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Beyond the Baseline: A Multifactorial Review of Tennis Injuries

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Abstract

Background: Tennis is widely practiced globally across all ages and skill levels. The sport involves high-speed strokes, rapid directional changes and complex kinetic-chain movements, placing substantial demands on the musculoskeletal system. Repetitive and asymmetrical actions, especially during the serve, increase the risk of acute and overuse injuries.

Aim: To provide an overview of the epidemiology, mechanisms, risk factors, as well as prevention strategies for tennis-related injuries across recreational, junior, and elite players, highlighting research gaps.

Material and Methods: A systematic review was conducted using PubMed, focusing on English-language peer-reviewed studies. Epidemiological and biomechanical assessments, intervention trials and professional injury surveillance data were analysed to summarize injury patterns, mechanisms, risk factors with preventive strategies.

Results: Injuries are most frequent in lower extremities, followed by upper extremities and trunk, with muscle–tendon injuries predominating. Shoulder injuries result from repetitive overhead actions, while ankle sprains and patellar tendinopathy arise from acute trauma or chronic overload. Risk factors include prior injury, kinetic-chain deficits, workload spikes, court surface and sex differences. Prevention requires workload management, kinetic-chain conditioning, serve-specific biomechanics, core stability, functional screening, combined with psychological support.

Conclusions: Tennis injuries are multifactorial, with the serve central to risk due to kinetic-chain demands. Effective prevention includes physical conditioning, technique optimization, workload regulation and psychosocial strategies. Future research should prioritize prospective studies evaluating multifactorial prevention programs and functional screening, integrating biomechanics, workload, and psychosocial factors across ages, sexes, along with competition levels.

Keywords: tennis injuries, epidemiology, biomechanics, overuse injury, lower extremity, upper extremity, serve mechanics, injury prevention, kinetic chain, core stability.

Content

1. Introduction

Worldwide tennis participation represents the highest recorded level to date in 2024, with approximately 106 million individuals participating in tennis across 199 countries, comparing with the 84.4 million players reported in 2019, according to International Tennis Federation’s Global Tennis Report [1]. Tennis places considerable physical demands on athletes through recurrent overhead actions, rapid transitions between movement phases and high-intensity explosive efforts, all performed within technically demanding stroke and serve sequences. These demands contribute to an elevated risk of injury related to repetitive loading [2]. Unlike sports with a set time limit, tennis matches are open-ended, often lasting multiple hours depending on the progression of play. Moreover the performance of hundreds of strokes relies on the kinetic chain to produce high-speed racquet and ball movements with reduced joint loading. Force generation initiates from the feet and knees, flows through the core and trunk, passes through the shoulder and elbow, and concludes at the wrist, then hand with the racquet [3]. Serve is the most physically demanding stroke in tennis and a critical component of performance, often representing 45–60% of all strokes in a service game at the professional level, with each set comprising around 43 serves on average [4, 5, 6]. As a result, individuals competing in tennis, particularly at professional and elite levels, are exposed to a heightened risk of musculoskeletal injuries [7]. Overuse injuries predominantly affect the upper extremity and trunk, including internal shoulder impingement, superior labrum anterior-to-posterior (SLAP) lesions, medial and lateral epicondylitis, extensor carpi ulnaris (ECU) subluxation and tendinitis at the wrist, abdominal muscle and lumbar strains and degenerative changes of the intervertebral discs, whereas lower extremity injuries are more commonly acute in nature, such as hip injuries, knee meniscal tears and tendinopathy and ankle sprains [3, 5]. Considering the broad engagement in tennis across recreational and competitive populations, understanding the epidemiology and pathomechanics of tennis-related injuries is essential.

2. Epidemiology

Extensive research has examined musculoskeletal injury epidemiology in tennis players, supported by several review articles published during the past two decades. Inconsistent injury surveillance previously hindered epidemiological investigations in professional tennis, which was addressed by the establishment of a standardized consensus framework in 2009 [8]. Although the consensus recommends reporting injuries per 1,000 match hours, incomplete data on match durations in earlier studies has led to variability in reported injury rates, complicating direct comparisons. Pluim et al. demonstrated that across all levels of play reported injury incidence rates ranging from 0.04 to 3.0 injuries per 1,000 hours of participation [9]. In junior athletes, injury rates reached 3.5 per 1,000 hours of exposure during a single academy season, with seasonal prevalence spanning 46–54% [10, 11, 12]. The injury burden is even higher among adult players, with exposure-based rates reported up to 30.8 per 1,000 hours during humid outdoor events and as high as 56.6 per 1,000 hours in WTA events [13, 14].

