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Full Title: A multi-year injury epidemiology analysis of an elite national junior tennis program.

Abstract

Objective: To profile multi-year injury incidence and severity trends in elite junior tennis players from a national program. **Design:** Prospective Cohort. **Methods:** Injury data was collated by sex, age and region for all nationally-supported Australian junior players between 2012-2016. Injury was defined as a physical complaint from training/matchplay interrupting training/matchplay determined by presiding physiotherapists and doctors. Severity represented the days of interrupted training/matchplay per injury. Injury incidence was reported per 1,000 exposure hours. Incidence rates ± 95% confidence intervals and rate ratios (RR) were used to assess changes over time. **Results:** There was no difference in male and female injury incidence (2.7±0.0 v 2.8±0.0) yet male injuries were more severe (3.6±0.6 v 1.1±0.9 days). The lumbar spine was the most commonly and severely injured region in both sexes (4.3±0.2, 9.9±1.4 days). Second to the lumbar spine was shoulder injury incidence in both sexes (3.1±0.2) as well as male injury severity (7.3±1.4 days). Knee injuries were also common in males (2.3±0.2) yet reduced over time (0.4 RR) as pelvis/buttock injuries increased (3.4 RR). Females had high trunk and abdominal injury incidences (2.5±0.3) which increased over time (6.1 RR). Independent of sex, the incidence of injury increased with age from 13-18 years old (2.0±0.1, 2.9±0.1). **Conclusion:** Despite no sex-based difference in injury incidence, male injuries resulted in more interrupted days of training/matchplay. In both sexes, the lumbar spine and shoulder were the most commonly and severely injured body regions. The relative number of injuries sustained by players also increased as they aged.

Key Words: Injury rates, Racket sports, tennis epidemiology

Introduction

Limited evidence of the injury epidemiology of junior tennis players exists, and that which does is inconsistent in reporting of injury incidence by anatomical region or sex[1-3]. This is largely due to variation in study design and quality, the age and standard of athletes, injury classification, period of data capture and exposure measure are highly variable[1-3]. More specifically, much of the research has focused on the epidemiology of junior injuries at tournaments and thus ignores training settings[2,3]. Further, previous studies report injury profiles of predominantly recreational cohorts and also fail to provide empirical insight into injury severity[2-4]. The understanding of injury epidemiology in elite junior players is therefore incomplete and limits the acumen of medical, physiotherapy and strength and conditioning practitioners who monitor and manage the health of young elite tennis athletes.

Few studies have reported the injury incidence and trends of elite junior tennis players and of those, the majority are dated in their findings[3,5]. A three-year analysis of 16 to 20 year old players in a national program in the 1980's found that lower limb injuries were the most common in both genders as compared to trunk and upper limb injuries[5]. However, the findings were reported as absolute values and not relative to training volume or other extrinsic risk factors. Since then, the sport has observed dramatic changes in equipment and strategy [6,7], which has likely influenced the sport's injury profile[6]. More generally though, and as abovementioned, injuries have been reported across differing standards of players. For example, boys have been shown to be more prone to injury than girls over a 2-year period of injury data collection at a local tennis club[1]; but girls were reported as more susceptible to injury than boys during higher level national competitions[2]. As studies have also featured players of varying age within the same cohort, the examination of age as an intrinsic risk factor[8] has been limited. In sum, this highlights the need for further research from a homogenous sample of elite junior tennis players using the same exposure method, to establish if there are meaningful sex and age differences in injury patterns[9].

An understanding of the severity of injury is important for determining the extent to which injuries impede training, yet this has been poorly examined in the tennis injury literature. For example, the severity of injuries in Swedish local junior tennis players was collected over a two-year period via player recall[1]. However, the use of recall to quantify injury time-loss has been criticised for its bias and inaccuracy[10]. Conversely, a study of elite Brazilian juniors has described severity as the number of treatments per injury within national tournaments over a season[2]. The limitation with this measure of severity is that it doesn't reflect the actual time-loss of each injury which may extend outside the tournament timeframes. As a result of the definitional differences and reporting limitations, the findings from these studies are not generalisable. More so, no tennis injury study has described injury severity by region. An anatomical-based analysis of injury severity in tennis would therefore be a valuable addition to the sport's knowledge base.

