



Epidemiology of injuries in tennis players

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Abstract

Purpose of review To review the recent literature regarding the epidemiology of tennis injuries at all levels of play, and to discuss recent findings in injury surveillance by the Association of Tennis Professionals (ATP).

Recent findings Following the release of a consensus statement in 2009 calling for standardized documentation and analysis of tennis-related injuries, multiple studies have been published describing longitudinal injury incidences at Grand Slam tournaments and the Davis Cup. Recent efforts by the ATP have further elucidated injury patterns on tour. There have also been recent high-quality studies on injury trends among collegiate and elite junior tennis players, bringing attention to musculoskeletal injuries and systemic illnesses that young tennis players may be susceptible to.

Summary Recent efforts in injury surveillance by the ATP and at the collegiate and junior levels have highlighted injury trends that will help guide injury prevention strategies at various levels of play.

Keywords Tennis · Injury · Epidemiology · Professional tennis · Junior tennis · ATP

Introduction

Tennis is one of the most popular sports in the United States (US), with an estimated 17.9 million players, and significant growth in the number of youth tennis players in recent years [1]. Given the widespread popularity of tennis at the recreational level, as well as large numbers of players at higher levels of competition, it is important to characterize the epidemiology of tennis-related injuries at various levels of play.

Unlike other sports, tennis matches are not limited in duration by a predetermined length of play, and matches can often

last several hours [2]. In addition, tennis entails high aerobic and anaerobic demands, with repetitive stresses through a variety of strokes and movements [3, 4]. As a result, tennis players are susceptible to a range of injuries including chronic overuse conditions and acute traumatic injuries.

Through hundreds of strokes per match, the kinetic chain enables a player to generate high racquet and ball velocities while minimizing joint loads, especially with power shots including overhead serves, overhead smashes, and groundstrokes. This kinetic chain begins at the feet and knees, progressing to the core and trunk, to the shoulder and elbow, and finally to the wrist, hand, and racquet [5]. Serving in particular is the most demanding stroke in tennis, with supraphysiologic forces through the shoulder and elbow [6].

The most common overuse tennis-related injuries include internal impingement and superior labrum anterior-to-posterior (SLAP) tears in the shoulder, tendinopathy at the medial or lateral elbow, tendinitis and subluxation of the extensor carpi ulnaris tendon at the wrist, abdominal muscle strains, as well as lumbar strains and disc degenerative pathologies [7]. The lower extremities are more susceptible to acute injuries such as ankle sprains, meniscal knee injuries, tendinopathy at the knee, and hip injuries (Table 1). Furthermore, the incidence of injuries in tennis may also be affected by playing surface and evolution in racquet technology.

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Table 1 Reported tennis-related injuries by body region

Body region and injury	
Shoulder	Superior labrum anterior-to-posterior (SLAP) tears
	Internal or subacromial impingement
	Rotator cuff tendinopathy/tear
Elbow	Medial elbow tendinopathy
	Lateral elbow tendinopathy
Wrist	Extensor carpi ulnaris tendinitis/subluxation
	Carpal ligament sprain
Hip	Groin muscle strain
Knee/thigh	Thigh muscle strain
	Knee ligament sprain/rupture
	Meniscus tear
	Extensor tendinopathy/rupture
Ankle	Ankle sprain
	Ankle fracture
Trunk	Paraspinal muscle strain
	Rib muscle strain
	Lumbar disc degeneration and herniation
	Abdominal muscle strain

The purpose of this review is to critically examine the recent literature regarding the epidemiology of tennis injuries at all levels of play, and to discuss the recent findings in injury surveillance.

Professional and elite players

Epidemiological studies on injuries among elite-level professional tennis players have been historically lacking and limited by the absence of a consistent framework for injury reporting. Therefore, a consensus statement was published in 2009, and designed specifically to enable standardized documentation and analysis of tennis-related injuries [8•]. Since then, a number of longitudinal epidemiological reports of injury data from professional Grand Slam tournaments and the Davis Cup have been published [9•, 10•, 11•, 12•].

