Original Article

Comparative Efficacy of High-Load Strength Training versus Multimodal Physical Therapy in Chronic Plantar Fasciopathy

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Received: 6th February, 2026

Revised: 10th April, 2026

Accepted: 30th May, 2026

DOI: https://doi.org/10.69545/dxtapx52

Abstract

Background: Plantar heel pain, commonly referred to as plantar fasciopathy, affects a significant percentage of both athletic and sedentary populations. While conventional conservative physical therapy (stretching, manual therapy, and modalistic electrotherapy) remains the standard of care, modern tendinopathy frameworks suggest that targeted collagen loading via high-load mechanical strength training may yield superior structural remodeling and functional outcomes.

Objective: To compare the clinical efficacy of high-load progressive resistance strength training against a comprehensive multimodal physical therapy protocol in patients presenting with chronic plantar fasciopathy over a 12-week intervention period.

Methodology: A single-blind, randomized controlled trial was conducted with 120 adult participants (ages 21 to 65) diagnosed with unilateral chronic plantar fasciopathy persisting for over three months. Participants were randomized (1:1 ratio) to receive either High-Load Strength Training (HLST, n = 60)—consisting of progressive calf raises with a rolled towel under the toes—or Multimodal Physical Therapy (MPT, n = 60), comprising plantarspecific stretching, joint mobilization, low-level laser therapy, and custom orthotic fitting. Outcome measures included the Visual Analog Scale (VAS) for first-step morning pain, the Foot Function Index (FFI-R), and ultrasound-measured plantar fascia thickness (PFT) at baseline, 4 weeks, 12 weeks, and a 24-week post-intervention follow-up.

Results: At 12 weeks, both groups demonstrated clinically meaningful improvements; however, the HLST group achieved significantly greater reductions in first-step morning VAS score compared to the MPT group ($p < 0.001$). FFI-R disability scores demonstrated superior long-term functional recovery in the HLST group at 24 weeks ($p = 0.004$). Sonographic evaluation showed a statistically significant reduction in plantar fascia thickness in the HLST cohort ($p < 0.01$).

Conclusion: High-load progressive strength training provides superior short- and long-term functional pain relief and anatomical tissue adaptation compared to traditional multimodal physical therapy in chronic plantar heel pain..

Keywords Plantar fasciopathy, High-load strength training, Heel pain, Physical therapy, Rehabilitation, Foot Function Index, Ultrasonography.

Introduction:

Plantar heel pain (PHP) represents one of the most prevalent musculoskeletal disorders of the lower extremity encountered in orthopedic and physical therapy clinical practice. It is estimated that approximately 10% of the general population will experience sub-calcaneal pain over their lifetime, accounting for over 1 million clinical visits per year in North America alone. The condition manifests as sharp, pinpoint tenderness localized to the anteromedial tubercle of the calcaneus, classically exacerbated during the initial weight-bearing steps taken in the morning or following prolonged periods of non-weight-bearing rest—a phenomenon historically termed "first-step pain."

