

EFFECTS OF TENDON NEUROPLASTIC TRAINING VERSUS SLOW REVERSAL HOLD ON PAIN, FUNCTION, AND REARFOOT EVERSION DURING GAIT IN INDIVIDUALS WITH ACHILLES TENDINOPATHY

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Abstract

Background: Achilles tendinopathy is a prevalent overuse disorder characterized by persistent tendon pain, impaired functional capacity, and biomechanical alterations that may affect lower-limb movement during gait. Although several rehabilitation approaches have demonstrated clinical benefits, comparative evidence regarding Tendon Neuroplastic Training and Slow Reversal Hold remains limited.

Objective: This study aimed to compare the effectiveness of Tendon Neuroplastic Training and Slow Reversal Hold in reducing pain, improving functional capacity, and correcting rearfoot eversion during gait in individuals with Achilles tendinopathy.

Methods: A randomized clinical trial was conducted over a period of 6 months among 42 individuals aged 30–60 years with clinically diagnosed Achilles tendinopathy. Participants were randomly allocated to either a Tendon Neuroplastic Training group or a Slow Reversal Hold group. Both groups received their respective interventions three times weekly for 12 weeks, with each session lasting 30–45 minutes. Tendon Neuroplastic Training focused on enhancing tendon load tolerance, neuromuscular control, and motor coordination, whereas Slow Reversal Hold was based on proprioceptive neuromuscular facilitation principles. Pain intensity, functional status, and rearfoot eversion during gait were assessed using the Numeric Pain Rating Scale, Victorian Institute of Sport Assessment–Achilles questionnaire, and video-based motion analysis, respectively. Data normality was examined using the Shapiro–Wilk test. Within-group differences were assessed using paired-samples t-tests or Wilcoxon signed-rank tests, while between-group differences were evaluated using independent-samples t-tests or Mann–Whitney U tests. Statistical significance was established at $p < 0.05$.

Results: Both interventions produced statistically significant improvements across the assessed outcomes ($p < 0.001$). Pain intensity decreased from 6.67 ± 1.39 to 2.62 ± 1.32 in the Tendon Neuroplastic Training group and from 7.52 ± 1.29 to 4.52 ± 1.40 in the Slow Reversal Hold group. Improvements

in functional capacity and rearfoot eversion were also observed in both groups, with greater biomechanical correction demonstrated following Tendon Neuroplastic Training.

Conclusion: Both Tendon Neuroplastic Training and Slow Reversal Hold were effective rehabilitation approaches for Achilles tendinopathy. However, Tendon Neuroplastic Training demonstrated superior overall clinical effectiveness, particularly in pain reduction, functional improvement, and restoration of gait-related biomechanics.

1. INTRODUCTION

The Achilles tendon is the largest and one of the strongest tendons in the human body and plays a crucial role in lower-limb locomotion, propulsion, and energy transfer during walking, running, and jumping. It connects the gastrocnemius and soleus muscles to the calcaneus and withstands substantial mechanical forces during dynamic activities [1]. Despite its high tensile capacity, repetitive mechanical loading can exceed the tendon's adaptive capacity, contributing to the development of Achilles tendinopathy, a common overuse disorder characterized by pain, impaired function, and altered tendon properties [2].

Achilles tendinopathy represents a considerable musculoskeletal problem in both physically active and occupational populations. Its reported incidence in the general population is approximately 1.85 per 1,000 individuals annually, with greater occurrence among middle-aged adults [3]. A systematic review and meta-analysis reported a pooled prevalence of approximately 6% among physically active individuals, with higher rates observed in older populations [4]. The condition is also frequently observed among athletes involved in repetitive running and jumping activities, including football players [5]. Moreover, occupational activities involving prolonged standing and repetitive lower-limb loading may contribute to Achilles tendon symptoms [6].

The etiology of Achilles tendinopathy is multifactorial, involving intrinsic factors such as reduced ankle mobility, muscular weakness, flexibility deficits, and altered lower-limb biomechanics, as well as extrinsic factors including excessive training loads, inappropriate footwear, and inadequate load management [7,8]. Among

biomechanical factors, altered foot and ankle mechanics have received particular attention. Excessive rearfoot eversion during gait or running may modify the mechanical loading of the Achilles tendon and contribute to abnormal lower-limb movement patterns [9]. Individuals with Achilles tendinopathy may demonstrate altered lower-limb biomechanics, including changes in rearfoot and ankle motion and impaired functional performance compared with healthy individuals [10].

Functional impairment is an important clinical feature of Achilles tendinopathy and may affect activities requiring single-limb loading, propulsion, and force generation. Therefore, rehabilitation should address not only pain but also functional capacity and movement mechanics. Functional assessment provides valuable information regarding the patient's recovery and response to treatment [11]. Furthermore, biomechanical factors such as excessive rearfoot motion have been proposed as potential contributors to Achilles tendon loading, although the relationship between rearfoot mechanics and tendinopathy is complex and remains incompletely understood [12].

Exercise-based rehabilitation remains the primary approach for managing Achilles tendinopathy, with progressive tendon loading, strengthening, and neuromuscular training commonly incorporated into treatment programs [13]. More recently, Tendon Neuroplastic Training (TNT) has been proposed as a rehabilitation approach that combines tendon loading with externally paced movement to facilitate motor control, neuromuscular coordination, and adaptation to tendon loading [14]. Evidence also suggests that sensorimotor training can improve pain and

functional outcomes in individuals with Achilles tendinopathy, supporting the potential value of neuromuscular rehabilitation strategies [15].

Slow Reversal Hold (SRH), based on proprioceptive neuromuscular facilitation principles, incorporates controlled muscular contractions and sustained holds to facilitate strength, stability, and coordinated movement. Such neuromuscular approaches may assist in improving functional control and movement efficiency during rehabilitation [16]. However, despite the potential benefits of both TNT and SRH, limited research has directly compared their effects on pain, functional capacity, and rearfoot eversion during gait in individuals with Achilles tendinopathy.

