Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 24 May 2026
Revised 23 June 2026
Accepted 19 July 2026

Natural Resources for Human Health 2026, Vol. 6 (10s): 1184–1195

KEYWORDS:
Achilles tendinopathy; Kinetic Control; Dynamic balance.

Effects of a Lower Extremity Kinetic Control Exercise Program on Postural Stability and Functional Outcomes in Patients with Achilles Tendinopathy: A Randomized Controlled Trial

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ABSTRACT: Background: Achilles tendinopathy (AT), represent a clinical term referred to for an injury to the Achilles tendon bit not rupture. It causes pain in the affected area and functional impairment while performing mechanical loading. Kinetic control is the balanced presentation of motion options with optimal communication among the main elements for sensorimotor neuromuscular control.

Purpose: To evaluate the effectiveness of adding Kinetic Control training to a conventional rehabilitation program on pain intensity, ankle ROM, dynamic balance, and foot and ankle function in patients with AT.

Methods: A randomized controlled trial was carried out including participants with AT who were allocated to two groups. Both groups received treatment two times weekly for eight weeks (16 sessions). Outcome measures included the Visual Analogue Scale (VAS), ankle range of motion (ROM), the Biodex Balance System Overall Stability Index (OSI), in addition to the Foot and Ankle Outcome Score (FAOS), measured before and after the intervention.

Results: Fifty subjects were randomized into both the conventional group (n = 25) and the Kinetic Control group (n = 25). Both groups showed significant improvements in pain intensity, ankle ROM, dynamic balance, and foot and ankle function after the 8-week intervention ($P < 0.05$). But, the Kinetic Control group showed significantly larger improvements in pain intensity ($P < 0.05$), dynamic balance ($P < 0.05$), and ankle ROM ($P < 0.05$), compared with the conventional rehabilitation group. Despite significant enhancement in the FAOS in both groups ($P < 0.05$), there was no significant difference among the groups ($P = 0.374$).

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eISSN: 2583-1194

Conclusion: Kinetic Control training combined with conventional rehabilitation improved pain, ankle ROM, dynamic balance, and foot and ankle function in individuals with AT.

1. INTRODUCTION

Nonrupture injuries of the Achilles tendon, known as Achilles tendinopathy (AT), are clinically defined as (1) localized pain along with functional impairment with mechanical loading (2). Twenty percent of all tendon injuries occur in this one tendon, making it the most injured tendon in the body (3). AT affects both athletic and non-athletic populations and poses a considerable socioeconomic burden due to its prolonged recovery time and high recurrence rate. The estimated annual incidence in the general population ranges from 1.85 to 2.35 cases per 1,000 individuals (4).

According to the recent evidence, there are several factors that contribute to the development of AT, but recurrent tendon stress is one of them (5). However, the condition extends beyond structural tendon abnormalities. It is also associated with altered mechanical loading, neuromuscular dysfunction, sensorimotor deficits, and impaired movement control, all of which contribute to pain and functional disability (4,6,7). Although AT is commonly associated with running and jumping sports, it is also prevalent among sedentary individuals and middle-aged adults (8). In addition, increasing evidence suggests that systemic factors such as obesity, diabetes, dyslipidaemia (9), and age-related tendon degeneration have a role in both the development and persistence of the disorder (10).

Recent evidence has also highlighted that Achilles tendinopathy is accompanied by alterations in sensorimotor control, proprioception, muscle activation patterns, and postural stability (11). Individuals with AT frequently demonstrate impaired neuromuscular coordination throughout the lower extremity, including deficits in ankle, knee, and hip control during functional activities (6,7,12). Collectively, these findings indicate that Achilles tendinopathy involves not only local tendon pathology but also broader impairments in lower-extremity sensorimotor function and movement control.

Conservative management remains the 1st-line treatment for AT, with progressive tendon-loading exercise recognized as the cornerstone of rehabilitation. Exercise interventions, including eccentric loading, heavy slow resistance training, and progressive loading programs, have consistently been shown to improve pain and function, while adjunctive treatments such as extracorporeal shockwave therapy may provide additional benefits for selected patients. Despite these advances, many individuals continue to experience persistent symptoms and incomplete functional recovery, highlighting the need for rehabilitation strategies that address impairments beyond the tendon itself (6,7).

