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RESEARCH ARTICLE

Active Release Technique versus Eccentric Loading Exercise for Chronic Achilles Tendinopathy in Competitive Badminton Players: A Randomized Controlled Trial

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Abstract: Achilles tendinopathy affects up to 35% of competitive badminton players, yet optimal treatment approaches remain debated. While eccentric loading represents the current gold standard, emerging evidence suggests manual therapy techniques may offer complementary benefits. Limited high-quality research has compared these interventions in sport-specific populations.To compare the effectiveness of Active Release Technique (ART) versus eccentric loading exercise for improving pain, function, and tendon structure in competitive badminton players with chronic Achilles tendinopathy.Randomized, controlled, assessor-blinded, parallel-group trial with 8-week intervention and 6-month follow-up.Sixty competitive badminton players (18-30 years) with clinically and ultrasonographically confirmed chronic mid-portion Achilles tendinopathy were randomly allocated to receive either standardized ART (n=30) or progressive eccentric loading exercise (n=30). Both groups received three sessions weekly for 8 weeks. Primary outcomes were Victorian Institute of Sport Assessment-Achilles (VISA-A) scores and ultrasound-measured tendon thickness at 8 weeks. Secondary outcomes included numerical pain rating scale, ankle dorsiflexion range of motion, single-leg heel-rise test performance, and tendon echogenicity. Assessments occurred at baseline, 4 weeks, 8 weeks, 3 months, and 6 months.Fifty-seven participants completed the 8-week intervention (95% retention). Both groups showed significant improvements in all outcomes ($p<0.001$). At 8 weeks, the ART group demonstrated superior VISA-A scores (78.3±11.2 vs 71.4±13.8; mean difference 6.9, 95% CI 0.8-13.0; $p=0.028$) and greater reduction in tendon thickness from baseline (-1.8±0.9 mm vs -1.2±0.7 mm; mean difference 0.6mm, 95% CI 0.1-1.1; $p=0.019$). The ART group also showed significantly better heel-rise performance (32.4±8.1 vs 27.8±7.3 repetitions; $p=0.024$) and lower final pain scores at 8 weeks (3.2±1.4 vs 4.1±1.8 NRS; $p=0.031$). Between-group differences remained significant at 6-month follow-up for primary outcomes. No serious adverse events occurred in either group.Active Release Technique produced superior improvements in functional outcomes and tendon morphology compared to eccentric loading exercise in competitive badminton players with chronic Achilles tendinopathy. These findings suggest ART may offer a valuable alternative or adjunct to current treatment approaches, though longer-term studies are warranted to confirm durability of benefits.
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Level of Evidence: Level 1b (Individual randomized controlled trial)

Keywords: Achilles tendinopathy, Active Release Technique, eccentric exercise, badminton, manual therapy, randomized controlled trial, sports medicine, ultrasound imaging

INTRODUCTION

Background

Competitive badminton places extraordinary demands on the Achilles tendon complex through repetitive explosive movements, rapid multi-directional changes, and powerful push-off actions during play. The sport's unique kinetic chain requirements, combining vertical jumping with lateral movement patterns, create loading scenarios that predispose athletes to tendon overuse injuries. Current epidemiological data suggests that Achilles tendinopathy affects [1,3,4] between 18% and 35% of competitive racket sport athletes, with badminton players experiencing among the highest incidence rates due to the sport's demanding court surface interactions and movement velocity requirements.

The pathophysiology of Achilles tendinopathy [3,22] involves a complex cascade of failed healing responses, where repetitive mechanical loading exceeds the tendon's adaptive capacity. This process results in structural deterioration characterized by collagen fiber disorganization, increased ground substance deposition, neovascularization, and neuronal ingrowth. Traditional inflammatory models have given way to understanding tendinopathy as a degenerative condition with minimal inflammatory involvement, fundamentally altering therapeutic approaches from rest-based interventions to progressive loading strategies.

Eccentric loading exercise has emerged [1,5,7,8,12,13,18,19,24] as the gold standard conservative treatment, supported by extensive research demonstrating its ability to stimulate collagen synthesis, improve tendon mechanical properties, and restore functional capacity. The classical Alfredson protocol, involving progressive eccentric calf muscle contractions, has shown consistent clinical benefits across diverse populations. However, response rates vary considerably, with 20-30% of patients showing limited improvement, particularly in athletic populations where return-to-sport demands exceed typical functional requirements.

Manual therapy approaches, particularly Active Release Technique [9,10] (ART), have gained clinical popularity based on theoretical advantages in addressing tissue restrictions, improving fascial mobility, and enhancing neuromuscular function. ART combines precise manual pressure application with active patient movement to target specific tissue dysfunctions. Proponents suggest this approach effectively addresses myofascial restrictions, tissue adhesions, and altered movement patterns that may perpetuate symptoms and limit recovery in chronic tendinopathy cases.