Therefore, the present study aimed to compare the effects of Tendon Neuroplastic Training and Slow Reversal Hold on pain, functional capacity, and rearfoot eversion during gait in individuals with Achilles tendinopathy. The findings may provide clinically relevant evidence for selecting appropriate neuromuscular rehabilitation strategies for improving both symptomatic and functional outcomes in this population.

2. CRITICAL ANALYSIS AND RESEARCH GAP

The reviewed literature indicates that Achilles tendinopathy is a multifactorial disorder involving pain, impaired plantarflexor performance, altered neuromuscular control, and disturbed gait biomechanics. Individuals with Achilles tendinopathy demonstrate reduced plantarflexor strength and rate of torque development, restricted ankle mobility, and altered gait patterns, including prolonged rearfoot eversion [19,23,26]. These findings suggest that effective rehabilitation should address both symptomatic and biomechanical impairments.

Evidence supports exercise-based and neuromuscular interventions for improving pain, function, strength, mobility, and tendon-related outcomes [17,24,25]. Neurophysiological adaptations may also contribute to clinical recovery, as isometric loading has been associated with analgesia and changes in corticospinal

excitability [22]. However, much of this evidence originates from different tendinopathies or non-Achilles populations, limiting its direct applicability to Achilles tendinopathy [20,22,25].

Biomechanical evidence further highlights the importance of rearfoot mechanics. Prolonged rearfoot eversion has been associated with lower-limb injury, while gait retraining can modify Achilles tendon loading and rearfoot kinematics [18,21,23]. Nevertheless, these studies frequently involved healthy runners or examined biomechanical outcomes without simultaneously assessing pain and function. Thus, whether therapeutic exercise can improve both clinical symptoms and rearfoot mechanics in symptomatic Achilles tendinopathy remains unclear.

A further limitation is the heterogeneity of intervention protocols, populations, and outcome measures across existing studies [17–26]. Although neuromuscular exercise, isometric loading, gait retraining, PNF, and eccentric exercise have shown beneficial effects, there is limited evidence directly comparing Tendon Neuroplastic Training (TNT) with Slow Reversal Hold (SRH). Moreover, no reviewed study has simultaneously evaluated their effects on pain, functional status, and rearfoot eversion during gait in individuals with Achilles tendinopathy.

The available evidence supports the role of tendon loading, neuromuscular rehabilitation, and gait modification in improving clinical and biomechanical outcomes in Achilles tendinopathy [17–26]. However, substantial heterogeneity exists in intervention protocols, study populations, and outcome measures, while direct comparisons between specific neuromuscular techniques remain limited. In particular, there is insufficient evidence regarding the comparative effects of Tendon Neuroplastic Training (TNT) and Slow Reversal Hold (SRH) on pain, functional ability, and rearfoot eversion during gait. Previous studies have generally examined these outcomes independently or investigated populations other than individuals with Achilles tendinopathy [18–26]. Therefore, the present study aims to compare the effects of TNT and SRH on pain, function, and rearfoot eversion during gait in individuals

with Achilles tendinopathy. By evaluating both clinical and biomechanical outcomes, this study seeks to determine whether one intervention provides superior benefits and to contribute evidence toward optimizing neuromuscular rehabilitation for Achilles tendinopathy.

3. OBJECTIVE AND HYPOTHESES

The objective of this study was to compare the effects of Tendon Neuroplastic Training (TNT) and Slow Reversal Hold (SRH) on pain, functional ability, and rearfoot eversion during gait in individuals with Achilles tendinopathy. The null hypothesis (H_0) stated that there would be no statistically significant difference between TNT and SRH in reducing pain, improving functional ability, or reducing rearfoot eversion during gait. In contrast, the alternative hypothesis (H_1) proposed that a statistically significant difference would exist between the two interventions across these outcomes.

4. PROBLEM STATEMENT

Achilles tendinopathy is a prevalent overuse disorder characterized by persistent tendon pain, structural and mechanical dysfunction, compromised neuromuscular control, and aberrant gait mechanics, collectively contributing to diminished functional capacity. Despite the availability of diverse rehabilitation approaches, the comparative efficacy of Tendon Neuroplastic Training (TNT) and Slow Reversal Hold (SRH) remains inadequately established, particularly with respect to their influence on pain, functional ability, and rearfoot eversion during gait. This paucity of comparative evidence limits the ability to identify an optimal neuromuscular rehabilitation strategy capable of simultaneously addressing symptomatic, functional, and biomechanical impairments. Therefore, the present study seeks to comparatively evaluate TNT and SRH to determine their relative effectiveness in improving clinical outcomes and modulating gait-related biomechanics in individuals with Achilles tendinopathy.

5. MATERIALS AND METHODS

Study Design and Setting

A randomized controlled trial was conducted to compare the effects of Tendon Neuroplastic Training and Slow Reversal Hold on pain, functional status, and rearfoot eversion during gait in individuals with Achilles tendinopathy. The study was conducted in the physiotherapy departments of Saad Hospital Daska, Fatima Medical Complex Daska, and Al Sadique Hospital Daska, Pakistan. The study was conducted over a period of six months, including participant recruitment, intervention, follow-up assessment, and data analysis.

Participants and Sample Size

The study included individuals aged 30–60 years with clinically diagnosed Achilles tendinopathy. Diagnosis was based on clinical findings including localized Achilles tendon pain, tenderness on palpation, and functional limitations. The sample size was calculated using G*Power version 3.1 based on a two-tailed independent-samples *t*-test, an effect size of 0.80, an alpha level of 0.05, and 90% statistical power. The required sample consisted of 42 participants, with 21 participants allocated to each group.

Participants were recruited using a non-probability sampling approach according to the predefined eligibility criteria. Eligible participants were informed about the study procedures and enrolled after providing written informed consent.

