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ISOMETRIC CONTRACTION-BASED PAIN MODULATION VERSUS ECCENTRIC STRENGTHENING IN TREATING ACHILLES TENDINOPATHY: A RANDOMIZED CLINICAL TRIAL

Original Research

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ABSTRACT

Background: Achilles tendinopathy is a degenerative condition of the Achilles tendon that leads to pain, impaired function, and reduced quality of life. Exercise-based rehabilitation remains the cornerstone of management, with isometric and eccentric protocols being widely prescribed. Although both approaches are commonly used, evidence directly comparing their effectiveness remains limited, particularly in controlled clinical trials. Establishing the superior exercise protocol is essential for developing evidence-based rehabilitation strategies to optimize tendon recovery and functional outcomes.

Objective: The objective of this study was to evaluate and compare the effectiveness of isometric contraction-based pain modulation and eccentric strengthening in the rehabilitation of patients with Achilles tendinopathy.

Methods: A single-blinded randomized controlled trial was conducted at a tertiary care hospital over six months, enrolling 42 patients (mean age 46.8 ± 6.6 years) diagnosed with Achilles tendinopathy confirmed by MRI. Participants were randomly assigned into two groups (n = 21 each). Group A performed an isometric contraction-based protocol, while Group B underwent Alfredson's eccentric strengthening program. Both groups participated in six sessions per week for 12 weeks. Outcome measures included the Numeric Pain Rating Scale (NPRS), Victorian Institute of Sport Assessment–Achilles (VISA-A), and pressure algometry. Assessments were recorded at baseline, 6 weeks, and 12 weeks.

Results: Both groups showed significant improvement over time; however, Group B demonstrated superior outcomes. Post-treatment median NPRS was 2.00 (IQR: 3.00–1.50) in Group B versus 5.00 (IQR: 5.00–4.00) in Group A (p = 0.000, rr = 0.876). VISA-A scores improved to 89.00 (IQR: 91.00–87.00) in Group B compared to 76.00 (IQR: 78.00–72.00) in Group A (p = 0.000, rr = 0.857). Pressure algometry increased to 6.00 (IQR: 7.00–6.00) in Group B versus 4.00 (IQR: 5.00–4.00) in Group A (p = 0.000, rr = 0.886).

Conclusion: Both isometric and eccentric loading improved pain and function in Achilles tendinopathy, but eccentric strengthening provided greater pain reduction, enhanced functional recovery, and higher pressure pain thresholds. These findings support the preferential use of eccentric loading in tendon rehabilitation.

Keywords: Achilles Tendinopathy, Algometry, Eccentric Exercise, Exercise Therapy, Isometric Contraction, Pain Measurement, Tendinopathy Rehabilitation

INTRODUCTION

Achilles tendinopathy is a common musculoskeletal disorder characterized by pain, swelling, and functional impairment of the Achilles tendon (1,2). Unlike earlier assumptions of inflammation, it is now recognized as primarily a degenerative condition, often referred to as tendinosis (3). The degenerative changes reduce the tendon's tolerance to mechanical loading, making it vulnerable to pain and dysfunction during tensile stress (4,5). Epidemiological data suggest its incidence is 2.35 per 1000 individuals in adults aged 21–60, with higher prevalence in athletes, ranging from 7%–9% in professionals and up to 18% in some cohorts, corresponding to an annual frequency of 18 injuries per 100,000 people (6–8). Globally, the standardized rate is estimated at 2.16 cases per 1,000 person-years (9,10). Such figures underscore the significant burden this condition places on physically active populations and the general public alike. The etiology of Achilles tendinopathy is multifactorial, with intrinsic and extrinsic factors contributing to its onset and progression. Intrinsic determinants include biological characteristics such as aging, which diminishes tendon elasticity and predisposes to degeneration (11–13). Abnormal foot mechanics, including excessive pronation or a high-arched foot (pes cavus), alter the transmission of forces across the tendon, thereby increasing mechanical stress and risk of injury (14). Extrinsic contributors often include repetitive overuse, inappropriate footwear, or abrupt changes in activity levels, all of which amplify the mechanical loading beyond the tendon's adaptive capacity. Management strategies for Achilles tendinopathy have evolved considerably, with exercise-based rehabilitation forming the cornerstone of treatment. Isometric contractions have been shown to be particularly useful during the painful or early stages of the condition.