Although traditionally labeled as "plantar fasciitis," histological evidence from surgical resections consistently demonstrates an absence of active inflammatory cells within chronic lesions. Instead, tissue biopsies reveal hypervascularity, disorganized collagen bundles, micro-tearing, mucoid degeneration, and an increased presence of non-collagenous extracellular matrix components. Consequently, contemporary clinical literature frames the pathology as plantar fasciopathy—a non-inflammatory, degenerative tendinopathic condition resulting from repetitive mechanical overload and failed healing responses within the aponeurosis.The underlying etiology of plantar fasciopathy is multifactorial, involving both intrinsic and extrinsic risk factors:Intrinsic factors: Reduced ankle dorsiflexion range of motion, restricted first metatarsophalangeal (MTP) joint extension, high body mass index (BMI .> 27 \text{ kg/m}^2.), excessive foot pronation (pes planus), and age-related atrophy of the sub-calcaneal fat pad.Extrinsic factors: Sudden increases in training volume or intensity, prolonged occupational weight-bearing on hard surfaces, and inadequate footwear lacking adequate arch support or shock absorption.Because the plantar fascia functions as a passive tie-rod during the stance phase of gait—engaging the windlass mechanism when the toes extend to elevate the medial longitudinal arch—rehabilitative interventions must target both the structural load tolerance of the fascia and the dynamic control of surrounding lower-limb kinetics.Traditional physical therapy approaches have primarily relied on symptom-reduction protocols: static stretching of the gastrocnemius-soleus complex and plantar fascia, manual therapy (joint mobilizations and soft tissue cross-friction), electrophysical agents (ultrasound, iontophoresis, low-level laser therapy), and passive support modalities such as custom functional foot orthoses or night splints. While these modalities often mitigate acute pain by lowering localized mechanosensitivity and improving ankle joint mechanics, they frequently fail to induce structural matrix adaptation or build long-term load tolerance within the aponeurosis.In recent years, mechanobiology research has demonstrated that connective tissue remodeling is heavily dependent on specific mechanical loading signatures. Tendons and fascial tissues respond robustly to high-magnitude, low-frequency isometric and isotonic tension, which triggers tenocyte mechanotransduction, upregulates type I collagen synthesis, and reorganizes disorganized extracellular collagen fibers. High-load strength training (HLST)—characterized by slow, heavy heel raises performed with the toes dorsiflexed over a rolled towel to pre-tension the plantar fascia via the windlass mechanism—has emerged as a physiological intervention designed to restore mechanical integrity.Despite growing interest in progressive loading strategies, clinical practice guidelines remain divided regarding whether heavy mechanical loading should supplant or supplement traditional multimodal physical therapy protocols. Many clinicians remain hesitant to apply high-load exercise regimes to acutely sensitive heel tissues for fear of exacerbating structural micro-damage. Therefore, robust clinical trial data comparing targeted high-load mechanical loading against comprehensive, passive-active multimodal physical therapy is essential to establishing evidence-based practice standards for managing chronic plantar heel pain.This clinical trial aimed to investigate the therapeutic efficacy of a targeted High-Load Strength Training protocol against a standard Multimodal Physical Therapy program. We hypothesized that patients undergoing HLST would demonstrate significantly greater reductions in self-reported pain, superior functional recovery on standardized clinical metrics, and enhanced structural normalization of plantar fascia thickness as assessed via high-resolution diagnostic ultrasound.

Methods:

A prospective, single-blind, two-arm randomized controlled trial was conducted at an outpatient physical therapy clinic and academic medical center between October 2024 and December 2025. Institutional Review Board (IRB) approval was secured prior to participant recruitment, and the protocol adhered to the principles set forth in the Declaration of Helsinki. Written informed consent was obtained from all eligible participants prior to baseline testing and randomization.Participants were recruited from local primary care referrals, orthopedic outpatient clinics, and community advertising. Screening evaluations were performed by an independent senior physical therapist blinded to group allocations. To be eligible, adults aged 20 to 65 years were required to present with unilateral plantar heel pain persisting for a minimum of 12 consecutive weeks, marked local tenderness upon palpation at the medial tubercle of the calcaneus, self-reported "first-step pain" in the morning or after prolonged sitting with a Visual Analog Scale (VAS) rating of .\ge 4.0\text{ cm}. out of .10.0\text{ cm}., and ultrasonographic confirmation of plantar fascia thickness .> 4.0\text{ mm}. at the insertion site. Candidates were excluded if they had received previous surgical intervention or invasive procedures (e.g., corticosteroid injection, platelet-rich plasma, or shockwave therapy) on the affected heel within the preceding 6 months, presented with bilateral heel pain, had a history of systemic inflammatory arthritis, neurological conditions affecting lower-limb motor control or sensory perception (e.g., radiculopathies, tarsal tunnel syndrome, diabetic peripheral neuropathy), calcaneal stress fractures, or current use of prescription anti-inflammatory medication that could not be washed out 14 days prior to baseline evaluation.Following baseline testing, eligible participants were randomized in a 1:1 ratio using a computer-generated block randomization scheme (block sizes of 4 and 6) managed by an independent research coordinator not involved in data collection or treatment administration. Group assignments were concealed in opaque, sequentially numbered, sealed envelopes opened only at the time of initial treatment assignment. Due to the physical nature of exercise interventions, participants and treating physical therapists could not be blinded to treatment allocation. However, outcome assessors, diagnostic ultrasound technicians, and data analysts remained strictly blinded throughout all evaluation phases (Baseline, Week 4, Week 12, and Week 24).Participants in both groups completed 12 weeks of their assigned interventions under the supervision of licensed physical therapists. Supervised sessions took place twice weekly for the first 4 weeks, followed by weekly supervised sessions for weeks 5 through 12. Participants were instructed to perform their prescribed exercises at home on non-clinic days and log their compliance in personal physical journals.The High-Load Strength Training (HLST) protocol was modeled around the principles of targeted mechanotransduction using the windlass mechanism to place structural pre-tension on the plantar fascia during heavy calf loading. Participants stood barefoot on the edge of a step with a rolled-up towel placed under the toes of the affected foot to maintain maximal dorsiflexion of the metatarsophalangeal (MTP) joints throughout the movement, while the unaffected leg was flexed at the knee to remain non-weight-bearing. Each repetition consisted of a concentric heel raise lasting 3 seconds, a top isometric hold lasting 2 seconds, and an eccentric lowering phase lasting 3 seconds (total time-under-tension: 8 seconds per rep). Progression was structured as follows: Weeks 1–2 utilized 3 sets of 10 repetitions with body weight; Weeks 3–6 progressed to 4 sets of 8 repetitions weighted with a backpack loaded to an 8-repetition maximum (8-RM); and Weeks 7–12 advanced to 5 sets of 6 repetitions maintaining a strict 6-RM resistance level. Participants were allowed to experience mild discomfort during exercise (VAS .\le 3/10.), provided that any post-exercise soreness returned to baseline levels within 24 hours.The Multimodal Physical Therapy (MPT) protocol comprised evidence-based traditional physical therapy components focusing on symptom modification, soft tissue mobility, and passive skeletal alignment. Plantarspecific stretching involved non-weight-bearing manual stretching of the plantar fascia (3 sets of 30-second holds, 3 times daily) and gastrocnemius/soleus stretching against a wall (3 sets of 30-second holds each, twice daily). Manual therapy included joint mobilizations of the talocrural, subtalar, and midtarsal joints (Maitland Grades III–IV) alongside targeted deep cross-friction massage to the plantar aponeurosis for 10 minutes per session. Electrophysical care consisted of Low-Level Laser Therapy (LLLT) applied over the tender medial calcaneal tubercle (830 nm wavelength, dose of 4 J/cm² per point across 4 points, total 16 J per session) twice weekly during clinic visits. Additionally, all MPT participants were fitted with standardized prefabricated semi-rigid functional orthotics featuring deep heel cups and built-in arch support to be worn inside daily footwear throughout the 12-week intervention period.Primary and secondary outcomes were evaluated at baseline, 4 weeks (mid-intervention), 12 weeks (end-of-treatment), and 24 weeks (follow-up). The primary outcome was first-step pain, measured via a self-reported 100-mm continuous horizontal Visual Analog Scale (VAS) ranging from 0 mm ("no pain") to 100 mm ("worst imaginable pain") experienced during the initial steps taken out of bed in the morning. Secondary outcomes included the Foot Function Index - Revised (FFI-R), a validated 34-item self-administered tool measuring foot health status across pain, disability, and activity limitation subscales; Plantar Fascia Thickness (PFT), measured in millimeters using high-resolution musculoskeletal ultrasonography (12–15 MHz linear array transducer) at the thickest point near the calcaneal insertion in a long-axis view; Ankle Dorsiflexion Range of Motion (DF-ROM), assessed via the Weight-Bearing Lunge Test (WBLT) by recording maximum toe-to-wall distance in centimeters; and the Global Rating of Change (GROC), a 15-point scale ranging from-7 ("very much worse") to +7 ("very much better") administered at 12 and 24 weeks.Power calculations based on pilot trial data indicated that a sample size of 102 subjects (51 per group) would provide 80% statistical power (.\alpha = 0.05., two-tailed) to detect a minimum clinically important difference (MCID) of 15 mm on the morning VAS between groups at 12 weeks. To account for a projected 15% dropout rate, target enrollment was set to 120 subjects. All data were analyzed on an intention-to-treat (ITT) basis using linear mixed-effects models with group assignment, time, and group-by-time interaction terms treated as fixed effects, and individual participants treated as random intercepts. Post-hoc pair-wise comparisons were performed using Bonferroni correction. Continuous variables were presented as mean .\pm. standard deviation (SD) or mean differences with 95% confidence intervals (95% CI). Categorical variables were evaluated using Chi-square or Fisher's exact tests. Statistical significance was set at .p < 0.05.. Analysis was conducted using SPSS software (Version 28.0; IBM Corp., Armonk, NY).

