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Are serve velocity and ground reaction forces altered following prolonged tennis?

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ABSTRACT

Serving performance is likely to deteriorate when players become fatigued, and since fatigue induces a decrease in leg muscle strength, the contribution of the lower limbs to the stroke may be affected. This study aimed to examine this effect by investigating the impact of prolonged tennis playing on stroke velocity and peak vertical forces during first (flat and slice) and second (topspin) serves. Results are discussed and suggestions are offered for training players to cope with effects of fatigue.

Key words: Fatigue, Tennis serve, Lower limbs.
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INTRODUCTION

Recent biomechanical analyses of the tennis serve have focused on lower extremity kinematics (movements/motion), ground reaction forces or EMG activity of selected leg muscles, underlying the importance of a forceful lower limb drive to produce efficient strokes (Bonnefoy et al. 2009; Girard et al. 2005; Reid et al. 2008).

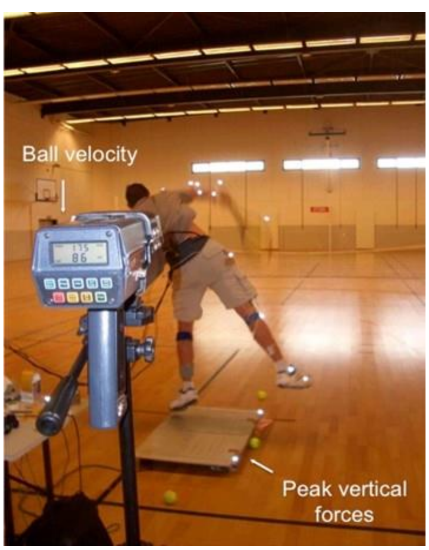

Figure 1. Peak vertical forces and post- impact ball velocity were determined by means of force platform and radar, respectively.

A decrease in isometric maximal voluntary strength of both knee extensors (Girard et al. 2008) and plantar flexors (Girard et al. 2011) has been reported after prolonged (3-h) tennis playing. However, strength losses with fatigue - as measured from isolated leg muscle contractions - do not necessarily reflect changes in lower limb involvement during dynamic/functional and complex multi- segmental movements such as tennis strokes (Wilson and Murphy, 1996). Therefore, it is unclear whether fatigue actually alters stroke efficiency through a modified lower limb contribution during the serve. The purpose of this study was to examine the impact of prolonged tennis playing on ball velocity and peak vertical ground reaction forces during three different types of serve.

METHODS

Nine competitive tennis players (mean ± SD: age 26.1 ± 4.7 years; height 181.5 ± 6.8 cm; body mass 76.3 ± 7.6 kg) competing at regional to national levels (International Tennis Number ranging from 2 to 4) participated in the study. They randomly executed 10 flat (first, FS), 5 slice (first, SS) and 5 topspin (second, TS) serves before and after a 150-min tennis match against an opponent of similar standard. All serve trials were completed from the deuce service court. Peak vertical forces and post-impact ball velocity were determined for each trial by means of force platform (dimension: 100 x 80 x 7 cm; Captels, France) and radar (precision: 0.1 km.h-1; Stalker, USA) fixed on a 2.5 m high tripod situated two meters behind the players, respectively (Figure 1). Heart rate was recorded continuously and averaged every five seconds during the match using short range radio telemetry (S610; Polar Electro Oy, Kempele, Finland). Values are means ± S.D, compared by ANOVA.

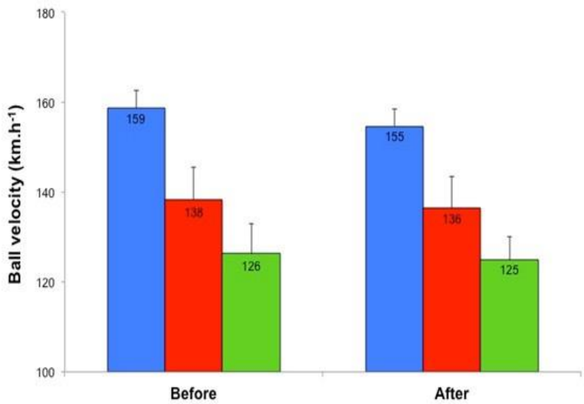

Figure 2. Ball velocity during the first (blue bars), slice (red bars) and topspin (green bars) serves before and after prolonged (150-min) tennis playing.

RESULTS

Ball velocity did not change from pre- to post-match for all serve conditions (Figure 2). In the fatigued state, peak vertical forces were 8.2% higher ($P<0.05$) for TS, but remained unchanged in FS and SS (Figure 3). There was no significant correlation between changes in peak vertical forces and ball velocity ($0.03 < r < 0.62$; $P>0.05$) from pre- to post-match. During the 150 min tennis match, the mean heart rate was 140±8 beats/min, which represents a mean intensity of 75± 7% of maximal heart rate (estimated as 220-age).

