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Peroneal Muscle Training Effects on Tennis Player Lateral Ankle Sprain Prevention

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Abstract. The majority of lower extremity injuries in tennis practice consist of ankle injuries. Lateral ankle sprains frequently occur among tennis athletes due to their unique, rapid lateral movements. The purpose of this review paper is to review the significance of peroneal training on tennis players' lateral ankle sprain prevention and to highlight the potential effects of each current mainstream training method. From the previous studies, strength training of the peroneal muscles is shown to improve joint load tolerance and fatigue resistance, which contribute to increased mechanical stability of the ankle. Besides, neuromuscular and proprioceptive training further enhances reaction time and sensorimotor coordination during unpredictable movements. Evidence from rehabilitation research in chronic ankle instability indicates that balance training and landing-based programs may reduce instability symptoms and lower the risk of recurrent sprains. Furthermore, multimodal training programs that combine strength and neuromuscular reinforcement may improve the quality of rehabilitation. As a whole, peroneal muscle-focused multimodal training is the optimal prevention or rehabilitation method for sports involving rapid lateral court movement, particularly tennis. Combined strength and neuromuscular training may help enhance ankle stability and prevent future ankle sprain recurrence.

Keywords: Tennis athletes' ankle injuries, peroneal muscle strength training, lateral ankle sprain prevention, isokinetic training, proprioceptive training.

1. Introduction

Lateral ankle sprains are one of the most common lower extremity injuries in sports, especially among sports that involve rapid changes in an athlete's center of mass and unpredictable jumping and landing. The ankle ligaments can be overloaded and hence result in LAS due to excessive inversion and plantarflexion of the foot [1]. Tennis is a court sport characterized by frequent lateral cuttings, repeated split-step landings, and the movements of the sport often force the players to overstress their ankle joint with sudden loaded force. The peroneal muscles played a crucial role in dynamic ankle stabilization by providing supporting force, generating eversion torque in order to counteract the loaded force on the ankle joint during unstable movements [2,3]. In this case, understanding the muscle mechanisms and training method for improving peroneal muscular function is essential for preventing lateral ankle sprains in tennis players.

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Previous studies on related topics have investigated various rehabilitation strategies involving different training methods for LAS prevention. Strength training and neuromuscular training are the two most popular approaches. Peroneal strength training activated and reinforced the muscle groups through controlled muscle contractions. It is shown to improve muscle force, joint stability, and load tolerance of the ankle [4,5]. On the other hand, neuromuscular training is inclined to improve postural control to maintain body alignment, reduce reflex latency to exchange for shorter activation time, and ensure dynamic stability during unanticipated movements. The outcomes showed that the neuromuscular training may reduce the risk of recurrent lateral ankle sprains [6,7]. Based on recent research, multimodal training was considered to be a relatively more effective rehabilitation and prevention method for LAS [4,5]. However, the current study field was mostly conducted on general populations with chronic ankle instability, which means the lack of tennis-specific research involving unique movement patterns and injury mechanisms [1].

This paper aims to evaluate the role of strengthening and neuromuscular training in lateral ankle sprain prevention, while the effectiveness of peroneal muscle training in preventing lateral ankle sprains in tennis players remains unclear. This paper reviews the epidemiology of LAS in Tennis, the anatomical function of peroneal muscles, LAS injury mechanisms in Tennis, methods and effects of peroneal muscles' strength training and neuromuscular training, and the existing research gaps.

2. Effects of the peroneal muscle on lateral ankle sprain prevention

2.1. Epidemiology of lateral ankle sprains in tennis

Lateral ankle sprains (LAS) are one of the most commonly reported musculoskeletal injuries within athletic populations worldwide [1]. In professional and recreational court-sport athletes, ankle sprains represent 16–40% of all injuries, and are the most prevalent lower-extremity injury, associated with significant impacts on athlete availability, performance and long-term joint health [6]. LASs occur predominantly in court sports which demand rapid directional changes, repetitive landings and sudden dynamic contact with the playing surface, as these movements frequently force the ankle into excessive inversion and plantarflexion, resulting in excessive mechanical stress through the lateral ligament complex [1,7].

