that serve ball velocity did not change between the beginning and the end of a 2h30 tennis match while it has been reported that a prolonged tennis training session induced decreases in serve ball velocity (Rota et al., 2014). Previous studies carried out in other activities have shown that muscular fatigue can alter kinetic and kinematics variables in baseball throwing (Murray et al., 2001; Escamilla et al., 2007). To the best of our knowledge, no study has analyzed the influenced of muscular fatigue on serve biomechanics during a prolonged tennis match. Yet, understanding the ways by which muscular fatigue can influence serve biomechanics and performance has considerable interests for tennis players, coaches and medical practitioners. Because altered serve biomechanics due to muscular fatigue may be detrimental to a player performance and increase injury risk, the purpose of this study was to quantify kinematic, kinetic and performance changes that occur in the tennis serve throughout a prolonged match.

METHODS: Eight male tennis players performed 3h competitive tennis matchplay against a matched opponent. Before and after each match, electrodes of a Wireless surface EMG system were placed over eight muscles of each player (deltoid, trapezius, pectoralis major, serratus anterior, latissimus dorsi, biceps, infraspinatus, supraspinatus). When the electrodes were placed, maximal voluntary isometric contractions were performed for each muscle using standard manual muscle testing positions. Median power frequency from these tests was compared before and after the tennis match to detect the presence of muscle fatigue. RPE was collected every 30 minutes during the match. Motion capture sessions of serves with a Vicon MX-40 system were performed before (T0), after 90 minutes (T90) and after (T180) the match. During each session, the players performed 5 successful “flat” serves. Ball velocity was measured with radar. Kinematic and kinetic variables were computed. Data were tested using an ANOVA for repeated measures on ranks. Paired T-tests were used to compare MPF values between T0 and T180.

RESULTS: Biceps brachii, anterior deltoid, pectoralis major, middle trapezius, and triceps brachii showed significant decreases of MPF for IMVC tests performed at T0 and T180. Ball impact height and ball velocity at T180 were significantly reduced in comparison with T0 (-1.8 $m.s^{-1}$, p=0.002) and T90 (-0.8 $m.s^{-1}$, p=0.002). RPE increased significantly from T0 to T180 (T0: 7.2 ± 1.6; T180: 17.3 ± 1.3) ($p<0.001$). Between T0 and T180, the results show significant decreases in maximal angular velocity of shoulder internal rotation (-7.5%), elbow extension (-6.0%), wrist flexion (-13.8%), pelvis longitudinal rotation (-4.7%), trunk transversal rotation (-5.1%), trunk sagittal rotation (-6.0%) (Figure 1) and rear knee extension (-13,1%).

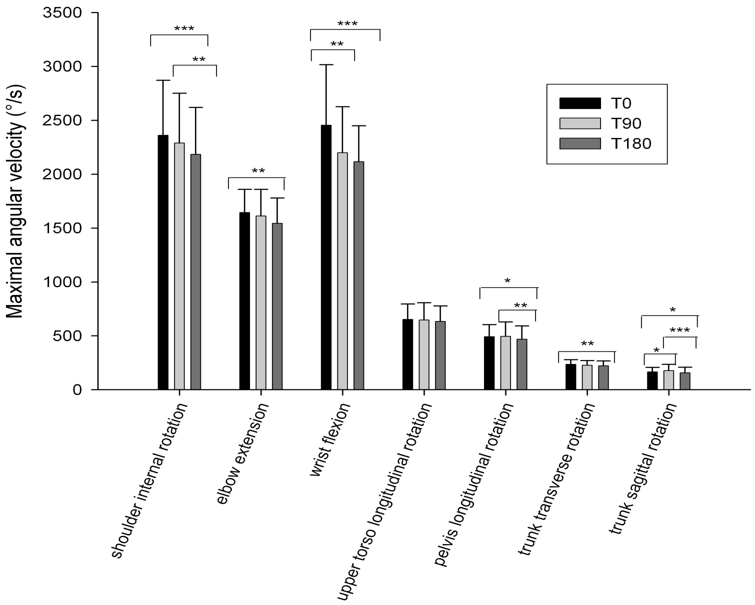

Figure 1. Upper body maximal angular velocities before (T0), during (T90) and after the match (T180). Values are mean ± SD. ***p < 0.001; ** p <0.01; * p < 0.05.