Several epidemiological investigations have indicated that the lower extremity accounts for the greatest proportion of injuries (48-56%), followed by the upper extremity (25–40%) and the trunk (12–25%) [5, 9, 14, 15, 16, 17, 18, 19, 20, 21]. The ankle and thigh are most frequently injured in the lower extremity, whereas the shoulder and elbow predominate in the upper extremity, and the lumbar spine represents the most commonly affected region of the trunk. Muscle and tendon injuries accounted for the majority of both acute (84%) and chronic (87.7%) cases, followed by joint, ligament, skin, and bone injuries [5, 21, 22]. Acute injuries requiring medical attention appear to be more frequent than chronic overuse conditions, although chronic injuries demonstrate a more balanced distribution between the upper and lower extremities [21]. Among acute injuries of the lower limb, the ankle was the most commonly involved site, followed by the thigh and the knee. With respect to chronic conditions, spinal complaints were reported most frequently, accounting for 20.5% of cases, whereas the lower extremity represented 15.8% of chronic injuries, with the knee emerging as the predominant location [23]. Distribution of injuries by body region is presented in Table 1.

Table 1. Distribution of acute and chronic injuries in tennis players by body region.

Body region	**Share of total injuries (%)**	**Predominant acute injuries**	**Predominant chronic injuries**
Lower extremity	48–56	Ankle, thigh, knee	Knee (most common)
Upper extremity	25–40	Shoulder, elbow	Evenly distributed
Trunk	12–25	Lumbar spine	Lumbar spine

Using ATP and WTA data from 2011–2016, Gescheit et al. reported that injury rates correlated more closely with games played than matches or sets, and male players exhibited lower injury rates compared with female players. Injury patterns also differed by sex: women most commonly sustained shoulder, wrist, knee and foot injuries, whereas men were more frequently affected in the knee, thigh and ankle. Moreover, the study observed a gradual increase in upper extremity injuries over the study period [18]. Since 2011, the ATP and WTA have used a web-based medical surveillance system to monitor injuries and illnesses in professional tennis. Data from this system indicate that overuse injuries show characteristic profiles, including a predominance of medial over lateral elbow tendinopathy and a higher frequency of patellar than quadriceps tendon injuries, supporting the presence of consistent injury patterns among elite players [3].

Only four published studies have examined injury epidemiology at Grand Slam tournaments (Australian Open, Wimbledon, US Open, and Roland Garros), and their findings show considerable variability. Differences in reported injury rates and patterns may be partly explained by the distinct and largely non-overlapping time periods analyzed across tournaments. While some studies reported higher injury rates in female players, others observed comparable rates between sexes. Similarly, certain investigations identified stable injury rates over time, whereas others reported increasing trends. Reported primary injury locations varied by Grand Slam event, including shoulder and knee involvement at the Australian Open, shoulder and thigh injuries at Roland Garros, wrist and groin injuries at Wimbledon and ankle injuries at the US Open. However, all studies consistently reported a higher proportion of lower extremity injuries compared with trunk and upper extremity injuries, and muscle or muscle–tendon injuries as the most common injury types [18, 20, 21, 22]. These discrepancies may reflect variations in environmental conditions, seasonal timing, and court surface characteristics, all of which can influence player workload and injury risk.

3. Risk factors

Several extrinsic and intrinsic factors have been identified as contributors to injury risk in tennis. Court surface transitions, cumulative playing exposure and acute-to-chronic workload ratios exceeding 1.3 appear to be particularly influential in amplifying injury susceptibility [14]. General risk factors consistently associated with tennis-related injuries include a history of previous injury, extensive static stretching performed before and after play, participation in additional sports and the use of rackets with increased length or weight. Furthermore, increases in age, height, body mass or weekly tennis volume have all demonstrated significant associations with a higher incidence of tennis injuries [4]. With regard to upper-extremity injuries, kinetic-chain impairments of the shoulder, including a loss of at least 15° of glenohumeral internal rotation, scapular dyskinesis, core instability and posterior capsule tightness, have been shown to approximately double the risk of time-loss shoulder injuries [14]. Owing to the high velocities, large joint loads, and sequential interdependence of its phases,
the tennis serve represents the most injury-prone stroke in tennis. Mechanical deficiencies or previous injuries in any segment of the kinetic chain can propagate through the serve motion, substantially increasing the risk of upper- and lower-extremity as well as spinal injuries.
The biomechanics of the loading phase of the tennis serve substantially influence the kinematics

