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**Review article**

# Eccentric Training for Tendinopathies in Athletes: A Scoping Review and Evidence Gap Map

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## Abstract

Tendinopathies are prevalent in athletic populations, particularly in sports requiring repetitive high-load activities. Eccentric training is widely recommended for rehabilitation, yet variability in protocols and inconsistent methodological reporting limit standardization. This scoping review aimed to map existing evidence on eccentric training for tendinopathies in athletes, characterize intervention parameters, evaluate clinical outcomes and safety, and identify methodological gaps to inform future practice and research. Searches of PubMed, Scopus, and Web of Science were conducted. Eligible studies included athletes with tendinopathy undergoing eccentric training interventions. Randomized and non-randomized controlled trials were considered. Data extraction included intervention design, tendon site, loading parameters, outcomes, and adverse events. Critical appraisal was performed using RoB 2 and ROBINS-I tools. Thirty-one studies were included. Most examined patellar tendinopathy in volleyball and basketball players or Achilles tendinopathy in runners and soccer athletes. Protocols varied substantially in load, frequency, and progression strategies. Pain monitoring was integral, often allowing exercise into moderate discomfort. Eccentric training consistently improved pain and function, with heavy slow resistance and adjunct modalities showing comparable or additive effects. Return-to-sport rates were high, and adverse events were minimal. However, performance outcomes, tendon structure, and safety reporting were inconsistently assessed. Eccentric training consistently reduces pain and improves function in athletes with tendinopathy. Evidence is less consistent regarding performance outcomes, tendon remodeling, and comparative superiority over alternative interventions. Standardized reporting of protocols, safety, and sport-specific adaptations is needed to strengthen recommendations for athletic rehabilitation.

**Key words:** Tendinopathy, athletes, exercise therapy, eccentric training, rehabilitation.

## Introduction

Tendinopathies are chronic tendon disorders characterized by pain, swelling, and impaired function, typically resulting from repetitive mechanical loading (Millar et al., 2021). Unlike acute tendon injuries, these conditions involve degenerative changes in the tendon matrix, including collagen disorganization, increased ground substance, and neovascularization, rather than classic inflammatory responses (Sandrey, 2003). Tendinopathies are highly prevalent in athletic populations; they account for approximately 30 - 50% of overuse injuries in sports (Florit et al., 2019), affecting both recreational and elite athletes. The Achilles tendon, patellar tendon, rotator cuff tendons, and lateral elbow extensor tendons are most commonly involved (Maffulli et al., 2003), reflecting the repetitive high-load demands of running, jumping, throwing, and racquet sports. For example, Achilles tendinopathy is reported in 8-15% of runners (Munteanu and Barton, 2011), while patellar tendinopathy may affect up to 40% of volleyball players (Lian et al., 2003).

The pathophysiology of tendinopathy is multifactorial (Millar et al., 2021). Mechanical overload - both in magnitude and frequency - is a key trigger for degenerative changes (Magnusson et al., 2010). Central mechanisms include failed healing responses, collagen disorganization, neovascularization, and altered tendon metabolism (Fouda et al., 2017). Neuromuscular and biomechanical factors, such as muscle-tendon imbalances, decreased flexibility, and abnormal load distribution, also contribute to the development and persistence of tendon disorders (Mersmann et al., 2017). The interplay between mechanical stress and cellular response is mediated by mechanotransduction, where tendon cells convert mechanical loading into biochemical signals, promoting collagen synthesis and tendon remodeling (Stańczak, 2024).

Conservative management aims to reduce pain, restore tendon function, and prevent recurrence (Cardoso et al., 2019). Modalities include activity modification, soft tissue therapy, pharmacologic interventions, shockwave therapy, and progressive loading programs (Cardoso et al., 2019). Among these, eccentric exercise (ECC) has gained prominence due to its physiological basis and evidence of clinical efficacy (Camargo et al., 2014; O'Neill et al., 2015). Eccentric exercise involves controlled lengthening of a muscle-tendon unit under load, as opposed to concentric contractions where the muscle shortens (Couppé et al., 2015). It generates higher tendon tension with lower metabolic cost, making it particularly effective for stimulating tendon remodeling while minimizing fatigue (Camargo et al., 2014). Eccentric loading may enhance collagen synthesis, tendon matrix organization, and upregulation of growth factors like IGF-I, facilitating tendon healing (KJaer, 2004).

Protocols such as those described by Alfredson et al. (Alfredson et al., 1998) for Achilles tendinopathy have demonstrated safety and effectiveness, typically involving repeated sets of slow, controlled eccentric contractions, while load and volume are adjusted based on the athlete's pain response rather than maximal strength testing. Cur-

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win's method (Curwin and Stanish, 1984) similarly emphasizes pain-guided progression, combining concentric and eccentric movements while performing the eccentric phase at a faster rate, targeting 20 - 30 repetitions per set with 3 sets of 10 repetitions and adjusting load or speed to maintain a moderate level of discomfort consistent with functional activity. Specific tendon-targeted exercises have been described to optimize loading: for the Achilles, athletes progress from flat-ground calf raises to leaning calf raises and stair-based exercises, incorporating supine calf raises on a leg press machine to modulate load, and anterior step-downs to engage the soleus as a decelerator of tibial motion during dorsiflexion (Lorenz, 2010); for the patellar tendon, leg press, decline squats, and eccentric step-downs are employed, ensuring concentric movements are performed with both legs and the eccentric phase solely with the involved tendon (Lorenz, 2010); for lateral epicondylitis, eccentric wrist extension, eccentric radial deviation, and eccentric supination exercises are performed with passive return to the start position, with progression achieved by increasing lever arm or external load (Lorenz, 2010). Evidence suggests that these interventions are effective in reducing pain, improving function, and supporting return to sport, yet most studies emphasize clinical outcomes rather than detailed methodological reporting, including load prescription, exercise progression, and sport-specific adaptation (Habets and van Cingel, 2015; Chen and Baker, 2021).

Although eccentric exercise is widely used, no scoping review has synthesized both the clinical and methodological aspects of eccentric training interventions in athletes. Athletes have unique performance demands, and tendon loading must be carefully adjusted. Mapping existing evidence can highlight methodological gaps, such as variability in sets, repetitions, load progression, pain monitoring, and reporting of functional outcomes, ultimately guiding standardized, evidence-based protocols for athletic populations. Therefore, a scoping review is warranted to systematically map the existing literature on eccentric training for tendinopathies in athletes, describe the parameters and progression strategies of interventions, and identify gaps in methodological reporting, ultimately informing standardized, evidence-based protocols for athletes. In this way, this scoping review aims to: (i) map existing studies on eccentric training for tendinopathies in athletes; (ii) characterize intervention protocols (load, frequency, volume, progression, pain monitoring); (iii) summarize clinical outcomes and efficacy; (iv) identify harms or adverse effects; and (v) identify methodological gaps and inform recommendations for future research and practice in sports-specific populations.

## Methods

### Protocol and registration

The protocol for this scoping review was prepared following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines. A pre-defined protocol was registered on the Open Science Framework (OSF) platform on August 21, 2025. The registration can be publicly accessed at the following URL: osf.io/q4vy3.

### Eligibility criteria

The selection of studies for inclusion in the review was guided by a set of well-defined eligibility criteria based on the Population-Concept-Context (PCC) framework, a standard approach for scoping reviews. No restrictions on language or publication years were applied.

### Inclusion Criteria

Population: Studies on human participants who are diagnosed with tendinopathy and are identified as athletes (Tier 2 or more in Participants Classification Framework) (McKay et al., 2022). This includes individuals who exercise to improve performance or who participate in organized sports. The definition was broad to include different levels of athleticism based on training volume and competition level, such as competitive athletes and recreational athletes.

Concept: Studies that investigate any form of eccentric training for tendinopathy, regardless of the specific protocol (e.g., heavy slow resistance).

Context: Studies that investigate eccentric training for tendinopathies within the context of athletic training, sports rehabilitation, or recovery protocols. Considered study designs included randomized experimental and controlled studies and non-randomized experimental and controlled studies.

### Exclusion Criteria

Population: Studies on non-human subjects or on individuals who do not have a diagnosis of tendinopathy or who do not meet the definition of an athlete. This includes those classified as "exercisers" or "physically active practitioners," who primarily engage in physical activity for general health and fitness, typically with a training volume of less than 2.5 hours per week. Studies that focus on individuals with specific physical impairments classified as Paralympic athletes will also be excluded, as their classification system is distinct.

Concept: Studies that do not investigate eccentric training as an intervention for tendinopathy.

Context: Studies that do not investigate eccentric training within the context of athletic training, sports rehabilitation, or recovery protocols. Review articles, case reports, and studies without accessible full texts were excluded, as they do not offer the primary, unbiased data required for systematic analysis.

### Information sources

A search was conducted across multiple electronic databases on August 21, 2025. The databases selected for this review - PubMed, Scopus, and Web of Science - were chosen for their strong relevance to the fields of biomedicine, physical therapy, and allied health. The search covered all records available from each database's inception up to the search date. To enhance the thoroughness of the review, additional literature was located through a supplementary search on Google Scholar, aimed at capturing both peer-

reviewed and gray literature; this step was finalized on August 21, 2025. Additionally, a manual review of reference lists from all included studies and related systematic reviews was carried out to identify any further eligible articles not retrieved through database searches. This manual screening was also completed on August 21, 2025.

## Searches

The search strategy was carefully developed to ensure specificity by combining keywords with controlled vocabulary terms. Customized search strings were created for each database, taking into account the unique syntax and indexing systems of each platform. The search was organized around three main concepts: the target population (athletes), the intervention (eccentric training), and the condition (tendinopathy). This method was designed to capture all relevant studies, regardless of the specific terminology used by the authors.

A broad range of terms and their variants was included to maximize retrieval. Boolean operators (AND/OR) were employed to combine these terms logically, increasing the precision and relevance of the search results.

The finalized search strategy, along with the selected databases and specific terms used, is detailed in Table 1.

## Selection of sources of evidence

The selection of sources of evidence followed a two-stage process. The initial search results were de-duplicated and imported into a review management software (Endnote online). Two independent authors (R.T. and G.O.) then screened the titles and abstracts of all identified records against the established eligibility criteria. At this stage, studies were categorized as "include," "exclude," or "unclear." Any record flagged as "unclear" or "include" by at least one author proceeded to the next stage. In the second stage, the full texts of all selected records were retrieved and assessed for final inclusion by the same two authors. Any discrepancies between the authors' decisions were resolved through a formal consensus meeting, with a third author (K.G.) serving as an arbiter if a consensus could not be reached. This systematic, multi-stage process was designed to minimize the risk of author bias and ensure the final selection of studies was both comprehensive and objective.

## Data charting process

Following the study selection process, data were extracted from each included article using a pre-defined data charting form. This form was developed collaboratively by the author's team and was piloted on a subset of studies (n = 5) to ensure consistency and accuracy before its use. The extraction process was standardized and systematic, ensuring that data collection was consistent regardless of which author was charting the data. The variables extracted from each study included the study design, participant characteristics, type and location of tendinopathy, specifics of the intervention (e.g., protocol, duration, and frequency), outcome measures used, and key findings reported.

## Data items

In accordance with the objectives of this review, data were extracted across several domains.

Intervention-related variables included the type of eccentric exercise (e.g., decline squat, slow heavy resistance), targeted tendon, load prescription (absolute or relative, such as % of body weight or repetition maximum), frequency (sessions per week), volume (sets, repetitions), duration of intervention (weeks), and overall program length. Progression strategies were charted (e.g., weekly load increments, speed variation, range of motion adjustments, or pain-guided progression criteria). Where reported, pain monitoring strategies were recorded (e.g., allowance of up to 5/10 pain on a numerical rating scale [NRS] during exercise, visual analogue scale [VAS] criteria for progression or modification).

Efficacy outcomes were summarized, including: (i) Pain (e.g., VAS, NRS, or tendon-specific pain scores during activity or at rest); (ii) Function (e.g., Victorian Institute of Sport Assessment [VISA-A, VISA-P, VISA-H], Lower Extremity Functional Scale, Disabilities of the Arm, Shoulder and Hand [DASH]); (iii) Performance and return to sport (e.g., time to return to training or competition, sport-specific performance tests such as hop test, jump height, or strength testing); and (iv) Tendon structure and physiology (where assessed, e.g., ultrasound imaging measures of tendon thickness, Doppler activity, MRI findings, or stiffness using elastography).

Safety outcomes were extracted wherever reported, including: (i) Adverse events (e.g., exacerbation of symptoms, increase in pain beyond baseline, development of compensatory injuries); (ii) Withdrawal or discontinuation of intervention due to pain or intolerance; (iii) Incidence of serious adverse effects (e.g., tendon rupture or significant musculoskeletal injury during intervention).

Methodological and reporting variables included intervention fidelity (e.g., whether supervised or unsupervised), adherence (e.g., reported completion rates of sessions), co-interventions (e.g., adjunct therapies such as shockwave, injections, or stretching), and level of detail in reporting according to exercise intervention.

## Critical appraisal of individual sources of evidence

Although critical appraisal is not mandatory in scoping reviews, it was undertaken in this study to provide greater insight into the methodological quality of the available evidence and to contextualize the strength and limitations of reported findings. Given the diversity of study designs eligible for inclusion (randomized and non-randomized experimental and controlled studies), design-specific risk of bias tools was applied.