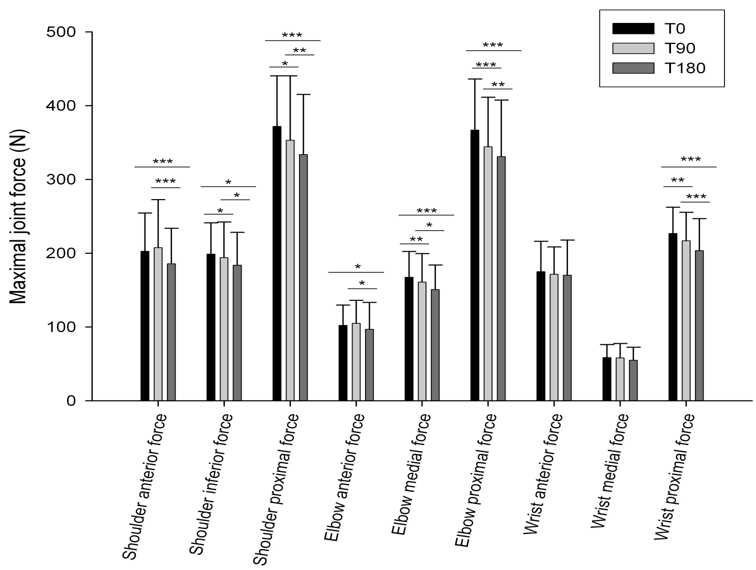

Figure 2. Maximal values of upper limb joint forces before (T0), during (T90) and after the match (T180). Values are mean ± SD. ***p<0.001; ** p<0.01; * p<0.05.

Maximal values of shoulder forces, shoulder internal rotation, shoulder horizontal adduction, shoulder abduction torques, elbow forces and wrist proximal force significantly decreased from T0 to T180 ($p<0.05$). Maximal values of wrist anterior and medial forces, and elbow flexion and extension torques did not change between T0 and T180 (Figures 2 and 3).

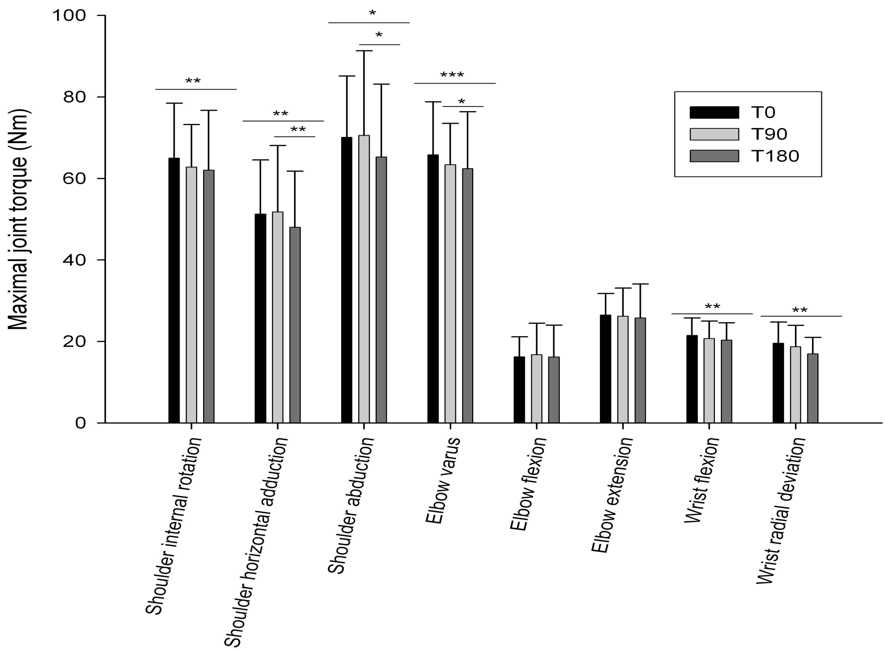

Figure 3. Maximal values of upper limb joint torques before (T0), during (T90) and after the match (T180). Values are mean ± SD. ***p < 0.001; ** p <0.01; * p < 0.05.