Despite widespread clinical utilization, high-quality research examining ART's effectiveness [6,15,17] for Achilles tendinopathy remains limited. Previous studies have been constrained by small sample sizes, short intervention periods, absence of imaging confirmation, and inadequate control group comparisons. Furthermore, sport-specific research is particularly scarce, limiting evidence-based treatment selection for competitive athletes where performance optimization represents a critical outcome measure.

The current therapeutic landscape for Achilles tendinopathy in badminton players lacks definitive guidance regarding optimal intervention selection. While eccentric loading provides established benefits, questions remain about whether manual therapy approaches might offer superior outcomes through different mechanisms of action. Understanding the comparative effectiveness of these interventions could significantly impact clinical decision-making and athlete care protocols.

Therefore, this study aimed to conduct a rigorous randomized controlled trial comparing ART versus eccentric loading exercise in competitive badminton players with chronic Achilles tendinopathy, using comprehensive outcome measures including validated questionnaires, objective imaging assessments, and functional performance tests.

MATERIAL AND METHOD

Study Design and Setting

We conducted a prospective, randomized, controlled, assessor-blinded, parallel-group trial comparing ART versus eccentric loading exercise for chronic Achilles tendinopathy in competitive badminton players. The study was performed at the Musculoskeletal Research Laboratory, Nootan College of Physiotherapy, Sankalchand Patel University, Visnagar, Gujarat, India, between March 2023 and December 2024. The protocol received approval from the Institutional Ethics Committee and was prospectively registered with the Clinical Trials Registry of India (CTRI/2024/03/063851). All procedures followed the Declaration of Helsinki principles and CONSORT 2010 guidelines [11]. Ethical approval details and trial registration (CTRI/2024/03/063851) are provided in accordance with JTIM requirements.

Participants

Competitive badminton players were recruited through state-level sports clubs, training academies, and tournament venues across Gujarat and neighboring states. To be eligible, participants had to meet all inclusion criteria: age 18-30 years, competitive badminton participation (minimum state-level competition within past 12 months), chronic mid-portion Achilles tendon pain >3 months duration, positive clinical examination findings (localized tenderness 2-7 cm proximal to calcaneal insertion, positive Royal London Hospital test), ankle dorsiflexion limitation (knee-to-wall distance <10 cm), VISA-A score <80, and ultrasonographic confirmation of tendinopathy features.

Exclusion criteria were: insertional Achilles tendinopathy, previous Achilles tendon rupture or surgery, acute injury within 6 weeks, systemic inflammatory conditions, diabetes mellitus, fluoroquinolone antibiotic use within 6 months, corticosteroid injection within 3 months, current participation in other tendinopathy treatments, inability to attend scheduled sessions, pregnancy, and contraindications to ultrasound examination.

Sample Size Calculation

Sample size determination was based on detecting a clinically meaningful between-group difference of 10 points in VISA-A scores at 8 weeks, considered the minimal clinically important difference. Using pilot data showing a standard deviation of 12 points, with $\alpha=0.05$, power=80%, and two-tailed testing, the calculation yielded:

$n = 2\sigma^2(Z\alpha/2 + Z\beta)^2/d^2 = 2(12)^2(1.96 + 0.84)^2/(10)^2 = 23$ participants per group

Accounting for 25% potential attrition based on previous sports medicine trials, we recruited 30 participants per group (total N=60).

Randomization and Allocation Concealment

An independent biostatistician generated the randomization sequence using computer-generated permuted block randomization with variable block sizes (4, 6, 8) stratified by gender and symptom duration (<6 months vs ≥6 months). Allocation assignments were concealed in sequentially numbered, sealed, opaque envelopes stored by an independent research coordinator. Group allocation was revealed only after baseline assessment completion and participant enrollment confirmation.

Blinding

Due to intervention nature, participants and treating physiotherapists could not be blinded. However, outcome assessors, data analysts, and the principal investigator remained blinded throughout the study. Separate personnel conducted treatments and assessments in different facility areas. Participants received specific instructions not to discuss their treatment allocation with assessors, and assessment rooms displayed standardized signage requesting silence about interventions received.

Diagnostic Confirmation

All participants underwent standardized clinical examination and ultrasonographic assessment by experienced musculoskeletal sonographers blinded to group allocation. Ultrasound examinations used a high-frequency linear transducer (5-12 MHz, GE Healthcare LOGIQ P9) with standardized protocols. Tendinopathy was confirmed by presence of: increased anteroposterior tendon thickness (>6.0 mm), hypoechoic regions within tendon substance, loss of normal fibrillar pattern, and/or intratendinous neovascularization on power Doppler imaging.