**Table 1. Search strategy.**

| Participants | | Intervention | | Condition |
|---|---|---|---|---|
| Athlete* OR player* OR sportspeople OR sportman OR sportwoman OR sportmen OR sportwomen OR sport* OR competitor* | AND | Eccentric* OR "resistance training" OR "strength training" OR exercise | AND | Tendinopathy OR tendinosis OR tendonitis OR epicondylosis OR epicondylitis OR "tennis elbow" |

Randomized controlled trials (RCTs) were assessed using the Cochrane Risk of Bias 2 (RoB 2) tool (Flemyng et al., 2023). This instrument evaluates risk of bias across five domains: (i) bias arising from the randomization process; (ii) bias due to deviations from intended interventions; (iii) bias due to missing outcome data; (iv) bias in measurement of the outcome; and (v) bias in selection of the reported result. Each domain is rated as low risk, some concerns, or high risk of bias, based on a structured series of signaling questions. These domain-level judgments are then synthesized into an overall risk of bias judgment for each outcome.

Non-randomized intervention studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool (Sterne et al., 2016). This instrument evaluates seven domains of bias: (i) bias due to confounding; (ii) bias in selection of participants; (iii) bias in classification of interventions; (iv) bias due to deviations from intended interventions; (v) bias due to missing data; (vi) bias in measurement of outcomes; and (vii) bias in selection of the reported result. Each domain is judged on a scale from low risk, moderate risk, serious risk, critical risk of bias, or no information. As with RoB 2, signaling questions guide the assessment, and judgments across domains are combined to provide an overall risk of bias rating for each study.

Appraisal findings were charted alongside study data to identify trends in methodological quality (e.g., inadequate reporting of progression strategies, limited monitoring of adverse effects, lack of blinding in outcome measurement) and guided the formulation of recommendations for future research.

## Synthesis of results

The charted data were synthesized using both descriptive and visual approaches to provide an overview of eccentric training interventions for tendinopathy in athletes. Study characteristics (e.g., design, population, tendon involved, and context) and intervention features (e.g., load, frequency, volume, progression, pain monitoring) were summarized using frequency counts, and narrative description. Clinical and safety outcomes were grouped into domains (pain, function, performance/return-to-sport, tendon structure/physiology, and adverse events) and summarized to highlight patterns of evidence across different study designs and athletic populations. The results of the critical appraisal were integrated descriptively to contextualize the methodological rigor of included studies and to identify recurrent areas of bias, incomplete reporting, or heterogeneity in outcome measures.

In addition to narrative and tabular synthesis, an evidence gap map was developed to visually display the distribution of evidence across key dimensions, including study design, athlete population (e.g., sport, competition level), tendon site, intervention parameters (e.g., type of eccentric exercise, progression strategy), and outcome domains (pain, function, performance, tendon structure, safety). Data visualization was employed to enhance interpretability and highlight areas of strength and paucity in the evidence base.

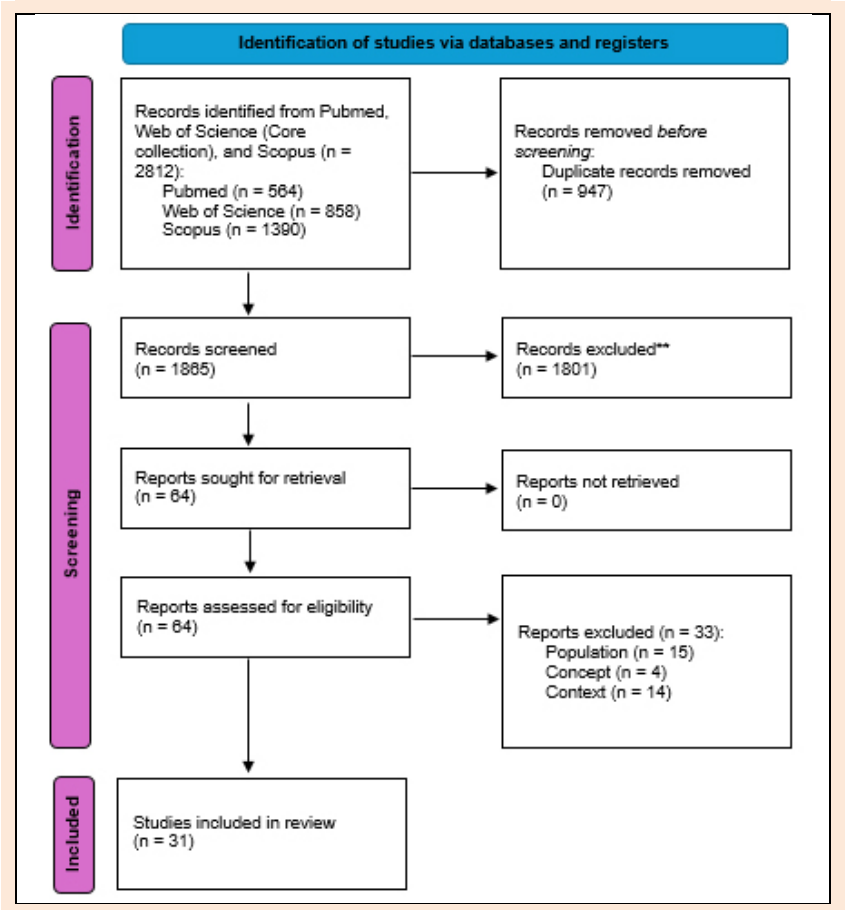


**Figure 1. PRISMA flowchart (Page et al., 2021).**

## Results

### Selection of sources of evidence

The study selection process for this systematic review followed the PRISMA flowchart (Figure 1). Initially, a total of 2812 records were identified through database searches across PubMed (n = 564), Web of Science (n = 858), and Scopus (n = 1390). After removing duplicate records (n = 947), 1865 records remained for screening.

Following the screening process, 1801 records were excluded based on title and abstract review. A total of 64 reports were sought for retrieval. All 64 reports were successfully retrieved and assessed for eligibility. Of these, 33 reports were excluded due to the following reasons: 15 based on population criteria (e.g., no tendinopathy, no athletes), 4 based on concept relevance (e.g., no eccentric training), and 14 based on context criteria (e.g., no control groups, retrospective studies). Ultimately, 31 studies were included in the final scoping review.

### Characteristics of sources of evidence

Across the included studies focusing on Pattelar tendon (Table 2), Achilles tendon (Table 3), and hamstring tendon (Table 4), the majority of trials focused on participants in their late teens to early thirties, particularly competitive athletes in jumping sports (Visnes et al., 2005; Bahr et al., 2006; Breda et al., 2021). A smaller subset of interventions recruited middle-aged recreational exercisers with chronic symptoms, often with Achilles involvement (Beyer et al., 2015; Habets et al., 2021; Demir Benli et al., 2022). In terms of sex distribution, most studies enrolled predominantly or exclusively male athletes, especially in soccer and volleyball cohorts (Visnes et al., 2005; Langberg et al., 2007; Niering and Muehlbauer, 2023), though some reported a balanced or mixed representation (Stergioulas et al., 2008; Cunha et al., 2012; Demir Benli et al., 2022).

**Table 2. Characteristics of the included studies focusing on Pattelar tendon.**

| Study | Design | Randomized | Controlled | Number of Groups | Sample Size (N per Group) | Participants | Sport Type (s) | Age Range / Mean | Sex | Tendon Involved | Outcomes Collected | Follow-up Duration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Abat et al., 2016) | Randomized Controlled Trial (RCT, parallel groups) | Yes | Yes | 2 (Electro-physiotherapy + eccentric; USGET + eccentric) | G1: 32; G2: 32 (60 completed) | Athletes with unilateral insertional patellar tendinopathy | Athletically active (not sport-specific) | 20–60 yrs (mean ~31) | G1: 24M/8F; G2: 27M/5F | Patellar tendon (inferior pole) | VISA-P, USG (thickening, hypoechoic areas, calcifications, vascularization) | 2 months (or until VISA-P ≥ 90), biweekly |
| (Bahr et al., 2006) | RCT (parallel groups + secondary surgical arm) | Yes | Yes | 2 (Eccentric training; Surgery); Secondary: Surgery after failed training | G1: 15 knees; G2: 16 knees; Secondary: 9 knees | Athletes/active adults with patellar tendinopathy (Blazina grade IIIB) | Various | ≥18 yrs (mean ~25–30) | Mixed | Patellar tendon (proximal) | VISA, VAS pain, satisfaction, 1RM leg press, CMJ | 3, 6, 12 months |
| (Biernat et al., 2014) | RCT (rehabilitation during season) | Yes | Yes | 2 (Eccentric squat + functional training; Control, volleyball only) | G1: 15; G2: 13 | Male youth volleyball players | Volleyball | 16–19 yrs (mean 17.7 E; 16.5 C) | All male | Patellar tendon (jumper's knee) | VISA-P, USG + Doppler, isokinetic strength, CMJ | 24 wks (baseline, 12, 24) |
| (Breda et al., 2021) | RCT (stratified, investigator-blinded; JUMPER trial) | Yes | Yes | 2 (PTLE; EET [control]) | G1: 38; G2: 38 (76 total) | Athletes with patellar tendinopathy | Basketball, volleyball, others | 18–35 yrs (mean: 24 ± 3.5 PTLE; 24 ± 4.2 EET) | PTLE: 82%M; EET: 71%M | Patellar tendon (inferior pole) | VISA-P (primary), return to sport, satisfaction, adherence, USG, VAS | 12 and 24 wks |

CT = Concentric Training; CON = Control group; CMJ = Countermovement Jump; DJ = Drop Jump; ESWT = Extracorporeal Shockwave Therapy; ECC = Eccentric Exercise / Eccentric Training; EET = Eccentric Exercise Therapy; ET = Eccentric Training group (sometimes "Eccentric Quadriceps Training"); HSR = Heavy Slow Resistanc; RCT = Randomized Controlled Trial; FAOS = Foot and Ankle Outcome Score; F = Female; M = Male; NRS = Numeric Rating Scale (pain); VAS = Visual Analog Scale (pain); VISA-P = Victorian Institute of Sport Assessment – Patellar; SLDS = Single Leg Decline Squat; KOOS = Knee Injury and Osteoarthritis Outcome Score; PT = Patellar Tendinopathy.

**Table 2. Continue…**

| Study | Design | Randomized | Controlled | Number of Groups | Sample Size (N per Group) | Participants | Sport Type (s) | Age Range / Mean | Sex | Tendon Involved | Outcomes Collected | Follow-up Duration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Cannell et al., 2001) | RCT | Yes | Yes | 2 (Drop squats [ecc]; Leg extension/curl [conc]) | G1: 10; G2: 9 | Athletes with jumper's knee | Basketball, soccer, running, volleyball, tennis, squash, rowing, football, gymnastics | 15–50 yrs (mean 26) | 13M/6F | Patellar tendon (inferior pole) | VAS pain, return to sport, isokinetic strength, thigh girth | 12 wks |
| (Cunha et al., 2012) | RCT (prospective) | Yes | Yes | 2 (Pain group [ecc with max pain]; No-pain group) | G1: 10; G2: 7 | Athletes with PT (US/MRI confirmed) | Track & field, basketball, capoeira, soccer, handball, combat sports, triathlon, volleyball | PG: 24.1 ± 8.3; WP: 26 ± 5.9 | 14M/3F | Patellar tendon | VISA-P, VAS | 12 wks |
| (Frohm et al., 2007) | RCT (prospective clinical trial) | Yes | Yes | 2 (Eccentric overload in Bromsman device; Standard decline squat) | G1: 11; G2: 9 | Athletes with PT (≥3 mo continuous or ≥6 mo recurrent; US/MRI confirmed) | Competitive (17), recreational (3) | G1: 26 ± 8 yrs; G2: 28 ± 8 yrs | 16M/4F | Patellar tendon | VISA-P, VAS, isokinetic strength, CMJ, one-leg triple hop | 12 wks |
| (Jonsson and Alfredson, 2005) | RCT (prospective) | Yes | Yes | 2 (Quadriceps eccentric; Quadriceps concentric) | ET: 10 tendons; CT: 9 tendons | Athletes with chronic PT (≥8 mo) | Running, soccer, basketball, handball, floorball | ET: 25.7 ± 9.9; CT: 24.1 ± 6.4 | ET: 7M/1F; CT: 6M/1F | Patellar tendon (proximal) | VAS (pain), VISA, satisfaction | 12 wks; 32.6 mo FU |
| (Kongsgaard et al., 2009) | Single-blind RCT | Yes | Yes | 3 (Corticosteroid inj.; Eccentric; HSR) | 39 (13 per group) | Recreational male athletes with PT | Running, soccer, ball sports | 32 ± 9 yrs | 67%M | Patellar tendon | VISA-P, VAS, FAOS, Microcirculation | 12 wks + 6 mo FU |
| (Knež and Hudetz, 2023) | Multicenter single-blind RCT | Yes | Yes | 2 (17° decline board; 25° decline board) | 70 total (35 per group) | Adults with chronic PT (>3 mo) | Soccer, basketball, running | 25.0 ± 6.8 (17°); 24.1 ± 7.0 (25°) | 74.3%M (17°); 65.7%M (25°) | Patellar tendon (midportion) | VAS, VISA-P, KOOS, Lysholm/Tegner | 12 wks |
| (Lee et al., 2020) | RCT | Yes | Yes | 2 (Exercise; Exercise+ESWT) | Ex: 14; Comb: 16 | Competitive athletes with PT (≥3 mo, US-confirmed) | Volleyball, basketball, handball | 21–24 yrs | Mixed | Patellar tendon | VISA-P, VAS, tendon strain/stiffness, EMG | 12 wks |
| (Niering and Muehlbauer, 2023) | Longitudinal RCT | Yes | Yes | 2 (CON; ALT) | CON: 18; ALT: 16 | Elite youth soccer players with PT | Soccer | CON: 15.1 ± 0.8; ALT: 15.4 ± 1.0 | 100%M | Patellar tendon (proximal) | VAS, DJ, JaR, CODS, Speed, Endurance, AMS | 20 wks |
| (Ruffino et al., 2021) | RCT | Yes | Yes | 2 (Inertial flywheel; HSR) | 20; 21 | Adults with PT | Volleyball, basketball, soccer, running | IF: 27.5 ± 5.4; HSR: 31.7 ± 8.7 | IF: 0F; HSR: 1F | Patellar tendon | VISA-P, PSFS, EQ-5D, US imaging, load test | 12 wks |
| (Sánchez-Gómez et al., 2022) | Double-blind RCT | Yes | Yes | 2 (HMB vs Placebo) | 4; 4 | Federated athletes with PT | Basketball, volleyball, handball, athletics | 18–49 yrs | Mixed (2M/2F per group) | Patellar tendon | VISA-P, VAS, CMJ, power, 5RM | 4 wks + 4 wks FU |