Another gap in the current junior tennis injury epidemiology literature, particularly among elite players, is the lack of systematic investigation of the change in injury profile over time. This is particularly important among adolescent cohorts where maturation and risk of injury have been linked[11]. Specifically, the relevance of previous attempts has been limited by their timing[3,5], tournament-only focus[3], length of data collection[4] and lack of trend analysis[4,5]. Therefore, the aim of this study was to comprehensively examine the injury epidemiology of junior, elite tennis players of both sexes over a five-year time period. Specifically, we assessed the injury incidence between the ages of 13 and 18, utilising a recommended exposure measure[12], and evaluated injury incidence and severity over time.

Methods

Fifty-eight male and forty-three female Australian junior tennis players were included in the study The mean ± SD age and national rankings for the male and female players were 16.1 ± 1.7y, 117 ± 139 and 15.8 ± 1.7y, 57 ± 48 respectively. All players were full-time scholarship-holders between 2012 and 2016 in a national tennis academy governed by Tennis Australia. The players did not participate in other sports. Given the lack of data prior to 2012, this year was used as the base year for ensuing analysis. Data was collected and stored in a secure, Tennis Australia managed data repository

(Athlete Management System). This study received human ethics committee approval from Australian Catholic University (reference number 2015-196N) with informed consent obtained from all players.

An injury was diagnosed by Tennis Australia's physiotherapists and doctors and defined as a physical complaint from training/matchplay resulting in interrupted training or matchplay[13]. Interruptions to training were defined as any restrictions to tennis and off-court training resulting in an athlete unable to take a part in the full session[13]. Injuries were calculated as injury incidence, which describes the number of new injuries within the population over the period of time[14]. Severity was defined as the mean number of days since injury onset to a particular region to the day that the player returned to full training[12] both on and off court. Injury data was classified by region as per the Orchard Sports Injury Classification System (OSICS)[15]. The injury data was entered and stored on the Athlete Management System by the designated Tennis Australia treating physiotherapist (n = 32, mean 2.3 ± 1.3 years treating Tennis Australia athletes) and doctors (n = 14, mean 3.1 ± 2.0 years). Injury severity was also entered and stored in the repository via athlete self-reporting. All consultations and injury severity on the studied population between 2012-2016 were exported for analysis. This included 327 male injuries and 258 female injuries. Injury incidence was reported per 1,000 exposure hours which is consistent with recommendations in the consensus statement on epidemiological studies of medical conditions in tennis[12]. Exposure hours include the durations of both on and off court training and matchplay. This was recorded via athlete self-reporting and equated to a mean ± SD of 648.8 ± 108.6 and 661.8 ± 112.6 training hours per year for male and female players respectively.

Statistical programming (R Core Team, 2012) was used for the all analyses. The 'metafor' package was used to implement the fixed-effects meta-regression analysis of incidence rates ± 95% CI with precision weights. Incidence rates represent the year-on-year change in injury counts by region and severity, where 2012 was the base year. The magnitude of change over time is inferred by rate ratios (RR) whereby a ratio of greater than 1 is considered to be an increase, and less than 1, a decrease. Results are reported as mean ± SD, incidence rates ± 95% CI, and rate ratios.

Results

Injuries were comparable between sexes over the time period with 2.7 ± 0.0 and 2.8 ± 0.0 in female and males per 1,000 exposure hours respectively (Table 1).

Insert Table 1 here

The lumbar spine, followed by the shoulder, had the highest incidence of injuries by region in both sexes over the observed time period (Table 1). Junior female tennis players experienced an increase in upper limb (shoulder, elbow, wrist), neck, thoracic spine, trunk and abdominal, knee and foot injury incidence over time (RR≥2.3). There was also a reduction in hip and groin and lower leg injuries over time (0.4 RR; Table 2). Males experienced an increase pelvis/buttock injuries (3.4 RR) over time, with a reduction in thoracic spine, knee, ankle and wrist injuries (RR≤0.4; Table 1).