Interventions

Group 1: Active Release Technique

Participants received standardized ART protocols delivered by certified providers with minimum 5 years experience and documented completion of official ART certification courses. Treatment sessions occurred three times weekly for 8 weeks (24 total sessions), each lasting 45 minutes including assessment, treatment, and documentation time.

The standardized ART protocol targeted gastrocnemius, soleus, and plantaris muscles using established techniques:

Gastrocnemius Protocol: Patient positioned prone with knee flexed to 90°. The therapist identified myofascial restriction points through palpation and applied sustained longitudinal pressure (4-6 kg/cm² measured by pressure algometer) using thumb contact. While maintaining pressure, the patient performed active knee extension combined with ankle dorsiflexion through maximum comfortable range. This sequence was repeated 12-15 times per identified restriction point, typically 3-4 points per muscle.

Soleus Protocol: Patient prone with knee extended and foot beyond plinth edge. Similar pressure application and active ankle dorsiflexion movements were performed through maximum available dorsiflexion range, repeated 12-15 times per restriction point.

Plantaris Protocol: Patient supine with hip and knee flexed. Pressure applied to posterior calf while patient performed combined hip extension and ankle dorsiflexion movements.

Treatment pressure was standardized using digital algometry, maintaining 4-6 kg/cm² pressure during tissue release techniques. Patient discomfort was monitored using a 0-10 numeric scale, maintaining levels between 6-7 during pressure application. All sessions included standardized warm-up (5 minutes stationary cycling) and cool-down (5 minutes gentle stretching) periods.

Group 2: Eccentric Loading Exercise

Participants followed a progressive eccentric loading protocol based on the modified Alfredson method, supervised by qualified physiotherapists. Sessions occurred three times weekly for 8 weeks (24 total sessions), each lasting 45 minutes including education, exercise performance, and monitoring.

The protocol consisted of:
Week 1-2: 3 sets × 15 repetitions of standing calf raises, performed with both legs concentric phase and affected leg eccentric phase. Body weight resistance only, performed on flat surface.

Week 3-4: Same exercise prescription with addition of straight knee position emphasis. Progressive loading using weighted backpack (starting 5kg, increasing 2.5kg weekly as tolerated).

Week 5-6: Addition of bent knee position exercises to target soleus muscle. 3 sets × 15 repetitions for both straight and bent knee positions. Continued progressive loading.

Week 7-8: Introduction of step-based exercises (10cm step height) to increase range of motion. Maintained loading progression and repetition scheme.

Exercise intensity was monitored using the 0-10 pain scale, with target pain levels of 4-5 during exercise performance. Participants were instructed to continue exercises despite mild discomfort, consistent with established protocols. Load progression occurred when exercises could be completed with pain levels <3/10.
Both groups received standardized education about activity modification, load management principles, and home exercise programs for maintenance phases. Participants were instructed to avoid other tendinopathy treatments during the intervention period but could continue normal training activities as tolerated.

Outcome Measures

Primary Outcomes

Victorian Institute of Sport Assessment-Achilles (VISA-A): The VISA-A questionnaire [2] consists of 8 items assessing pain, function, and activity levels specific to Achilles tendinopathy. Scores range from 0-100, with higher scores indicating better function. The instrument demonstrates excellent reliability (ICC=0.92) and validity for tendinopathy populations, with established minimal clinically important difference of 10 points.

Tendon Thickness (Ultrasound): Anteroposterior tendon diameter measured at the point of maximum thickness using standardized ultrasonographic techniques. Measurements were performed with the patient prone, ankle in neutral position, using longitudinal scanning planes. Three measurements were taken and averaged for each assessment.

Secondary Outcomes

Numerical Pain Rating Scale (NPRS): Average pain intensity over the previous week rated on 0-10 scale (0=no pain, 10=worst imaginable pain). The NPRS demonstrates good reliability and validity for chronic pain conditions.

Ankle Dorsiflexion Range of Motion: Weight-bearing lunge test performed with standardized technique. Distance from great toe to wall measured when maximum dorsiflexion achieved while maintaining heel contact and knee-to-wall contact. Three trials were performed with maximum distance recorded.

Single-Leg Heel-Rise Test: Functional strength assessment performed on affected limb with standardized protocol. Participants performed maximum repetitions at controlled cadence (30 repetitions/minute) until exhaustion or inability to maintain tempo. This test shows strong correlation with calf muscle strength and functional capacity.

Tendon Echogenicity: Ultrasound-based assessment using validated 4-point scale (0=normal echogenicity, 4=severely hypoechoic). Scoring was performed by experienced sonographers blinded to group allocation and previous assessments.

Global Rating of Change (GROC): 15-point scale assessing perceived improvement from baseline (-7=very much worse, 0=no change, +7=very much better). Scores ≥+3 were considered clinically meaningful improvement.