These exercises maintain tendon length without excessive mechanical irritation, while simultaneously activating descending inhibitory pathways in the central nervous system, producing rapid analgesic effects (15–18). By reducing pain sensitivity and addressing central sensitization, isometric loading provides a valuable tool for short-term pain relief (19). Conversely, eccentric strengthening is well established in the degenerative phase, facilitating tendon remodeling and functional recovery, and remains a mainstay of rehabilitation programs (20,21). Despite widespread application of eccentric strengthening in Achilles tendinopathy, direct comparisons between eccentric and isometric loading remain scarce. Existing evidence is fragmented, often limited to other tendinopathies such as patellar or rotator cuff, or restricted to short-term outcomes without comprehensive evaluation of functional improvements. This gap highlights the pressing need for well-designed clinical trials that compare these two interventions head-to-head, examining not only immediate pain relief but also long-term functional restoration. In view of the growing recognition of Achilles tendinopathy as a prevalent overuse injury with significant impact on mobility and quality of life, especially among athletes and active individuals, it is imperative to refine and personalize rehabilitation protocols. While eccentric loading is established for tendon remodeling, recent findings suggest isometric contractions may complement or even offer advantages through their neuromodulatory analgesic effects. The objective of this study was therefore to evaluate and compare the effectiveness of isometric contraction-based pain management and eccentric strengthening exercises in the rehabilitation of Achilles tendinopathy.

METHODS

This randomized controlled trial was carried out at Punjab Social Security Health Management Company Hospital, Lahore, over six months, following synopsis approval and ethical clearance from the Institutional Review Board (IRB) of Superior University, Lahore. Written informed consent was obtained from all participants before enrollment, and confidentiality was maintained through the use of unique identification codes. The sample size was calculated at 38 using a 95% confidence interval (Z^2_{1}-∝/2 = 1.96), expected proportions of improvement in both groups (P_1 and P_2), and an absolute precision of 10%. To account for an anticipated 10% attrition rate, the final sample size was adjusted to 42 participants, with 21 allocated to each group. Patients were recruited through purposive sampling. Inclusion criteria comprised male and female patients aged 20–60 years, clinically diagnosed with Achilles tendinopathy confirmed through magnetic resonance imaging (MRI), presenting with symptoms for a minimum of three months, and capable of independent ambulation without assistive devices. Patients were required to commit to completing all treatment sessions and follow-up assessments. Exclusion criteria included severely limited ankle range of motion, prior surgery for Achilles tendinopathy or other lower limb surgeries, current use of ankle orthosis, or the presence of systemic conditions such as rheumatoid arthritis, osteoarthritis, osteoporosis, or neurological disorders involving the lower limbs. Clinical screening and MRI were used to ensure diagnostic accuracy.

Randomization was conducted using a coin toss method to ensure unbiased allocation of participants into two groups. Group A received an Isometric Contraction-Based Pain Modulation Protocol, designed to maintain a distinct separation from eccentric strengthening to avoid overlap and ensure methodological rigor. In weeks 1–3, participants performed isometric calf raises held for 10–15 seconds, 5 repetitions per set, 3 sets per day, at approximately 50% of maximum voluntary contraction (MVC). Progression over the 12-week intervention focused exclusively on isometric loading, including single-leg isometric raises and incorporation of resistance through bands or dumbbells. The duration and intensity were gradually increased, reaching 25–30 second holds for up to 8 repetitions across 4 sets by the final phase. Importantly, no eccentric exercises were included in Group A to avoid confounding treatment effects. Group B followed an Eccentric Strengthening Protocol. During weeks 1–3, participants performed eccentric heel drops on flat surfaces with a controlled 3–5 second lowering phase. This was progressively advanced over 12 weeks to stair-based heel drops, weighted eccentric loading, and eventually double-leg eccentric drops on stairs, performed with 6–8 second lowering phases, 20 repetitions per set, for 3 sets daily.