Tennis places additional demands on the lower extremity, which increases the risk of LAS. Compared to other court sports, tennis players frequently change direction rapidly, alter the centre of gravity of the body during the split-step landing phase, take large aggressive 'cut' or 'pound' steps towards the net during points, and make multiple explosive lateral cutting movements to retrieve wide shots across multiple rallies [8]. Consistent with these biomechanical demands, Robinson et al. reported an overall injury rate of 4.41 injuries per 1000 AE, of which lateral ankle ligament injuries comprised 8.5% of all competitive and training injuries [8]. Additionally, the lower extremity and ankle have been reported as highly vulnerable to injury in professional tennis. Injury surveillance of the US Open Tennis Championships from 1994 to 2009 reported that lower extremity injuries (23.0 per 1000 ME) occurred at a significantly greater rate than trunk injuries (6.12 per 1000 ME) and upper extremity injuries (17.7 per 1000 ME), and the ankle was the most commonly injured body site [9]. These data provide strong evidence that the ankle joint is highly vulnerable to injury in competitive and recreational tennis participation.

Although the incidence of LAS is greater in basketball and volleyball compared to tennis, injury mechanisms are markedly different between sports: vertical ankle injuries in basketball and volleyball result from landing from vertical jumps and awkward landings from aerial movements, whereas tennis injuries result from repetitive lateral movements, high-speed directional changes and

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continuous court coverage throughout long rallies. These different biomechanical demands of each sport will induce different injury patterns and create sport-specific neuromuscular risk factors. Therefore, evidence from vertical-jump sports cannot be extrapolated to tennis injury aetiology or prevention. Despite the large body of literature dedicated to understanding LAS in vertical-jump sports, the specific anatomy and targeted epidemiology of tennis remain poorly understood, highlighting the need for sport-specific research to guide sport-specific prevention strategies [1,8].

2.2. Anatomy and function of the peroneal muscles

The peroneus longus and peroneus brevis represent the major musculotendinous structures of the lateral lower leg, running upon the fibula within the lateral compartment of the crus, and providing stabilization of the lateral ankle and hindfoot by limiting ankle eversion and inversion motion, maintaining dynamic hindfoot alignment during weight-bearing gait activities, and resisting the excessive inversion torque that predisposes tennis athletes to lateral ankle sprain [2].

The peroneus longus arises from the proximal fibula, running distally behind the lateral malleolus, its tendon passing beneath the plantar surface of the foot to insert upon the base of the first metatarsal and medial cuneiform bone [2]. The PL helps to actively evert the ankle, somewhat weakly plantarflexes the foot, and provides static and dynamic foot arch support during weight-bearing gait activities such as cutting, running, and landing [2]. The peroneus brevis arises from the distal fibula, its tendon inserting distally onto the base of the fifth metatarsal; of the ankle evertors, the PB is the largest and most potent muscle providing active lateral ankle stabilization during dynamic functional movements [2].

Nearly all CAI mechanisms of injury involve a vector of combined ankle inversion (sole turning medially) and plantarflexion (toes pointing downward), a position that places the lateral ligament complex under extreme tensile strain [2]. Biomechanically, the peroneal muscles produce controlled eversion torque that directly counters the excessive, injurious, and impulsive inversion torque, maintaining both static and dynamic lateral foot and ankle passive and dynamic stabilization, and reduction of excessive mechanical torque and loading on the lateral ligaments during high-demand cutting, landing, and running tennis movements and activities [2].

Peroneal muscle function begins with static strength, but is not limited to it. Normal peroneal muscle function also includes reactive neuromuscular control: in response to an applied ankle inversion perturbation, peroneal training programs increase muscle activation speed such that the peroneal muscles can provide a rapid response to an unanticipated sudden ankle inversion load (typically <90 milliseconds) [3]. This extremely rapid response time, the time it takes a motor unit to produce a detectable change in muscle length (reflex latency), is the fastest the human body can physiologically achieve [3]. In CAI, diminished activation speed and prolonged reflex latency allow the ankle to undergo excessive inversion before the muscle stabilizer can switch on to offload the stretched, weakened, and sprain-prone lateral ligaments, and thus allows excessive mechanical torque and loading to shift onto the passive lateral collateral ligament complex, increasing the risk of sprain injury [3]. People with CAI have decreased peroneal muscle strength and prolonged reflex latency, resulting in a neuromuscular fault that places them at high risk for recurrent ankle sprain and persistent functional foot and ankle instability [3].