Eligibility Criteria

Participants were included if they were aged 30–60 years, had clinically diagnosed Achilles tendinopathy with symptoms persisting for at least three months, reported a Numeric Pain Rating Scale score of ≥ 5 , and experienced increased pain during loading activities such as running or jumping. Participants were excluded if they had a history of Achilles tendon surgery, systemic inflammatory disease, recent corticosteroid injection, extensive lower-limb injury, or neurological disorders affecting gait.

Randomization and Group Allocation

Following baseline assessment, eligible participants were randomly allocated into two

equal groups. Group A received Tendon Neuroplastic Training, whereas Group B received Slow Reversal Hold. Both groups received the conventional rehabilitation program in addition to their respective intervention.

Intervention Protocol

Both groups participated in a supervised rehabilitation program consisting of three sessions per week for 12 weeks, with each session lasting approximately 30–45 minutes. The conventional rehabilitation program included activity modification, cryotherapy, gastrocnemius and soleus stretching, isometric exercises, and, where clinically indicated, heel lifts, orthotics, supportive footwear, manual therapy, and therapeutic ultrasound.

Tendon Neuroplastic Training

The Tendon Neuroplastic Training group received a progressive tendon-loading and neuromuscular training program. The intervention progressed from isometric and bilateral loading to unilateral, resisted, functional, and dynamic exercises. The program emphasized controlled movement, tendon load tolerance, neuromuscular coordination, and gradual exposure to functional loading. Exercises included isometric calf holds, seated and standing calf raises, resisted plantarflexion, heel raises on a step, eccentric heel drops, single-leg calf raises, externally resisted heel raises, functional heel-raise drills, and low-level plyometric activities. Exercises were performed using slow, externally paced movements, with progression based on exercise tolerance and symptom response. The detailed exercise protocol is presented in Table 1.

Table 1 Tendon Neuroplastic Training Exercise Protocol

Technique / Exercise	Dosage	Targeted Muscles	Metronome Frequency (Tempo)	Progression Rule
Isometric calf hold (seated/standing)	5 holds × 10 sec, 2–3 sets	Soleus, Gastrocnemius	20 BPM	Begin with pain-free activation; reduce pain
Seated calf raises (controlled tempo)	10–12 reps × 2–3 sets	Soleus	20 BPM	Maintain slow, controlled movement
Bilateral standing heel raises	10–12 reps × 3 sets	Gastrocnemius, Soleus	20 BPM	Progress to weight-bearing loading
Resisted plantarflexion (theraband)	10–12 reps × 3 sets	Soleus, Tibialis Posterior	20 BPM	Gradually increase resistance
Heel raises on step (full ROM)	10–12 reps × 3 sets	Gastrocnemius, Soleus	20 BPM	Increase range of motion
Eccentric heel drops (slow lowering)	8–10 reps × 3 sets	Gastrocnemius, Soleus	20 BPM	Emphasize slow eccentric control
Single-leg calf raises	8–10 reps × 3 sets	Gastrocnemius, Soleus	20 BPM	Progress to unilateral loading
Dumbbell-assisted heel raises	10 reps × 3 sets	Gastrocnemius, Soleus	20 BPM	Add external resistance
Single-leg heel raises on step	10–12 reps × 3 sets	Gastrocnemius, Soleus	20 BPM	Increase balance demand
Eccentric overload training	8–10 reps × 3 sets	Achilles tendon complex	20 BPM	Add load during eccentric phase

Functional heel raises (stairs/walking drills)	10–15 min	Whole lower limb	20 BPM	Integrate into functional tasks
Low-level plyometric exercises (mini hops)	8–10 reps × 2–3 sets	Gastrocnemius, Soleus	20 BPM	Final progression if pain-free

Note. BPM = beats per minute; ROM = range of motion. Exercise progression was based on participant tolerance and symptom response.

Slow Reversal Hold

The Slow Reversal Hold group received a progressive proprioceptive neuromuscular facilitation-based exercise program. The intervention incorporated alternating muscular contractions and sustained isometric holds to improve neuromuscular control, strength, stability, and coordinated lower-limb movement. The program progressed from non-weight-bearing ankle exercises to resisted movements, weight-bearing strengthening, balance training, and functional activities. Exercises included ankle

plantarflexion and dorsiflexion, mid-range isometric ankle holds, hip and knee movement patterns, diagonal proprioceptive neuromuscular facilitation patterns, inversion-biased ankle exercises, resisted plantarflexion, calf raises, single-leg strengthening, balance exercises, and functional gait and step-up activities. Progression was based on exercise tolerance, movement control, and symptom response. The detailed Slow Reversal Hold protocol is presented in **Table 2**.

Table 2 Slow Reversal Hold Exercise Protocol

Intervention Type	Technique/Exercise	Dosage	Targeted Muscles	Progression Rule
SRH	Ankle plantarflexion–dorsiflexion (non-weight-bearing)	10 reps × 2–3 sets; 5–10 s hold	Gastrocnemius, soleus, tibialis anterior	Begin with pain-free, controlled activation
SRH	Isometric ankle hold (mid-range)	5–10 s hold × 8–10 reps	Gastrocnemius, soleus	Improve neuromuscular control and reduce pain
SRH	Hip and knee flexion–extension	10 reps × 2–3 sets	Quadriceps, hamstrings, gluteals	Add proximal control for lower-limb alignment
SRH	D1 flexion pattern (hip, knee, and ankle coordination)	8–10 reps × 3 sets	Hip flexors, dorsiflexors, invertors	Introduce coordinated movement patterns
SRH	D2 flexion pattern (functional diagonal movement)	8–10 reps × 3 sets	Gluteus medius, tibialis posterior	Enhance dynamic stability and control
SRH	Ankle SRH with inversion bias	8–10 reps × 3 sets; 5–8 s hold	Tibialis posterior, gastrocnemius, soleus	Improve rearfoot control through invertor activation
SRH	Resisted plantarflexion with slow reversal	10 reps × 3 sets	Gastrocnemius, soleus	Introduce manual or elastic resistance

SRH	Double-leg calf raises with isometric hold	10–12 reps × 3 sets; 5–10 s hold	Gastrocnemius, soleus	Progress to weight-bearing strengthening
SRH	Single-leg calf raises with hold	8–10 reps × 3 sets	Gastrocnemius, soleus, intrinsic foot muscles	Increase unilateral loading and stability demand
SRH	Static balance with SRH	30 s × 3 sets	Intrinsic foot muscles, tibialis posterior	Add postural control and proprioception
SRH	Dynamic balance with SRH on unstable surface	30–45 s × 3 sets	Whole lower-limb stabilizers	Progress to foam or balance-board surfaces
SRH	Functional tasks with SRH (gait and step-ups)	10–15 min	Whole lower limb	Integrate SRH into functional movement patterns

Note. SRH = Slow Reversal Hold; D1 = diagonal 1; D2 = diagonal 2. Progression was individualized according to participant tolerance, movement quality, and symptom response.