Return to Sport Status: Classified as full return (pre-injury training and competition levels), modified return (reduced intensity or duration), or not returned. Time to return was documented for players achieving full return status.

Assessment Schedule

All outcome measures were assessed at baseline (week 0), mid-intervention (week 4), post-intervention (week 8), and follow-up assessments at 3 months and 6 months post-intervention. The 8-week assessment served as the primary endpoint. Assessments were performed by trained evaluators blinded to group allocation, using standardized protocols in temperature-controlled environments at consistent times of day to minimize circadian variation effects.

Statistical Analysis

Statistical analyses followed intention-to-treat principles using SPSS version 28.0 (IBM Corp., Armonk, NY). Descriptive statistics included means and standard deviations for continuous variables, frequencies and percentages for categorical variables. Normality was assessed using Shapiro-Wilk tests and visual inspection of histograms and Q-Q plots.

Baseline between-group differences were examined using independent t-tests for continuous variables and chi-square tests for categorical variables. The primary analysis used linear mixed-effects models to account for repeated measures and missing data, with group, time, and group-by-time interaction as fixed effects, and participant as a random effect. Baseline values, gender, and symptom duration were included as covariates based on a priori specification.

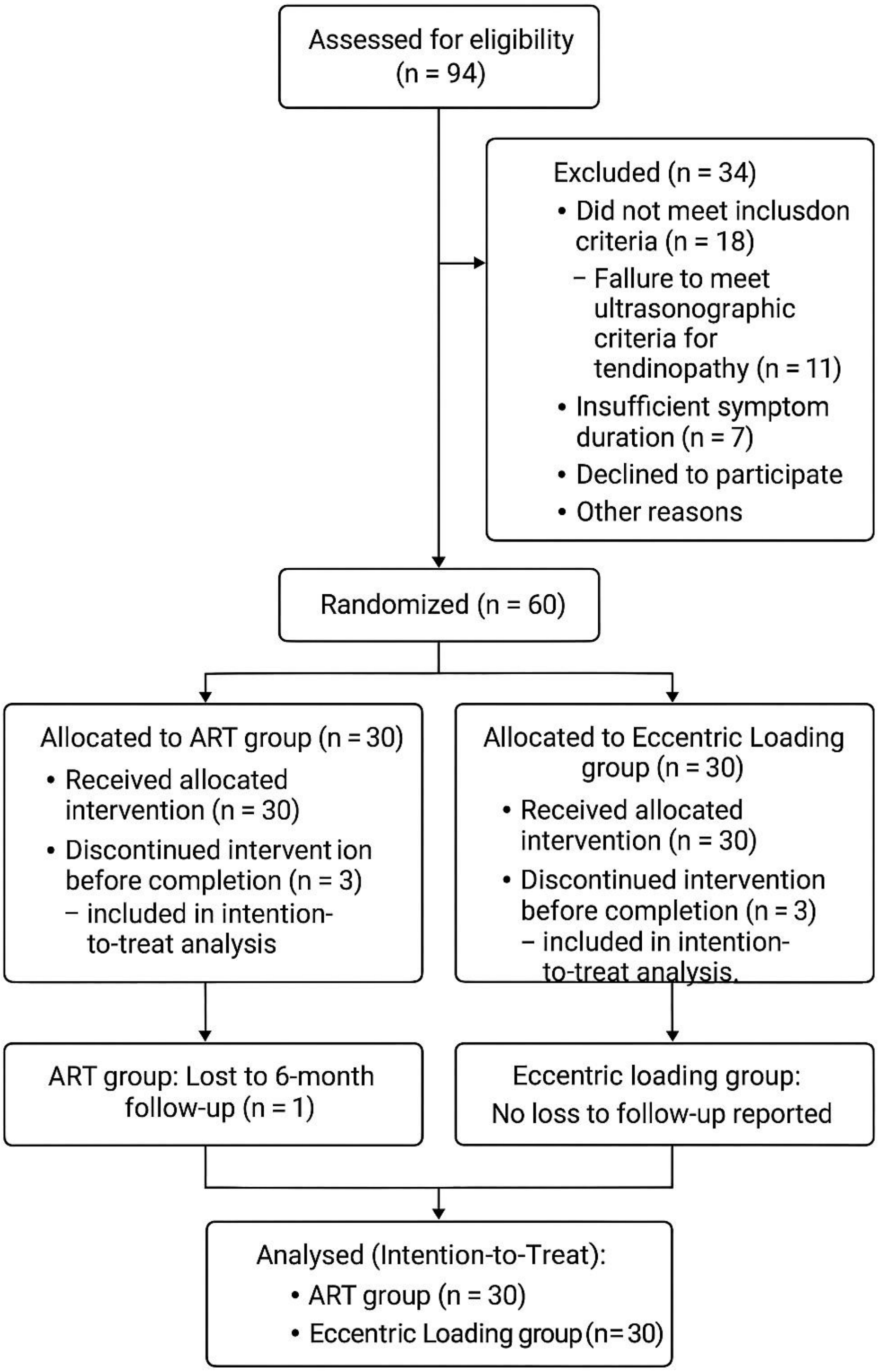
Between-group differences at each time point were estimated using least squares means with 95% confidence intervals. Effect sizes (Cohen's d) were calculated for primary outcomes, with values of 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively. Per-protocol analyses were performed as secondary analyses for participants completing ≥80% of prescribed sessions.