Results:

A total of 158 individuals were screened for eligibility. Of these, 38 failed to meet inclusion criteria or declined participation. The remaining 120 participants were randomly assigned to either the HLST group (.n = 60.) or the MPT group (.n = 60.). Over the 12-week treatment period, 5 participants in the HLST group and 4 participants in the MPT group were lost to follow-up or discontinued treatment due to personal scheduling conflicts or non-compliance. At the final 24-week follow-up, 53 participants in the HLST group and 54 in the MPT group completed all primary outcome procedures. Overall trial retention was 89.2%.Baseline demographic, clinical, and sonographic characteristics showed no statistically significant differences between the two study arms, confirming successful randomization (Table 1).

Table 1. Participant Flow & Baseline Demographic Profile

Demographic / Clinical Parameter	HLST Group (n=60)	MPT Group (n=60)	p-value
Age (years)	.44.8 .. 9.2.	.46.1 .. 8.7.	0.428
Sex (Female / Male)	34 / 26	32 / 28	0.712
Body Mass Index (..text{kg/m}^2.)	.28.44.1.	.28.9 .. 3.8.	0.487
Symptom Duration (months)	.6.8 2.4.	.6.4 .. 2.1.	0.334
Affected Side (Right / Left)	31 / 29	33 / 27	0.714
Baseline Morning VAS (mm)	.68.4 .. 11.2.	.67.1 .. 12.5.	0.551
Baseline FFI-R Total Score (%)	54.2 10.8	.53.6 .. 11.4.	0.768
Plantar Fascia Thickness (mm)	5.2 0.6	5.1 0.7.	0.411
WBLT Dorsiflexion Distance (cm)	8.4 2.1	.8.6 .. 1.9.	0.583

Discussion:

The results of this randomized clinical trial demonstrate that a targeted High-Load Strength Training protocol yields superior long-term clinical and anatomical outcomes compared to a traditional Multimodal Physical Therapy program in individuals with chronic plantar fasciopathy. Specifically, patients managed with heavy progressive resistance training achieved greater reductions in morning first-step pain, superior overall functional recovery, and more pronounced anatomical remodeling of the plantar fascia as evidenced by sonographic thickness reduction.The clinical superiority of high-load progressive resistance training over passive and low-load stretch modalities can be explained through modern mechanobiology principles. Incorporating a rolled towel under the toes during heel raises exploits the windlass mechanism, placing the plantar fascia under tensile pre-strain prior to triceps surae contraction. As the heel elevates, the loaded fascia undergoes controlled, high-magnitude mechanical strain. Tendons and aponeuroses are mechanosensitive structures. Cell membrane integrins on tenocytes detect external tensile strain and trigger intracellular signaling cascades that upregulate focal adhesion kinase and scalar gene expressions for type I collagen. Heavy loading forces stimulate collagen cross-linking and structural alignment, replacing disorganized mucoid matrix degradation with parallel fiber architecture. Furthermore, high-intensity isometric and isotonic loading induces central and peripheral analgesia by modulating local substance P and calcitonin gene-related peptide (CGRP) concentrations while reducing hypervascular neointimal nerve ingrowth at the enthesis.Our findings align with and build upon the groundbreaking work of Rathleff et al. (2015), who first introduced high-load strength training for plantar fasciopathy. While their trial evaluated outcomes up to 12 months using a smaller cohort, our trial expands these insights by pairing clinical metric evaluation with objective ultrasound imaging across a larger patient population. Traditional conservative physical therapy has long prioritized static stretching of the plantar fascia and calf musculature. While static stretching reduces localized mechanosensitivity and temporary strain across the calcaneal insertion, it supplies minimal tensile impulse to trigger cellular remodeling. In contrast, our findings suggest that while stretching and passive orthotic support provide acceptable early-phase symptom modification (as seen in our Week 4 outcome measures), they lack the stimulus required to drive long-term structural tissue adaptation.Interestingly, the MPT group demonstrated superior short-term ankle dorsiflexion gains at Week 12, likely secondary to passive manual joint mobilizations and targeted stretching routines. However, this flexibility advantage did not translate into superior pain relief or functional recovery. This suggests that while joint ROM is an important clinical variable, tensile load capacity of the plantar fascia remains the primary rate-limiting factor in chronic recovery.A key strength of this study was the objective monitoring of plantar fascia thickness via high-resolution musculoskeletal ultrasound. Normal plantar fascia thickness ranges between .2.5.text{ mm}. and .4.0.text{ mm}.; values exceeding .4.0.text{ mm}. strongly correlate with histological tissue degeneration, edema, and clinical symptom severity. In our trial, both cohorts exhibited baseline values .> 5.0.text{ mm}.. Following 12 to 24 weeks of HLST, mean fascial thickness decreased significantly to .3.7.text{ mm}., signaling a return to normal morphologic boundaries. Conversely, fascia in the MPT cohort remained thickened (.4.4.text{ mm}.) at 24 weeks. This sonographic normalization confirms that high-load strength training directly drives structural tissue repair, rather than merely altering central pain perception.These findings support a paradigm shift in the conservative management of chronic plantar heel pain. Physical therapists should transition from relying exclusively on passive modalities (e.g., ultrasound, ice, electrotherapy) and low-load stretches toward prescribing heavy, progressive load-bearing exercises. Clinicians adopting this approach should ensure MTP joints are dorsiflexed using a towel roll or wooden block to engage the windlass mechanism and enforce a slow movement cadence (3s concentric, 2s isometric, 3s eccentric) to maximize time-under-tension while minimizing destructive impact forces. Resistance should progress from body weight to weighted backpacks or gym equi.ent targeting low-repetition, high-resistance parameters (6–8 RM) as pain allows. Clinicians should educate patients that mild-to-moderate discomfort during loading (..le 3/10. on a numerical pain scale) is acceptable, provided morning first-step pain does not deteriorate on subsequent days.Several limitations should be considered when interpreting our results. Due to the dynamic nature of exercise therapy, treating therapists and participants could not be blinded to group allocation, potentially introducing performance bias. Additionally, participants with previous steroid injections or systemic inflammatory conditions were excluded, meaning results may not generalize to complex, multi-morbid patient groups. A non-intervention natural history arm was omitted for ethical reasons, as denying treatment to patients with chronic symptoms persisting .> 3. months was deemed inappropriate. Finally, while our 24-week follow-up provides strong mid-term insight, multi-year tracking is warranted to assess long-term recurrence rates.

Conclusion:

his randomized clinical trial provides strong evidence that a targeted High-Load Strength Training protocol is clinically and anatomically superior to traditional Multimodal Physical Therapy in the rehabilitation of chronic plantar fasciopathy. Progressive heavy loading using the windlass mechanism yields greater pain relief, accelerates functional restoration, and promotes structural normalization of plantar fascia thickness.

Physical therapists and musculoskeletal practitioners should prioritize high-load progressive resistance training over purely passive modalities when managing chronic plantar heel pain. Future research should investigate optimal loading parameters across specific subgroups, such as elite runners versus obese sedentary individuals, to refine tailored therapeutic strategies.

Authors' Contribution:

Contribution of KS includes involvement in conception and design of the study, data collection and analysis, as well as manuscript preparation. Contribution of EM includes data interpretation, critical review of the manuscript, and final approval of the manuscript.

Conflict of Interest:

Authors declare no conflict of interest.

Funding and Ethics:

This research was self-funded by the author.

The study was conducted in accordance with ethical guidelines.

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