CT = Concentric Training; CON = Control group; CMJ = Countermovement Jump; DJ = Drop Jump; ESWT = Extracorporeal Shockwave Therapy; ECC = Eccentric Exercise / Eccentric Training; EET = Eccentric Exercise Therapy; ET = Eccentric Training group (sometimes "Eccentric Quadriceps Training"); HSR = Heavy Slow Resistanc; RCT = Randomized Controlled Trial; FAOS = Foot and Ankle Outcome Score; F = Female; M = Male; NRS = Numeric Rating Scale (pain); VAS = Visual Analog Scale (pain); VISA-P = Victorian Institute of Sport Assessment – Patellar; SLDS = Single Leg Decline Squat; KOOS = Knee Injury and Osteoarthritis Outcome Score; PT = Patellar Tendinopathy

**Table 2. Continue…**

| Study | Design | Randomized | Controlled | Number of Groups | Sample Size (N per Group) | Participants | Sport Type (s) | Age Range / Mean | Sex | Tendon Involved | Outcomes Collected | Follow-up Duration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Gómez et al., 2023) | Longitudinal (rehab) | No | Yes | 1 (Combined intervention: ECC + stretching + ESWT + manual therapy) | 8 (6M/2F) | Federated athletes with PT | Basketball, volleyball, handball, jumping | 18–49 yrs (mean 27.1 ± 8.3) | 6M/2F | Patellar tendon | VISA-P, VAS, CMJ, Back Squat, 5RM | 8 wks |
| (van Ark et al., 2016) | RCT | Yes | Yes | 2 (Isometric; Isotonic) | 13; 16 | Volleyball/ basketball players with PT | Volleyball, basketball | 16–32 yrs | Mixed | Patellar tendon | NRS pain (SLDS), VISA-P, global rating, adherence | 4 wks |
| (Visnes et al., 2005) | RCT (2-group repeated measures) | Yes | Yes | 2 (Eccentric; Control) | 13; 16 | Elite & 1st division volleyball players with PT | Volleyball | 19–35 yrs (mean 26.6) | Mixed (5F each group) | Patellar tendon (majority); some quadriceps | VISA, global eval, jump tests | 12 wks + 6 mo FU |
| (Young et al., 2005) | RCT (parallel, repeated measures) | Yes | Yes | 2 (Decline squat; Step squat) | 17 total | Elite volleyball players (Victorian State League) with PT | Volleyball | 27.3 ± 1.8 yrs | 13M/4F | Patellar tendon (proximal) | VISA, VAS | 12 wks; 12 mo FU |

CT = Concentric Training; CON = Control group; CMJ = Countermovement Jump; DJ = Drop Jump; ESWT = Extracorporeal Shockwave Therapy; ECC = Eccentric Exercise / Eccentric Training; EET = Eccentric Exercise Therapy; ET = Eccentric Training group (sometimes "Eccentric Quadriceps Training"); HSR = Heavy Slow Resistanc; RCT = Randomized Controlled Trial; FAOS = Foot and Ankle Outcome Score; F = Female; M = Male; NRS = Numeric Rating Scale (pain); VAS = Visual Analog Scale (pain); VISA-P = Victorian Institute of Sport Assessment – Patellar; SLDS = Single Leg Decline Squat; KOOS = Knee Injury and Osteoarthritis Outcome Score; PT = Patellar Tendinopathy

**Table 3. Characteristics of the included studies focusing on Achilles tendon.**

| Study | Design | Randomized | Controlled | Number of Groups | Sample Size (N per Group) | Participants | Sport Type (s) | Age Range / Mean | Sex | Tendon Involved | Outcomes Collected | Follow-up Duration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Alfredson et al., 1998) | Controlled Clinical Trial (surgical comparator) | No | Yes | 2 (Eccentric training; Surgery) | G1: 15; G2: 15 | Recreational athletes with chronic Achilles tendinosis | Jogging, soccer | Training: 44.3 ± 7.0 yrs; Surgery: 39.6 ± 7.9 yrs | Training: 12M/3F; Surgery: 11M/4F | Achilles tendon (mid-portion) | VAS pain, isokinetic calf strength, USG | Training: 12 wks; Surgery: 24 wks postop |
| (Demir Benli et al., 2022) | RCT (parallel groups) | Yes | Yes | 2 (Eccentric exercise; ESWT) | G1: 30; G2: 30 | Adults with chronic midportion Achilles tendinopathy | Fitness, soccer, volleyball, pilates, walking | 18–55 yrs (mean 37.3 ± 12.2) | 40F/23M | Achilles tendon (mid-portion) | VAS pain, VISA-A, USG, tendon strain | 12 wks treatment, 2 yrs follow-up |
| (Beyer et al., 2015) | RCT (parallel groups) | Yes | Yes | 2 (Eccentric exercise; HSR) | G1: 25; G2: 22 | Recreational athletes with midportion Achilles tendinopa-thy | Fitness, volleyball, badminton | 31–60 yrs (mean 48 ± 2) | ECC: 18M/7F; HSR: 14M/8F | Achilles tendon (mid-portion) | VISA-A, VAS, Doppler US, activity level | 12 wks treatment, 52 wks follow-up |

AG = Alfredson Group (isolated eccentric protocol); ALT = Alternative Training Group; AMS = Achievement Motivation Scale (psychological); AT = Achilles Tendinopathy; CMJ = Countermovement Jump; CODS = Change of Direction Speed; CON = Control group; CSA = Cross-Sectional Area; CT = Concentric Training; DJ = Drop Jump; ECC = Eccentric Exercise / Eccentric Training; EET = Eccentric Exercise Therapy; EMG = Electromyography; EQ-5D = EuroQol 5 Dimensions (Quality of Life); ESWT = Extracorporeal Shockwave Therapy; ET = Eccentric Training group (sometimes "Eccentric Quadriceps Training"); FAOS = Foot and Ankle Outcome Score; F = Female; FU = Follow-up; HMB = β-Hydroxy β-Methylbutyrate (supplement); HSR = Heavy Slow Resistance; KOOS = Knee Injury and Osteoarthritis Outcome Score; M = Male; MRI = Magnetic Resonance Imaging; NRS = Numeric Rating Scale (pain); NPRS = Numeric Pain Rating Scale; PHT = Proximal Hamstring Tendinopathy; PICP = Procollagen type I C-peptide (collagen synthesis marker); PSFS = Patient Specific Functional Scale;; PTLE = Progressive Tendon-Loading Exercise; RCT = Randomized Controlled Trial; SG = Silbernagel Group (concentric–eccentric protocol); SLDS = Single Leg Decline Squat; SWT = Shockwave Therapy; US = Ultrasound; USG = Ultrasonography; VAS = Visual Analog Scale (pain); VISA-A = Victorian Institute of Sport Assessment – Achilles; 1RM / 5RM = One / Five Repetition Maximum (strength test); YYIRL1 = Yo-Yo Intermittent Recovery Level 1 Test.

**Table 3.** **Continue…**

| Study | Design | Randomized | Controlled | Number of Groups | Sample Size (N per Group) | Participants | Sport Type (s) | Age Range / Mean | Sex | Tendon Involved | Outcomes Collected | Follow-up Duration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Habets et al., 2021) | Multicenter single-blind RCT | Yes | Yes | 2 (Alfredson eccentric; Silbernagel conc-eccentric) | AG: 18; SG: 22 | Recreational athletes with chronic midportion AT | Walking, running, ball sports | AG: 44.7 ± 9 yrs; SG: 49.9 ± 10 yrs | AG: 8F/10M; SG: 10F/12M | Achilles tendon (midportion) | VISA-A, VAS, EQ-5D, Global Perceived Effect | 12, 26, 52 wks |
| (Knobloch et al., 2007) | RCT | Yes | Yes | 3 (AirHeel+ eccentric; Eccentric only; Symptomatic eccentric) | 112 total (54, 64, 62) | Adults with unilateral AT | Running, soccer, others | 48 ± 12 yrs | 59–61%M | Achilles tendon (midportion /insertional) | VAS, FAOS | 12 wks |
| (Knobloch et al., 2008) | RCT | Yes | Yes | 2 (Eccentric+ AirHeel; Eccentric only) | 116 (57, 59) | Adults with unilateral AT | Running, soccer, others | 47–48 ± 11 yrs | 63–67%M | Achilles tendon (main body) | VAS, FAOS, Microcirculation | 12 wks |
| (Langberg et al., 2007) | RCT (prospective) | Yes | Yes | 2 (Injured vs. healthy) | 6 | Elite male soccer players with unilateral AT | Soccer | Injured: 26 ± 1; Healthy: 22 ± 1 | 100%M | Achilles tendon (main body) | VAS, collagen turnover (PICP, ICTP), microdialysis | 12 wks |
| (Malliaras et al., 2013) | RCT (4-group) | Yes | Yes | 4 (Control; Con-centric; Standard ECC; High-load ECC) | 38 total (~9–10 per group) | Healthy males, 18–35 yrs | Soccer, track & field, racquet | 26–29 yrs | All male | Achilles tendon | 5RM, torque, stiffness, modulus, CSA, stress | 12 wks |
| (Radovanović et al., 2022) | Controlled clinical trial | Yes | Yes | 3 (Passive therapy; Alfredson; High-load) | 14; 15; 15 | Males with chronic AT | Soccer, volleyball | 24 ± 8 yrs | 100%M | Achilles tendon | VISA-A, NRS pain, stiffness, Young's modu-lus, jump height | 12 wks; 6 mo FU |
| (Rompe et al., 2007) | RCT (primary care) | Yes | Yes | 3 (Eccentric; SWT; Wait-and-see) | 25 each | Adults with chronic non-insertional AT | Various | 48 ± 9 yrs | 64%F | Achilles tendon | VISA-A, NRS pain, tenderness, US size | 12 wks; 4 mo FU |
| (Rompe et al., 2009) | RCT (primary care) | Yes | Yes | 2 (ECC; ECC+SWT) | 34 each | Adults with midportion AT | Various | G1: 46.2 ± 10.2; G2: 53.1 ± 9.6 | ~59%F | Achilles tendon | VISA-A, NRS pain, tenderness, US size | 12 wks; 4 mo FU |
| (Stergioulas et al., 2008) | RCT | Yes | Yes | 2 (Laser; Placebo laser) | 13; 13 | Adults with chronic AT | Basketball, volleyball, various | Laser: 30.1 ± 4.8; Placebo: 28.8 ± 4.8 | Mixed | Achilles tendon | VAS pain, stiffness, crepita-tion, tenderness, dorsiflexion | 8 wks; 12 wks FU |

AG = Alfredson Group (isolated eccentric protocol); ALT = Alternative Training Group; AMS = Achievement Motivation Scale (psychological); AT = Achilles Tendinopathy; CMJ = Countermovement Jump; CODS = Change of Direction Speed; CON = Control group; CSA = Cross-Sectional Area; CT = Concentric Training; DJ = Drop Jump; ECC = Eccentric Exercise / Eccentric Training; EET = Eccentric Exercise Therapy; EMG = Electromyography; EQ-5D = EuroQol 5 Dimensions (Quality of Life); ESWT = Extracorporeal Shockwave Therapy; ET = Eccentric Training group (sometimes "Eccentric Quadriceps Training"); FAOS = Foot and Ankle Outcome Score; F = Female; FU = Follow-up; HMB = β-Hydroxy β-Methylbutyrate (supplement); HSR = Heavy Slow Resistance; KOOS = Knee Injury and Osteoarthritis Outcome Score; M = Male; MRI = Magnetic Resonance Imaging; NRS = Numeric Rating Scale (pain); NPRS = Numeric Pain Rating Scale; PHT = Proximal Hamstring Tendinopathy; PICP = Procollagen type I C-peptide (collagen synthesis marker); PSFS = Patient Specific Functional Scale;; PTLE = Progressive Tendon-Loading Exercise; RCT = Randomized Controlled Trial; SG = Silbernagel Group (concentric–eccentric protocol); SLDS = Single Leg Decline Squat; SWT = Shockwave Therapy; US = Ultrasound; USG = Ultrasonography; VAS = Visual Analog Scale (pain); VISA-A = Victorian Institute of Sport Assessment – Achilles; 1RM / 5RM = One / Five Repetition Maximum (strength test); YYIRL1 = Yo-Yo Intermittent Recovery Level 1 Test.

**Table 4. Characteristics of the included studies focusing on hamstring tendon.**

| Study | Design | Randomized | Controlled | Number of Groups | Sample Size (N per Group) | Participants | Sport Type (s) | Age Range / Mean | Sex | Tendon Involved | Outcomes Collected | Follow-up Duration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Verma et al., 2022) | RCT (2-arm pretest–posttest) | Yes | Yes | 2 (Experimental HPLT; Conventional PT) | 18; 18 | National-level track & field athletes with PHT | Track & field | 18–35 yrs (mean ~22.5) | Mixed | Proximal hamstring tendon | NPRS pain, Isokinetic Peak Torque | 3 wks |

HPLT = High Power Laser Therapy; PT: personal training; NPRS = Numeric Pain Rating Scale

Regarding the sports represented, the most common discipline was volleyball, featured prominently in studies on patellar tendinopathy (Young et al., 2005; Visnes et al., 2005; Biernat et al., 2014; van Ark et al., 2016; Lee et al., 2020), followed by soccer, particularly in Achilles-related trials (Langberg et al., 2007; Malliaras et al., 2013; Niering and Muehlbauer, 2023). Basketball and track & field also appeared frequently as representative jumping or running sports (Cannell et al., 2001; Cunha et al., 2012; Ruffino et al., 2021). With respect to the tendon involved, patellar tendinopathy was the most commonly studied condition in competitive athletes (Bahr et al., 2006; Breda et al., 2021; Ruffino et al., 2021), while Achilles midportion tendinopathy dominated in mixed or recreational cohorts (Alfredson et al., 1998; Rompe et al., 2007; Beyer et al., 2015; Habets et al., 2021). A few studies extended the scope to other regions such as the proximal hamstring tendon (Verma et al., 2022) or quadriceps tendon (Visnes et al., 2005).