OUTCOME MEASUREMENT TOOLS

Three outcome measures were used to evaluate the effects of the interventions on pain intensity, functional status, and gait biomechanics.

Numeric Pain Rating Scale

Pain intensity was assessed using the Numeric Pain Rating Scale (NPRS). This is a self-reported numerical scale ranging from 0 to 10, where 0 represents no pain and 10 represents the worst imaginable pain. The NPRS has demonstrated high test-retest reliability in individuals with chronic pain ($r \geq 0.95$) and strong construct validity through correlations with other established pain measures, including the Visual Analog Scale (VAS) [5,6]. Pain scores were interpreted as mild (0–3), moderate (4–6), and severe (7–10). A reduction of ≥ 2 points was considered a clinically meaningful improvement in chronic musculoskeletal pain [27,28].

Victorian Institute of Sport Assessment–Achilles

Functional severity was evaluated using the Victorian Institute of Sport Assessment–Achilles (VISA-A) questionnaire. The VISA-A is an eight-item, disease-specific instrument designed to assess pain, functional capacity, and activity limitations associated with Achilles tendinopathy. Scores range from 0 to 100, with higher scores indicating fewer symptoms and better functional status. The instrument demonstrates excellent reliability, with reported test-retest reliability of $r = 0.93$,

intrarater reliability of $r = 0.90$, and interrater reliability of $r = 0.90$ [7]. Scores below 50 indicate severe symptoms and functional impairment, scores of 50–75 indicate moderate dysfunction, and scores above 90 indicate near-normal functional status. Healthy or fully recovered individuals generally demonstrate scores above 95–96 [29].

Rearfoot Eversion During Gait

Rearfoot eversion was assessed through clinical gait observation using video or smartphone recording. Participants were recorded from posterior and sagittal views while walking at their normal speed over a 10–15 m walkway. Anatomical landmarks, including the lateral malleolus and heel, were marked using adhesive tape to facilitate visual assessment of the maximum rearfoot eversion occurring during the stance phase of gait. The eversion angle was estimated numerically in degrees. Smartphone-based video analysis has demonstrated substantial to almost perfect reliability for assessment of joint kinematics in clinical settings [8]. Rearfoot eversion exceeding approximately 8–10° during stance was considered indicative of altered foot mechanics potentially associated with Achilles tendinopathy, while a reduction in eversion following intervention was interpreted as an improvement in neuromuscular control and gait mechanics [30].

Data Collection Procedure

Baseline demographic and clinical information, including age, sex, and clinical history, was recorded before intervention. Baseline measurements of pain, functional status, and rearfoot eversion were subsequently obtained. Participants then completed their assigned intervention under the supervision of a licensed physiotherapist. Following completion of the intervention period, the same outcome measures were reassessed using procedures consistent with the baseline assessment.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26. Continuous variables were summarized as mean $\pm$ standard deviation, whereas categorical variables were presented as frequencies and percentages. The Shapiro-Wilk test was used to assess the normality of continuous variables. For normally distributed variables, paired-samples *t*-tests were used for within-group pre- and post-intervention comparisons, while independent-samples *t*-tests were used to compare changes between groups. Non-parametric alternatives were used when distributional assumptions were not satisfied. A *p*-value ≤ 0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the relevant institutional ethics committee before commencement of data collection, and permission was obtained from the participating healthcare facilities. All participants provided written informed consent after receiving information regarding the study objectives, procedures, potential benefits, and risks. Participation was voluntary, and participants were informed of their right to withdraw at any stage without consequences. Participant privacy and confidentiality were maintained throughout the study, and collected information was used solely for research purposes.

6. RESULTS

Table 3 presents the baseline demographic and clinical characteristics of the participants. Each group comprised 21 participants. The mean age

was 43.76 ± 8.02 years in the TNT group and 42.71 ± 10.31 years in the SRH group. Mean BMI was 27.78 ± 3.01 kg/m² and 26.97 ± 3.26 kg/m², respectively. The mean duration of symptoms was 9.33 ± 5.20 months in the TNT group and 11.19 ± 4.45 months in the SRH group. In the TNT group, 7 (33.3%) participants were male and 14 (66.7%) were female, whereas the SRH group included 11 (52.4%) males and 10 (47.6%) females.

Table 4 demonstrates descriptive changes in all three outcomes following intervention. NPRS scores decreased in both groups, with a greater reduction in the TNT group. Total VISA-A scores increased in both groups, indicating improved Achilles tendon function. Rearfoot eversion angle also decreased in both groups, from 11.50° to 8.27° in the TNT group and from 11.81° to 9.24° in the SRH group. Overall, both interventions showed favorable descriptive changes in pain, Achilles tendon function, and rearfoot eversion.

Table 5 shows favorable categorical changes following intervention in both groups. Pain intensity shifted toward lower severity, particularly in the TNT group, where 66.7% of participants had mild pain post-intervention compared with none at baseline. VISA-A severity improved from severe dysfunction in all participants at baseline to moderate dysfunction in most participants after intervention, with a slightly greater proportion reaching the moderate category in the TNT group (71.4%) than in the SRH group (85.7%). Rearfoot eversion also improved, with normal angles observed in 52.4% of TNT participants and 19.0% of SRH participants after intervention. Overall, the categorical findings indicate improvement in all three outcomes in both groups, with comparatively greater improvement in the TNT group for pain intensity and rearfoot alignment.