2.3. Mechanism of injury of lateral ankle sprain in tennis athletes

A lateral ankle sprain is characterized as the abnormal stretching or partial/complete tearing of the lateral ankle ligament complex, comprised of the anterior talofibular ligament (ATFL),

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calcaneofibular ligament (CFL) and posterior talofibular ligament (PTFL). Inversion-type injuries constitute~85% of all LAS, with isolated injury to the ATFL being the most common clinical presentation. The ATFL is the primary static stabilizer against excessive inversion when the ankle is in a plantarflexed position; due to its relatively small size and low tensile strength, the ATFL is the first structure to fail when forced inversion and plantarflexion occur simultaneously.

Tennis athletes must adopt a plantarflexed, forefoot-weight-bearing body position during play to reduce reaction time and allow for more efficient movement changes, placing the ATFL in a pre-stressed state and the ankle in a mechanically vulnerable position for an inversion injury. During a competitive tennis rally, lateral cutting movements, rapid repositioning and dynamic split-step landings generate large rotational inversion torques at the ankle as players shift momentum in all directions to maintain an optimal hitting position and centre of gravity. When the ATFL cannot resist excessive inversion forces, an acute LAS occurs, resulting in ligamentous damage, joint instability and functional weakness.

The eversion torque produced by the peroneal muscles provides the primary dynamic counterforce to excessive inversion, reducing tensile loading on the ATFL and augmenting the passive stabilising role of the lateral ligaments. As the primary musculotendinous group responsible for active eversion, the peroneals provide stabilisation during the mediolateral momentum shifts and sudden inversion perturbations associated with tennis play. However, sufficient peroneal activation can be impeded or considerably delayed by muscle fatigue, baseline weakness or poor neuromuscular control, leaving the athlete in a state of significant instability as the passive ligaments of the lateral ankle attempt to absorb excessive dynamic loads. Other extrinsic risk factors unique to tennis include inappropriate footwear design, poor court surface traction and uneven playing conditions, all of which further contribute to increased inversion risk. These findings highlight the important role of peroneal muscle strengthening and neuromuscular training in reducing the risk of LAS among tennis athletes [3].

2.4. Peroneal strength training effects

Peroneal strength training not only serves to enhance maximal eversion force production, but also improves functional ankle range of motion (ROM), joint load tolerance and muscular fatigue resistance-three additional adaptations that facilitate injury prevention during prolonged tennis match play. Various evidence-based training approaches are commonly used to strengthen the peroneal muscles in clinical, sports injury and athletic populations, including isometric, isotonic, isokinetic and heavy slow resistance (HSR) training, which are all incorporated into rehabilitation and injury prevention programmes for athletic populations.

Isometric training is frequently performed in the early stages of rehabilitation following injury or as part of prehabilitation, with controlled muscle contraction around a fixed ankle joint position. A typical protocol might involve isometric contraction of the peroneals, with engagement of the desired muscle whilst avoiding painful joint movement. Isometric peroneal training aims to re-establish peroneal neuromuscular activation and ROM without inducing additional ligamentous stress .2021 clinical practice guidelines for ankle sprain management recommend early, pain-free muscle activation followed by progressive ROM restoration [10].

Isotonic training involves simulating tennis-specific dynamic movements, with concentric and eccentric muscle contractions against a controlled external resistance. Typical drills might include multi-planar resistance band over multiple loading moments (anterior, posterior, medial, lateral) engaged at the ankle, exercising each eversion, inversion, plantarflexion and dorsiflexion movement pattern through a full, pain-free functional ROM (e.g. eccentric-concentric muscle actions during

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ankle eversion on a resistance band). This modality is only applied after some partial ankle ROM has been restored and athletes can reliably activate the peroneal muscles without significant pain, as it will induce dynamic muscle lengthening and shortening similar to that required for tennis cutting and landing [6].

A 2022 RCT demonstrated that a focused programme of isokinetic peroneal training using resistance bands can significantly improve dorsiflexion ROM and self-reported measures of functional stability and dynamic balance in individuals with CAI [11].

Isokinetic dynamometry measures isometric and isotonic torque and power output at the ankle joint whilst controlling movement velocity, providing objective, quantitative measures of movement function which can be compared between movement speeds and between affected and non-affected limbs. Isokinetic testing can be used to determine the extent of contraction efficiency, power deficit and peak torque deficits in the affected ankle, and to objectively quantify recovery following intervention and rehabilitation. This modality allows clinicians to objectively quantify athletes' isokinetic training response and ensure that athletes have achieved sufficient strength to resist the high-speed cutting and landing patterns required for tennis before returning to full sport. An RCT published in 2022 found significantly larger improvements in inversion and eversion strength in the isokinetic training group compared to the standard resistance band training group after 7 months of isokinetic training in individuals with functional ankle instability [4].