The eccentric training protocols (Table 5) described across the studies showed considerable heterogeneity. Bodyweight decline squats performed on a 25° board were the most common exercise strategy for patellar tendinopathy (Young et al., 2005; Visnes et al., 2005; Jonsson and Alfredson, 2005; Bahr et al., 2006; Breda et al., 2021). For Achilles tendinopathy, the Alfredson heel-drop program - consisting of eccentric calf raises with the gastrocnemius and soleus (straight and bent-knee variations) - was the most widely used (Alfredson et al., 1998; Knobloch et al., 2007; 2008; Rompe et al., 2007; 2009; Habets et al., 2021). These core protocols were often modified with additional resistance (typically backpack weights with incremental loading of 5 - 10 kg) or adapted with alternative devices, such as barbell-guided squats (Frohm et al., 2007), inertial flywheels (Ruffino et al., 2021), or adjunctive modalities like AirHeel wraps (Knobloch et al., 2007; 2008). In some studies, eccentric protocols were paired with comparators such as shockwave therapy (Rompe et al., 2007, 2009; Demir Benli et al., 2022), laser therapy (Stergioulas et al., 2008), or high-load slow resistance (Beyer et al., 2015; Ruffino et al., 2021).

**Table 5. Characteristics of the eccentric training.**

| Study | Eccentric Training Protocol | Load | Frequency | Volume | Progression Strategy | Pain Monitoring | Comparator Group | Comparator Details | Adverse Events/Harms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ***Pattelar tendon*** | | | | | |
| (Abat et al., 2016) | Incline eccentric squats (25° decline), single-leg | Bodyweight only | 3×/week | 3×15 reps | Fixed (no structured progression; until VISA-P ≥ 90) | VISA-P | Yes | Group 1: Electro-physiotherapy (US, Laser $CO_2$, IFC, 3×/week × 8w); Group 2: USGET (every 2w, 3 punctures, US-guided) | None reported |
| (Bahr et al., 2006) | Decline-board eccentric squats (25°), single-leg eccentric | Bodyweight → backpack (5-kg increments) | 2×/day | 3×15 reps per session | Load adjusted to maintain pain 4–5/10 | VISA, VAS | Yes | Group 2: Open surgical debridement + postop rehab; Secondary surgery if training failed | None reported |
| (Biernat et al., 2014) | Decline-board squats (25°), added unstable surface + functional training | Bodyweight | Daily (except match/training days) | 3×15 reps (per leg) | Progression by unstable surface/ functional additions | VAS (stop if >4/10) | Yes | Control: Volleyball training only | None reported |

ADL = Activities of Daily Living; ALT = Alternative Therapy; BW = Bodyweight; CMJ = Countermovement Jump; CON = Control group; CONC = Concentric; CT = Concentric Training; ECC = Eccentric; EMG = Electromyography; ESWT = Extracorporeal Shock Wave Therapy; FAOS = Foot and Ankle Outcome Score; HMB = β-Hydroxy β-Methylbutyrate; HPLT = High-Power Laser Therapy; HSR = Heavy Slow Resistance; IFC = Interferential Current Therapy; IPT = Isokinetic Peak Torque; KOOS = Knee Injury and Osteoarthritis Outcome Score; MVC = Maximal Voluntary Contraction; NRS = Numeric Rating Scale; NPRS = Numeric Pain Rating Scale; PT = Patellar Tendinopathy; PTLE = Progressive Tendon-Loading Exercise; RM = Repetition Maximum; SG = Silbernagel Program; SLDS = Single-Leg Decline Squat; SWT = Shock Wave Therapy; US = Ultrasound; USGET = Ultrasound-Guided Galvanic Electrolysis Technique; VAS = Visual Analog Scale; VISA-A = Victorian Institute of Sport Assessment–Achilles; VISA-P = Victorian Institute of Sport Assessment–Patella; WP = Without Pain group.

**Table 5.** Continue…

| Study | Eccentric Training Protocol | Load | Frequency | Volume | Progression Strategy | Pain Monitoring | Comparator Group | Comparator Details | Adverse Events / Harms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ***Pattelar tendon*** | | | | | |
| (Breda et al., 2021) | Pain-provoking EET, single-leg decline squat (25° board) | Bodyweight → backpack weights | 2×/day | 3×15 reps | Increase load with backpack if pain ≤3/10 | Pain ≥5/10 during exercise; ≤3/10 to progress | Yes | PTLE (progressive tendon-loading: isometric → isotonic → plyometric → sport-specific) | None reported |
| (Cannell et al., 2001) | Drop squats, rapid knee unlocking | Bodyweight → hand weights (2–18 kg) | 5×/week | 3×20 reps | Gradual increase in weights; return-to-run progression | Pain expected; icing post-exercise | Yes | Leg extension/curl (concentric, progressive 4.5–32 kg, 5×/week) | None reported |
| (Cunha et al., 2012) | Decline squat (25°), single-leg eccentric | Squat bar + plates (5 kg increments) | 3×/week | 3×15 reps | PG: max tolerated pain; WP: pain-free | PG: "max pain possible"; WP: no pain | Yes | WP: same protocol without pain allowed | None reported |
| (Frohm et al., 2007) | Bromsman device (eccentric overload) | Up to 320 kg barbell (machine) | 2×/week (supervised) | ~70 min/ session | Load set by device, real-time feedback | VAS (stop if >5) | Yes | Group II: One-legged decline squat (25° board, 3×15 reps, backpack) | None |
| (Jonsson and Alfredson, 2005) | 25° decline squats, 3×15 reps, twice daily | Backpack (gradual increase) | 2×/day | 90 reps/day | Load increased if pain-free | Pain allowed, increase load when pain eased | Yes | CT: Concentric training | 4/9 tendons in CT group dropped out due to pain |
| (Kongsgaard et al., 2009) | Decline squats, 3×15 reps, 2×/day | Backpack (gradual) | 2×/day | 90 reps/day | Increase with pain decrease | VAS ≤ 3–5 | Yes | CORT: Steroid injections + eccentric | None re-ported |
| (Knež and Hu-detz, 2023) | Decline squats (17° board) | Backpack (gradual increase) | 2×/day | 90 reps/day | Increase if pain tolerated | VAS ≤ 5 | Yes | 25° decline board | No adverse events |
| (Lee et al., 2020) | Decline squats (25° board), 3×15 reps | Bodyweight → backpack (+5 kg) | 2×/day | 90 reps/day | Progress if VAS 4–5; reduce if >6–7 | VAS before/ after | Yes | ESWT + eccentric | None reported |
| (Niering and Muehlbauer, 2023) | Eccentric squats (flat and decline board) + stretching | 80% concentric–eccentric 1RM | 2–3×/week | 40–60 reps/week | Adjust load to fatigue | VAS ≤ 5 | Yes | ALT therapy (balance, isometrics) | None reported |
| (Ruffino et al., 2021) | Heavy slow resistance: squats, leg press, hack squat | 15–6 RM pro-gression | 3×/week | 4 sets/exer-cise | Gradual load increase | Pain <4/10 post-exercise | Yes | Flywheel training | Muscle soreness only |
| (Sánchez-Gómez et al., 2022) | Decline squats + HMB supplementation | HMB 3 g/day | 2×/day | 30 reps/day | Progression if VAS <4 | VAS <4 for progression | Yes | Placebo supplementation | None reported |
| (Gómez et al., 2023) | Decline squats (daily) | Weight vest (5 kg) if VAS <3 | 6×/week | 30 reps/day | Increase with vest if pain ≤3 | VAS ≤3 | No | N/A | Muscle soreness only |

ADL = Activities of Daily Living; ALT = Alternative Therapy; BW = Bodyweight; CMJ = Countermovement Jump; CON = Control group; CONC = Concentric; CT = Concentric Training; ECC = Eccentric; EMG = Electromyography; ESWT = Extracorporeal Shock Wave Therapy; FAOS = Foot and Ankle Outcome Score; HMB = β-Hydroxy β-Methylbutyrate; HPLT = High-Power Laser Therapy; HSR = Heavy Slow Resistance; IFC = Interferential Current Therapy; IPT = Isokinetic Peak Torque; KOOS = Knee Injury and Osteoarthritis Outcome Score; MVC = Maximal Voluntary Contraction; NRS = Numeric Rating Scale; NPRS = Numeric Pain Rating Scale; PT = Patellar Tendinopathy; PTLE = Progressive Tendon-Loading Exercise; RM = Repetition Maximum; SG = Silbernagel Program; SLDS = Single-Leg Decline Squat; SWT = Shock Wave Therapy; US = Ultrasound; USGET = Ultrasound-Guided Galvanic Electrolysis Technique; VAS = Visual Analog Scale; VISA-A = Victorian Institute of Sport Assessment–Achilles; VISA-P = Victorian Institute of Sport Assessment–Patella; WP = Without Pain group.

**Table 5.** Continue…

| Study | Eccentric Training Protocol | Load | Frequency | Volume | Progression Strategy | Pain Monitoring | Comparator Group | Comparator Details | Adverse Events / Harms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ***Pattelar tendon*** | | | | | |
| (van Ark et al., 2016) | Isometric vs isotonic leg extension | 80% MVC (iso), 80% 8RM (isoT) | 4×/week | 5×45s (iso); 4×8 reps (isoT) | Increase load 2.5% weekly | NRS | Yes | Isometric vs isotonic | None reported |
| (Visnes et al., 2005) | Decline squats (25° board), 3×15 reps, 2×/day | Bodyweight → backpack (+5 kg) | 2×/day | 90 reps/day | Load increase if pain ≤3–4; reduce if ≥6–7 | Target pain ≈5/10 tolerated | Yes | Control: training only | None reported |
| (Young et al., 2005) | Decline vs step squats | Bodyweight → backpack (+5 kg) | 2×/day | 90 reps/day | Decline: add load if pain eased; Step: progress speed then load | Decline: moderate pain allowed; Step: minimal pain only | Yes | Step group | None reported |
| | | | | ***Achilles Tendon*** | | | | | |
| (Alfredson et al., 1998) | Heel drops, straight knee (gastroc) & bent knee (soleus); eccentric only | Bodyweight → backpack weights → weight machine if needed | 2×/day, 7d/wk | 3×15 reps for each exercise (2 variations) | Progressive overload when pain subsided | Pain VAS during running | Yes | Surgical treatment + postop rehab (12m follow-up) | Muscle soreness only |
| (Demir Benli et al., 2022) | Alfredson protocol: 3×15 reps, 2×/day, 12w | Bodyweight → backpack weights | 2×/day | 3×15 reps | Progress load if tolerated, pain <5/10 | VAS | Yes | Group 2: ESWT (4 weekly sessions) | None reported |
| (Beyer et al., 2015) | Eccentric heel drops (straight and bent knee) | Bodyweight → backpack (1 kg every 2w) | 2×/day | 3×15 reps | Gradual increase as pain diminished | VAS (during activity) | Yes | Group 2: HSR (3×/week, heavy resistance) | One tendon rupture (ECC group) |
| (Habets et al., 2021) | Alfredson protocol (heel drops, straight + bent knee) | Bodyweight → backpack (+5 kg) | 2×/day | 180 reps/day | Load increased when pain-free | Pain allowed unless disabling | Yes | SG: Silbernagel program (concentric–eccentric progression + plyometrics) | One dropout (SG group) |
| (Knobloch et al., 2007) | Eccentric heel drops + AirHeel wrap | Backpack (5–10 kg) | 2×/day | 90 reps/day | Load increase if tolerated | VAS ≤ 5 | Yes | Eccentric only (no AirHeel) | None reported |
| (Knobloch et al., 2008) | Same as above | Backpack (5–10 kg) | 2×/day | 90 reps/day | Load increase if tolerated | VAS ≤ 5 | Yes | Eccentric only (no AirHeel) | None reported |
| (Langberg et al., 2007) | Heel drops (straight/ bent knee) | Backpack (+20% BW) | 2×/day | 90 reps/day | Increase if tolerated | VAS ≤ 3–5 | Yes | Healthy tendon comparison | None reported |

ADL = Activities of Daily Living; ALT = Alternative Therapy; BW = Bodyweight; CMJ = Countermovement Jump; CON = Control group; CONC = Concentric; CT = Concentric Training; ECC = Eccentric; EMG = Electromyography; ESWT = Extracorporeal Shock Wave Therapy; FAOS = Foot and Ankle Outcome Score; HMB = β-Hydroxy β-Methylbutyrate; HPLT = High-Power Laser Therapy; HSR = Heavy Slow Resistance; IFC = Interferential Current Therapy; IPT = Isokinetic Peak Torque; KOOS = Knee Injury and Osteoarthritis Outcome Score; MVC = Maximal Voluntary Contraction; NRS = Numeric Rating Scale; NPRS = Numeric Pain Rating Scale; PT = Patellar Tendinopathy; PTLE = Progressive Tendon-Loading Exercise; RM = Repetition Maximum; SG = Silbernagel Program; SLDS = Single-Leg Decline Squat; SWT = Shock Wave Therapy; US = Ultrasound; USGET = Ultrasound-Guided Galvanic Electrolysis Technique; VAS = Visual Analog Scale; VISA-A = Victorian Institute of Sport Assessment–Achilles; VISA-P = Victorian Institute of Sport Assessment–Patella; WP = Without Pain group.