In the first study utilizing the consensus injury classification methodology, Sell et al. reported injury trends from the US Open Tennis Championships from 1994 to 2009 [12•]. They showed an overall injury rate of 48.1 injuries per 1000 match exposures (ME), with two MEs per singles match (two players per match) and four MEs for each doubles match (four

players per match). The authors also found a significantly higher rate of acute injuries requiring medical assistance than chronic overuse injuries (27.7 vs. 19.5 per 1000 MEs), and that the vast majority of injuries occurred during matches rather than training. In addition, injuries to the lower extremities (23.0 per 1000 MEs) significantly outnumbered injuries to the trunk (6.12 per 1000 MEs) and the upper extremities (17.7 per 1000 MEs), with the ankle being the most common location of acute injuries, followed by the wrist, knee, foot, and shoulder. Among chronic-onset injuries, the distribution was more even between lower extremity (9.3 per 1000 MEs) and upper extremity (8.2 per 1000 MEs) injuries. Finally, in terms of injury type, muscle/tendon injuries comprised the overwhelming majority of cases (84.0% of acute injuries and 87.7% of chronic injuries), followed by joint/ligament, skin, and bony injuries [12•].

Similarly, McCurdie et al. reported on injury data from The Championships, Wimbledon, from 2003 to 2012 [11•]. Over this 10-year period, they found an overall rate of 20.7 injuries per 1000 sets played. As with other retrospective studies of injury incidence at tennis tournaments, only injuries reported to tournament physicians were captured in the data collection; therefore, reported injury rates are likely underestimates of the true incidence of injury occurrence. Nevertheless, from this Wimbledon data, the authors further sub-classified the chronological onset of injury beyond simply acute or chronic. Of note, they found that 39% of injuries were acute new presentations that occurred during the tournament, while 34% of injuries were classified as “acute-prior”, or acute traumatic exacerbations of injuries initially sustained prior to the tournament. In addition, 16% of injuries were chronic and pre-existing from prior to the tournament, and 11% were deemed to be recurrent injuries, or injuries that were within 8 weeks of recovering from the same injury to the same site. Interestingly, the authors also found a lower injury rate among male players (17.7 injuries per 1000 sets played) compared to female players (23.4 injuries per 1000 sets played), though there was variability over the 10-year study period. In terms of body site of injury, the authors similarly found that the lower extremities were most commonly injured, followed by upper extremity, and axial injuries [11•].

Though the consensus statement on the epidemiological reporting of tennis injuries recommends the use of 1000 match hours as the reporting frequency, match durations are not always readily available for previous matches, and therefore, there is a variety of injury frequencies reported in the literature making direct comparisons difficult. Using data on minutes played for all professional tennis events from the Association of Tennis Professionals (ATP) and Women’s Tennis Association (WTA) between 2011 and 2016, Gescheit et al. found that games played was more strongly correlated to minutes played than sets or matches [9•]. Using this methodology, the authors examined injury data from the Australian Open Grand Slam through the

same time period, and found injury rates of 201.7 injuries per 10,000 game exposures for women, and 148.6 for men. In addition, they noted significant differences in the injury distribution between men and women, with the shoulder, foot, wrist, and knee being the most commonly injured sites among women, and knee, ankle, and thigh injuries being the most prevalent in men [9••]. Interestingly, through the study periods from 2011 to 2016, the authors noted an increasing rate of upper extremity injuries in both men and women over time.

In terms of actual match retirements due to medical conditions, Maquirriain et al. studied the epidemiology of injury-related retirements at the Davis Cup from 2006 to 2013 [10••]. Given the competition format of the Davis Cup, there are what the authors termed “effective” matches and “residual matches”, which were defined as matches after the result of the series had already been determined. Notably, they found a significantly higher rate of retirements in “residual” matches (6.41%) compared to “effective” matches (1.66%); therefore, only injury data from “effective” matches were subsequently analyzed. The authors found an overall injury rate of 6.05 injuries per 1000 playing hours, and that players were rendered inactive for an average of 73.4 days following the injury. Injury location was similar to other studies in that most injuries occurred in the lower extremities (41.7%), followed by upper extremities (25.0%), and trunk (16.7%).

In 2011, both the ATP and WTA tours developed and initiated a web-based medical documentation system to record all injuries and illnesses occurring on tour. Results from this online documentation system from the ATP show very consistent injury rates from 2014 to 2017, with injuries changing year over year from 1 to 3%. (unpublished data) The injury

distribution by body region over the years of surveillance between 2012 and 2016 was shown in Fig. 1. The leading areas of musculoskeletal injury were spine, shoulder, thigh, and foot/ankle. These predominant injury patterns have remained largely consistent among professional tennis players.

