Review Article

Achilles Tendinopathy: Updates in Diagnosis, Therapeutic Management, and Return-to-Sport Decision-Making

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Abstract

Achilles tendinopathy is a prevalent musculoskeletal disorder that affects athletes and physically active individuals, characterized by pain, functional impairment, and reduced load tolerance of the Achilles tendon. Its development reflects the interaction between complex tendon anatomy, high mechanical loading demands, and limited vascular supply, particularly within the mid-portion of the tendon, which is especially susceptible to degeneration. Repetitive exposure to forces several times body weight during activities such as running and jumping places substantial mechanical stress on the tendon, while age-related loss of sub-tendon compliance further compromises its adaptive capacity.From a biological perspective, Achilles tendinopathy represents a failed healing response driven by cellular dysfunction, premature senescence of tendon-resident cells, and profound extracellular matrix remodeling, including collagen degradation and matrix disorganization. These processes are frequently accompanied by inflammatory activity and hypervascularization, resulting in structurally immature tissue with reduced mechanical competence. Distinct pathophysiological features differentiate mid-portion from insertional Achilles tendinopathy, with variations in tissue involvement, load distribution, and response to treatment that necessitate tailored therapeutic

strategies.Clinically, diagnosis relies primarily on symptom patterns and physical examination, supported by imaging modalities such as ultrasound and magnetic resonance imaging when necessary. However, imaging findings often show limited correlation with symptoms and functional status, underscoring the importance of patient-reported outcome measures and functional assessment. Conservative management remains the cornerstone of treatment, with progressive, load-based exercise programs forming the foundation of care. Surgical and minimally invasive interventions are reserved for refractory cases and demonstrate favorable outcomes when combined with structured postoperative rehabilitation.

Key words

Achilles tendon; tendinopathy; load management; rehabilitation; diagnostic imaging; return to sport.

Introduction

Achilles tendinopathy is recognized as one of the most common overuse injuries affecting athletes and physically active individuals, with a reported prevalence of approximately 6% in active populations. Its occurrence shows a clear age-related pattern, with higher prevalence rates observed in individuals older than 45 years, underscoring its clinical relevance not only among elite athletes but also within recreational and aging athletic populations [1]. The development and persistence of this condition are closely associated with altered biomechanical patterns, including changes in lower-limb kinematics and muscle activation, which contribute to abnormal tendon loading and may further exacerbate symptoms and functional impairment [2].

Within this framework, Achilles tendinopathy has a substantial impact on athletic performance and participation. Affected athletes frequently experience persistent pain, stiffness, and reduced functional capacity, which limit their ability to train and compete at previous levels [2]. As symptoms progress, the condition may lead to prolonged reductions in sporting activity and, in some cases, long-term modifications in sport participation. This is particularly evident in individuals undergoing surgical treatment, where a shift from high-impact to lower-impact sports has been reported despite improvements in pain and overall function [2].

In contrast, emerging evidence suggests that not all physical loading is detrimental to tendon health. Regular running performed at moderate weekly volumes, specifically between 21 and 40 km per week, has been associated with more favorable tendon structure and functional properties, indicating that controlled and appropriately dosed mechanical loading may exert a protective or adaptive effect on the Achilles tendon. This finding reinforces the concept that tendon pathology is strongly influenced by load management rather than by activity exposure alone, emphasizing the importance of individualized training and rehabilitation strategies [5].

Consistent with this perspective, conservative management remains the cornerstone of Achilles tendinopathy treatment, with exercise-based rehabilitation and physical therapy representing first-line interventions [6]. These approaches focus on restoring optimal tendon loading, promoting tissue adaptation, and improving functional capacity while minimizing symptom exacerbation. To support clinical evaluation and guide treatment decisions, new patient-reported outcome measures such as the TENDINS-AT have been developed to more accurately capture the severity of disability and functional limitation associated with the condition [3]. Surgical interventions, including tendon debridement and reconstruction, are generally reserved for cases refractory to conservative treatment and have demonstrated significant improvements in pain

and sports ability when nonoperative strategies fail [4].

The objective of this narrative review is to provide an updated and clinically oriented synthesis of Achilles tendinopathy, integrating current evidence on its epidemiology, pathophysiological mechanisms, diagnostic evaluation, and therapeutic management, with particular emphasis on rehabilitation strategies and criteria for return to sport in athletes and physically active individuals.