**Table 5.** **Continue…**

| Study | Eccentric Training Protocol | Load | Frequency | Volume | Progression Strategy | Pain Monitoring | Comparator Group | Comparator Details | Adverse Events / Harms |
|---|---|---|---|---|---|---|---|---|---|
| (Malliaras et al., 2013) | Standard eccentric (80% concentric–eccentric 1RM) vs high-load eccentric (80% eccentric 1RM) | 80% 1RM | 3×/week | 45–60 reps/week | Load adjusted to fatigue | Pain monitored; stop if intolerable | Yes | Control: no exercise | None reported |
| (Radovanović et al., 2022) | Alfredson protocol vs high-load isometric plantarflexion | Alfredson: progressive load (5 kg/wk) | 2×/day | 45 reps/day (Alfredson); 4×4 reps (High-load) | Load progression if NRS <6, exertion <3 | NRS | Yes | Passive therapy (no loading) | None reported |
| (Rompe et al., 2007) | Heel drops, 3×15 reps, twice daily | Bodyweight → backpack (5 kg) | 2×/day | 45 reps/day | Load increased when pain subsided | Pain should remain mild/moderate | Yes | SWT (radial shock-wave therapy) | None reported |
| (Rompe et al., 2009) | Heel drops, 3×15 reps, twice daily | Bodyweight → 5 kg rucksack | 2×/day | 45 reps/day | Load increased when pain subsided | Pain mild/ moderate only | Yes | Eccentric + SWT | None reported |
| (Stergioulas et al., 2008) | Decline squats (progress to backpack load) | Weight vest (4 kg) | 4×/week | 144 reps/week | Progress load if VAS <50 mm | VAS <50 mm | Yes | Placebo laser | None reported |
| | | | | ***Hamstring tendon*** | | | | | |
| (Verma et al., 2022) | HPLT monotherapy | Laser (50 J/cm², 5W) | 3×/week | 6 min/session | Fixed (dose-based) | NPRS | Yes | Conventional: US + heat + Nordic hamstring eccentrics | None reported |

ADL = Activities of Daily Living; ALT = Alternative Therapy; BW = Bodyweight; CMJ = Countermovement Jump; CON = Control group; CONC = Concentric; CT = Concentric Training; ECC = Eccentric; EMG = Electromyography; ESWT = Extracorporeal Shock Wave Therapy; FAOS = Foot and Ankle Outcome Score; HMB = β-Hydroxy β-Methylbutyrate; HPLT = High-Power Laser Therapy; HSR = Heavy Slow Resistance; IFC = Interferential Current Therapy; IPT = Isokinetic Peak Torque; KOOS = Knee Injury and Osteoarthritis Outcome Score; MVC = Maximal Voluntary Contraction; NRS = Numeric Rating Scale; NPRS = Numeric Pain Rating Scale; PT = Patellar Tendinopathy; PTLE = Progressive Tendon-Loading Exercise; RM = Repetition Maximum; SG = Silbernagel Program; SLDS = Single-Leg Decline Squat; SWT = Shock Wave Therapy; US = Ultrasound; USGET = Ultrasound-Guided Galvanic Electrolysis Technique; VAS = Visual Analog Scale; VISA-A = Victorian Institute of Sport Assessment–Achilles; VISA-P = Victorian Institute of Sport Assessment–Patella; WP = Without Pain group.

Training frequency was consistently high, with the majority prescribing two daily sessions, 7 days per week following the Alfredson or decline squat model (Alfredson et al., 1998; Visnes et al., 2005; Jonsson and Alfredson, 2005; Bahr et al., 2006). Alternative approaches reduced frequency to 3 sessions per week in heavy slow resistance programs (Beyer et al., 2015; Ruffino et al., 2021) or supervised gym-based regimens (Cannell et al., 2001; van Ark et al., 2016). Training volumes typically amounted to 3 sets of 15 repetitions per exercise, leading to ~90 reps/day in most eccentric-only models, while heavy resistance protocols varied intensity through progressive loading based on percentage of 1RM (repetition maximum) or RM ranges (15RM → 6RM) (Malliaras et al., 2013; Ruffino et al., 2021). Pain monitoring was an integral feature of nearly all protocols, with eccentric programs generally allowing participants to exercise into moderate pain (VAS 4 - 5/10) as part of progression (Visnes et al., 2005; Jonsson and Alfredson, 2005; Bahr et al., 2006), whereas comparator protocols (e.g., isotonic or isometric training) emphasized pain minimization (VAS <3/10) (van Ark et al., 2016; Sánchez-Gómez et al., 2022).

## Critical appraisal within sources of evidence

Across the 29 randomized trials (Table 6), the most frequent source of bias was lack of blinding of participants and reliance on self-reported outcomes such as VISA-P/VISA-A and pain scores. In nearly all studies, interventions were obvious - e.g., eccentric decline squats (Jonsson and Alfredson, 2005; Visnes et al., 2005), heavy slow resistance (Kongsgaard et al., 2009; Beyer et al., 2015), extracorporeal shockwave therapy (Rompe et al., 2007; Rompe et al., 2009), and adjuvant modalities like low-level laser (Stergioulas et al., 2008) - making patient blinding impossible. This inevitably creates “some concerns” in the domains of deviations from intended interventions and measurement of the outcome, since participants’ expectations and therapists’ involvement may have influenced adherence and reporting in many trials (e.g., Bahr et al., 2006; Abat et al., 2016; Lee et al., 2020; Habets et al., 2021; Ruffino et al., 2021). A rare counter-example was Malliaras et al. (2013), which achieved low risk across all domains.

**Table 6.** Risk of bias in randomized controlled trials.

| Study | Randomization process | Deviations from intended interventions | Missing outcome data | Measurement of outcome | Selection of reported result | Overall RoB |
|---|---|---|---|---|---|---|
| (Abat et al., 2016) | Low risk | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Bahr et al., 2006) | Low risk | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Demir Benli et al., 2022) | Low risk | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Beyer et al., 2015) | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| (Biernat et al., 2014) | High risk | Some concerns | Low risk | Some concerns | Some concerns | High risk |
| (Breda et al., 2021) | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| (Cannell et al., 2001) | Some concerns | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Cunha et al., 2012) | Some concerns | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Frohm et al., 2007) | Some concerns | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Habets et al., 2021) | Some concerns | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| (Jonsson and Alfredson, 2005) | Some concerns | Some concerns | High risk | Some concerns | Some concerns | High risk |
| (Knež and Hudetz, 2023) | Low risk | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Knobloch et al., 2007) | Some concerns | Some concerns | High risk | Some concerns | Some concerns | High risk |
| (Knobloch et al., 2008) | Low risk | Some concerns | Some concerns | Some concerns | Some concerns | Some concerns |
| (Kongsgaard et al., 2009) | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| (Langberg et al., 2007) | High risk | Some concerns | Low risk | Some concerns | Some concerns | High risk |
| (Lee et al., 2020) | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| (Malliaras et al., 2013) | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk |
| (Niering and Muehlbauer, 2023) | Some concerns | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Radovanović et al., 2022) | Some concerns | Some concerns | Low risk | Low risk | Low risk | Some concerns |
| (Rompe et al., 2007) | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| (Rompe et al., 2009) | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| (Ruffino et al., 2021) | Some concerns | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Stergioulas et al., 2008) | Low risk | Some concerns | Some concerns | Low risk | Some concerns | Some concerns |
| (van Ark et al., 2016) | Low risk | Some concerns | Some concerns | Some concerns | Some concerns | Some concerns |
| (Verma et al., 2022) | Some concerns | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |
| (Visnes et al., 2005) | Low risk | Some concerns | Some concerns | Some concerns | Some concerns | Some concerns |
| (Young et al., 2005) | Some concerns | Some concerns | Low risk | Some concerns | Some concerns | Some concerns |

Another common issue was selective reporting and trial registration, especially in older studies. Several trials conducted before 2010, such as Visnes et al. (2005), Jonsson and Alfredson (2005), and Knobloch et al. (2007), had no preregistration and limited outcome justification, resulting in some concerns or high risk in the "selection of reported results" domain. Conversely, modern trials like Demir Benli et al. (2022) and Knež and Hudetz (2023) reported robust randomization, balanced attrition, and registration, leaving only performance/measurement bias as residual concerns.

Both non-randomized studies (Table 7) were judged to be at serious overall risk of bias. In Alfredson et al. (1998) concerns arose from reliance on unblinded self-reported outcomes, placing outcome measurement at serious risk of bias. In Gómez et al. (2023), although objective measures such as echography and performance tests were included, the small sample size, absence of blinding, and concurrent athletic participation contributed to moderate to serious concerns. Across both studies, selective reporting could not be excluded due to the absence of preregistered protocols.

## Results of individual sources of evidence

Across patellar tendinopathy studies (Table 8), eccentric loading consistently reduced pain and improved function (Jonsson and Alfredson, 2005; Knež and Hudetz, 2023), with HSR providing comparable or superior long-term outcomes (Kongsgaard et al., 2009; Ruffino et al., 2021). Adjunctive modalities such as US-guided galvanic electrolysis, ESWT, or

supplementation accelerated early symptom relief in some cases - typically within the first 4 - 6 weeks (up to 8 weeks in some protocols) - although in-season interventions often showed limited short-term functional gain, with no meaningful improvements across the 0 - 12-week competitive-season period (Abat et al., 2016; Lee et al., 2020; Sánchez-Gómez et al., 2022; Visnes et al., 2005). Most programs demonstrated high return-to-sport (RTS) rates (Cannell et al., 2001; Bahr et al., 2006), while performance improvements were variable (Biernat et al., 2014; Niering and Muehlbauer, 2023). Structural responses favored high-load resistance with reduced neovascularization and enhanced tendon quality (Kongsgaard et al., 2009), though remodeling was inconsistent in other protocols (Lee et al., 2020). Overall, exercise-based care was safe and well tolerated, with occasional discomfort and low dropout except when using concentric-only loading (Jonsson and Alfredson, 2005).

**Table 7. Risk of bias of the non-randomized controlled trials.**

| ROBINS-I Domain | (Alfredson et al., 1998) | (Gómez et al., 2023) |
|---|---|---|
| Bias due to confounding | Serious | Serious |
| Bias in selection of participants into the study | Moderate | Moderate |
| Bias in classification of interventions | Low | Low |
| Bias due to deviations from intended interventions | Moderate | Moderate |
| Bias due to missing data | Low | Low |
| Bias in measurement of outcomes | Serious | Moderate |
| Bias in selection of the reported result | Moderate | Moderate |

**Table 8. Synthesis of the main findings for Pattelar tendon.**

| Study | Pain Outcomes | Function Outcomes | Performance / RTS | Tendon Structure / Physiology | Safety / Adherence |
|---|---|---|---|---|---|
| (Abat et al., 2016) | Pain not separated from VISA-P. | VISA-P ↑ in both arms. USGET+ECC higher success (72.4% vs 36.1%, $\chi^2$=10.3, p=0.001). Subgroup Δ (VISA-P<90): MD +10.1 (95% CI 6.3–13.8, p<0.001). Subgroup Δ (≥90): MD +29.2 (95% CI 13.4–24.7, p<0.001). | RTS not directly assessed. "Healed" defined as VISA-P ≥90; 50% healed at 28–56 d with USGET (2–4 sessions). At 42 d: 58.7% healed (USGET) vs 12.5% (Electro-physio), p<0.01. | Not assessed. | No AEs; withdrawals NR. |
| (Bahr et al., 2006) | VAS0–10 during tests ↓ in both at 12m (all p<0.01); no between-group diff. | VISA-P ≈30→70 by 12m in both; no between-group diff (ANOVA p=0.87). | No jump/leg-press between-group diff; both ↑ strength to 12m. RTS distributions similar at 12m. | Not assessed. | One post-op quad pain; 25% ECC knees crossed to surgery. |
| (Biernat et al., 2014) | Pain reflected by VISA-P. | VISA-P ↑ with ECC (85→90 at 24w, p<0.05 vs control). Control ~NS. | Jump height / power: NS. RTS NR. | US: trend to fewer morph changes / neovasc in ECC. | No AEs; no dropouts. |
| (Breda et al., 2021) | Pain during tendon-specific exercise at 24w: PTLE 2 vs EET 4; diff=2 (95% CI 1–3), p=0.006. | VISA-P: BL 55 both. 24w: PTLE 84 vs EET 75 (p=0.023). MCID (≥13): 87% vs 77% (NS). | RTS: 24w 43% (PTLE) vs 27% (EET) (NS). | Imaging collected; results in supplement. | Satisfaction "excellent" higher with PTLE (38% vs 10%, p=0.009). No serious AEs. |
| (Cannell et al., 2001) | VAS0–10 ↓ both arms over 12w (p<0.01); NS between groups. | No VISA used. | RTS: 90% (drop squat) vs 67% (leg ext/curl) at 12w (NS). Strength: quads NS; hamstrings ↑ both (p<0.001). | Not assessed. | All completed ≥55/60 sessions; no AEs. |

ADL: activities of daily living; AE: adverse event; AG: Alfredson group; ALT: alternative therapy; AP: anteroposterior; ACSA: anatomical cross-sectional area; AT: Achilles tendinopathy; BL: baseline; CA: color area (Doppler neovascularity); CMJ: countermovement jump; CODS: change-of-direction speed; CON: conventional therapy; CONC: concentric exercise; CORT: corticosteroid injection; CSA: cross-sectional area; DJ: drop jump; Doppler: power/color Doppler ultrasound; ECC: eccentric exercise; EET: eccentric exercise therapy; EOT: end of treatment; ESWT: extracorporeal shock-wave therapy; FAOS: Foot and Ankle Outcome Score; FU: follow-up; GPE: global perceived effect; GRC: global rating of change; HMB: β-hydroxy β-methylbutyrate; HPLT: high-power laser therapy; HP/LP: hydroxylysyl-/lysyl-pyridinoline ratio; HSR: heavy slow resistance; ICTP: carboxy-terminal telopeptide of type-I collagen; IP: intrapatient; IPT: isokinetic peak torque; IQR: interquartile range; KOOS: Knee injury and Osteoarthritis Outcome Score; LLLT: low-level laser therapy; MD: mean difference; m/M: months; MVC: maximal voluntary contraction; MVIC: maximal voluntary isometric contraction; N/A or NR: not assessed / not reported; NRS or NPRS: numeric (pain) rating scale (0–10); NS: not significant; P-CSA: patellar tendon cross-sectional area; PFP: patellofemoral pain; PICP: procollagen type-I C-terminal propeptide; PP: peak power; PPKG: load at peak power (kg); PPMV: mean velocity at peak power; PPPP: peak power in watts; PT: patellar tendinopathy; PTLE: progressive tendon-loading exercise; PHT: proximal hamstring tendinopathy; QoL: quality of life; rHb: postcapillary venous filling pressure (relative hemoglobin); RTS: return to sport; SG: Silbernagel group; SLDS: single-leg decline squat; $StO_2$: tissue oxygen saturation; SWT: shock-wave treatment; US: ultrasound; USGET: ultrasound-guided electrolysis therapy (as named in Abat 2016); VAS0–10: visual analogue scale 0–10; VAS0–100: visual analogue scale 0–100 mm; VISA-A: Victorian Institute of Sport Assessment—Achilles; VISA-P: Victorian Institute of Sport Assessment—Patella; wk/w: week(s). Symbols — ↑: increase; ↓: decrease; →: to; ≈: approximately.