Male injury severity was greater than females with 3.6 ± 0.6 days lost (Table 2), compared to a female injury severity of 1.1 ± 0.9 days lost. Lumbar spine injury severity was the highest in both sexes (>4.6 ± 0.6 days lost). The shoulder, hip and groin and wrist also had high injury severity in male tennis players, with an increase in pelvis/buttock injury severity (3.4 RR) and a reduction in trunk and abdominal severity (0.3 RR) over time. Female tennis players experienced high elbow, ankle and knee injury severity with an increase in neck (2.3 RR), elbow (2.5 RR) , thoracic spine (6.1 RR) and foot (7.5 RR) injury severity over time.

Insert Table 2 here

Injury incidence increased with age with 13 through to 18 year-olds incurring 2.0, 2.3, 2.2, 2.9, 3.0 and 2.9 injuries per 1,000 exposure hours respectively. The lumbar spine featured as the most common injury region for 14 to 18 year olds, whereas the shoulder and hip and groin were the most common injury regions for 13 year old players (Table 3). Changes over time highlighted an increase in wrist injuries in the 13th (9.2 RR) and 18th birth years (3.4 RR), pelvis/buttock injuries in the 14th (5.2 RR) and 15th birth year (2.2 RR), knee injuries in the 16th (3.0 RR) birth year and shoulder injuries in the 17th (6.0 RR) birth year (Table 3).

*** Insert Table 3 here***

Discussion

This study provides a comprehensive longitudinal examination of injury incidence and severity in elite junior tennis players by sex and region. Injury incidence was also assessed by athlete age inclusive of injury region and time. Injury incidence in junior male and female tennis players were comparable when expressed relative to exposure hours. This finding is novel in elite junior tennis, although this homogeniety in injury incidence has been reported in collegiate tennis playing populations[16]. While numerous studies have highlighted training volume as an injury risk factor[16,17], it seems that both sexes in this cohort had the same injury response when reported relative to exposure hours. Further, and in line with previous research[3], the lumbar spine was the most commonly and severely injured region across both sexes. Additionally, when all body regions were considered, male junior players experienced higher injury severity than female juniors.

A novel outcome was the profiling of injury incidence by age and time-loss per region. This showed that the lumbar spine was most commonly and severely injured region among 14 to 18 year-olds in both sexes. Previous research has identified the mechnical loading of serving, primarily through lateral flexion and extension, as a risk factor for the development of low back pain in adolescent tennis players[18]. The performance of the kick serve is known to be particularly problematic in this regard with coaches generally introducing and then emphasising this type of serve to players between the ages of 12 to 15[18]. The combination of high joint loads, increased repetition of an unaccustomed skill and physical growth during this time may therefore contribute to the high incidence of lumbar region injuries[18]. Interestingly, the high eccentric-concentric activation of the abdominals during the serve would also appear to be implicated in the high incidence and growth of trunk and abdominal injuries sustained by junior female players[19]. Further research is required to determine why this injury is less common among junior male players. Given trunk injuries are of concern in elite junior tennis players, careful monitoring of serve loads, technique via biomechanical analyses and targetted injury prevention programs may mitigate the risk of occurence and severity.

The shoulder was found to be the second most common region of injury in both sexes and the second most severe in junior males. Consistently, the shoulder has been highlighted to be the most common upper limb injury region in tennis irrespective of age and standard[20]. Shoulder injuries in tennis are generally reported to be overuse injuries as opposed to acute[20]. As the joint is utilized in all strokes in tennis, it is likely the repetitive strain on the shoulder results in the large injury incidence often observed[20]. As context, profiling of junior tennis matchplay suggests that players hit 2.5 to 3 strokes per point[21] and in excess of 90 serves per tennis match[22]. When extrapolated to include the potential multiple singles and doubles matches completed in a day and then on repeated days[23], the escalation in shoulder joint loading from hitting volumes and intensity may be cause for concern[20]. Similarly, these playing demands expose the wrist to large forces which may explain the high incidence and severity of wrist injuries in both sexes in this study. Alongside the total hitting load, the eccentric forces through wrist extension during the backhand movement have been associated with wrist injuries in tennis players[8]. In turn, these ballistic and repetitive movements are performed with equipment that is selected with little systematic regard to the loading implications for the upper limb[6]. The adverse effects of the inappropriate selection of equipment are likely to be magnified by biomechanical limitations that may also be associated with injury[24]. Consequently, when these factors are coupled with high or increasing hitting volumes and intensities, the high incidence of wrist and global upper limb injuries among juniors is explicable.

