Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

ASSESSING TENNIS PLAYER INTERACTIONS WITH TENNIS COURTS

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Different types of tennis injury have been associated with play on different court surfaces and current knowledge of tennis player and court interactions is limited. This paper provides a brief overview of tennis injury incidence, player movements and the biomechanics of slips. The discussion proposes a new direction for assessing tennis player-surface interactions and outlines current work. It is envisaged that current work will contribute to the understanding of tennis player-surface interactions and be of practical use in the future regulation of tennis courts.

KEYWORDS: tennis, player, court, friction, assessment.

INTRODUCTION: A defining characteristic of tennis is that it is played on a variety of court surfaces (ITF, 2010). Indeed, Grand Slam tournaments (i.e. Wimbledon, Roland Garros, Australian Open and US Open) are played on grass, clay and acrylic surfaces. Competitive tennis events are regulated by the International Tennis Federation (ITF) which is responsible for developing technological aspects of tennis to improve safety, performance and participation while preserving the sports' integrity. As such, a fundamental role of the ITF is to determine the rules and specifications of tennis to help regulate the sport (ITF, 2010). Properties of tennis courts used for competition, e.g. friction, energy restitution, dimension etc., must meet standards published by the ITF to ensure safety of use and consistency between competitions (ITF, 2010). For example, the ITF has implemented a court pace rating protocol that assesses ball-surface interactions of different court surfaces to categorise court pace (ITF CS 01/02; ITF, 2010). However, current knowledge of player-surface interactions with different court surfaces is limited (Miller, 2006).

Player-surface friction is a dynamic quantity that depends on loading conditions at the shoe-surface interface. The tennis shoe provides an important middle-link between player and court, as kinetic chain movements and task constraints originate from this interface. Shoe-surface interactions are therefore an important consideration in tennis injury incidence. For example, courts providing a high coefficient of friction (COF) have been associated with knee and ankle joint injuries (Nigg & Sesser, 1988) whereas courts providing a low COF have been associated with slipping injuries (Biener & Caluori, 1977). Currently, there is limited research addressing how tennis players interact with tennis courts. This paper briefly reviews tennis injury incidence, player movements and slip biomechanics. The discussion will propose a new direction for assessing player-surface interactions and outline current work.

Tennis injury incidence: Playing tennis, as participating in other sports, increases risk of injury due to physical exertion (Hjelm et al., 2010). Tennis injuries are commonly reported as overuse injuries or muscle and ligament strains and sprains, reflecting the various demands placed on anatomical structures (Bylak & Hutchinson, 1998). Indeed, tennis has a unique 'injury profile' when compared to other sports (Pluim et al., 2006). However, tennis is an evolving sport. The 'wooden racket era' of tennis reflects a period when game style was characterised by style and finesse. At that time, injuries were predominantly to the hands and arms; injuries to the feet and back occurred less frequently and with lower severity (Frey, 1969). Following the introduction of aluminium, oversized rackets in 1975, the 'modern era' of tennis refers to a game now characterised by more powerful strokes, higher rates of ball spin and more athletic court movements (Fernandez et al., 2006). The 'modern era' of tennis therefore has different physiological requirements of players and as such, frequently injured sites differ to those of the 'wooden racket era'. In a recent review of 28 epidemiological tennis injury studies published between 1976 and 2005, Pluim et al. (2006) identified that the lower extremities now comprise the most frequently injured sites in tennis (31.1 – 67.0%), followed by the upper extremities (20.0 – 48.6%) and trunk (3.0 – 22.0%). Further, the review highlights a progression from predominantly upper extremity injuries, (four studies), to lower extremity injuries, (23 studies; Pluim et al., 2006). The review also highlighted that the nature of lower extremity injuries are predominantly acute injuries, in contrast to chronic, upper extremity injuries. This shift in injury profile reflects the increased pace and intensity of 'modern era' tennis and highlights the importance of player-surface interactions.