**Table 8.** **Continue…**

| Study | Pain Outcomes | Function Outcomes | Performance / RTS | Tendon Structure / Physiology | Safety / Adherence |
|---|---|---|---|---|---|
| (Cunha et al., 2012) | VAS0–10: ECC-with-pain and ECC-pain-free both ↓ at 8w/12w (p<0.05); NS between groups. | VISA-P ↑ both (p<0.05); NS between groups. | RTS NR. | Not assessed. | 17→14 completed. |
| (Frohm et al., 2007) | VAS0–10: Device 4→0 (p=0.003); Decline 5→1 (p=0.008); NS between groups. | VISA-P: Device 49→86; Decline 36→75 (both p<0.001). | One-leg triple hop ↑ both (p<0.001). RTS: majority resumed. | Not reported. | No AEs; full adherence. |
| (Jonsson and Alfredson, 2005) | VAS0–100: ECC 73→23 (p<0.005); CONC 74→68 (NS). | VISA-P: ECC 41→83 (p<0.005); CONC 41→37 (NS). | RTS: 9/10 tendons (ECC) satisfied & returned by 12w; 0/9 (CONC); all CONC later needed surgery/sclerosing. ~32m FU: ECC VAS ~18; VISA-P ~88.5. | Not assessed. | CONC had dropouts due to pain; ECC tolerated. |
| (Kongsgaard et al., 2009) | VAS0–10: all ↓ at 12w; at 6m, CORT deteriorated; ECC maintained; HSR best (lower pain vs CORT, p<0.05) | VISA-P: all ↑ at 12w; at 6m, CORT regressed; ECC stable; HSR highest (HSR > CORT; ECC > CORT, p<0.05) | Satisfaction at 6m highest in HSR (73%) | Thickness ↓ in CORT & HSR; Doppler ↓ CORT & HSR; collagen turnover ↑ only in HSR (↑HP/LP, ↓pentosidine). Mechanics unchanged. | No AEs; adherence high. |
| (Niering and Muehlbauer, 2023) | Pain-related training interruptions: ALT fewer (0.1±0.3 vs 1.3±1.3; p=0.002, d=1.16). | Physical performance improved in both; CODS improved more in ALT (left-leg interaction p=0.007). | ALT shorter program (47±16 d vs 58±25 d). | Structure not assessed. | Injury incidence lower in ALT (p=0.023, d=0.82). Attendance ALT 96% vs CON 89%. |
| (Ruffino et al., 2021) | Provocative VAS0–10 ~7→~3 at 12w both; NS between groups. | VISA-P: ↑ both; NS between groups at 6/12w. PSFS ↑ both; EQ-5D / EQ-VAS ↑ both. | CMJ, hop, strength tests improved similarly; RTS NR. | Patellar AP diameter unchanged; neovasc distributions converged by 12w; NS between groups. | Adherence high (88–90%); no AEs. |
| (Sánchez-Gómez et al., 2022) | VISA-P: NS over time (p=0.202). | — (same as pain). | CMJ ↑ (35.3→39.5 cm, p=0.031). Back squat: PPKG ↑ (55.0→73.6 kg, p=0.033); PP ↑ POST vs PRE (p=0.037, overall trend p=0.060); PPMV NS. 5-RM ↑ (60.4→75.4 kg, p=0.001). | US: thickness ↓ injured (7.74→5.69 mm, p=0.045); side-to-side diff resolved by POST. | ~5.6 sessions/wk; no AEs. |

ADL: activities of daily living; AE: adverse event; AG: Alfredson group; ALT: alternative therapy; AP: anteroposterior; ACSA: anatomical cross-sectional area; AT: Achilles tendinopathy; BL: baseline; CA: color area (Doppler neovascularity); CMJ: countermovement jump; CODS: change-of-direction speed; CON: conventional therapy; CONC: concentric exercise; CORT: corticosteroid injection; CSA: cross-sectional area; DJ: drop jump; Doppler: power/color Doppler ultrasound; ECC: eccentric exercise; EET: eccentric exercise therapy; EOT: end of treatment; ESWT: extracorporeal shock-wave therapy; FAOS: Foot and Ankle Outcome Score; FU: follow-up; GPE: global perceived effect; GRC: global rating of change; HMB: β-hydroxy β-methylbutyrate; HPLT: high-power laser therapy; HP/LP: hydroxylysyl-/lysyl-pyridinoline ratio; HSR: heavy slow resistance; ICTP: carboxy-terminal telopeptide of type-I collagen; IP: intrapatient; IPT: isokinetic peak torque; IQR: interquartile range; KOOS: Knee injury and Osteoarthritis Outcome Score; LLLT: low-level laser therapy; MD: mean difference; m/M: months; MVC: maximal voluntary contraction; MVIC: maximal voluntary isometric contraction; N/A or NR: not assessed / not reported; NRS or NPRS: numeric (pain) rating scale (0–10); NS: not significant; P-CSA: patellar tendon cross-sectional area; PFP: patellofemoral pain; PICP: procollagen type-I C-terminal propeptide; PP: peak power; PPKG: load at peak power (kg); PPMV: mean velocity at peak power; PPPP: peak power in watts; PT: patellar tendinopathy; PTLE: progressive tendon-loading exercise; PHT: proximal hamstring tendinopathy; QoL: quality of life; rHb: postcapillary venous filling pressure (relative hemoglobin); RTS: return to sport; SG: Silbernagel group; SLDS: single-leg decline squat; $StO_2$: tissue oxygen saturation; SWT: shock-wave treatment; US: ultrasound; USGET: ultrasound-guided electrolysis therapy (as named in Abat 2016); VAS0–10: visual analogue scale 0–10; VAS0–100: visual analogue scale 0–100 mm; VISA-A: Victorian Institute of Sport Assessment—Achilles; VISA-P: Victorian Institute of Sport Assessment—Patella; wk/w: week(s). Symbols — ↑: increase; ↓: decrease; →: to; ≈: approximately.

**Table 8.** **Continue…**

| Study | Pain Outcomes | Function Outcomes | Performance / RTS | Tendon Structure / Physiology | Safety / Adherence |
|---|---|---|---|---|---|
| (Gómez et al., 2023) | VISA-P / pain: NS for intervention, supplement, or interaction. | — | CMJ: significant intervention×supplement (HMB ↑ ~+3 cm, p=0.049). Back squat: PPKG ↑ overall (p=0.028). PPPP ↑ only in HMB (p=0.049). 5-RM ↑ both groups (p=0.001). PPMV NS. | Body comp: NS. | No AEs; small n=8; full adherence. |
| (van Ark et al., 2016) | NRS0–10 during SLDS: Isometric 6.3→4.0 (p=0.012); Isotonic 5.5→2.0 (p=0.003); NS between groups. | VISA-P: Isometric 66.5→75.0 (p=0.028); Isotonic 69.5→79.0 (p=0.003); NS between groups. | Athletes maintained full in-season loads; GRC +2.3 (improved). | Not assessed. | Median 3 sessions/wk (~81%); no AEs. |
| (Visnes et al., 2005) | VISA-P: no change ECC (71.1→70.2, NS) or control (76.4→75.4, NS); transient week-1 pain dip only. | Global knee function: NS between groups. | Jump tests: small within-group CMJ both-legs +1.2 cm (p=0.046); other tests NS; no RTS advantage. | Not assessed. | ECC compliance ~59% of prescription; low external load; one new PFP case; otherwise safe. |
| (Young et al., 2005) | VAS0–100: both improved at 12w & 12m (both p<0.05). At 12w step more likely ↓ pain; at 12m groups similar. | VISA-P: both improved at 12w & 12m (both p<0.05). 12m: decline squat had higher likelihood of ≥20-pt gain (94% vs 41%). | Athletes trained/competed; decline showed more durable functional benefit at 12m. | Not assessed. | Compliance ~72%; no AEs. |

ADL: activities of daily living; AE: adverse event; AG: Alfredson group; ALT: alternative therapy; AP: anteroposterior; ACSA: anatomical cross-sectional area; AT: Achilles tendinopathy; BL: baseline; CA: color area (Doppler neovascularity); CMJ: countermovement jump; CODS: change-of-direction speed; CON: conventional therapy; CONC: concentric exercise; CORT: corticosteroid injection; CSA: cross-sectional area; DJ: drop jump; Doppler: power/color Doppler ultrasound; ECC: eccentric exercise; EET: eccentric exercise therapy; EOT: end of treatment; ESWT: extracorporeal shock-wave therapy; FAOS: Foot and Ankle Outcome Score; FU: follow-up; GPE: global perceived effect; GRC: global rating of change; HMB: β-hydroxy β-methylbutyrate; HPLT: high-power laser therapy; HP/LP: hydroxylysyl-/lysyl-pyridinoline ratio; HSR: heavy slow resistance; ICTP: carboxy-terminal telopeptide of type-I collagen; IP: intrapatient; IPT: isokinetic peak torque; IQR: interquartile range; KOOS: Knee injury and Osteoarthritis Outcome Score; LLLT: low-level laser therapy; MD: mean difference; m/M: months; MVC: maximal voluntary contraction; MVIC: maximal voluntary isometric contraction; N/A or NR: not assessed / not reported; NRS or NPRS: numeric (pain) rating scale (0–10); NS: not significant; P-CSA: patellar tendon cross-sectional area; PFP: patellofemoral pain; PICP: procollagen type-I C-terminal propeptide; PP: peak power; PPKG: load at peak power (kg); PPMV: mean velocity at peak power; PPPP: peak power in watts; PT: patellar tendinopathy; PTLE: progressive tendon-loading exercise; PHT: proximal hamstring tendinopathy; QoL: quality of life; rHb: postcapillary venous filling pressure (relative hemoglobin); RTS: return to sport; SG: Silbernagel group; SLDS: single-leg decline squat; $StO_2$: tissue oxygen saturation; SWT: shock-wave treatment; US: ultrasound; USGET: ultrasound-guided electrolysis therapy (as named in Abat 2016); VAS0–10: visual analogue scale 0–10; VAS0–100: visual analogue scale 0–100 mm; VISA-A: Victorian Institute of Sport Assessment—Achilles; VISA-P: Victorian Institute of Sport Assessment—Patella; wk/w: week(s). Symbols — ↑: increase; ↓: decrease; →: to; ≈: approximately.

For Achilles tendinopathy (Table 9), eccentric approaches demonstrated consistent analgesic and functional benefits across populations (Alfredson et al., 1998; Habets et al., 2021), while HSR achieved similar or sometimes superior long-term results (Beyer et al., 2015). Adjuncts such as ESWT and laser therapy were effective when combined with exercise but showed less uniform benefits alone (Stergioulas et al., 2008; Rompe et al., 2009). Return-to-activity outcomes were strong (Alfredson et al., 1998) and comparable to surgical interventions without the associated risk profile (Bahr et al., 2006). High-load protocols led to the greatest structural and physiological adaptations, including improved collagen turnover and stiffness (Langberg et al., 2007; Radovanović et al., 2022), while bracing improved microcirculation (Knobloch et al., 2007, 2008). Across studies, interventions were safe, with transient soreness the most common adverse effect.

Evidence for proximal hamstring tendinopathy remains sparse (Table 10), but a combined protocol using high-power laser therapy with exercise demonstrated significant short-term reductions in pain and gains in strength in track-and-field athletes, with no reported complications (Verma et al., 2022). While early responses are promising, the lack of long-term and structural data limits definitive conclusions for this tendon site.