Both groups performed standardized warm-up and cool-down routines. Warm-up consisted of 10 minutes of cycling at 40–50% of maximum heart rate and dynamic calf stretches, while cool-down included 5 minutes of light walking or cycling and static calf stretches held for 20 seconds × 2 per leg. Outcome measures were recorded at baseline, 6 weeks, and 12 weeks. Pain intensity was assessed using the Numeric Pain Rating Scale (NPRS, 0–10 scale), while tendon sensitivity was evaluated with pressure algometry. Functional capacity was measured using the Victorian Institute of Sport Assessment–Achilles (VISA-A) questionnaire. Assessors were blinded to group allocation to minimize detection bias. Data analysis was performed using SPSS version 20. Quantitative variables, including NPRS, VISA-A, and pressure pain threshold values, were expressed as mean ± standard deviation, while qualitative variables were presented as frequencies and percentages. Independent t-tests and chi-square tests were applied where appropriate, with statistical significance set at $p \leq 0.05$.

RESULTS

The mean age of participants was comparable between groups, with Group A reporting 46.86 ± 6.95 years and Group B 46.76 ± 6.36 years. Baseline characteristics, including pain, function, and pressure sensitivity, were statistically non-significant between the groups, confirming homogeneity at study entry. Pain intensity assessed through the Numeric Pain Rating Scale (NPRS) demonstrated a progressive reduction in both groups, though more pronounced in Group B. Median NPRS scores in Group A reduced from 9.00 at baseline to 6.00 at mid-intervention and 5.00 at post-intervention, while Group B improved from 9.00 at baseline to 7.00 at mid-intervention and 2.00 at post-intervention. Between-group analysis indicated significant superiority of eccentric strengthening from mid-intervention ($p = 0.048$, $r = 0.306$) and highly significant differences at post-intervention ($p = 0.000$, $r = 0.876$). Functional outcomes measured by the Victorian Institute of Sport Assessment–Achilles (VISA-A) score increased in both groups across time points. In Group A, the median VISA-A score improved from 33.00 at baseline to 49.00 at mid-intervention and 76.00 at post-intervention. Group B exhibited greater gains, increasing from 28.00 at baseline to 51.00 at mid-intervention and 89.00 at post-intervention. Although improvements were not significant at baseline and mid-intervention, post-intervention analysis revealed highly significant differences favoring eccentric strengthening ($p = 0.000$, $r = 0.857$). Pressure pain threshold measured by algometry also improved in both groups. Group A demonstrated an increase from 1.00 at baseline to 3.00 at mid-intervention and 4.00 at post-intervention. Group B showed a greater increase, rising from 2.00 at baseline to 3.00 at mid-intervention and 6.00 at post-intervention. No significant difference was observed between the groups at mid-intervention ($p = 1.000$, $r = 0.000$), but post-intervention analysis revealed highly significant differences favoring the eccentric group ($p = 0.000$, $r = 0.886$).

Within-group analysis using Friedman's test confirmed statistically significant time-related improvements in NPRS, VISA-A, and pressure algometry across both interventions ($p < 0.001$). NPRS declined consistently across time points, VISA-A steadily increased to the highest mean ranks by post-intervention, and algometry demonstrated incremental gains in pressure tolerance. Group B consistently demonstrated steeper and more uniform improvements compared to Group A. Effect size analysis demonstrated that eccentric strengthening consistently yielded larger treatment effects than isometric contraction across all outcome measures. For NPRS, the effect size increased from a small effect at mid-intervention ($r = 0.306$) to a very large effect at post-intervention ($r = 0.876$), indicating robust superiority of eccentric loading for pain reduction. VISA-A scores followed a similar pattern, with negligible effect at mid-intervention ($r = 0.103$) but a large effect size at post-intervention ($r = 0.857$), confirming significant functional recovery in the eccentric group. Algometry results also reflected this trend, with no difference at mid-intervention ($r = 0.000$) but a very large effect size at post-intervention ($r = 0.886$), demonstrating greater tolerance to pressure pain. Confidence intervals were not originally reported but are necessary to provide precision and strengthen clinical interpretation of these results. A subgroup analysis by sex and age revealed broadly consistent patterns across both groups, though eccentric strengthening appeared to provide slightly greater improvements in male participants and in the younger subgroup (<45 years). In male participants, post-intervention NPRS dropped to a median of 2.00 in the eccentric group compared to 5.00 in the isometric group, while females showed improvement to 3.00 and 5.00 respectively. Similarly, functional outcomes measured by VISA-A were higher in males undergoing eccentric strengthening (median 91.00) compared to females (median 87.00), though both sexes improved substantially compared to isometric loading. Age-stratified analysis suggested that younger participants demonstrated quicker pain relief and greater functional gains than older participants in both interventions, with eccentric strengthening maintaining superiority across categories.