Player movements: Tennis movements typically consist of an initial split step followed by a combination of side steps and strides to reach an incoming ball (Hughes & Meyers, 2005). Within a rally, approximately 80% of strokes are played within 2.5 m of the players' ready position; 10% of strokes are played between 2.5 – 4.5 m of the ready position and less than 5% of strokes are played beyond 4.5 m of the ready position (Fernandez et al. 2006). During an average rally, players travel 8 – 12 m and change direction four times; constituting 300 – 500 high intensity efforts during a three set match (Fernandez et al., 2006). However, player movement patterns differ between grass, clay and acrylic tennis surfaces. O'Donoghue & Ingram (2001) identified that rallies played at Roland Garros (clay surface) were longer and consisted of more baseline play than rallies played at the US and Australian Opens (acrylic surfaces). Similarly, rallies at the US and Australian Opens were longer and consisted of more baseline play than rallies played at Wimbledon (grass surface). As such, court surface characteristics, e.g. COF, have been suggested to influence both player movement patterns and subsequently, player injury risk (Girard et al., 2007). Recently, Girard et al. (2007) assessed in-shoe plantar pressure during specific turning manoeuvres on Greenset and clay tennis court surfaces (high and low COF respectively). Girard et al. (2007) highlighted that manoeuvres performed on Greenset resulted in greater mean forces (whole foot) and shorter contact times when compared to the same manoeuvres performed on clay. Further, plantar loading was characterised by peak loads occurring under the hallux on Greenset, whereas peak loads occurred under the midfoot on clay. Such research highlights that the court surface effects player movements and lower-limb loading strategies in tennis.

Biomechanics of slips: The ratio of 'available' and 'utilised' COF describes the stability of the shoe-surface interface; if the ratio is greater than one, a slip should not occur (Redfern et al., 2001). However, friction models that assume friction is entirely a material property, e.g. Amontons-Coulomb model, are not appropriate during dynamic loading conditions such as human locomotion. Shoe-surface friction is a dynamic quantity, dependent on contact area, pressure, velocity, contact time and numerous other variables (Chang et al., 2001). Recent 'biofidelic' assessments of shoe-surface friction have attempted to quantify events that develop from perturbation to unrecoverable fall. In walking trials, research has indicated that foot kinematics prior to contact, specifically foot-floor angle and vertical heel velocity, decrease during alerted and known slip trials, in contrast to normal dry and unexpected slip trials (Chambers et al., 2003). This suggests kinematic mediation in response to a known slip hazard, resulting in the stabilisation of shoe-surface interactions. Recently, McGorry et al. (2010) assessed slip mechanics when available and utilised COF differences were minimised, creating 'marginally slippery' conditions. Findings demonstrated that in walking, conditions at heel strike were not responsible for slip propagation. Rather, McGorry et al. (2010) suggested that utilised COF and heel velocity 25 – 30 ms after heel contact were critical to the development of a recoverable or unrecoverable slip.

In racket sports, foot loading characteristics are predominantly a result of stroke type. In 1991, Chapman et al. highlighted that squash court COF varied depending on contact type, e.g. heel or whole foot, and court surface contamination, e.g. dust or water. Chapman et al. (1991) controlled foot contact via stroke type, e.g. side-step or lunging forehand, and demonstrated that limiting friction could be exceeded on dusty surfaces with a whole foot contact but not a heel contact, and on damp surfaces with a heel contact but not a whole foot contact. This highlights the dynamic nature of player-surface interactions. Recent laboratory research has assessed translation COF during specific tennis manoeuvres performed on different surfaces. However, Stiles & Dixon (2006) found no differences in peak translation COF for carpet, acrylic and artificial turf, despite distinctly different mechanical characteristics of these surfaces. Further, no differences were observed in lower-limb kinematics or peak vertical or horizontal ground reaction forces (Stiles & Dixon, 2006). The authors suggested their findings were insensitive due to possible overcompensation to the relatively stiff, force plate baseline trial. However, findings highlight well known difficulties in assessing task specific manoeuvres in laboratory settings and suggest a need to qualify manoeuvre data collected in laboratories.

DISCUSSION: In light of tennis injury incidence, the physical demands of modern tennis manoeuvres and effects of different court surfaces, it is important to identify biofidelic loading conditions of player-surface interactions during tennis manoeuvres. Further, it is important to replicate and measure such interactions for the systematic assessment of tennis surfaces.