**Table 9. Synthesis of the main findings for Achilles tendon.**

| Study | Pain Outcomes | Function Outcomes | Performance / RTS | Tendon Structure / Physiology | Safety / Adherence |
|---|---|---|---|---|---|
| (Alfredson et al., 1998) | VAS0–100 during activity: ECC 81.2→4.8 at 12w (p<0.001); comparator 71.8→21.2 at 24w (p<0.01). Between-group: ECC faster/larger ↓. | No VISA. | RTS: 100% ECC back to pre-injury running at 12w. Strength deficits at BL resolved after ECC. | NR. | No AEs with ECC. |
| (Demir Benli et al., 2022) | VAS0–10: at 3m both ≈2.6; NS between groups. At 2y: ECC 1.2 (↑, p<0.001) vs ESWT 5.4 (NS) → long-term benefit only with ECC. | VISA-A: both ↑ to ≈80 at 3m (both p<0.001), NS between groups. | RTS not direct; "recovery" 81% ECC vs 77% ESWT at EOT. | US: thickness ↑ with ECC (4.7→5.2 mm, p=0.002); stiffness ↑ (strain ratio 2.1→3.1, p=0.039); ESWT NS. Neovasc: NS. | 63/63 completed; no major AEs. |
| (Beyer et al., 2015) | VAS0–10 (running, heel-rise) ↓ 0–12w, maintained 52w (both p<0.0001); NS between ECC and HSR. | VISA-A: ECC 58→84; HSR 54→89 (time p<0.0001); NS between groups. | Activity level ↑ modestly; RTS NR. | US: thickness ↓ both (p<0.001). Doppler ↓ both (time p<0.005). | Satisfaction 12w higher in HSR (100% vs 80%, =0.052); adherence: ECC 78% vs HSR 92% p<0.005). No major AEs. |
| (Habets et al., 2021) | VAS0–100 ADL: AG 28.6→5.8; SG 28.6→9.0 (both p=0.004); NS between groups. Sports: AG 44.8→13.1; SG 46.6→12.8 (both p=0.027); NS. | VISA-A: AG 60.7→89.4; SG 59.8→83.2 (both p<0.001). NS treatment effect (2.4; 95% CI −8.5 to 13.3; p=0.656). | GPE: more "improved" in SG (77% vs 50%, p=0.04). RTS NR. | NR. | Adherence high (AG 74%, SG 77%). One SG dropout after race. |
| (Knobloch et al., 2007) | VAS0–10: Wrap+ECC 5.1→3.2 (−37%, p=0.0001); ECC 5.5→3.6 (−35%, p=0.0001); NS between groups. | FAOS: both ↑; larger % gains with Wrap+ECC (all p≤0.006 vs ECC). | RTS NR; FAOS-Sport ↑ more with Wrap+ECC. | Microcirculation: Wrap+ECC $StO_2$ ↑, venous pressure ↓ more vs ECC; capillary flow patterns differed. | 81% completed; no AEs. |
| (Knobloch et al., 2008) | VAS0–10: Wrap+ECC 5.1→2.9 (−43%, p=0.0001); ECC 5.4→3.6 (−33%, p=0.0001); NS at final. | FAOS: ↑ both; no between-group diff at end. | RTS NR. | Wrap+ECC: $StO_2$ ↑ tendon & paratendon; venous pressure ↓ broadly. ECC alone: limited microvascular change. | Safe; no AEs. |
| (Langberg et al., 2007) | VAS0–100: injured 44→13 after 12w ECC (p<0.05). | — | RTS: all 6 injured elite soccer players returned. | Microdialysis: collagen synthesis ↑ (PICP 3.9→19.7 µg/L, p<0.05) in injured; no change healthy; degradation (ICTP) unchanged. | 100% adherence; no AEs. |

ADL: activities of daily living; AE: adverse event; AG: Alfredson group; ALT: alternative therapy; AP: anteroposterior; ACSA: anatomical cross-sectional area; AT: Achilles tendinopathy; BL: baseline; CA: color area (Doppler neovascularity); CMJ: countermovement jump; CODS: change-of-direction speed; CON: conventional therapy; CONC: concentric exercise; CORT: corticosteroid injection; CSA: cross-sectional area; DJ: drop jump; Doppler: power/color Doppler ultrasound; ECC: eccentric exercise; EET: eccentric exercise therapy; EOT: end of treatment; ESWT: extracorporeal shock-wave therapy; FAOS: Foot and Ankle Outcome Score; FU: follow-up; GPE: global perceived effect; GRC: global rating of change; HMB: β-hydroxy β-methylbutyrate; HPLT: high-power laser therapy; HP/LP: hydroxylysyl-/lysyl-pyridinoline ratio; HSR: heavy slow resistance; ICTP: carboxy-terminal telopeptide of type-I collagen; IP: intrapatient; IPT: isokinetic peak torque; IQR: interquartile range; KOOS: Knee injury and Osteoarthritis Outcome Score; LLLT: low-level laser therapy; MD: mean difference; m/M: months; MVC: maximal voluntary contraction; MVIC: maximal voluntary isometric contraction; N/A or NR: not assessed / not reported; NRS or NPRS: numeric (pain) rating scale (0–10); NS: not significant; P-CSA: patellar tendon cross-sectional area; PFP: patellofemoral pain; PICP: procollagen type-I C-terminal propeptide; PP: peak power; PPKG: load at peak power (kg); PPMV: mean velocity at peak power; PPPP: peak power in watts; PT: patellar tendinopathy; PTLE: progressive tendon-loading exercise; PHT: proximal hamstring tendinopathy; QoL: quality of life; rHb: postcapillary venous filling pressure (relative hemoglobin); RTS: return to sport; SG: Silbernagel group; SLDS: single-leg decline squat; $StO_2$: tissue oxygen saturation; SWT: shock-wave treatment; US: ultrasound; USGET: ultrasound-guided electrolysis therapy (as named in Abat 2016); VAS0–10: visual analogue scale 0–10; VAS0–100: visual analogue scale 0–100 mm; VISA-A: Victorian Institute of Sport Assessment—Achilles; wk/w: week(s). Symbols — ↑: increase; ↓: decrease; →: to; ≈: approximately.

**Table 9. Continue…**

| Study | Pain Outcomes | Function Outcomes | Performance / RTS | Tendon Structure / Physiology | Safety / Adherence |
|---|---|---|---|---|---|
| (Malliaras et al., 2013) | — (no symptoms) | — | Strength: 5RM ↑ all groups; greatest in High-load ECC. | Tendon: modulus/stiffness ↑ all at 50–75% MVIC; only High-load ECC ↑ at 75–100% MVIC. CSA unchanged. | Training pain ~1.3–2.0% sessions; no consequential AEs. |
| (Radovanović et al., 2022) | NRS0–10: modest ↓ all (−0.55±0.9, p<0.001); NS between groups. | VISA-A: ↑ ≈+20 pts in all (time p<0.001; no interaction). | High-load only: MVC ↑7% (p=0.045). CMJ ↓ slightly all. | High-load only: stiffness ↑20% (p=0.049), CSA ↑9% (p<0.001), max strain ↓12% (p=0.001); modulus NS. | Compliance similar (80–90%); no AEs. |
| (Rompe et al., 2007) | NRS0–10: ECC 7.0→3.6; SWT 6.8→4.0; Wait 7.9→5.9. ECC & SWT > Wait (p<0.001); ECC vs SWT NS. | VISA-A: ECC 51→76; SWT 50→70; Wait 48→55. ECC & SWT > Wait (p<0.001); ECC vs SWT NS. | Likert recovery 1–2: 60% (ECC), 52% (SWT), 24% (Wait). | Tendon diameter: no change. | Minor transient effects only; no ruptures. |
| (Rompe et al., 2009) | NRS0–10: ECC 7.0→3.9; ECC+SWT 6.8→2.4; between-group −1.5 (95% CI 0.5–2.5, p=0.0045). | VISA-A: ECC 51→73; ECC+SWT 50→87; between-group +13.5 (p=0.0016). | Likert 1–2: 56% vs 82% (p=0.001). At 12m, differences diminished due to crossovers/surgeries. | NR. | Minor transient effects; analgesic use associated with failure. |
| (Stergioulas et al., 2008) | VAS0–100 during activity: LLLT better at 4w (53.6 vs 71.5, p=0.0003), 8w (37.3 vs 62.8, p=0.0002), 12w (33.0 vs 53.0, p=0.007). | Secondary function: morning stiffness ↓, dorsiflexion ↑, palpation tenderness/crepitation ↓ more with LLLT (all p<0.05). | RTS NR; clinical recovery accelerated (LLLT 4w ≈ placebo 12w). | NR. | High adherence; 4 transient calf aches resolved; no serious AEs. |

ADL: activities of daily living; AE: adverse event; AG: Alfredson group; ALT: alternative therapy; AP: anteroposterior; ACSA: anatomical cross-sectional area; AT: Achilles tendinopathy; BL: baseline; CA: color area (Doppler neovascularity); CMJ: countermovement jump; CODS: change-of-direction speed; CON: conventional therapy; CONC: concentric exercise; CORT: corticosteroid injection; CSA: cross-sectional area; DJ: drop jump; Doppler: power/color Doppler ultrasound; ECC: eccentric exercise; EET: eccentric exercise therapy; EOT: end of treatment; ESWT: extracorporeal shock-wave therapy; FAOS: Foot and Ankle Outcome Score; FU: follow-up; GPE: global perceived effect; GRC: global rating of change; HMB: β-hydroxy β-methylbutyrate; HPLT: high-power laser therapy; HP/LP: hydroxylysyl-/lysyl-pyridinoline ratio; HSR: heavy slow resistance; ICTP: carboxy-terminal telopeptide of type-I collagen; IP: intrapatient; IPT: isokinetic peak torque; IQR: interquartile range; KOOS: Knee injury and Osteoarthritis Outcome Score; LLLT: low-level laser therapy; MD: mean difference; m/M: months; MVC: maximal voluntary contraction; MVIC: maximal voluntary isometric contraction; N/A or NR: not assessed / not reported; NRS or NPRS: numeric (pain) rating scale (0–10); NS: not significant; P-CSA: patellar tendon cross-sectional area; PFP: patellofemoral pain; PICP: procollagen type-I C-terminal propeptide; PP: peak power; PPKG: load at peak power (kg); PPMV: mean velocity at peak power; PPPP: peak power in watts; PT: patellar tendinopathy; PTLE: progressive tendon-loading exercise; PHT: proximal hamstring tendinopathy; QoL: quality of life; rHb: postcapillary venous filling pressure (relative hemoglobin); RTS: return to sport; SG: Silbernagel group; SLDS: single-leg decline squat; $StO_2$: tissue oxygen saturation; SWT: shock-wave treatment; US: ultrasound; USGET: ultrasound-guided electrolysis therapy (as named in Abat 2016); VAS0–10: visual analogue scale 0–10; VAS0–100: visual analogue scale 0–100 mm; VISA-A: Victorian Institute of Sport Assessment—Achilles; wk/w: week(s). Symbols — ↑: increase; ↓: decrease; →: to; ≈: approximately.

**Table 10. Synthesis of the main findings for hamstring tendon.**

| Study | Pain Outcomes | Function Outcomes | Performance / RTS | Tendon Structure / Physiology | Safety / Adherence |
|---|---|---|---|---|---|
| (Verma et al., 2022) | NPRS0–10: HPLT ↓61% (p≤0.001); Conventional ↓41% (p≤0.001). Between-group: HPLT better (p≤0.001). | IPT (isokinetic peak torque): HPLT ↑13% (p=0.028); Conventional +1.5% (NS); between-group NS (p=0.113). | RTS NR. | Not assessed. | No AEs; short protocol; compliance implied high. |

AE: adverse event; VAS0–10: visual analogue scale 0–10; HPLT: high-power laser therapy; IPT: isokinetic peak torque.

## Evidence Gap Map

To provide a visual overview of the research landscape, three evidence gap maps were constructed (Figure 2, Figure 3 and Figure 4). Figure 2 shows the distribution of studies by tendon site and sport type. The majority of evidence focuses on patellar tendinopathy in volleyball and basketball athletes and Achilles tendinopathy in running-related sports. Only a single study addressed proximal hamstring tendinopathy in track and field athletes (Verma et al., 2022), highlighting a clear evidence gap.

Figure 3 summarizes tendon site versus outcome domains. Pain and function are the most consistently reported outcomes across both patellar and Achilles tendinopathy. In contrast, performance/return-to-sport and tendon structural/physiological adaptations are less frequently measured. Safety and adverse events were systematically reported in fewer studies, often limited to minor soreness or calf ache, indicating under-reporting of potential harms.

Figure 4 illustrates intervention type versus outcome domains. The majority of trials investigated eccentric-only protocols, while eccentric exercise combined with adjuncts such as heavy slow resistance, shockwave therapy, laser therapy, or electrolysis have become increasingly frequent. Multimodal rehabilitation programs remain less explored but tended to include structural and performance outcomes beyond pain and function.