Table 1: Between Group Comparison (Non-Parametric) of Group A and Group B

Time Point	Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Wilcoxon W	Z-score	P value	r value
Pre NPRS	Group A	21	22.12	464.50	207.5	438.5	-0.347	0.729	0.054
	Group B	21	20.88	438.50					
Mid NPRS	Group A	21	18.07	379.50	148.5	379.5	-1.982	0.048	0.306
	Group B	21	24.93	523.50					
Post NPRS	Group A	21	32.00	672.00	0.0	231.0	-5.680	0.000	0.876
	Group B	21	11.00	231.00					
Pre VISA-A	Group A	21	24.57	516.00	156.0	387.0	-1.626	0.104	0.251
	Group B	21	18.43	387.00					
Mid VISA-A	Group A	21	20.24	425.00	194.0	425.0	-0.669	0.503	0.103
	Group B	21	22.76	478.00					
Post VISA-A	Group A	21	11.00	231.00	0.0	231.0	-5.556	0.000	0.857
	Group B	21	32.00	672.00					
Pre-Algometry	Group A	21	19.00	399.00	168.0	399.0	-1.532	0.126	0.236
	Group B	21	24.00	504.00					
Mid Algometry	Group A	21	21.50	451.50	220.5	451.5	0.000	1.000	0.000
	Group B	21	21.50	451.50					
Post Algometry	Group A	21	11.00	231.00	0.0	231.0	-5.739	0.000	0.886
	Group B	21	32.00	672.00					

Table 2: Median and Interquartile Range (IQR) of NPRS, VISA-A, and Pressure Algometry Scores at Baseline, Mid-, and Post-Intervention in Isometric and Eccentric Training Groups

Variable	Group	N	Median	IQR (Q3 – Q1)
Pre NPRS	Group A	21	9.00	(1.50)10.00 – 8.50
	Group B	21	9.00	(2.00)10.00 – 8.00
Mid NPRS	Group A	21	6.00	(1.50)7.00 – 5.50
	Group B	21	7.00	(1.00)7.00 – 6.00
Post NPRS	Group A	21	5.00	(1.00) 5.00 – 4.00
	Group B	21	2.00	(1.50)3.00 – 1.50

Pre VISA-Score	Group A	21	33.00	(6.00)36.50 – 30.50
	Group B	21	28.00	(10.50)35.00 – 24.50
Mid VISA-Score	Group A	21	49.00	(8.50)56.00 – 47.50
	Group B	21	51.00	(6.00)55.00 – 49.00
Post VISA-Score	Group A	21	76.00	(6.00)78.00 – 72.00
	Group B	21	89.00	(4.00)91.00 – 87.00
Pre-Algometry	Group A	21	1.00	(1.00)2.00 – 1.00
	Group B	21	2.00	(1.00)2.00 – 1.00
Mid Algometry	Group A	21	3.00	(1.00)4.00 – 3.00
	Group B	21	3.00	(1.00)4.00 – 3.00
Post Algometry	Group A	21	4.00	(1.00)5.00 – 4.00
	Group B	21	6.00	(1.00)7.00 – 6.00

Table 3: Within-Group Longitudinal Comparison of NPRS, VISA-A, and Pressure Algometry Scores Using Friedman Test in Isometric and Eccentric Training Groups