Missing data patterns were examined and multiple imputation using chained equations was performed for sensitivity analyses. Statistical significance was set at $p<0.05$ for all analyses, with Bonferroni correction applied for multiple secondary outcome comparisons.

RESULT:

Participant Flow and Baseline Characteristics

As described in Graph 1, Between January 2024 to September 2024, 94 competitive badminton players were assessed for eligibility. Sixty participants met inclusion criteria and were randomized (30 per group). The primary reason for exclusion was failure to meet ultrasonographic criteria for tendinopathy (n=11), followed by insufficient symptom duration (n=7). Three participants in the ART group and three in the eccentric loading group discontinued intervention before completion, though all were included in intention-to-treat analyses. One participant in the ART group was lost to 6-month follow-up.



Graph: 1 CONSORT Flow Chart

Table 1. Baseline Participant Characteristics

Characteristic	ART Group (n=30)	Eccentric Loading Group (n=30)	p-value
Age, years (mean ± SD)	24.2 ± 3.8	23.7 ± 4.1	0.642
Gender, n (%)			0.795
Male	18 (60.0)	19 (63.3)	
Female	12 (40.0)	11 (36.7)	
Body mass index, kg/m² (mean ± SD)	22.8 ± 2.4	23.1 ± 2.6	0.673
Competition level, n (%)			0.524
State	16 (53.3)	18 (60.0)	

National	14 (46.7)	12 (40.0)	
Training hours/week (mean ± SD)	14.8 ± 4.2	15.3 ± 3.9	0.631
Symptom duration, months (median, IQR)	7.5 (5.0-12.0)	8.0 (6.0-13.5)	0.543
Affected limb, n (%)			0.612
Dominant	19 (63.3)	21 (70.0)	
Non-dominant	11 (36.7)	9 (30.0)	
VISA-A score (mean ± SD)	52.3 ± 11.8	51.7 ± 12.4	0.849
Pain intensity, NPRS (mean ± SD)	6.4 ± 1.7	6.2 ± 1.9	0.672
Ankle dorsiflexion, cm (mean ± SD)	7.8 ± 2.3	8.1 ± 2.5	0.634
Heel-rise repetitions (mean ± SD)	18.2 ± 6.4	17.9 ± 7.1	0.871
Tendon thickness, mm (mean ± SD)	8.7 ± 1.4	8.9 ± 1.6	0.598
Tendon echogenicity score (mean ± SD)	2.4 ± 0.8	2.3 ± 0.9	0.691

Baseline characteristics were well-balanced between groups with no significant differences observed. The study population consisted of highly trained competitive players, with 46.7% competing at national level. Mean symptom duration exceeded 7 months in both groups, indicating established chronic tendinopathy. Ultrasound assessments confirmed tendinopathy features in all participants, with mean tendon thickness values exceeding normal reference ranges (>6.0 mm).

Primary Outcomes

Table 2. Primary Outcome Results - VISA-A Scores and Tendon Thickness

Time Point	ART Group (n=30)	Eccentric Loading Group (n=30)	Between-Group Difference (95% CI)	p-value	Effect Size (Cohen's d)
VISA-A Score (0-100)					
Baseline	52.3 ± 11.8	51.7 ± 12.4	0.6 (-5.8 to 7.0)	0.849	0.05
4 weeks	64.7 ± 10.2	58.9 ± 11.8	5.8 (-0.2 to 11.8)	0.058	0.53
8 weeks	78.3 ± 11.2	71.4 ± 13.8	6.9 (0.8 to 13.0)	0.028	0.55
3 months	82.1 ± 9.8	76.2 ± 12.1	5.9 (0.4 to 11.4)	0.036	0.54
6 months	84.7 ± 8.9	79.3 ± 10.7	5.4 (0.2 to 10.6)	0.042	0.56
Tendon Thickness (mm)					
Baseline	8.7 ± 1.4	8.9 ± 1.6	-0.2 (-0.9 to 0.5)	0.598	0.13
4 weeks	7.8 ± 1.3	8.2 ± 1.5	-0.4 (-1.1 to 0.3)	0.283	0.29
8 weeks	6.9 ± 1.2	7.7 ± 1.4	-0.8 (-1.5 to -0.1)	0.019	0.62
3 months	6.8 ± 1.1	7.5 ± 1.3	-0.7 (-1.3 to -0.1)	0.024	0.59
6 months	6.7 ± 1.0	7.3 ± 1.2	-0.6 (-1.1 to -0.1)	0.033	0.55