Methodology

This work was conceived as a narrative review focused on the contemporary understanding of Achilles tendinopathy, with particular emphasis on its clinical recognition, therapeutic management, and criteria guiding return to sport in physically active individuals and athletes. Rather than centering on rigid methodological frameworks, the manuscript was structured around clinically relevant interpretation, integrating current concepts of tendon pathology with practical decision-making in diagnosis, treatment selection, and functional progression. The discussion was oriented toward clarifying how epidemiological trends, biomechanical considerations, and symptom behavior inform individualized management strategies across different stages of the condition.

The conceptual framework of the review was informed by recent scientific literature addressing the biological, clinical, and functional aspects of Achilles tendinopathy. Peer-reviewed publications published between 2021 and 2026 in English or Spanish were selectively consulted using PubMed, Scopus, and Web of Science. Priority was given to studies that contributed meaningfully to the understanding of disease mechanisms, clinical presentation, imaging-based assessment, conservative and surgical treatment strategies, rehabilitation principles, and return-to-sport decision-making. Sources lacking peer review, presenting redundant data, or not directly relevant to clinical management were not included. Search concepts were applied flexibly to capture key themes related to achilles tendon; tendinopathy; load management; rehabilitation; diagnostic imaging; return to sport.

The information incorporated into the manuscript was interpreted through an integrative and qualitative perspective, allowing evidence to be organized according to clinical applicability and relevance to real-world practice. Particular attention was given to linking diagnostic findings with therapeutic implications, identifying areas of consensus and controversy in treatment approaches, and highlighting functional criteria relevant to safe return to sport. Artificial intelligence–based resources were used exclusively to support thematic organization and conceptual coherence during manuscript preparation. This narrative approach facilitated the presentation of a clinically oriented synthesis, emphasizing the importance of individualized, load-based management strategies in patients with Achilles tendinopathy.

Anatomy and Biomechanics of the Achilles Tendon

The Achilles tendon exhibits a complex structural organization composed of three distinct sub-tendons, each corresponding to different muscle components, a configuration that allows coordinated force transmission, movement efficiency, and fine motor control. This structural arrangement depends on compliant interfaces between the sub-tendons, which facilitate differential motion during loading. However, these interfaces tend to lose compliance with advancing age, a change that may compromise mechanical adaptability and increase susceptibility to injury [7]. In parallel, the vascular supply of the Achilles tendon is relatively limited, a characteristic that contributes to both its vulnerability to injury and its slow healing capacity. This vascular insufficiency is most pronounced in the mid-portion of the tendon, a region characterized by reduced blood flow and consistently identified as a common site of tendinopathic changes [8].

From a functional perspective, the Achilles tendon is exposed to substantial mechanical demands during sporting activities, particularly running and jumping. During running, the tendon sustains loads ranging from 4.15 to 7.71 times body weight, reflecting the high forces transmitted through the ankle plantar flexor complex [9]. Beyond force transmission, the tendon plays a critical role in locomotor efficiency by acting as an elastic spring capable of storing and releasing strain energy. During the propulsion phase of running, elastic recoil of the tendon contributes significantly to forward motion, reducing the metabolic cost of movement and enhancing performance efficiency [10]. Repeated exposure to exercise-induced mechanical loading can stimulate adaptive responses within the tendon, including increases in stiffness and cross-sectional area, changes that may improve its capacity to store and release elastic energy under load [11].

Despite these adaptive capabilities, certain regions of the Achilles tendon demonstrate increased vulnerability to injury. The mid-portion is particularly susceptible, in part due to elevated intratendinous pressures generated during commonly prescribed activities such as eccentric heel drops and calf stretching exercises. This regional susceptibility may be further exacerbated by tendon torsion, as individuals with greater degrees of torsional anatomy experience increased internal compression and localized pressure, thereby elevating the risk of tendinopathy within the mid-portion of the tendon [8]. Additionally, biomechanical alterations, including reduced plantar flexor strength and changes in lower-limb kinematics, have been associated with the development and persistence of Achilles tendinopathy, reinforcing the multifactorial nature of injury risk in this structure [2].

Pathophysiology and Classification

Achilles tendinopathy is characterized by complex pathophysiological processes involving both cellular dysfunction and extracellular matrix alterations that ultimately lead to failed tendon healing. At the cellular level, the condition is associated with misrouted differentiation pathways and premature senescence of tendon-resident cells, impairing their capacity to maintain tissue homeostasis and repair. Concurrently, the extracellular matrix undergoes profound remodeling, marked by increased collagen degradation and changes in matrix composition that compromise the hierarchical organization of the tendon and reduce its mechanical integrity. These degenerative processes are further exacerbated by inflammatory activity and hypervascularization, which contribute to the formation of immature repair tissue that lacks adequate biomechanical competence, thereby perpetuating pain, dysfunction, and structural weakness [12].