Table 6 indicates that VISA-A scores and most rearfoot eversion measurements were normally distributed ($p > .05$). However, NPRS scores were non-normally distributed for most assessments, and the change scores for NPRS were also non-normal ($p < .05$). The change in rearfoot eversion was non-normal in the TNT group but normal in

the SRH group. Therefore, non-parametric tests should be considered for outcomes that violate the normality assumption, while parametric analyses may be used for normally distributed outcomes when other assumptions are satisfied.

Table 7 demonstrates that both Tendon Neuroplastic Training (TNT) and Slow Reversal Hold (SRH) produced statistically significant improvements in all three outcome measures. For NPRS, a significant reduction in pain was observed within both groups ($p < 0.001$). The between-group comparison was also statistically significant ($p < 0.001$), with a moderate effect size ($r = 0.564$), indicating greater pain reduction in the TNT group. For VISA-A, both groups showed significant improvement in Achilles tendon function following intervention ($p < 0.001$). The

between-group difference was statistically significant ($p = 0.011$), with a large effect size (Cohen's $d = 0.82$), demonstrating that TNT resulted in greater improvement in Achilles tendon function compared with SRH. Similarly, rearfoot eversion angle significantly decreased in both groups ($p < 0.001$). The between-group comparison showed a statistically significant difference ($p = 0.003$), with a moderate effect size ($r = 0.461$), indicating that TNT produced greater improvement in rearfoot alignment than SRH. Overall, both interventions were effective; however, TNT demonstrated significantly greater improvements across pain, Achilles tendon function, and rearfoot eversion angle compared with SRH.

Table 3 Baseline Demographic and Clinical Characteristics of Participants

Characteristic	TNT (n = 21)	SRH (n = 21)
Age, years	43.76 ± 8.02	42.71 ± 10.31
BMI, kg/m ²	27.78 ± 3.01	26.97 ± 3.26
Duration of symptoms, months	9.33 ± 5.20	11.19 ± 4.45
Sex, n (%)		
Male	7 (33.3)	11 (52.4)
Female	14 (66.7)	10 (47.6)

Note. Values are presented as $M \pm SD$ unless otherwise indicated. TNT = Tendon Neuroplastic Training; SRH = Slow Reversal Hold; BMI = body mass index.

Table 4 Descriptive Statistics of NPRS, VISA-A, and Rearfoot Eversion Angle Before and After Intervention

Outcome measure	Group	Pre-intervention, $M \pm SD$	Post-intervention, $M \pm SD$
NPRS	TNT	6.67 ± 1.39	2.62 ± 1.32
	SRH	7.52 ± 1.29	4.52 ± 1.40
Total VISA-A score	TNT	29.14 ± 6.26	53.76 ± 7.04
	SRH	33.67 ± 5.99	55.62 ± 6.18

Rearfoot eversion angle (°)	TNT	11.50 ± 1.56	8.27 ± 1.73
	SRH	11.81 ± 1.02	9.24 ± 1.26

Note. M = mean; SD = standard deviation; NPRS = Numeric Pain Rating Scale; VISA-A = Victorian Institute of Sport Assessment–Achilles; TNT = Tendon Neuroplastic Training; SRH = Slow Reversal Hold. n = 21 participants per group.

Table 5 Categorical Distribution of Pain Intensity, VISA-A Dysfunction Severity, and Rearfoot Eversion Angle Before and After Intervention

Outcome measure	Group	Pre-intervention, n (%)	Post-intervention, n (%)
Pain intensity	TNT	Mild: 0 (0.0%); Moderate: 12 (57.1%); Severe: 9 (42.9%)	Mild: 14 (66.7%); Moderate: 7 (33.3%); Severe: 0 (0.0%)
	SRH	Mild: 0 (0.0%); Moderate: 6 (28.6%); Severe: 15 (71.4%)	Mild: 4 (19.0%); Moderate: 16 (76.2%); Severe: 1 (4.8%)
VISA-A dysfunction severity	TNT	Severe: 21 (100%); Moderate: 0 (0.0%); Mild: 0 (0.0%); Near full recovery: 0 (0.0%)	Severe: 6 (28.6%); Moderate: 15 (71.4%); Mild: 0 (0.0%); Near full recovery: 0 (0.0%)
	SRH	Severe: 21 (100%); Moderate: 0 (0.0%); Mild: 0 (0.0%); Near full recovery: 0 (0.0%)	Severe: 3 (14.3%); Moderate: 18 (85.7%); Mild: 0 (0.0%); Near full recovery: 0 (0.0%)
Rearfoot eversion angle	TNT	Normal: 0 (0.0%); Mildly increased: 5 (23.8%); Excessive: 16 (76.2%)	Normal: 11 (52.4%); Mildly increased: 6 (28.6%); Excessive: 4 (19.0%)
	SRH	Normal: 0 (0.0%); Mildly increased: 1 (4.8%); Excessive: 20 (95.2%)	Normal: 4 (19.0%); Mildly increased: 12 (57.1%); Excessive: 5 (23.8%)

Note. n = frequency; % = percentage; TNT = Tendon Neuroplastic Training; SRH = Slow Reversal Hold; VISA-A = Victorian Institute of Sport Assessment–Achilles. Pain intensity categories were classified as mild, moderate, and severe. VISA-A dysfunction severity was classified as severe (<50), moderate (50–75), mild (76–90), and near full recovery (>90). Rearfoot eversion angle was classified as normal (≤8°), mildly increased (8.1°–10°), and excessive (>10°). Percentages are based on n = 21 participants per group.