HSR training is performed in the later stages of prehabilitation and return-to-sport, involving slow, controlled muscle contractions against an applied resistance that is progressively increased to a maximal isometric load. This modality is best suited for improving peroneal fatigue resistance during prolonged tennis matches, which is a common factor in late-match injuries associated with muscular fatigue and exhaustion. Evidence demonstrates that progressive HSR peroneal training can improve muscle strength, static and dynamic balance and neuromuscular control in individuals with CAI, reducing the risk of recurrent LAS injuries [6].

Although clear benefits of peroneal strength training have been documented, several important limitations are apparent in the literature: (1) the majority of studies have involved CAI patients or healthy athletic populations, with limited tennis-specific RCTs that examine sport- and movement-pattern–specific variables and injury outcomes; (2) the majority of available peroneal training programs are short-term (≤3 months) with a dearth of long-term data showing sustained injury reduction and prevention effects; and (3) the majority of most effective peroneal training programs are incorporated into comprehensive lower-extremity protocols, making it challenging to examine the independent effects of isolated peroneal strengthening. Because LAS prevention involves multiple modifiable risk factors, strength training alone is not sufficient to address all of the CAI risk factors, and an integrated approach including strength, neuromuscular, and proprioceptive training is necessary for maximal prevention efficacy [3,6].

2.5. Neuromuscular and proprioception training effects and interventions

Neuromuscular and proprioceptive training represents an important complementary intervention to peroneal strength training that can enhance joint position sense, reduce reflex latency, improve postural control, and provide additional dynamic stability during unanticipated, tennis-specific movements. The 2021 Journal of Orthopaedic & Sports Physical Therapy (JOSPT) clinical practice guideline strongly recommends that proprioceptive and neuromuscular exercise be performed by persons with CAI because proprioceptive and neuromuscular exercise has been shown to improve dynamic postural stability and joint confidence as perceived by the patient [10].

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Balance training with external perturbation training is the most commonly performed and most widely available modality and can take the form of static or dynamic balance training on unstable surfaces (ie, balance boards, foam pads) combined with unexpected external perturbations (ie, catch/throw drills, manual perturbations, sudden landing tasks). This form of training creates a situation in which the sensorimotor system must rapidly make neuromuscular adjustments to maintain the lower extremity in proper alignment. Training using this approach directly addresses many of the unexpected, tennis-specific lower-extremity movements (injury mechanism: off-center landings, single-leg loading, and deceleration) and has been shown to reduce kinesiophobia (fear of movement) in injured lower extremities, promoting confidence and better functional outcomes during dynamic activities [7].

Reflex latency training focuses on the speed at which peroneal muscles are activated following a sudden ankle inversion event (shorter = faster). The speed of protective peroneal activation is a major determinant of injury prevention because prolonged reflex latency delays the immediate muscular stabilizing response and allows excessive inversion to occur, thus shifting injurious load to the lateral ligaments [6,12]. Specifically, prolonged reflex latency prevents a protective peroneus longus activation from occurring immediately after the unexpected loading event, which allows the foot to overinvert and pronate, thereby increasing the risk of LAS. A large, 2026 systematic review found significantly longer reflex latencies in those with CAI, thus documenting delayed neuromuscular responses as a modifiable intrinsic risk factor for both primary and recurrent LAS [5]. Because it takes time for the neuromuscular system to react to the unexpected loading event and produce a protective peroneal activation, the faster the protective peroneal activation, the less time the ligaments have to absorb the load. Perturbation-based training directly targets this intervention by reducing reaction time and slowing the protective peroneal muscle's activation [12]. For example, a 2025 observational rehabilitation study reported that a specific neuromuscular training protocol can significantly improve peroneal activation speed and neuromuscular responsiveness and reduce the number of delayed protective reflexes in individuals with acute LAS and CAI [12].

Lateral hop and controlled landing training are sport-specific neuromuscular drills that emphasize tennis movement patterns and involve multi-planar hopping and controlled, aligned landings to attenuate ground reaction force vectors and promote optimal landing mechanics. Lateral hop and controlled landing training is superior to static balance training for reducing tennis injuries, because it is designed to meet the demands for rapid reactive stabilization and optimal landing mechanics in the face of lateral loading and rapid stabilization demands during competitive tennis rallies and directly transfers to the tennis court [5]. Taken in aggregate, neuromuscular training programs emphasize the need for rapid reactive stabilization, optimal landing mechanics, and dynamic postural control under sport-specific conditions that are associated with neuromuscular deficits that are not addressed by strength training alone.