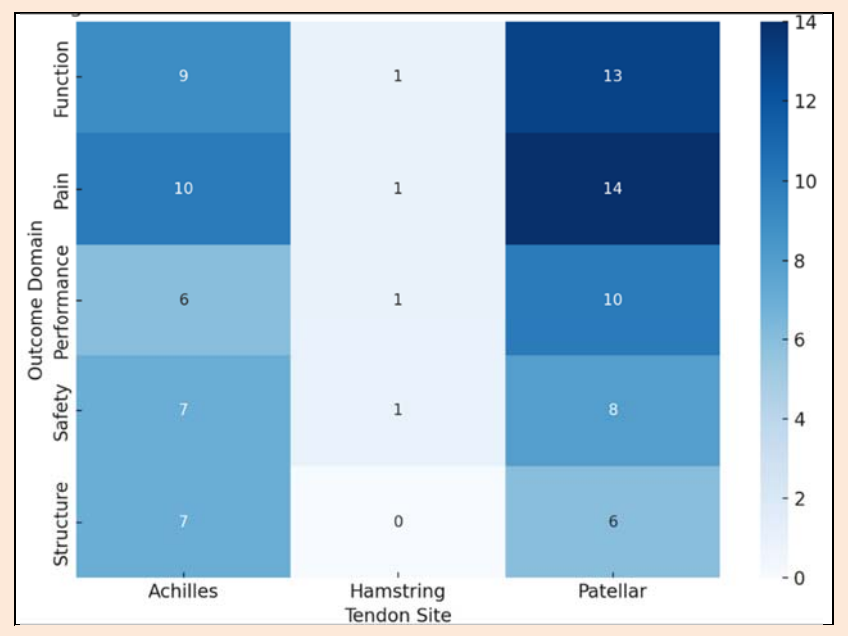


**Figure 2. Heatmap visualizing how commonly each clinical outcome domain is assessed at different tendon sites.**

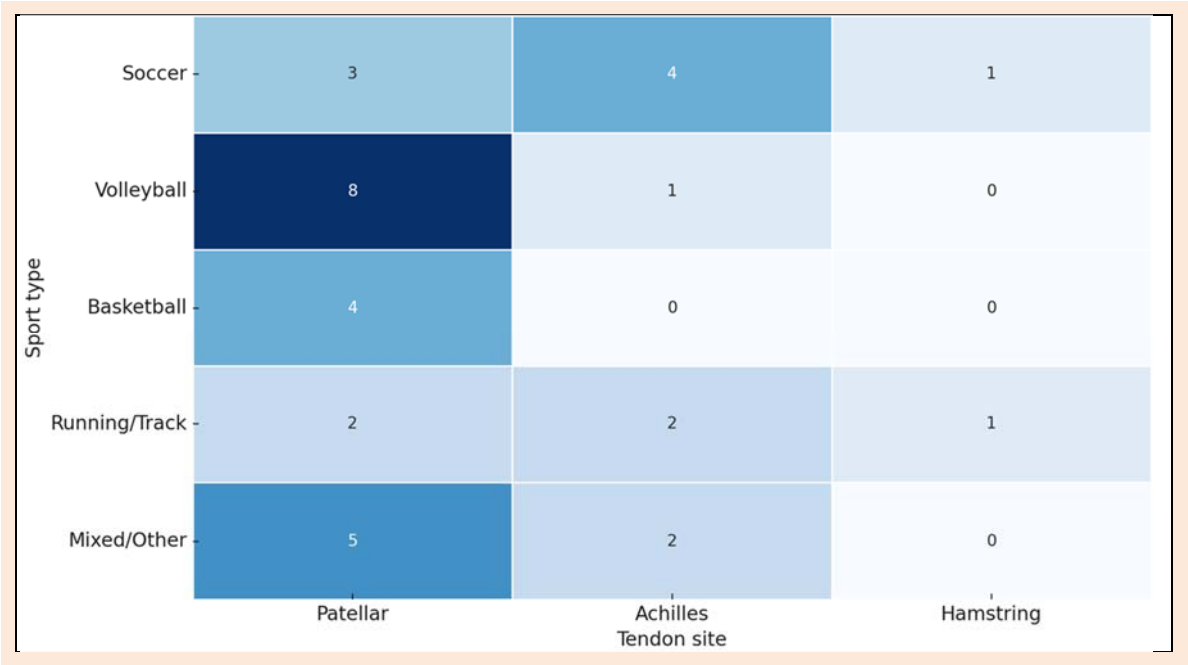


**Figure 3. Heatmap illustrating how often each tendon site is studied in athletes from various sports, with color intensity representing the number of cases.**

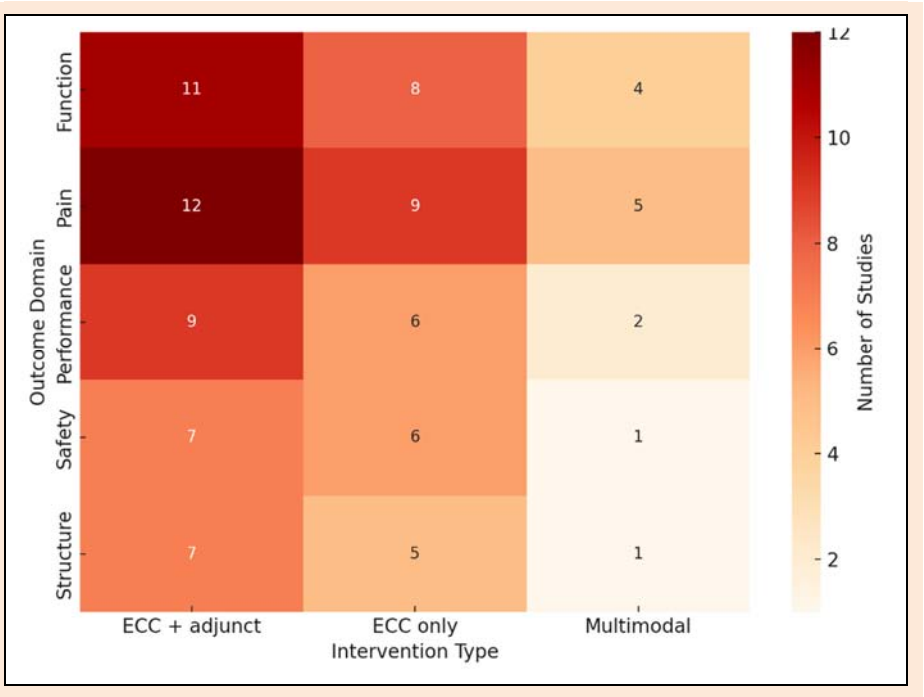


**Figure 4.** **Relationship between intervention type and measured outcome domains. ECC: eccentric training.**

## Discussion

This scoping review synthesized evidence from 31 studies investigating eccentric training (ECC) for tendinopathies in athletic populations, spanning patellar, Achilles, and proximal hamstring tendinopathies, with most interventions involving competitive or elite athletes in volleyball, basketball, soccer, and track and field. While the majority were randomized controlled trials, sample sizes were often modest and protocols varied markedly in load progression, dosing frequency, and pain monitoring strategies. Comparator interventions ranged from surgery and heavy slow resistance (HSR) to shockwave therapy (ESWT), laser, or conservative physiotherapy, highlighting a broad translational context but complicating direct synthesis. Across outcomes, ECC consistently demonstrated reductions in pain and improvements in tendon-related function, with more heterogeneous findings for return-to-sport (RTS), athletic performance, and tendon structural remodeling. Adverse effects were infrequent and mild. Nevertheless, uncertainties remain regarding long-term durability, sport-specific reintegration, and standardized safety tracking.

### Pattelar tendon

Evidence for patellar tendinopathy overwhelmingly supports eccentric loading as an effective intervention for reducing pain and improving tendon-related function in athletes, with clinically meaningful VISA-P gains reported in nearly all trials, including improvements from approximately 30 - 55 to 70 - 90 points within 12 - 24 weeks (Abat et al., 2016; Frohm et al., 2007; Breda et al., 2021; Kneˇz and Hudetz, 2023). When compared directly with alternative exercise or conventional rehabilitation, eccentric training was consistently superior or equivalent, and greatly outperformed concentric training, which showed minimal improvement and poor tolerance (Jonsson and Alfredson, 2005). Multimodal or progressive loading programs such as progressive tendon-loading exercise revealed advantages over traditional eccentric exercise in reducing pain during tendon-loading tasks and promoting improvements in load tolerance, movement quality, lower-limb strength, and the ability to perform sport-specific tasks without symptom escalation (Breda et al., 2021). Performance outcomes were less consistent: some interventions increased jump performance, change-of-direction speed, and lower-limb strength (Frohm et al., 2007; Sánchez-Gómez et al., 2022; Niering and Muehlbauer, 2023), while others showed only small or nonsignificant changes despite clear clinical gains (Biernat et al., 2014). RTS was infrequently reported but generally favorable when included, with 67 - 90% return to sport by 12 weeks in studies using structured decline protocols (Cannell et al., 2001; Jonsson and Alfredson, 2005). Structural adaptations varied: high-load and injection-comparison studies revealed reductions in tendon neovascularity and improved collagen turnover (Kongsgaard et al., 2009), while others found symptomatic relief without remodeling (Lee et al., 2020), suggesting a potential disconnect between symptom change and tissue response. Importantly, adherence influenced outcomes - low compliance in some in-season studies may explain the absence of improvement (Visnes et al., 2005). Across the body of evidence, safety was strong, with no serious adverse events and withdrawals primarily linked to poorly tolerated concentric loading. These findings endorse eccentric and progressive tendon-loading programs as an effective cornerstone rehabilitation strategy in athletic patellar tendinopathy, particularly when external load is adequately progressed and adherence is supported.

### Achilles tendon

Midportion Achilles tendinopathy research demonstrated highly consistent pain relief and VISA-A improvements with eccentric heel-drop protocols across recreational and competitive athletes, with typical improvements of 30 - 40

VISA-A points over 12 weeks (Alfredson et al., 1998; Habets et al., 2021; Rompe et al., 2007). Although ESWT and other adjuncts yielded short-term benefits when combined with exercise (Rompe et al., 2009; Stergioulas et al., 2008), ECC and HSR produced greater or more durable clinical change, with the latter showing the highest patient satisfaction and adherence (Beyer et al., 2015; Radovanović et al., 2022). Return-to-sport outcomes were favorable where reported - Alfredson et al. (1998) demonstrated 100% return to running by 12 weeks - yet most trials failed to track long-term RTS consistency or match recovery timelines to competitive calendars. Performance capacity was seldom evaluated, though selective studies noted strength or maximum voluntary contraction improvements with high-load protocols (Radovanović et al., 2022). Tendon structure and physiology responses differed by loading strategy: conventional ECC improved symptoms more than morphology, while high-load training demonstrated superior improvements in tendon stiffness, collagen turnover markers, and cross-sectional area, aligning with a mechanotransduction-driven restoration of tendon capacity (Langberg et al., 2007; Radovanović et al., 2022; Malliaras et al., 2013). Importantly, ESWT alone did not significantly alter tendon structure despite reducing symptoms (Rompe et al., 2007), underlining that structural recovery is load-dependent. Adherence remained high across studies, and adverse effects were minimal, typically limited to transient soreness. The Achilles literature therefore presents a mature evidence base supporting ECC and progressive loading strategies for pain and function, while highlighting critical ongoing gaps in performance return, season-specific rehabilitation design, and long-term tendon health monitoring.

### Hamstring tendon

The evidence for proximal hamstring tendinopathy in athletes is notably sparse, with only one included controlled trial meeting criteria. The findings suggest that an eccentric-informed protocol integrating high-power laser therapy promotes meaningful reductions in pain and improvements in hamstring strength, while the comparator program produced more modest change (Verma et al., 2022). Although these outcomes indicate that tendon loading can be beneficial for PHT, the trial did not evaluate VISA-style function metrics, jump or performance outcomes, RTS, or tendon structural adaptation, limiting interpretation. Moreover, follow-up did not extend beyond the short post-intervention phase, and sample size was small with no imaging verification of tendon change. Given the high recurrence risk and major performance implications of PHT in sprinting and change-of-direction sports, the lack of robust evidence represents a concerning gap. High-quality randomized trials including season-specific outcomes and tendon capacity measures are urgently required.

### Study limitations and practical implications

The heterogeneity of ECC prescriptions - spanning frequency, external load, progression rules, and pain-monitoring - hinders the ability to define optimal dosing for athletes. Outcome reporting prioritized pain and VISA measures, while RTS measures, tendon remodeling, and performance capacity were inconsistently collected despite their importance for athletic return and reinjury prevention. Most studies enrolled young male athletes, limiting generalization to female athletes, older competitors, or athletes in endurance or collision sports. Methodological limitations included limited blinding, short follow-up, inadequate adherence reporting, and insufficient monitoring for adverse events and reinjury. Research should prioritize long-term, sport-focused RCTs with clear RTS criteria, sex-balanced recruitment, and standardized tendon-loading parameters. Improved reporting of structural adaptation, intervention fidelity, safety, and athletic performance is needed. Comparative and multimodal studies may clarify optimal loading strategies and personalization of tendon rehabilitation in high-performance sport.

Despite the limitations, ECC remains a safe, accessible, and effective first-line treatment for patellar and Achilles tendinopathy in athletes, improving pain and function without interrupting participation for many cases. High-load resistance strategies (e.g., HSR) may enhance long-term outcomes and tendon mechanical properties. However, clinicians should supplement ECC with comprehensive RTS assessment, address sport-specific load demands, and tailor pain exposure and progression individually. Objective monitoring of performance and tendon health may help optimize rehabilitation and reduce recurrence risk. For under-studied tendon sites such as proximal hamstrings, evidence-based protocols cannot yet be standardized.

## Conclusion

This scoping review shows that most research on eccentric training in athletes has concentrated on patellar tendinopathy (particularly in volleyball and basketball players) and Achilles tendinopathy (especially in running and soccer populations), with limited attention to other tendon sites. The main outcome domains analyzed were pain reduction, functional improvement, return-to-sport rates, performance outcomes, and tendon structural or physiological adaptations. Findings consistently support pain and functional improvements, with generally favorable return-to-sport outcomes, while evidence for performance enhancement and tendon remodeling remains inconsistent. Reporting on safety outcomes was limited, though adverse events were rare. Significant methodological gaps persist, including heterogeneity in exercise prescriptions, inconsistent progression strategies, and limited long-term follow-up. There is a particular need for standardization of training regimens and parameters - such as load, frequency, volume, and pain-monitoring criteria - to improve comparability across studies. Addressing these gaps with harmonized protocols and comprehensive outcome reporting will be essential for developing evidence-based, sport-specific recommendations for athletes with tendinopathy.

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The author reports no actual or potential conflicts of interest. The datasets generated and analyzed in this study are not publicly available, but are available from the corresponding author who organized the study upon reasonable request. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was performed.

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## Key points

- Across 31 studies, eccentric training was the most frequently investigated conservative approach for athletic tendinopathies, applied across multiple tendon sites (patellar, Achilles, proximal hamstring) and sports, most often volleyball, soccer, and running.
- Evidence supports eccentric training as generally safe and effective for improving pain and function, while findings on performance, tendon structure, and return-to-sport remain inconsistent and underexplored.
- Evidence gaps include small sample sizes, limited sport-specific outcomes, scarce long-term follow-up, and insufficient safety reporting, informing priorities for future athlete-centered research.

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