Table 6 Shapiro–Wilk Test of Normality for Study Outcome Measures

Outcome measure	Group	W	p
NPRS before	TNT	0.850	.004
NPRS before	SRH	0.877	.013
NPRS after	TNT	0.854	.005

NPRS after	SRH	0.912	.059
Change in NPRS	TNT	0.815	.001
Change in NPRS	SRH	0.815	.001
VISA-A before	TNT	0.951	.358
VISA-A before	SRH	0.951	.356
VISA-A after	TNT	0.954	.411
VISA-A after	SRH	0.943	.255
Change in VISA-A	TNT	0.965	.627
Change in VISA-A	SRH	0.962	.561
Rearfoot eversion before	TNT	0.952	.368
Rearfoot eversion before	SRH	0.975	.846
Rearfoot eversion after	TNT	0.959	.501
Rearfoot eversion after	SRH	0.984	.973
Change in rearfoot eversion	TNT	0.894	.027
Change in rearfoot eversion	SRH	0.922	.097

Note. *W* = Shapiro–Wilk statistic; NPRS = Numeric Pain Rating Scale; VISA-A = Victorian Institute of Sport Assessment–Achilles; TNT = Tendon Neuroplastic Training; SRH = Slow Reversal Hold. A *p* value > .05 indicates no significant departure from normality.

Table 7 Within- and Between-Group Comparisons of NPRS, VISA-A, and Rearfoot Eversion Angle Scores

Outcome Measure	Within-Group Test	TNT <i>p</i> value	SRH <i>p</i> value	Between-Group Test	<i>p</i> value	Effect Size	Interpretation
NPRS	Wilcoxon Signed-Rank Test	<0.001	<0.001	Mann-Whitney U Test	<0.001	$r = 0.564$	Significant; greater pain reduction in TNT
VISA-A	Paired-Samples <i>t</i> -Test	<0.001	<0.001	Independent-Samples <i>t</i> -Test	0.011	Cohen's $d = 0.82$	Significant; greater functional improvement in TNT
Rearfoot Eversion Angle	Wilcoxon Signed-Rank Test	<0.001	<0.001	Mann-Whitney U Test	0.003	$r = 0.461$	Significant; greater improvement in TNT

Note. NPRS = Numeric Pain Rating Scale; VISA-A = Victorian Institute of Sport Assessment–Achilles; TNT = Tendon Neuroplastic Training; SRH = Slow Reversal Hold. $p < 0.05$ was considered statistically significant.

7. DISCUSSION

The present randomized clinical trial compared the effectiveness of Tendon Neuroplastic Training (TNT) and Slow Reversal Hold (SRH), combined with conventional physiotherapy, in individuals with chronic Achilles tendinopathy. The interventions were evaluated over 12 weeks using the Numeric Pain Rating Scale (NPRS), Victorian Institute of Sport Assessment-Achilles (VISA-A), and rearfoot eversion angle. Overall, both interventions produced significant improvements in pain, Achilles tendon function, and rearfoot mechanics. However, TNT demonstrated a greater reduction in pain and rearfoot eversion, suggesting a potential advantage of incorporating neuroplastic and neuromuscular components into tendon rehabilitation.

Pain reduction was one of the most prominent findings. NPRS scores decreased from 6.67 ± 1.39 to 2.62 ± 1.32 in the TNT group and from 7.52 ± 1.29 to 4.52 ± 1.40 in the SRH group. The between-group analysis demonstrated a significantly greater reduction in pain with TNT ($p < 0.001$; $r = 0.564$). The categorical analysis supported this finding, as 66.7% of participants receiving TNT were classified as having mild pain after treatment, with severe pain completely eliminated. In contrast, most participants receiving SRH remained in the moderate category. The greater analgesic response to TNT may be related to controlled tendon loading combined with neuromuscular and cortical motor-control strategies. Rio et al. demonstrated that tendon-loading exercise can produce analgesia and reduce pain-related inhibition, supporting the potential role of neuroplastic mechanisms in tendinopathy rehabilitation [31]. Similarly, Murphy et al. reported progressive improvements in pain and function during loading-based rehabilitation, with the greatest improvements occurring over a 12-week period [32].

Both interventions also produced significant improvements in Achilles tendon function. VISA-A scores increased from 29.14 ± 6.26 to 53.76 ± 7.04 in the TNT group and from 33.67 ± 5.99 to 55.62 ± 6.18 in the SRH group ($p < 0.001$). Although the final mean VISA-A score was slightly

higher in SRH, the magnitude of change was greater in TNT (24.62 ± 3.07 versus 21.95 ± 3.40), with a statistically significant between-group difference ($p = 0.011$; Cohen's $d = 0.82$). This indicates that both interventions were effective, while TNT produced a greater improvement relative to baseline. These findings are consistent with Murphy et al., who reported substantial improvements in VISA-A following progressive loading rehabilitation [22]. The findings are also supported by evidence that exercise-based rehabilitation is an effective first-line approach for improving pain and function in Achilles tendinopathy [33].

The VISA-A severity distribution further demonstrated clinically meaningful functional recovery. Initially, all participants in both groups had severe dysfunction (VISA-A < 50). Following intervention, 71.4% of TNT participants and 85.7% of SRH participants shifted to the moderate dysfunction category. Although participants did not generally reach the mild or near-full-recovery categories, the transition from severe to moderate dysfunction represents meaningful functional improvement over 12 weeks. Comparable improvements following progressive loading programmes have been reported by O'Neill et al. [34]. Improvements in functional activities and sports participation were also observed, particularly in the TNT group, suggesting that tendon rehabilitation may extend beyond pain relief to restoration of higher-level functional capacity. Stevens and Tan similarly reported improvements in functional performance and patient-reported outcomes following progressive tendon-loading programmes [35].