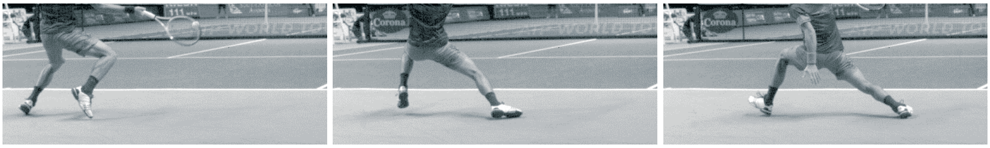

Figure 1: Sliding forehand groundstroke at ball contact (left), stabilising foot contact (centre) and maximum stabilising foot displacement (right).

Tennis player-surface assessment: It is proposed that a manoeuvre specific, shoe-surface testing device is developed. The device should be able to reproduce selected tennis manoeuvres and measure force to identify manoeuvre specific, shoe-surface loads. To quantify and replicate player-surface interactions, a three-phased approach is outlined:
Phase 1: Specific kinematics of real tennis manoeuvres performed on a variety of court surfaces must first be identified. Player-surface interactions of interest will be initially limited to forehand groundstrokes performed on grass, clay and acrylic court surfaces. Kinematic data will be collected during elite competition, e.g. Figure 1, to optimise the ecological validity of collated data and subsequent test protocols. Three-dimensional player (pseudo-centre of mass), feet and ball position data will be derived from footage of forehand groundstrokes. Three key forehand manoeuvres will be identified by dichotomising derivative data, e.g. slide distance. Recently, a pilot study was conducted at a major tennis tournament to assess the viability of quantifying player-ball kinematics. Two high-speed cameras (Phantom v4.3, Vision Resarch, NJ, USA) were mounted on tripods directly behind courtside perimeter advertising boards at the Barclays ATP World Tour Finals, 2010. Cameras were focussed on a location 1.5 m behind the deuce side baseline and operated at 100 Hz. Cameras were triggered manually to record 1 s pre- and 1 s post-ball contact during forehand groundstrokes; video clips were automatically downloaded to a laptop. The three-dimensional space of both cameras' field-of-view was inferred via a calibration process using still images of a planar calibration rig, e.g. checkerboard (Zhang, 1999). Player pseudo-centre of mass, feet and ball position data are currently being quantified using automated image processing techniques. Findings of the pilot work described above are to be presented for discussion.
Phase 2: Three test protocols will be developed from player-ball movement data, to enable the assessment of forehand groundstroke manoeuvres in greater detail. Elite standard tennis players will be recruited and asked to return projected tennis balls on a tennis court. A portable runway, housing a portable force platform, will be assembled on-court and surfaced with different court surfaces, e.g. grass, clay and acrylic. A three-dimensional motion analysis system will be integrated with the force platform to record three-dimensional position data of passive markers (affixed to participants) and three-dimensional ground reaction force data. Collected data will be analysed *post-hoc* to obtain relevant kinetic and kinematic data. Photocell timing gates will monitor participant movement speed; acceptable trial criteria include desirable movement speed, clean foot-force platform contact and successful groundstroke.
Phase 3: A portable shoe-surface testing device will be developed to replicate player-surface interactions recorded in phase two. The device will consist of pneumatic cylinders capable of producing vertical, horizontal and rotational movements of an artificial foot. The device will be

instrumented with solenoid valves to enable specific, computer controlled test protocols. Load cells will enable force measurement when the device is used in the field. The advantages of the proposed work include court friction assessment from a player-surface perspective, enhancing the ecological validity and applicability of measurements. However, current work is in its infancy and, due to development simplifications, will only address player-surface interactions using dichotomised forehand groundstroke data.

CONCLUSION: Presented work is currently in progress. The envisaged use of the shoe-surface testing device is to systematically measure shoe-surface interactions from a player-surface perspective. Current work contributes to the understanding of tennis player-surface interactions and is envisaged to be of practical use in the future regulation of tennis courts. Future work should explore different tennis manoeuvres and shoe-surface combinations.

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Acknowledgement
The authors would like to acknowledge that this research is part-funded by the ITF, Roehampton, UK.