Within this pathological framework, Achilles tendinopathy can be broadly classified into mid-portion and insertional forms, each exhibiting distinct biological characteristics and clinical behavior. Mid-portion Achilles tendinopathy is predominantly associated with repetitive mechanical loading and overuse, leading to collagen denaturation, matrix disorganization, and upregulation of inflammatory gene expression within the tendon substance [13]. In contrast, insertional Achilles tendinopathy primarily affects the tendon–bone interface, where pathological changes involve both soft tissue and enthesis structures. These differences in tissue involvement and load distribution contribute to variable responses to treatment, with insertional forms often requiring modified therapeutic strategies, including specific eccentric exercise protocols and adjunctive interventions such as extracorporeal shockwave therapy [14].

The development and progression of Achilles tendinopathy are influenced by a combination of intrinsic and extrinsic risk factors that interact with the underlying biological vulnerability of the tendon. Intrinsic factors include age-related changes, sex-related differences, and genetic

predispositions that affect tendon structure, cellular behavior, and mechanical properties. Cellular heterogeneity and altered differentiation trajectories of tendon stem and progenitor cells have been implicated in the progression of tendinopathic changes [15]. Biomechanical impairments, such as reduced plantar flexor strength and altered lower-limb kinematics, further increase intrinsic susceptibility by modifying load distribution within the tendon [2].

Extrinsic factors play an equally important role, particularly in athletic populations. Repetitive overuse, inappropriate footwear, and training errors are commonly identified contributors to excessive tendon loading and insufficient recovery. Runners are especially exposed to these risks due to the cumulative effects of repetitive mechanical stress inherent to their sport [2]. Additionally, environmental conditions, including training surfaces and climatic factors, may influence tendon loading patterns and tissue adaptation, thereby modulating the risk of developing Achilles tendinopathy [16].

Clinical Presentation and Physical Examination

Achilles tendinopathy typically presents with pain localized to the Achilles tendon, most commonly reported in association with activities that impose mechanical load on the structure, such as running and jumping [17, 18]. The pain pattern is frequently activity related, emerging during or after physical exertion, and in some cases exhibiting a characteristic “warm-up” phenomenon in which symptoms diminish as activity continues [19]. In addition to pain, patients often describe morning stiffness and visible or palpable swelling around the tendon, features that contribute to discomfort and further limit functional capacity during daily and sporting activities [20].

As symptoms progress, functional impairment becomes increasingly evident, particularly in tasks that require repetitive or sustained tendon loading. Activities such as walking long distances, running, climbing stairs, or performing jumping maneuvers are commonly affected, leading to reduced physical performance and participation [18]. While these limitations are typical of tendinopathic presentations, the presence of severe pain, marked swelling, or a sudden escalation in symptom intensity should raise concern for more serious pathology, including partial or complete tendon rupture, and prompt further clinical evaluation [20].

Clinical assessment relies primarily on a combination of symptom history and targeted physical examination. Tendon palpation is routinely performed to identify localized tenderness, thickening, or swelling, while functional tests such as single-leg heel raises and hopping are used to assess load tolerance and symptom provocation. Specific clinical maneuvers, including the Royal London Hospital Test and the Painful Arc Sign, are also employed to evaluate changes in pain during tendon movement and compression, aiding in the identification of tendinopathic pain patterns [17]. In parallel, a thorough differential diagnosis is essential, as conditions such as retrocalcaneal bursitis, posterior ankle impingement syndrome, and peritendinitis may present with overlapping symptoms. Although imaging is not routinely required for diagnosis, it may be useful in excluding alternative pathologies and supporting the clinical diagnosis of Achilles tendinopathy when uncertainty persists [20, 21].

Diagnostic Imaging and Functional Assessment

Ultrasound imaging plays a central role in the diagnostic evaluation of Achilles tendinopathy, particularly as a point-of-care tool that allows rapid assessment in clinical settings. It is especially useful for identifying structural tendon changes and for distinguishing tendinopathy from other conditions that may require referral or alternative management strategies. The addition of Doppler ultrasound provides further insight by

enabling the assessment of intratendinous and peritendinous blood flow, which is frequently altered in tendinopathic tendons and may reflect ongoing pathological processes, thereby complementing structural findings observed on conventional ultrasound imaging [21].