and kinetics of the subsequent phases, with prior lower-limb injury further increasing susceptibility to injury during this complex movement. During the cocking phase, characterized by maximal external rotation of the racket arm in preparation for acceleration, several variables demonstrate strong associations with injury risk, including excessive contralateral pelvic rotation, increased anterior pelvic tilt and elevated peak angular velocity of lead-knee extension. The acceleration phase, which directly follows the cocking phase and culminates in ball impact, has been linked to elevated internal joint loading, particularly high inferior shoulder forces and increased medial elbow forces, both of which are strongly associated with injury risk. Additionally, greater left lumbar rotation in the lower spine and increased left lateral flexion in the upper lumbar region have been associated with a higher likelihood of low back pain. At ball contact, wrist mechanics contribute significantly to racket-head speed, with greater wrist extension range of motion showing a strong association with lower-limb injuries and a moderate association with upper-limb injuries. Finally, during the deceleration phase after impact, increased posterior-dominant shoulder tightness has been shown to markedly elevate injury risk [4]. Overall, injury risk in tennis reflects the interaction between workload exposure, individual predispositions, and serve-specific biomechanical stresses, with kinetic-chain dysfunction amplifying mechanical load and increasing susceptibility to both acute and overuse injuries.

4. Mechanism of injuries

Tennis injuries arise from a combination of repetitive loading patterns and stroke-specific biomechanical demands affecting multiple anatomical regions. Upper limb injuries occur frequently and are primarily the result of cumulative microtrauma from rapid arm movements, with the shoulder and elbow being most commonly affected, followed by the wrist [2, 24, 25]. Shoulder pathologies, such as internal impingement and superior labrum anterior-to-posterior (SLAP) lesions, are primarily attributed to the high-volume repetitive overhead actions inherent to serving and overhead strokes. At the elbow, lateral tendinopathy is commonly associated with backhand strokes performed with excessive wrist flexion, whereas medial elbow tendinopathy has been linked to forceful wrist snapping during serves and forehand strokes, open-stance hitting and short-arming techniques. Wrist injuries, including extensor carpi ulnaris tendinitis, frequently result from repeated ulnar deviation of the non-dominant wrist during two-handed backhands, while extensor carpi ulnaris subluxation may occur due to sudden volar flexion and ulnar deviation stresses when executing low forehand shots. Trunk-related injuries also reflect stroke mechanics, with abdominal muscle strains often developing from repetitive uncoiling and flexion of the trunk during the overhead serve.

In the lumbar spine, strains are commonly associated with abrupt increases in training intensity or duration, as well as modifications in stroke technique, whereas lumbar disc degeneration and herniation are strongly linked to repetitive rotational loading and spinal hyperextension during serving [5]. Lower-limb injuries arise from both acute trauma and chronic overuse. Ankle sprains represent the most frequent acute injury and typically occur during rapid lateral movements, abrupt changes of direction or on slippery surfaces, particularly when athletes are fatigued. The most prevalent mechanism is inversion of the foot, leading to damage of the lateral ligament complex, most commonly the anterior talofibular ligament. Such injuries present with pain, swelling, and, in later stages, bruising, and they are associated with a high risk of recurrence due to residual ligamentous laxity. Knee injuries in tennis may be either traumatic or overuse-related as well. Acute knee trauma often involves twisting mechanisms that can result in meniscal or ligamentous lesions. The most common chronic knee condition is patellar tendinopathy or jumper's knee, which develops from repetitive overload of the knee extensor mechanism during sprinting, jumping, serving and rapid directional changes. Limited flexibility of the quadriceps and hamstrings, as well as lower-limb alignment variations (e.g., genu valgum, genu varum, flat feet), may increase tendon loading and contribute to symptom development. Clinically, athletes typically report activity-related anterior knee pain that may progress in intensity and be accompanied by stiffness or swelling. Hip injuries in tennis have increasingly been recognized beyond muscular strains, reflecting the high-impact, multidirectional demands of the sport. Conditions such as femoroacetabular impingement and acetabular labral tears have been reported in elite players and may require surgical management in some cases [26]. Common injury mechanisms for tennis players are summarized in Table 2.

Table 2. Common tennis injuries and their mechanisms.