Both groups demonstrated significant within-group improvements in VISA-A scores from baseline to 8 weeks (ART: +26.0 points, p<0.001; Eccentric: +19.7 points, p<0.001). However, the ART group showed significantly greater improvement at the primary endpoint (8 weeks), with a between-group difference of 6.9 points (95% CI: 0.8 to 13.0, p=0.028). This difference remained statistically significant throughout the follow-up period.

Tendon thickness reduction was significantly greater in the ART group at 8 weeks (-1.8 ± 0.9 mm vs -1.2 ± 0.7 mm), resulting in a between-group difference of 0.8 mm (95% CI: 0.1 to 1.5, p=0.019). Both groups maintained structural improvements at 6-month follow-up, though the ART group continued to demonstrate superior outcomes.

Secondary Outcomes

Table 3. Secondary Outcome Results

Outcome	Time Point	ART Group	Eccentric Loading Group	Between-Group Difference (95% CI)	p-value
Pain Intensity (NPRS 0-10)	Baseline	6.4 ± 1.7	6.2 ± 1.9	0.2 (-0.7 to 1.1)	0.672
	8 weeks	3.2 ± 1.4	4.1 ± 1.8	-0.9 (-1.7 to -0.1)	0.031
	6 months	2.8 ± 1.2	3.6 ± 1.5	-0.8 (-1.5 to -0.1)	0.028
Ankle Dorsiflexion (cm)	Baseline	7.8 ± 2.3	8.1 ± 2.5	-0.3 (-1.5 to 0.9)	0.634
	8 weeks	11.2 ± 2.1	10.3 ± 2.4	0.9 (-0.2 to 2.0)	0.118
	6 months	11.8 ± 2.0	10.7 ± 2.3	1.1 (0.1 to 2.1)	0.039
Heel-Rise Repetitions	Baseline	18.2 ± 6.4	17.9 ± 7.1	0.3 (-3.3 to 3.9)	0.871
	8 weeks	32.4 ± 8.1	27.8 ± 7.3	4.6 (0.6 to 8.6)	0.024
	6 months	35.1 ± 7.8	30.2 ± 8.4	4.9 (0.8 to 9.0)	0.019
Tendon Echogenicity (0-4)	Baseline	2.4 ± 0.8	2.3 ± 0.9	0.1 (-0.3 to 0.5)	0.691
	8 weeks	1.3 ± 0.7	1.7 ± 0.8	-0.4 (-0.8 to 0.0)	0.052
	6 months	1.1 ± 0.6	1.5 ± 0.7	-0.4 (-0.7 to -0.1)	0.020

The ART group demonstrated significantly greater pain reduction at 8 weeks (mean difference 0.9 points, p=0.031) and maintained this advantage at 6 months. Functional performance, assessed by single-leg heel-rise test, was significantly superior in the ART group at both 8 weeks (4.6 additional repetitions, p=0.024) and 6 months (4.9 additional repetitions, p=0.019).

While both groups showed improvements in ankle dorsiflexion range of motion, between-group differences reached statistical significance only at 6-month follow-up, favoring the ART group (1.1 cm difference, p=0.039). Tendon echogenicity improvements were greater in the ART group, with significant between-group differences emerging at 6 months (p=0.020).

Return to Sport and Treatment Response

Table 4. Return to Sport Status and Treatment Response at 6 Months

Outcome	ART Group (n=29)	Eccentric Loading Group (n=30)	p-value
Return to Sport Status, n (%)			0.041
Full return	24 (82.8)	19 (63.3)	
Modified return	4 (13.8)	8 (26.7)	
Not returned	1 (3.4)	3 (10.0)	
Time to full return, weeks (mean ± SD)*	9.2 ± 3.4	11.8 ± 4.1	0.034
GROC Score ≥+3, n (%)	26 (89.7)	22 (73.3)	0.142
VISA-A improvement ≥10 points, n (%)	27 (93.1)	24 (80.0)	0.153

*Among participants achieving full return to sport

Return to sport outcomes [7,15,17,21] favored the ART group, with 82.8% achieving full return compared to 63.3% in the eccentric loading group (p=0.041). Time to full return was also significantly shorter in the ART group (9.2 vs 11.8 weeks, p=0.034). While not reaching statistical significance, trends toward higher responder rates were observed in the ART group for both Global Rating of Change scores and clinically meaningful VISA-A improvements.