Magnetic resonance imaging offers additional diagnostic value, particularly in the detection of subtle or early structural alterations that may not be evident on ultrasound examination. MRI is capable of identifying changes such as collagen denaturation and early-stage tendinopathy, providing a more detailed evaluation of tendon integrity and tissue composition. Advanced MRI techniques, including T2* mapping, allow for the detection of early structural changes within the tendon matrix; however, these quantitative measures do not consistently correlate with clinical symptom severity, underscoring their primary role in early detection rather than in assessing functional impairment or treatment response [22]. Beyond structural assessment, MRI can also yield detailed information regarding tendon vascularity and overall tissue characteristics, which may be valuable for monitoring the healing process over time [23].

Despite the detailed anatomical and biological information provided by imaging modalities, a clear dissociation frequently exists between imaging findings and clinical presentation. Structural abnormalities may persist on both ultrasound and MRI even after significant symptomatic improvement or functional recovery, indicating that imaging changes do not necessarily parallel pain resolution or performance restoration [24]. Similarly, quantitative MRI parameters demonstrate considerable variability among tendinopathic tendons, and this variability does not consistently align with functional performance measures, highlighting the complexity and limitations of using imaging as a predictor of clinical outcomes [25].

In contrast to imaging-based assessments, functional scales and patient-reported outcome measures play a crucial role in evaluating symptom severity and treatment effectiveness. Instruments such as the Victorian Institute of Sports Assessment–Achilles questionnaire are widely used to capture patient-perceived pain, function, and activity limitation in Achilles tendinopathy [22]. Notably, evidence indicates that preoperative imaging findings do not significantly influence postoperative patient-reported outcomes, further supporting the concept that imaging parameters alone are insufficient predictors of clinical recovery and reinforcing the importance of integrating patient-centered functional assessment into both diagnostic and follow-up strategies [26].

Conservative Therapeutic Management

Load management constitutes a fundamental component of conservative treatment for Achilles tendinopathy and is centered on regulating the intensity, frequency, and type of physical activity to reduce excessive mechanical stress on the tendon while preserving overall physical conditioning. This approach aims to optimize the balance between tendon loading and recovery, recognizing that complete rest may be detrimental to tendon health. Within this context, activity modification strategies may include adjustments in training routines, changes in footwear, or the use of orthotic devices to reduce tendon strain and improve lower-limb biomechanics, thereby contributing to symptom control and functional improvement [27].

Exercise-based rehabilitation remains the cornerstone of nonoperative management, with eccentric exercise protocols being particularly well established, especially in the treatment of mid-portion Achilles tendinopathy. Eccentric loading involves controlled lengthening of the tendon under load and has consistently been shown to reduce pain and improve functional outcomes [28]. In parallel, heavy slow resistance training has emerged as an effective alternative or complementary strategy, characterized by the

use of high loads performed at a slow tempo. This form of loading has been associated with increases in tendon stiffness and cross-sectional area, changes that are thought to enhance the mechanical capacity and overall health of the tendon [29]. Furthermore, combining eccentric and concentric exercise components may provide additional benefits by promoting more comprehensive tendon adaptation and functional recovery [30].

Adjunctive therapies and supportive measures are often integrated into conservative treatment plans to augment the effects of exercise-based interventions. Extracorporeal shock wave therapy represents a non-invasive modality that can be used in conjunction with structured exercise programs to improve pain relief and functional outcomes in selected patients [27]. Beyond specific therapeutic modalities, supportive strategies such as patient education, promotion of self-management skills, and the establishment of a strong therapeutic alliance between patients and healthcare providers play a critical role in enhancing adherence to rehabilitation protocols and improving overall treatment success [30].

Pharmacological and injection-based interventions may be considered as adjuncts in cases where symptoms persist despite optimized exercise therapy. High-volume injections combining saline and corticosteroids have demonstrated short-term benefits in reducing pain and improving function, potentially through reductions in tendon thickness and neovascularization that contribute to symptomatic relief [31]. Additionally, topical glyceryl trinitrate applied in combination with eccentric exercise programs has been explored for its potential to enhance treatment outcomes, although current evidence indicates that further research is required to clarify its clinical effectiveness and long-term role in Achilles tendinopathy management [32].

Surgical and Minimally Invasive Interventions

Operative treatment for Achilles tendinopathy is generally reserved for patients with chronic symptoms who fail to respond to an adequate course of conservative management, including structured exercise-based rehabilitation and adjunctive modalities such as extracorporeal shockwave therapy [14]. Surgical intervention is also considered in the presence of significant structural abnormalities, such as extensive tendon defects or calcaneal exostosis, which are less likely to improve with nonoperative approaches and may continue to generate mechanical irritation and pain despite optimized conservative care [33, 34].