Injury type / location	Typical mechanism / cause
Shoulder: internal impingement, SLAP lesions	Repetitive overhead strokes and serves; high-volume, high-velocity shoulder loading
Elbow: medial and lateral tendinopathy	Medial: forceful wrist snapping during serve/forehand, open-stance, short-arming; Lateral: excessive wrist flexion during backhand strokes
Wrist: extensor carpi ulnaris tendinitis / subluxation	Repeated ulnar deviation during two-handed backhands; sudden volar flexion and ulnar deviation during low forehand shots
Trunk / abdomen: muscle strains	Repetitive trunk flexion and uncoiling during serves and overhead strokes
Lumbar spine: strains, disc degeneration / herniation	Abrupt increases in training intensity or duration; repetitive rotational loading; hyperextension during serving
Ankle: sprains	Rapid lateral movements, abrupt changes of direction, slippery surfaces; inversion causing lateral ligament injury (commonly ATFL)
Knee: acute (meniscal/ligament lesions), chronic (patellar tendinopathy)	Twisting mechanisms (acute); repetitive overload of knee extensor mechanism during sprinting, jumping, serving, and rapid directional changes (chronic); limited flexibility and malalignment contribute
Hip: muscular strains, FAI, labral tears	High-impact, multidirectional movements; chronic overload; surgical intervention may be required in some cases

SLAP – superior labrum anterior-to-posterior
ATFL – anterior talofibular ligament

Overall, injury mechanisms in tennis reflect the sport's repetitive, high-velocity and asymmetrical demands, in which technical execution, cumulative loading and abrupt directional changes interact to overload specific segments of the kinetic chain and predispose athletes to both acute and chronic conditions.

5. Prevention

Current evidence supports a multidimensional and tiered approach to injury prevention in tennis that integrates workload management, physical conditioning and technical optimization. Effective external-load regulation can be achieved through progressive training cycles, such as four-week ramp-up blocks, combined with continuous monitoring using acute-to-chronic workload ratios or session rating of perceived exertion (s-RPE).

At the neuromuscular level, kinetic-chain–focused conditioning programs incorporating core-stability training, eccentric strengthening of the scapular stabilizers and rotator cuff, and post-match mobility exercises appear essential for maintaining optimal movement quality and reducing injury susceptibility [14]. Functional screening tools, such as the Functional Movement Screen, together with core stability testing, are commonly used to identify movement deficits and asymmetries that may be associated with elevated injury risk. Evidence indicates that short-term interventions emphasizing trunk stabilization and neuromuscular training can improve functional movement patterns and trunk muscle endurance in tennis players, potentially supporting both performance enhancement and injury-risk reduction.