Furthermore, several additional injury patterns have also been identified from analysis of the 5-year data on the ATP world tour. The location of overuse elbow injury, or humeral epicondylitis, occurs at a 3:1 ratio (medial to lateral). This is likely due to the predominance of forehand groundstrokes and serve loading in the modern game, as well as high repetitive loads that stress the medial flexor-pronator region during the acceleration phases of the serve and forehand [13].

In addition, tendon injury in the knee is also a common finding in elite-level tennis players. ATP injury data show that patellar tendon injury occurs at a 2:1 ratio relative to the quadriceps tendon. Continued study and analysis of injury occurrence patterns in elite tennis players will further advance preventative programs and treatment strategies for clinicians who work with these high-level athletes.

Collegiate, youth, and recreational players

Along with increased reporting of elite-level tennis injury epidemiology, there has been recent emphasis on amateur and recreational levels as well. In a study of the National Collegiate Athletic Association (NCAA) Injury Surveillance Program (ISP) from 2009 to 2015 using a sample of 19 men’s and 25 women’s varsity tennis programs, Lynall et al. found an overall injury rate of 4.9

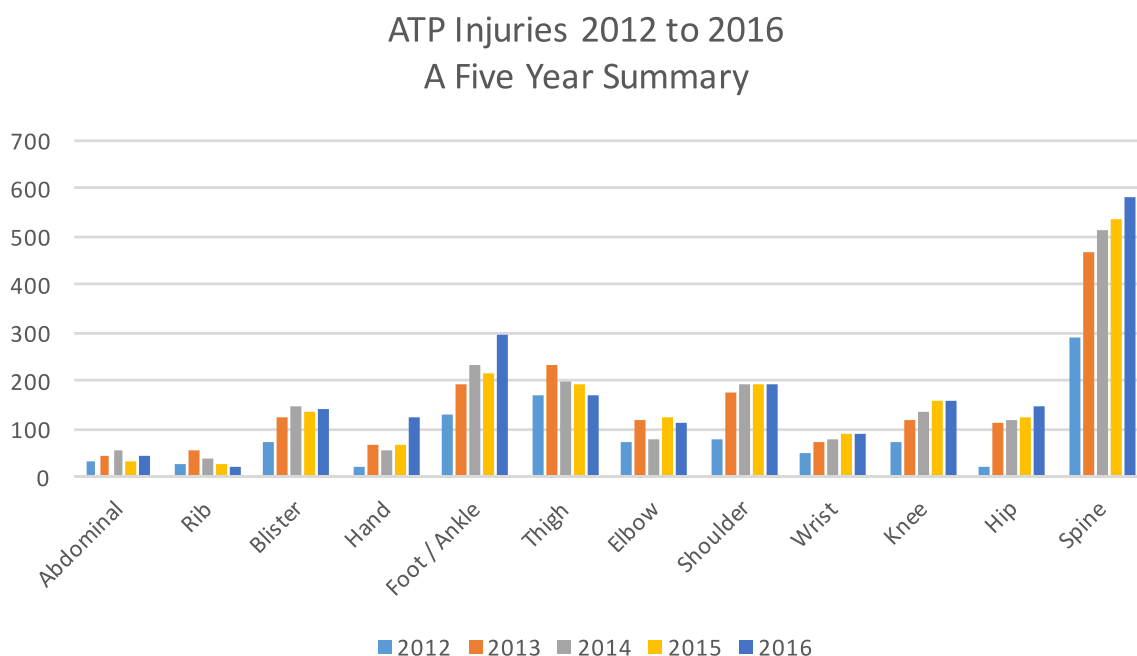


Fig. 1 Five-year summary of injury region in male professional tennis players (with permission from ATP, unpublished data)

injuries per 1000 athlete exposures (AE) [14]. In this study, an AE was defined as any single student-athlete participation in an official NCAA practice or match, regardless of duration. Both men and women had significantly higher injury rates during competition (8.9/1000 AE for men and 7.4/1000 AE for women) than in practice (3.8/1000 AE for men and 4.2/1000 AE for women). Of note, through the study period, while competition injury rates were largely unchanged, practice injury rates decreased by 32.2 and 63.9% in men's and women's tennis, respectively [14].