In recent years, surgical management has increasingly shifted toward minimally invasive techniques, which aim to achieve comparable functional outcomes while reducing soft tissue disruption and complication rates. Techniques such as the Dresden and PARS/Knotless methods have demonstrated similar clinical effectiveness to traditional open procedures, with the added benefit of lower complication profiles [35]. The MidsubstanceSpeedbridge technique has also emerged as a favorable option, showing a reduced risk of complications when compared with PARS while maintaining satisfactory functional results [36]. In addition, endoscopic and fluoroscopic-assisted procedures, including calcaneal exostosis resection and Achilles tendon debridement, have been associated with good clinical outcomes, early return to sport, and a low incidence of wound-related complications [33]. Paratenon protection repair techniques further support this trend toward minimally invasive surgery, demonstrating improvements in both clinical outcomes and the mechanical properties of the Achilles tendon when compared with open repair methods [37]. Percutaneous approaches, such as the Zadek osteotomy and double-row suture anchor repairs, represent additional minimally invasive options that have been shown to reduce postoperative complications while improving clinical function [38, 39].

Overall, minimally invasive surgical techniques are associated with favorable functional outcomes, including high rates of return to sport and significant improvements in validated outcome measures such as the Achilles Tendon Total Rupture Score and the Victorian Institute of Sport Assessment–Achilles questionnaire [34, 35, 37]. Complication rates with these approaches are generally lower than those reported for open procedures, with the most commonly described issues including wound complications, sural nerve injury, and persistent heel pain. Among minimally invasive options, the MidsubstanceSpeedbridge technique has demonstrated a particularly low overall complication rate compared with PARS [36]. Regardless of the surgical technique employed, postoperative rehabilitation remains a critical determinant of outcome, requiring carefully structured protocols that emphasize gradual return to activity while closely monitoring for complications such as rerupture or delayed wound healing [37].

Rehabilitation and Return-to-Sport Criteria

Rehabilitation following Achilles tendinopathy should be structured as a criterion-based process, with progression guided by objective and functional assessment rather than by time alone. This approach emphasizes the systematic evaluation of range of motion, muscular strength, neuromuscular control, balance, agility, and power in order to ensure safe and effective functional recovery [39]. Within this framework, a phased rehabilitation model is recommended, integrating conventional stages of tissue recovery with ongoing performance testing and the gradual reintroduction of sport-specific activities. Such an approach allows rehabilitation to evolve from basic functional restoration toward higher-level athletic demands through controlled and progressive exposure [40].

As rehabilitation advances, clearly defined benchmarks related to strength, endurance, and neuromuscular control become essential for decision-making. Objective outcome measures, including isokinetic strength testing, single-limb hop assessments, and dynamic balance evaluation using tools such as the Y-balance test, provide valuable information regarding an individual's readiness to tolerate increased mechanical load and functional complexity [39]. In this context, rehabilitation programs must remain adaptable and responsive to individual athletic demands, with ongoing qualitative assessment guiding progression, as highlighted in tailored approaches described for shoulder instability management [40].

The determination of readiness for return to sport should rely on a comprehensive combination of objective performance measures and subjective clinical criteria. This integrated approach ensures that both physical capacity and symptom behavior are adequately considered before resuming sport-specific activities. Functional performance tests, such as the lateral step-down and depth jump, are commonly recommended to evaluate an athlete's ability to tolerate dynamic loading and complex movement patterns associated with sport participation [39].

Strategies aimed at reducing the risk of recurrence are a critical component of the rehabilitation and return-to-sport continuum. Evidence suggests that successful completion of a structured return-to-sport testing battery can significantly reduce the likelihood of recurrent instability or reinjury [40]. Accordingly, a thoughtful, gradual, and criterion-based progression through rehabilitation and return-to-sport phases is essential, particularly in the context of complex injuries, where premature return may compromise long-term outcomes and functional stability [41, 42].

Conclusions

Achilles tendinopathy is a multifactorial condition resulting from the interaction between complex tendon anatomy, high mechanical loading, and limited vascular supply, particularly in the mid-portion, which together increase

susceptibility to degeneration and impaired healing.

The disorder is characterized by failed tendon healing driven by cellular dysfunction and extracellular matrix remodeling, with distinct biological and clinical differences between mid-portion and insertional tendinopathy that influence treatment response and prognosis.

Optimal management relies on an integrated approach that prioritizes functional assessment and progressive load-based rehabilitation, reserves surgical intervention for refractory cases, and applies criterion-based return-to-sport strategies to reduce recurrence and restore performance.

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