Junior males had a high yet diminishing incidence of knee injuries, similar to the pattern observed for ankle injuries. Australian tennis players have naturally trained on hard rather than clay tennis courts, yet almost the same amount of international junior tournaments are offered on clay as compared to hard[25]. As a result, Australian junior tennis players have recently increased their clay-court training leading to some of the juniors sampled in the current study spending up to 5 times more time training on clay over the time period than previous cohorts in this National program. The increase in time spent training on clay, as compared to hard, may play a role in the reduction in knee and ankle injuries over time, as clay courts transmit less force through the body and allows players to slide more freely[26]. However, the rise in pelvis/buttock injuries over the time period may have been a byproduct of this increased clay-based hitting, as the movement and sliding actions on clay courts result in greater strain on the gluteus muscles[27]. In comparison, a reduction in pelvis/buttock injuries over time was found at the Australian Open which is competed on hard court[28]. Court surface may impact on junior tennis injuries and should be considered by both athletes and performance staff during junior athetic development.

The age-based analysis of injury incidence in this study provides a novel insight into the increasing injury occurrence in a developing junior population. Peak height velocity is generally experienced between the ages of 13 to 15 years[11], whereby soon after, the risk of injury is suggested to be greatest[11]. In addition to physical growth, training and matchplay volume and intensity rise as junior tennis players begin to specialise in the sport and compete more often. This increase in load has been linked to a rise in injury risk[22]. Given the highest incidence of lumbar injuries across sexes in this cohort, the finding that lumbar spine injuries were the most common injury region for players aged 14 to 18 was anticipated. Shoulder, hip and groin injuries were the most common in 13 year-olds. The age analysis of injuries over time highlights a rise in upper limb injuries in early and late teen players (13, 17 and 18 year-olds) and lower limb and trunk injuries in mid teen players. This infers that junior tennis injury trends are not confined to to one anatomical region. Changes in technique, tactical approach, physicality of the players and matchplay, as well as equipment selection may all contribute to the variations in anatomical injury incidence by age over time[6,19,21].

Limitations in the study do exist. Although reporting tennis injuries per 1,000 exposure hours has been recommended as the best exposure measure[12], recent findings suggest that training/match duration may not be the optimal denominator for reporting injuries[29]. However, a more descript measure of training and matchplay, such as hitting volume and distance covered, was not available in the dataset. Additionally, no gender and severity analysis by age was undertaken due to limitations with sample size dilution[30]. Furthermore, there was a lack of control in the injury prevention and interventions implemented during the time period. This may have impacted injury incidence by region, gender and age over time.

Conclusion

The profile of junior injuries in the Australian national tennis program revealed that there was no sex difference in injury incidence, yet male injuries were more severe. The lumbar spine presented as the most frequent region of injury resulting in the most time-loss. Junior males experienced high shoulder, wrist and knee injury incidence and severity yet knee incidence reduced over time. Junior females also experienced a high incidence of shoulder as well as trunk and abdominal injuries which increased over time. The incidence of injuries also increased with age. Collectively, these findings describe common injury trends in elite junior tennis via assessment of injury incidence, severity, age and changes over time, whilst utilising a recommended exposure measure. In practice, this insight can inform injury prevention and training programs, equipment selection as well as tournament scheduling for elite junior tennis players.

Practical Implications

- No sex-difference in injury incidence relative to exposure hours, and greater junior male injury severity compared to females provides insight for sex-specific injury prevention and treatment programs
- There is a need for enhanced lumbar spine injury prevention strategies in both sexes and all junior ages
- The awareness of the increase with injury incidence with age from 13 through to 18 year old national, junior tennis players may assist with load monitoring, tournament scheduling, equipment selection and training programs to mitigate the injury risk.

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