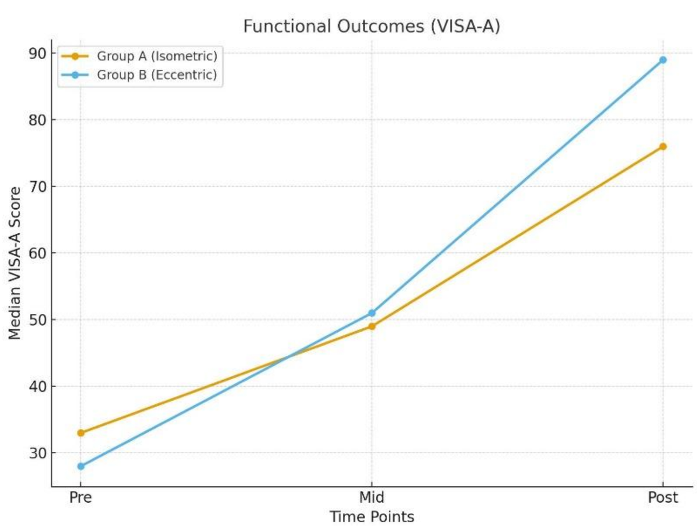
Group	Variable	Mean Rank	N	df	P value
Isometric Contraction	Pre NPRS	6.00	21	8	.000
	Mid NPRS	4.93	21		
	Post NPRS	3.52	21		
	Pre VISA-Score	7.00	21		
	Mid VISA-Score	8.00	21		
	Post VISA-Score	9.00	21		
	Pre-Algometry	1.00	21		
	Mid Algometry	2.19	21		
	Post Algometry	3.36	21		
Eccentric Strengthening	Pre NPRS	6.00	21	8	.000
	Mid NPRS	4.55	21		
	Post NPRS	1.76	21		
	Pre VISA-Score	7.00	21		
	Mid VISA-Score	8.00	21		
	Post VISA-Score	9.00	21		
	Pre-Algometry	1.33	21		
	Mid-Algometry	2.90	21		
	Post-Algometry	4.45	21		

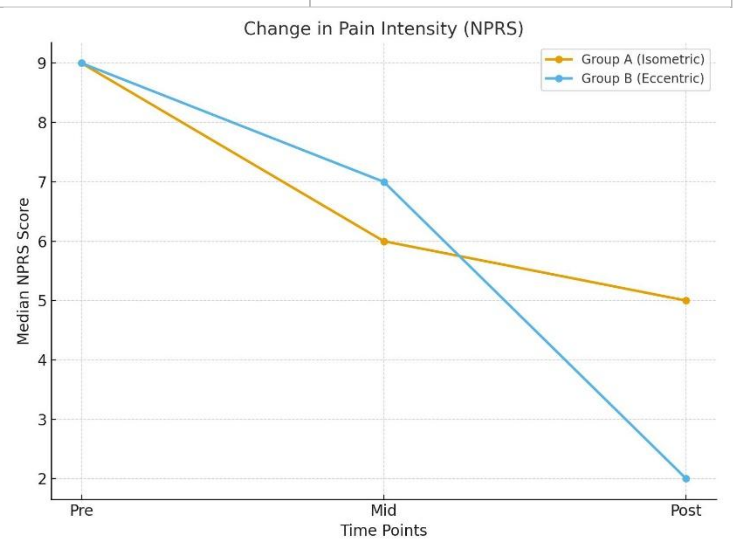
Table 4: Effect Sizes of Between-Group Comparisons

Outcome Measure	Time Point	Effect Size (r)	Interpretation
NPRS	Mid	0.306	Small–Moderate
NPRS	Post	0.876	Very Large
VISA-A	Mid	0.103	Negligible
VISA-A	Post	0.857	Large
Algometry	Mid	0.000	None
Algometry	Post	0.886	Very Large

Table 5: Subgroup Analysis by Sex and Age (Post-Intervention)

Variable	Group A (Isometric)	Group B (Eccentric)
Median NPRS (Males)	5.00	2.00
Median NPRS (Females)	5.00	3.00
Median VISA-A (Males)	76.00	91.00
Median VISA-A (Females)	74.00	87.00
Median NPRS (<45 years)	5.00	2.00
Median NPRS (≥45 years)	5.00	3.00
Median VISA-A (<45 years)	78.00	90.00
Median VISA-A (≥45 years)	75.00	87.00