A further important finding was the significant improvement in rearfoot eversion. The mean angle decreased from $11.50 \pm 1.56^\circ$ to $8.27 \pm 1.73^\circ$ in the TNT group and from $11.81 \pm 1.02^\circ$ to $9.24 \pm 1.26^\circ$ in the SRH group. The between-group analysis demonstrated a significantly greater reduction with TNT ($p = 0.003$; $r = 0.461$). The categorical findings were particularly notable: excessive rearfoot eversion decreased from 76.2% to 19.0% in TNT and from 95.2% to 23.8% in

SRH, while normal alignment increased to 52.4% and 19.0%, respectively. These findings suggest that both interventions positively influenced rearfoot mechanics, with a greater shift toward normal alignment following TNT. Previous research has identified altered lower-limb biomechanics and gait characteristics in individuals with Achilles tendinopathy, emphasizing the relevance of neuromuscular and movement-based rehabilitation [36]. Exercise-based rehabilitation may improve tendon load tolerance and neuromuscular control, thereby contributing to more efficient lower-limb mechanics [37].

The greater improvement observed with TNT may be explained by its emphasis on controlled tendon loading, motor retraining, and neuromuscular coordination. Rather than addressing tendon capacity alone, this approach may influence how the tendon and surrounding musculature respond to mechanical loading during functional movement. This interpretation is consistent with contemporary evidence supporting progressive exercise, neuromuscular rehabilitation, and movement retraining in Achilles tendinopathy [35–37].

Taken together, the present findings demonstrate that both TNT and SRH, when combined with conventional physiotherapy, can effectively reduce pain and disability and improve rearfoot mechanics in chronic Achilles tendinopathy. TNT, however, produced significantly greater improvements in pain and rearfoot eversion and a greater change in VISA-A scores. The moderate effect observed for pain and rearfoot eversion and the large effect for VISA-A change suggest that these differences may have clinical relevance in addition to statistical significance. Nevertheless, the baseline differences in NPRS and VISA-A should be considered when interpreting the comparative findings. Overall, the results support progressive and neuromuscular exercise-based rehabilitation as an important component of Achilles tendinopathy management, with TNT demonstrating particular promise for addressing pain and movement-related impairments [25,27].

8. CONCLUSION

The present study demonstrated that both Tendon Neuroplastic Training (TNT) and Slow Reversal Hold (SRH), when combined with conventional physiotherapy, significantly improved pain, Achilles tendon function, and rearfoot eversion in individuals with chronic Achilles tendinopathy. However, TNT produced greater improvements in pain reduction and rearfoot alignment, with a significant between-group advantage. These findings suggest that TNT may be a promising rehabilitation approach for addressing both symptomatic and movement-related impairments associated with chronic Achilles tendinopathy.

LIMITATIONS

There are some limitations in this study. First, the relatively small sample size and recruitment from a single clinical setting can limit the generalization of the results. Second, the 12-week intervention period did not allow for the assessment of long-term treatment effects or recurrence. Third, rearfoot eversion was measured using clinical and smartphone video analysis instead of using three-dimensional motion analysis. Psychological factors, physical activity levels, and adherence to the treatment during nonsupervised periods were not assessed and may have had an effect on the results. Lastly, patient and therapist blinding was not possible due to the type of treatment used, possibly creating performance bias.

9. RECOMMENDATIONS

Future studies need to recruit larger sample sizes from multiple clinical settings to increase their power and external validity. Longer follow-up times are also needed to determine the effectiveness of treatment over time and any recurrence rates. 3D motion analysis equipment must be used for more accurate evaluation of the foot and lower limb mechanics. Future studies will also need to study TNT in different ages, athletes, and degrees of Achilles tendinopathy. Finally, comparative studies looking at the use of TNT together with other rehabilitation techniques may

provide information on optimal treatment programs.

10. REFERENCES:

1. Winnicki K, Ochała-Kłos A, Rutowicz B, Pękala PA, Tomaszewski KA. Functional anatomy, histology and biomechanics of the human Achilles tendon—A comprehensive review. *Ann Anat.* 2020;229:151461.
2. Shamrock AG, Dreyer MA, Varacallo MA. Achilles tendon rupture. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.
3. de Jonge S, Van Den Berg C, de Vos RJ, Van Der Heide HJ, Weir A, Verhaar JA, et al. Incidence of midportion Achilles tendinopathy in the general population. *Br J Sports Med.* 2011;45(13):1026-8.
4. Wang Y, Zhou H, Nie Z, Cui S. Prevalence of Achilles tendinopathy in physical exercise: a systematic review and meta-analysis. *Sports Med Health Sci.* 2022;4(3):152-9.
5. ul Hussain MI, un Nisa M, Asif I, Amjad F. Frequency of Achilles tendinopathy among football players in Rawalpindi and Islamabad. *J Health Rehabil Res.* 2024;4(3):1-4.
6. Niazi EK, Riaz R, Ali A, Abbas S, Farhan A, Tariq Z. Prevalence of Achilles tendinopathy due to prolonged standing among salesperson working in shopping malls of twin cities. *J Nurs Allied Health.* 2024;2(1).
7. Verges J, Martínez N, Pascual A, Bibas M, Santiña M, Rodas G. Psychosocial and individual factors affecting quality of life in patients suffering from Achilles tendinopathy: a systematic review. *BMC Musculoskelet Disord.* 2022;23(1):1114.
8. Arequipa TA, Pérez JC, Ortega CN, Paredes SA, Pullupaxi ED. Intrinsic and extrinsic risk factors for tendinopathies. *Ciencia y Reflexión.* 2025;4(1):434-61.
9. Mousavi SH, van Kouwenhove L, Rajabi R, Zwerver J, Hijmans JM. The effect of changing foot progression angle using real-time visual feedback on rearfoot eversion during running. *PLoS One.* 2021;16(2):e0246425.
10. Quarmby A, Mönnig J, Mugele H, Henschke J, Kim M, Cassel M, et al. Biomechanics and lower limb function are altered in athletes and runners with Achilles tendinopathy compared with healthy controls: a systematic review. *Front Sports Act Living.* 2023;4:1012471.
11. Kurtz P, Quarmby A, Khajooei M, Cassel M, Engel T. Exploring single-leg jump testing as an assessment of functional capacity in Achilles tendinopathy: a cross-sectional study. *Transl Sports Med.* 2025;2025(1):4186587.
12. Aubol KG, Milner CE. Whipping or tearing? The biomechanics of Achilles tendinopathy in rearfoot strike runners. *Foot.* 2024;59:102082.
13. von Rickenbach KJ, Borgstrom H, Tenforde A, Borg-Stein J, McInnis KC. Achilles tendinopathy: evaluation, rehabilitation, and prevention. *Curr Sports Med Rep.* 2021;20(6):327-34.
14. Tedeschi R, Platano D, Donati D, Giorgi F. Functional approaches in tendinopathy rehabilitation: exploring the role of tendon neuroplastic training. *Manuelle Medizin.* 2025;63(3):177-83.
15. Kim MH, Martin W, Quarmby A, Stoll J, Engel T, Cassel M. Effects of sensorimotor training on functional and pain outcomes in Achilles tendinopathy: a systematic review. *Front Sports Act Living.* 2024;6:1414633.
16. Higgins M, Greer C. Proprioceptive neuromuscular facilitation for the upper extremity and scapula: review and update on rehabilitation of shoulder pathology. *Int J Sports Phys Ther.* 2025;20(9):1407.