The current body of evidence supports the notion that peroneal strength training and neuromuscular/proprioceptive training induce distinct and unique physiological adaptations, and that a multimodal training intervention is more effective than single-modality interventions for preventing LAS in tennis athletes [12]. CAI is a combination of deficits in muscular strength, proprioception, postural control, and neuromuscular response speed, all of which impair dynamic ankle stabilization during highly demanding movements—meaning that single-modality interventions cannot address all modifiable risk factors [5].

ST improves maximal Peroneus eversion torque and fatigue resistance but does not significantly change reflex latency or dynamic JPS. NMT provides an optimal training stimulus for reactive stability and proprioception but does not significantly change maximal muscle strength. The

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interacting effects of these two training modalities appear to be clinically meaningful, as clinical evidence has demonstrated the additive effect of neuromuscular training in reducing LAS recurrence. A 2009 RCT found that the proprioceptively trained athletes experienced a 22% recurrent LAS rate over the 1-year follow-up period, compared to 33% in untrained controls [13].

The optimal peroneus-focused multimodal program for preventing tennis-specific injuries includes isometric and isotonic strength training, perturbation-based balance drills, and sport-specific lateral hop/landing drills. Evidence-based parameters for a peroneal strength and neuromuscular program include 2–3 training sessions per week, moderate-to-high progressive intensity, and 8–12 weeks of consistent training to induce neuromuscular and strength adaptations. The training program must also be sport-specific concerning lateral movement and landing demands, and generalized lower extremity programs are not an appropriate training approach for preventing tennis-specific injuries.

2.6. Gaps and future research directions

Despite the established need for peroneal training in the general athletic population, several gaps exist that implicate the need for further research to facilitate the development of an evidence-based, tennis-specific LAS prevention program. Most existing LAS research has been conducted in basketball, volleyball, and general court sports, with very few RCTs examining the mechanisms of sport-specific injury, specific training modalities, or long-term outcomes in tennis athletes.

Future research should address large tennis-specific RCTs to compare the efficacy of multimodal peroneal training versus conventional training, with primary outcome measures being lateral ankle sprain incidence and recurrent injury rate, and also large prospective longitudinal studies to follow participants for 6 months or more to determine the lasting effects of training and the validity of an injury prevention intervention. Additional important areas of future research should include the validation of tennis-specific NMD drills that closely mimic the authentic lower body tennis movement patterns, the application and implementation of sensor wear technology to objectively measure peroneal activation, reflex latency and ankle kinematics and biomechanics during live play, and the extension of investigations to include youth and adolescent tennis athletes to guide age-specific training recommendations. Additionally, future studies should also address the cost-effectiveness of multimodal training regimens, determine the dosages that distinguish between recreational and professional tennis athletes, and explore specific strategies to improve long-term training adherence in competitive tennis athletes. These critical research gaps should ultimately allow for the development of targeted, effective peroneal training programs to reduce the overall incidence and long-term ankle injury burden, and to improve long-term ankle health and performance in competitive tennis athletes across all levels of play and age groups.

3. Conclusion

This paper investigated the effects of peroneal training for the prevention of lateral ankle sprains in tennis players. Rapid direction changes, lateral cuttings, sudden stoppings and vast other lower extremity movements are involved in tennis play, all of which require considerable participation of the ankle joint. Thus, maintaining ankle functional stability is important. Neuromuscular and proprioceptive training can further improve postural control, response time and sensorimotor coordination, which are important for maintaining joint alignment during unexpected movements. Furthermore, based on the results from studies of chronic ankle injuries. Multimodal training programs combining strength and neuromuscular training methods seem to result in greater

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improvements than single-method programs. In summary, the results of this study support the dynamic stabilizer hypothesis for the peroneal muscles, that is, the peroneal muscles play a dynamic stabilizer role at the ankle. These findings also highlight the importance of personal-focused training in sports, especially in tennis. High inversion forces, sudden deceleration, and single-leg loading are commonly experienced by tennis players during match play; thus, integrated training combining strength training with neuromuscular training may help reduce the incidence of lateral ankle sprains and improve long-term ankle stability in competitive tennis players.

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