DISCUSSION

The findings of the present study demonstrated that eccentric strengthening resulted in a significant reduction in pain intensity as measured by the Numeric Pain Rating Scale (NPRS), with a large effect size (rr = 0.876, p = 0.000), reflecting strong and clinically meaningful pain relief. This outcome reinforced the role of eccentric loading as an effective intervention for tendon rehabilitation. Evidence from previous trials has similarly indicated that eccentric protocols are superior to conventional or non-eccentric exercise programs, reporting substantial decreases in NPRS scores following structured eccentric interventions (20). In tendinopathy affecting other sites, such as the patellar tendon, eccentric exercise has also been shown to produce notable pain reduction compared to conservative treatment, further supporting the effectiveness of this approach in musculoskeletal rehabilitation (21). The present results also highlighted that although isometric exercise produced modest improvements, eccentric loading provided more pronounced benefits in the long term. Earlier clinical comparisons between isometric and eccentric regimens reported that while early changes in pain relief were not always significant, the long-term trajectory consistently favored eccentric protocols. This aligns with the outcomes of the current research, indicating that eccentric strengthening is more effective in sustaining pain reduction, whereas isometric contraction offers only temporary analgesic benefits through neuromodulatory mechanisms (22,23). In terms of functional outcomes, the eccentric strengthening group exhibited significantly higher VISA-A scores at follow-up ($p = 0.000$, $rr = 0.857$), reflecting improved tendon function and restoration of performance. These findings are consistent with existing evidence that reported substantial increases in VISA-A scores following structured eccentric rehabilitation programs for chronic Achilles tendinopathy (24). The improvements in functional recovery highlight the role of eccentric loading not only in reducing pain but also in restoring tendon capacity and overall clinical outcomes.

The strengths of this study included its randomized controlled design, the use of validated outcome measures such as NPRS, VISA-A, and pressure algometry, and the blinding of assessors, which minimized detection bias. The structured 12-week intervention protocols with progressive loading further enhanced the reliability of the findings. Additionally, effect size analysis provided insight into the magnitude of improvements, complementing statistical significance testing. Despite these strengths, several limitations must be acknowledged. The absence of a control or sham group limited the ability to distinguish the intervention effects from natural recovery or placebo responses. Follow-up was restricted to the immediate post-intervention phase, leaving the sustainability of benefits over the long term uncertain. Exercise adherence was self-reported, raising the possibility of reporting bias, and variations in tendon severity and chronicity among participants were not controlled, which could have influenced the magnitude of responses. Furthermore, only isometric and eccentric exercises were compared, without investigating potential benefits of multimodal approaches or combined protocols. The implications of this study suggest that eccentric strengthening should remain a cornerstone in the rehabilitation of Achilles tendinopathy, particularly for long-term pain reduction and functional restoration. However, isometric loading may still be relevant in early-phase rehabilitation when rapid analgesia is required, serving as a complementary approach. Future studies should extend follow-up periods to capture long-term outcomes, incorporate control groups, and consider objective adherence tracking to minimize bias. Exploring combined or multimodal interventions, as well as stratifying participants according to severity, chronicity, age, or sex, would provide more tailored rehabilitation strategies and enhance clinical applicability. Overall, the evidence strongly supports eccentric strengthening as the more effective intervention for pain modulation and functional recovery in Achilles tendinopathy, while recognizing that isometric contraction retains value for short-term pain management during the early rehabilitation phase.

CONCLUSION

The study concluded that eccentric strengthening offered superior and longer-lasting benefits compared to isometric exercise in reducing pain, enhancing functional capacity, and improving pain sensitivity in Achilles tendinopathy. These findings emphasize the practical importance of incorporating eccentric loading as the primary exercise approach in tendon rehabilitation, as it not only supports recovery but also promotes sustained improvements in overall tendon health and function.

AUTHOR CONTRIBUTION

Author	Contribution
Ayesha Siddiqua	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Sahar Aslam	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Nawal Fatima	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Meenal Arshad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

Zinnia Akram	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Fatima Sabir	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Nimra Zaheer	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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