17. Aphale S, Shinde S, Kale HY, Ambali MP. The effect of an aquatic neuromuscular exercise program on pain alleviation and functional performance in cases of chronic Achilles tendinopathy among overweight middle-aged women. *Cureus*. 2025;17(8):e.
18. Zhang X, Deng L, Xiao S, Fu W. Effects of a 12-week gait retraining program on the Achilles tendon adaptation of habitually shod runners. *Scand J Med Sci Sports*. 2024;34(1):e14516.
19. Crowley L, Vallance P, Clark R, Perraton L, Garofolini A, Malliaras P. Plantarflexor neuromuscular performance in insertional Achilles tendinopathy. *Musculoskelet Sci Pract*. 2022;62:102671.
20. Kruse A, Habersack A, Jaspers RT, Schrapf N, Weide G, Svehlik M, et al. Acute effects of static and proprioceptive neuromuscular facilitation stretching of the plantar flexors on ankle range of motion and muscle-tendon behavior in children with spastic cerebral palsy: a randomized clinical trial. *Int J Environ Res Public Health*. 2022;19(18):11599.
21. Mousavi SH, van Kouwenhove L, Rajabi R, Zwerver J, Hijmans JM. The effect of changing foot progression angle using real-time visual feedback on rearfoot eversion during running. *PLoS One*. 2021;16(2):e0246425.
22. Rio E. Corticospinal responses to patellar tendon pain and the effects of externally paced strength training [doctoral dissertation]. Melbourne: Monash University; 2017.
23. Becker J, James S, Wayner R, Osternig L, Chou LS. Biomechanical factors associated with Achilles tendinopathy and medial tibial stress syndrome in runners. *Am J Sports Med*. 2017;45(11):2614-2621.
24. Tumilty S, Mani R, Baxter GD. Photobiomodulation and eccentric exercise for Achilles tendinopathy: a randomized controlled trial. *Lasers Med Sci*. 2016;31(1):127-135.
25. Choi JH. Effects of elastic band exercise using proprioceptive neuromuscular facilitation on strength and dynamic balance of adults with ankle instability. *Med Leg Update*. 2019;19(2).
26. Kim S, Yu J. Changes of gait parameters and lower limb dynamics in recreational runners with Achilles tendinopathy. *J Sports Sci Med*. 2015;14(2):284-289.
27. Ferraz MB, Quaresma MR, Aquino LR, Atra E, Tugwell P, Goldsmith C. Reliability of pain scales in the assessment of literate and illiterate patients with rheumatoid arthritis. *J Rheumatol*. 1990;17(8):1022-4.
28. Alghadir AH, Anwer S, Iqbal A, Iqbal ZA. Test-retest reliability, validity, and minimum detectable change of visual analog, numerical rating, and verbal rating scales for measurement of osteoarthritic knee pain. *J Pain Res*. 2018:851-6.
29. Robinson JM, Cook JL, Purdam C, Visentini PJ, Ross J, Maffulli N, et al. The VISA-A questionnaire: a valid and reliable index of the clinical severity of Achilles tendinopathy. *Br J Sports Med*. 2001;35(5):335-41.
30. Wang XM, Smith DT, Zhu Q. A webcam-based machine learning approach for three-dimensional range of motion evaluation. *PLoS One*. 2023;18(10):e0293178.
31. Rio E, Kidgell D, Purdam C, Gaida J, Moseley GL, Pearce AJ, et al. Isometric exercise induces analgesia and reduces inhibition in patellar tendinopathy. *Br J Sports Med*. 2015;49(19):1277-83.

32. Murphy M, Travers M, Gibson W, Chivers P, Debenham J, Docking S, et al. Rate of improvement of pain and function in mid-portion Achilles tendinopathy with loading protocols: a systematic review and longitudinal meta-analysis. *Sports Med.* 2018;48(8):1875-91.
33. Van Der Vlist AC, Winters M, Weir A, Ardern CL, Welton NJ, Caldwell DM, et al. Which treatment is most effective for patients with Achilles tendinopathy? A living systematic review with network meta-analysis of 29 randomised controlled trials. *Br J Sports Med.* 2021;55(5):249-56.
34. O'Neill S, Watson PJ, Barry S. Why are eccentric exercises effective for Achilles tendinopathy? *Int J Sports Phys Ther.* 2015;10(4):552.
35. Stevens M, Tan CW. Effectiveness of progressive tendon-loading exercise therapy in Achilles tendinopathy: a systematic review. *Int J Sports Phys Ther.* 2021;16(4):1028-40.
36. Silbernagel KG, Hanlon S, Sprague A. Current clinical concepts: conservative management of Achilles tendinopathy. *J Athl Train.* 2020;55(5):438-47.
37. de Vos RJ, Van Der Vlist AC, Zwerver J, Meuffels DE, Smithuis F, Van Ingen R, et al. Dutch multidisciplinary guideline on Achilles tendinopathy. *Br J Sports Med.* 2021;55(20):1125-34.