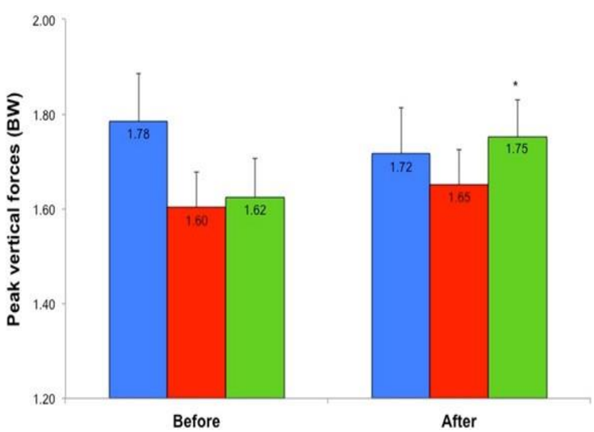

Figure 3. Peak vertical forces during the first (blue bars), slice (red bars) and topspin (green bars) serves before and after prolonged (150-min) tennis playing. * P < 0.05, significantly different from before.

DISCUSSION

During the last two decades, the occurrence of fatigue on skilled tennis performance has been researched increasingly (Davey et al. 2002; Vergauwen et al. 1998). The prevailing view of those investigations is that fatigue during a tennis match or experimental protocol manifests as mistimed shots (decreased velocity and precision). Consistent with other literature (Hornery et al. 2007), however, ball velocity did not change after prolonged tennis playing in this study. Contrasting effects of fatigue on tennis serve efficiency between studies may relate to discrepancy regarding service type, nature of fatiguing protocol or subjects' characteristics. In support of the last point, by comparing the effect of fatigue on attacking forehand drive proficiency between highly-skilled and recreational table tennis players, Aune et al. (2008) demonstrated that expertise enhances potential to adjust motor coordination strategies for minimizing the deleterious effects of physical fatigue.

> The use of pre-fatiguing situations (bouncing, in-depth jumping, plyometric exercise, medicine- ball) of specific muscle groups (i.e. knee extensors, shoulder internal rotators) followed by on-court high-intensity interval- training are recommended in order to widen one player's motor skill repertoire.

In the fatigued state, peak vertical forces were unchanged in FS and SS. In line with these findings, no significant changes in explosive strength - as measured from squat and countermovement jumps - were observed after a tennis match protocol of the same duration (Girard et al. 2006). Unexpectedly, our results also displayed increased peak vertical forces in TS under fatigue. Since the ball velocity was unchanged, this stronger lower limb involvement during TS suggests that the contribution of other body segments participating to the kinetic chain (trunk, upper limbs) could be altered with fatigue (Figure 4). This is further supported by the absence of significant correlation between changes in peak vertical forces and ball velocity from pre- to post-match, as already observed in a non-fatigued state (Girard et al. 2005). Given that the aetiology of muscle fatigue during prolonged tennis playing is complex and likely to include both muscular (muscle contractility) and neural (muscle activation) factors (Girard et al. 2008; Girard et al. 2011), compensatory mechanisms at various levels of the coordination kinematic chain may act to delay the effects of fatigue, thus efficiently maintaining the velocity of the serve. It is possible that this compensation in trunk and/or upper limb muscles may be obtained by a greater reliance on the lower limbs during the TS. This view is consistent with others showing that under fatigue, the segmental coordination of complex movements may be rearranged. In an incrementally fatiguing study of junior elite water polo players, Royal et al. (2006) observed modifications to technical skill proficiency despite no reductions in shot accuracy or velocity. Bonnard et al. (1994) also studied multi-segment movements under fatigue and showed that hopping could be maintained for long periods of time by using different coordination strategies.

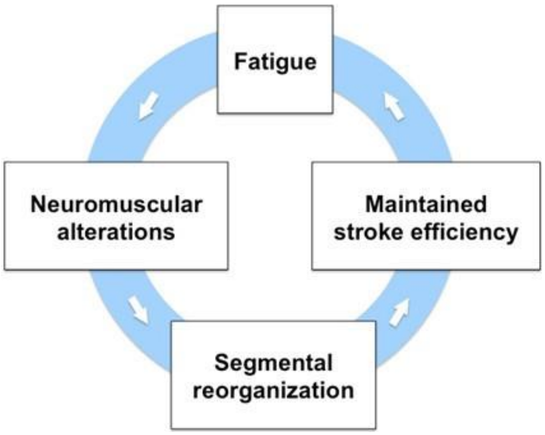

Figure 4. Hypothetical model of preserved serve efficiency under fatigue.

CONCLUSION

After a prolonged tennis match, ball velocity remained unchanged while the effects of fatigue on the lower limb drive were different according to the serve type. This may indicate a modification in inter-segmental coordination to maintain stroke efficiency under fatigue that requires further EMG (timing, muscle activation) and kinematic (linear and angular velocities, joint angles) data from leg, trunk and arm body segments. Results obtained on the serve must be expended to groundstrokes with, in parallel, a strict control of stroke proficiency including not only velocity but also reliable standardized measures of accuracy.

COACHING IMPLICATIONS

One main characteristic of the neuromuscular system is its adaptability. The training of competitive players should therefore focus on improving their ability not only to resist to fatigue but, more importantly, to adjust the coordination under fatigue. In other words, it is important to develop compensatory mechanisms at various levels of the inter-segmental chain in order to maintain the stroke efficiency when playing several hours. The use of pre- fatiguing situations (bouncing, in-depth jumping, plyometric exercise, medicine-ball) of specific muscle groups (i.e. knee extensors, shoulder internal rotators) followed by on-court high- intensity interval-training - possibly through the training version of the CREOPP tennis specific incremental test (Girard et al. 2006) - are recommended in order to widen one player's motor skill repertoire.

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