DISCUSSION: RPE score progressively increased between T0 and T180, where players perceived the fatigue as "very high". RPE values testify to the strenuous physical effort sustained during the matches. Results show decreases in MPF values between T0 and T180 for biceps brachii, anterior deltoid, pectoralis major, middle trapezius, infraspinatus and triceps brachii, revealing a shift toward lower frequencies of surface myoelectric signal power spectrum that is an indicator of local muscular fatigue (Cifrek et al., 2009).
The decrease in ball velocity could be explained by the decreases in maximal angular velocities measured between T0 and T180 for shoulder internal rotation, elbow extension, wrist flexion, pelvis longitudinal rotation, transverse and sagittal trunk rotations. Indeed, all these rotations contribute to increase serve ball velocity (Gordon & Dapena, 2006). Our results highlight the existence of fatigue in muscles responsible for the decrease in shoulder internal rotation (pectoralis major and anterior deltoid) and elbow extension angular velocities (triceps brachii). The decrease in maximal wrist flexion angular velocity between T0 and T180 could be caused by fatigue in flexor carpi radialis (Rota et al., 2014).
Decreases in ball impact height and velocity are probably caused by kinematical changes in lower limbs between T0 and T180 such as decrease in maximal rear knee angular velocity and increase in maximal internal knee flexion angle. It has been reported that both ball velocity and impact height significantly increase with an efficient leg drive: effective knee flexion and then vigorous knee extension (Reid et al., 2008). Previous works can explain our results. Decreases in maximal isometric voluntary contraction of the knee extensor muscles and in leg stiffness were measured after a 3-hour tennis match (Girard et al., 2006).
The absence of change in timing of maximal angular velocities suggests a consistent segmental coordination pattern. It seems that fatigue preferentially induced an adaptation in

muscle activity level rather than changes in the modular organization of the muscle coordination. However, this temporal stability in segmental coordination pattern could be questioned according to the expertise level of tennis players. In this study, it is possible that the high expertise level of the players allowed them to use a robust serve technique, in spite of the development of muscular fatigue.
Several maximal joint kinetic values were unchanged while the others significantly decreased between T0 and T180. It is unclear whether the significant changes in joint mechanics were a direct result of fatigue that occurs with extended play or if the body adopted protective mechanisms to minimize the risk of injury over the course of a match or the result of these two phenomena. Finally, all of the shoulder kinetics significantly decreased between T0 and T180, while it is only the case for 4 of the 6 kinetic values measured at the elbow and for 3 of the 5 kinetic values at the wrist. These results suggest that compensatory mechanisms at various levels of the coordination kinematic chain may act to delay the effects of fatigue and try to maintain an efficient level of play. Players seem to protect their shoulder as a priority by decreasing kinetics on it, since the shoulder is the most vulnerable joint during the serve (Martin et al., 2013). Conversely, several kinetic values of the most distal joints (wrist and elbow) did not change between T0 and T180, maybe to allow the players to maintain a satisfactory ball velocity level.

CONCLUSION: A 3-hour tennis match induces local muscular fatigue in several upper limb muscles. The results show decreases in serve ball velocity, ball impact height, maximal angular velocities and an increase in RPE score throughout the prolonged tennis match. With fatigue, the majority of the upper limb joint kinetics decreases between T0 and T180. No change in timing of maximal angular velocities was observed between T0 and T180. This consistency suggests that expert tennis players are able to use a robust segmental coordination, which allow them to maintain the temporal pattern of their serve technique, in spite of the muscular fatigue development.

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