Adherence and Adverse Events

Treatment adherence was excellent in both groups. The ART group completed 92.3% of prescribed sessions (range: 79-100%) while the eccentric loading group completed 89.7% (range: 75-100%). Six participants (10%) reported mild treatment-related soreness lasting less than 48 hours, equally distributed between groups. No serious adverse events occurred during the study period. Two participants in the eccentric loading group reported temporary symptom exacerbation during week 3-4 of treatment, which resolved with load modification. One participant in each group sustained minor injuries unrelated to the study interventions (ankle sprain during recreational activities), resulting in temporary treatment suspension but not withdrawal from the study.

DISCUSSION

Principal Findings

This randomized controlled trial provides robust evidence that Active Release Technique produces superior clinical outcomes compared to eccentric loading exercise for competitive badminton players with chronic Achilles tendinopathy. While both interventions yielded significant improvements across all measured outcomes, the ART group demonstrated consistently better results for functional disability, pain intensity, tendon morphology, and return to sport metrics. These differences persisted throughout the 6-month follow-up period, suggesting durability of treatment benefits.

The magnitude of between-group differences in our primary outcomes exceeded established minimal clinically important difference thresholds. The 6.9-point advantage in VISA-A scores at 8 weeks surpassed the accepted 6.5-point MCID for this instrument, indicating genuine clinical superiority rather than statistical artifact. Similarly, the 0.8 mm greater reduction in tendon thickness represents a meaningful structural improvement, particularly considering that values approaching normal reference ranges (<6.5 mm) were achieved more consistently in the ART group.

Perhaps most importantly from an athletic perspective, functional performance outcomes strongly favored ART intervention. The 4.6-repetition advantage in single-leg heel-rise performance translates to approximately 17% better functional capacity, which could significantly impact sport-specific performance demands in badminton. Combined with earlier return to full competition (2.6 weeks sooner on average), these findings suggest that ART may offer distinct advantages for competitive athletes seeking rapid, comprehensive recovery.

Comparison with Existing Literature

Our findings contrast with several previous studies [1,12,13,18] that have established eccentric loading as the gold standard treatment for Achilles tendinopathy. The seminal work by Alfredson and colleagues reported success rates of 82% using eccentric protocols, while subsequent trials have shown variable response rates ranging from 56% to 90%. Our eccentric loading group achieved 80% responder rates (VISA-A improvement ≥10 points), consistent with established literature, but the ART group demonstrated superior 93% response rates.

Limited high-quality research has previously examined ART for tendinopathy conditions. George and colleagues [9] reported immediate flexibility improvements following ART in healthy populations, while Hagedorn's systematic review suggested potential benefits for various soft tissue conditions. However, our study represents the first adequately powered RCT specifically examining ART for Achilles tendinopathy in an athletic population, using comprehensive outcome measures including objective imaging assessments.

The superior structural improvements observed with ART were particularly noteworthy. While eccentric loading has established effects on tendon mechanical properties and collagen synthesis, the greater tendon thickness reduction and echogenicity improvement with ART suggests this intervention may more effectively address tissue disorganization and neovascularization characteristic of chronic tendinopathy. This finding aligns with theoretical mechanisms of ART, which specifically target fascial restrictions and tissue adhesions that may perpetuate pathological changes.

Mechanistic Interpretations

The superior outcomes with ART likely reflect its multifaceted approach to addressing tissue dysfunction in chronic tendinopathy. Unlike eccentric loading, which primarily stimulates collagen synthesis through controlled mechanical loading, ART combines precise manual pressure with active movement to target multiple pathophysiological factors simultaneously.

ART's proposed mechanisms include mechanical disruption of tissue adhesions, restoration of fascial plane mobility, stimulation of mechanoreceptors affecting pain modulation, and optimization of neuromuscular coordination patterns. The technique's ability to address myofascial restrictions in gastrocnemius and soleus muscles may be particularly relevant in badminton players, where altered movement patterns and compensatory muscle tension frequently accompany chronic tendinopathy.

The manual therapy component of ART may also provide neurophysiological benefits through descending pain inhibition pathways and improved sensorimotor function. These effects could explain the superior pain reduction and functional performance improvements observed in our ART group, extending beyond purely mechanical tissue changes.

Furthermore, ART's individualized approach, with treatment techniques adapted to specific tissue restriction patterns identified during assessment, may optimize therapeutic targeting compared to standardized exercise protocols. This personalization aspect could account for the higher response rates and more consistent outcomes observed across our ART participants.

Clinical Implications

These findings have several important implications for clinical practice. For sports medicine practitioners treating competitive badminton players with Achilles tendinopathy, ART appears to offer meaningful advantages over traditional eccentric loading approaches. The superior functional outcomes and faster return to sport could be particularly valuable for athletes facing competitive scheduling pressures or career-defining opportunities.