In addition to large-scale retrospective surveillance data, there is also value in determining injury prevalence among players followed prospectively through time. In a prospective study of 58 NCAA tennis players through an entire season, Colberg et al. found an overall incidence of acute injuries of 1.1 injuries per 1000 playing hours of match play [15]. However, 67% of players had at least one musculoskeletal condition during the season. With further sub-analysis, the authors also found that all injuries sustained during match play were acute in nature, while 69.6% of injuries sustained during training were gradual onset. 27.6% of players had at least one chronic condition during the season [15].

With increasing participation rates at even younger ages, it is important to monitor injury rates among junior tennis players as well. Pluim et al. prospectively followed a cohort of 73 elite junior tennis players (ages 11–14 years) in the Dutch national high-performance program for 32 weeks [16••]. Players averaged 9.1 h of practice and 2.2 h of match play per week. The authors found that a total of 187 health problems were reported by 67 of the players, with an average weekly prevalence of any health problem of 21.3%. Overuse injury was the most common health problem (47%), followed by medical illness (36%, the most common being respiratory tract and gastrointestinal infections), and acute injuries (13%). The incidence of acute injuries was 1.2 injuries per 1000 h of tennis, which is in line with the previous literature. Considering the data in its entirety, however, about one in eight players were playing with pain every week, which is an area of concern given this cohort of school-age children.

Kovacs et al. surveyed 861 elite junior tennis players regarding injury incidence over the prior year to completing the survey [17]. They found that 41% of the respondents reported at least one injury in the prior year. Of note, among this subset of players that reported at least one injury, 33% of players reported having a second injury that year. In addition, there was a correlation between age and injury incidence, as injury rates were 11% in the 12 and underage group, 28% in the 14 and underage group, and 36% in the 16 and underage group. In terms of body region, the back, shoulder, ankle, knee, and wrist were the most commonly reported regions of injury among the 861 elite junior tennis players studied.

Playing surface

Tennis is also unique from other sports in that there is a variety of playing surfaces ranging from hard court (acrylic), clay, grass, and artificial grass. Hard court has the highest coefficient of friction and lowest shock absorption, which makes sliding much more difficult, leading to shorter stopping distances and theoretically higher peak loads [18]. From the Davis Cup data, 75% of all injuries occurred on hard courts [10••]. Higher ball speeds on hard courts may also lead to higher forces applied on the upper extremities [7]. Conversely, clay is considered a slower surface due to increased shock absorption and loss of ball speed. However, the lower coefficient of friction between the clay surface and the player means that sliding becomes an integral part of playing on clay, which might entail an entirely different set of stresses on the body [19].

Among recreational players, a study of 3656 recreational members of the Royal Netherlands Lawn Tennis Association found no association between court surface and injury rates among players that played primarily on one particular court surface [18]. However, a higher rate of overuse injuries was observed in players that played on multiple surfaces relative to players that played primarily on one surface. This switching between playing surfaces may be a risk factor for injury among elite players as well. For example, the French Open (played on clay) and the Wimbledon Championships (played on grass) are held only about one month apart, and the previously noted injury data from Wimbledon showed that 61% of injuries during the tournament were initially sustained prior to Wimbledon [11••].

Conclusions

While tennis is an overall safe and low-risk sport, it is nevertheless associated with its own unique set of acute and chronic injuries. Within the last several years, there have been a number of longitudinal studies on the epidemiology of injuries among tennis players at various levels, ranging from junior tennis to major Grand Slam tournaments. Consistent with previous literature, acute injuries tend to occur in the lower extremities, while chronic overuse injuries more often affect the upper extremities and trunk. Although direct comparisons of injury rates are difficult due to heterogeneity in injury incidence denominators, which include hours of play, games or sets played, and match exposures, elite levels of tennis appear to be associated with increased acute injury incidence compared to collegiate and junior tennis. However, when athletes are followed longitudinally, even junior tennis players are often afflicted with overuse musculoskeletal conditions. Additional research is needed in the development of injury prevention strategies at all levels of play.

Compliance with Ethical Standards

Conflict of interest Michael C. Fu and Per A. Renstrom declare that they have no conflicts of interest.

Todd S. Ellenbecker is a consultant for Cymedica Orthopaedics and Performance Health, an editorial board member of Sports Health, International Journal of Sports Physical Therapy, and Physical Therapy in Sport, and an employee of ATP World Tour.

Gary S. Windler reports stock ownership in Stryker.

David M. Dines reports royalties from Zimmer Biomet, personal fees from Thieme Publishers, and is on the board of directors to OLC at AAOS.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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