In addition, structured warm-up routines combining mobility, core activation, and neuromuscular drills appear beneficial for preparing the musculoskeletal system for tennis-specific demands [27]. Rehabilitation and preventive interventions for elbow injuries in tennis players prioritize improving strength and muscular endurance throughout the entire upper-extremity kinetic chain. Studies in elite athletes have demonstrated dominant-arm strength gains of approximately 20–30% in elbow extension, wrist flexion and extension, as well as forearm pronation compared with the non-dominant arm [5]. Technique- and equipment-related modifications, including individualized grip sizing and targeted serve-timing cues, further contribute to lowering mechanical stress on the upper limb [14]. Moreover injury prevention in tennis players should focus on comprehensive core stability training. Imbalances between trunk flexion and extension strength may increase lumbar injury risk, making it essential to strengthen both muscle groups evenly. Given the frequent trunk rotation in tennis strokes, exercises should emphasize rotational movements and target all three planes of motion - sagittal, frontal, and transverse [5]. Owing to its high frequency in match play, the serve represents an appropriate primary target for injury prevention strategies in tennis. Serve-specific biomechanical characteristics have been associated with a reduced risk of injury across multiple phases of the stroke. A lower likelihood of injury has been observed when force production originates efficiently in the lower extremities and is sequentially transferred through the trunk to the upper limb, reflecting optimal leg drive and integrated kinetic-chain coordination. Furthermore, lower-limb contributions to post-impact deceleration are critical, as greater hip extension range of motion in both the dominant and non-dominant limbs, particularly during landing on the non-dominant leg, has been moderately associated with lower injury and low back pain risk. Protective factors across the serve also include adequate lower trapezius and shoulder external rotation strength, balanced external-to-internal rotation ratios, optimal pelvis–shoulder separation, appropriate pelvic control and sufficient wrist extensor and flexor strength. In addition, technical parameters such as a more anterior ball contact position and adequate shoulder internal rotation range of motion during follow-through appear to further mitigate injury risk across the upper limb and lumbar spine [4]. Besides physical, biomechanical and workload-related factors, psychological and behavioral aspects are increasingly recognized as relevant components of injury prevention in tennis. Talented athletes can use self-regulatory skills to manage health and prevent injuries. Based on the study by van der Sluis et al., in junior tennis players, higher self-monitoring ability is associated with fewer time-loss overuse injuries, especially in girls, suggesting that monitoring one's own symptoms may help prevent minor complaints from escalating. Reflection, however, has been linked to higher weekly overuse injury severity, though the implications of this finding require further investigation. Coaches and support staff should consider individual differences in self-regulation when designing injury-prevention strategies and educate players to develop these skills for optimal health management [28]. In addition, evidence suggests that athletes characterized by elevated perfectionistic concerns, high athletic identity, increased life stress and suboptimal coach–athlete relationships are more frequently affected by overuse injuries [29]. Meta-analytic findings further indicate that preventive psychological interventions may moderately reduce injury incidence in athletic populations [30]. Consequently, fostering supportive interpersonal environments, promoting athlete autonomy and health education, and providing access to regular psychological support may facilitate earlier symptom recognition as well as more adaptive responses to training and competition demands. Incorporating stress-management strategies and monitoring selected psychological indicators, such as perceived stress, sleep quality and recovery status, may therefore complement existing physical and biomechanical prevention strategies [31]. Taken together, effective injury prevention in tennis requires a comprehensive and individualized strategy that integrates workload regulation, kinetic-chain–oriented physical conditioning, biomechanical optimization of the serve, and attention to psychological and behavioral factors influencing athlete health.

6. Discussion and conclusions

This review integrates current evidence on tennis-related injuries, demonstrating that injury patterns are shaped by the sport's repetitive, high-velocity movements and complex stroke biomechanics. Across competitive levels, injuries most frequently involve the lower extremities, followed by the upper extremities and trunk, with muscle–tendon disorders representing the predominant pathology. The serve emerges as a key contributor to injury development due to its high frequency and substantial mechanical demands, underscoring the importance of efficient kinetic-chain function and coordinated force transfer from the lower extremities through the trunk to the upper limb. A central contribution of this review is the synthesis of epidemiological, biomechanical, and preventive evidence supporting a multifactorial model of injury development in tennis. The findings indicate that effective injury prevention extends beyond isolated strengthening interventions and requires an integrated approach combining progressive workload management, kinetic-chain–oriented conditioning, comprehensive core stability training, biomechanical and technical optimization, and athlete education. In this context, functional movement screening and the development of self-regulatory skills may serve as complementary tools to support early identification of risk factors and improve injury-related decision-making, particularly in younger athletes. Despite the growing volume of research, several important gaps remain in the current literature. There is a notable lack of prospective, longitudinal studies in elite and professional tennis populations, with many existing investigations relying on retrospective designs or data derived from junior and recreational players. As a result, causal relationships between workload characteristics, biomechanical variables, and injury outcomes remain insufficiently established. Moreover, few studies have simultaneously integrated objective workload monitoring, detailed biomechanical assessment and injury surveillance, limiting insight into the interaction between these factors. Female athletes and developmental transitions from junior to senior competition also remain underrepresented, despite evidence suggesting sex- and age-related differences in injury patterns. Interpretation of existing findings is further constrained by methodological limitations, including heterogeneity in injury definitions, reporting methods, and exposure calculations. Overuse injuries may be underestimated due to delayed symptom onset, inconsistent medical documentation, or reliance on self-reported data. Additionally, many studies focus on isolated screening measures or single risk factors, which may inadequately reflect the multifactorial nature of injury risk in tennis. Environmental and contextual influences such as court surface, climatic conditions, and tournament scheduling are also inconsistently accounted for, despite their known impact on workload and injury susceptibility. Future research should therefore prioritize well-designed prospective studies that integrate biomechanical analysis, workload monitoring and psychosocial factors within comprehensive injury models. Establishing the long-term effectiveness of multifactorial prevention programs and clarifying the predictive value of functional screening tools across different ages, sexes, and competitive levels will be essential for advancing evidence-based injury prevention in tennis.

Disclossure

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