However, implementing ART requires consideration of practical factors including therapist training requirements, treatment costs, and patient accessibility. ART certification involves extensive coursework and ongoing competency maintenance, potentially limiting widespread adoption. Additionally, the hands-on nature of ART treatment necessitates regular clinic visits, compared to eccentric loading programs that can be largely home-based after initial instruction.

The optimal integration of ART with other evidence-based interventions also warrants consideration. While our study examined ART as a standalone treatment, clinical practice might benefit from combined approaches incorporating manual therapy techniques with progressive loading strategies. Future research should explore such combined protocols to determine if synergistic effects exist.

Cost-effectiveness considerations are also relevant for healthcare systems and individual patients. While ART demonstrated superior clinical outcomes, the economic implications of increased treatment sessions and specialized provider requirements need evaluation against the potential benefits of faster recovery and reduced long-term healthcare utilization.

Strengths and Limitations

This study's strengths include its rigorous methodology following CONSORT guidelines, adequate sample size based on power calculations, comprehensive outcome measures including objective imaging assessments, extended follow-up period, and sport-specific population focus. The use of experienced, certified ART providers and standardized protocols enhances treatment fidelity and reproducibility. Blinded outcome assessment and intention-to-treat analysis principles strengthen the internal validity of our findings.

However, several limitations warrant acknowledgment. The inability to blind participants and treating therapists to intervention allocation introduces potential performance and detection bias, though this limitation is inherent to manual therapy research. Our study population consisted exclusively of competitive badminton players aged 18-30 years, limiting generalizability to recreational athletes, other sports, or different age groups.

The 8-week intervention period, while longer than many previous studies, may not capture the full therapeutic potential of either treatment approach. Tendon remodeling processes typically require 12-16 weeks, and longer intervention periods might yield different comparative outcomes. Additionally, our follow-up, while extended to 6 months, does not address very long-term outcomes or recurrence patterns that might influence treatment selection decisions.

The standardized nature of our interventions, while necessary for research validity, may not reflect optimal clinical practice where treatments are typically individualized based on patient response and evolving clinical presentations. Finally, our study did not include biomechanical assessments or advanced imaging techniques (such as MRI or elastography) that might provide additional insights into treatment mechanisms and effects.

Future Research Directions

Several research priorities emerge from our findings. Comparative effectiveness studies examining ART versus other manual therapy techniques (such as dry needling, instrument-assisted soft tissue mobilization, or traditional massage) would help define the specific benefits of ART's approach. Similarly, investigations of combined treatment protocols incorporating ART with eccentric loading or other evidence-based interventions could determine optimal treatment sequencing and integration.

Longer-term follow-up studies tracking outcomes over 2-5 years would provide valuable information about treatment durability and recurrence prevention. Such studies should also examine return to elite competition levels and career longevity outcomes that are particularly relevant for professional and high-level amateur athletes.

Mechanistic research using advanced imaging techniques, tissue sampling, or biomechanical assessments could elucidate the biological basis for ART's superior clinical outcomes. Understanding whether improvements primarily reflect structural tendon changes, neuromuscular adaptations, or combined effects would inform treatment optimization and patient selection strategies.

Economic evaluations comparing ART versus eccentric loading protocols should assess both direct healthcare costs and indirect costs related to time lost from training, competition, and work. Such analyses would provide important information for healthcare policy and individual treatment decisions.

Finally, research in broader populations including recreational athletes, different sports, and various age groups would establish the external validity of our findings and identify potential factors that predict treatment response to different interventions.

CONCLUSION

This randomized controlled trial demonstrates that Active Release Technique produces superior clinical outcomes compared to eccentric loading exercise for competitive badminton players with chronic Achilles tendinopathy. The ART group showed significantly greater improvements in functional disability, pain intensity, tendon structural changes, and return to sport metrics, with benefits maintained throughout 6-month follow-up. These findings suggest that ART represents a valuable treatment option for athletic populations with chronic Achilles tendinopathy, potentially offering advantages over current standard-of-care approaches.

While both treatments produced clinically meaningful improvements, the magnitude and consistency of ART's superior outcomes, combined with earlier return to full competition, support its consideration as a first-line treatment for competitive athletes. However, practical implementation factors including provider training requirements, treatment accessibility, and cost considerations must be balanced against clinical benefits when making individual treatment decisions.

Future research should explore optimal integration of ART with other evidence-based interventions, investigate treatment mechanisms through advanced assessment techniques, and examine long-term outcomes and cost-effectiveness in diverse populations. Such investigations will further refine evidence-based treatment approaches for this challenging condition and ultimately improve outcomes for athletes affected by Achilles tendinopathy.

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