Kinetic control is the balanced presentation of motion options with optimal communication among the main elements for sensorimotor neuromuscular control, which is accomplished by afferent sensory input, particularly proprioceptive input, central nervous system (CNS) integration, optimal motor coordination, and physiological stresses to ensure functional dynamic stability as well as controlled mobility. The kinetic control exercises include testing of lumbar rotation/side bending movement control, testing of uncontrolled lumbar extension, as well as testing of flexion coordination. These involuntary motions can be a segmental axis at a single point or multiple segmented hypermobility. The motor control relearning approach includes participant education regarding their involuntary movement, relearning the balanced presentation of movement direction control, and retraining muscle synergy. Kinetic control is the ability to move with maximum coordination of the neurological as well as musculoskeletal control and physical stress. It would better be performed with the suitable power and programing. The movement system necessitates coordination of various body systems, which include the neurological, myofascial, articular system, and connective tissue systems, as well as the CNS, psychosocial, and physical factors (13,14).

Lower-extremity kinetic control exercises are designed to improve neuromuscular control along with coordinated movement patterns, thereby optimizing lower-limb biomechanics and improving postural stability during functional activities. Although sensorimotor-based rehabilitation has shown promising results, the available evidence supporting its effectiveness in patients with Achilles tendinopathy remains limited and heterogeneous. Consequently, further randomized controlled trials (RCT) are required to determine whether incorporating kinetic control exercises into conventional rehabilitation can improve postural stability and functional outcomes in this population (6,7).

So, this RCT was carried out to examine the impacts of a lower-limb kinetic control exercise program on postural stability and functional outcomes in patients with AT.

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MATERIAL AND METHODS

Study Design

This study was a RCT. According to the Helsinki Declaration, the study followed the rules for using human subjects. Under the identifier (NCT07730866), the research protocol was registered online at clinical trial.gov. The study's methods were approved by the Scientific Research Ethical Committee of Badr University's physical therapy department in Cairo (IRB00014233-89).

INCLUSION CRITERIA

After receiving an in-depth explanation of the processes and management details, all participants had a comprehensive understanding of the study's goal. To participate in this study, each individual had to initial a permission form. The months of June through August 2026 were used for this comparison analysis. All participant's diagnosis was Achilles Tendinopathy and History of Achilles tendon surgery or lower-extremity surgery within the previous 12 months by the referred physician, Symptoms (pain, stiffness, and impaired function) persisting for at least 3 months, The outpatient physical rehabilitation clinic at Cairo University's Faculty of Health was recommended to those who were able to walk without assistance. When the inclusion criteria were satisfied, subjects were chosen in this research.

Exclusion Criteria

Participants were excluded if they had a partial or complete Achilles tendon rupture, a history of lower-limb fracture within the previous 12 months, systemic inflammatory, rheumatologic, or neurological disorders affecting balance, gait, or lower-limb function or vestibular disorders or any other condition that could impair postural stability.

Subjects and Randomization

The study included 50 Adolescents and adults aged from 16-35 years with Achilles Tendinopathy, recruited via outpatient clinic in Faculty of Physical Therapy, Cairo University (Cairo, Egypt). Data were collected directly from participants during the baseline and post-intervention assessments using standardized clinical outcome measures. All evaluations were performed by the same trained assessor before the initiation of treatment and after completion of the 16 treatment sessions over an 8-week period, with no additional follow-up assessments conducted.

Methodology

Methods for assessment

Demographic data, involving name, age, weight, height, in addition to body mass index (BMI), were documented in the participants' data sheets before the baseline assessment.

Based on the methodology, the outcomes could be classified as follows:

The Primary outcome was

The Visual Analogue Scale (VAS) was used for determining the level of pain both before and after the treatment. This validated self-reporting tool has a 10-centimeter line that is anchored by the words "no pain" and "worst possible pain." Each participant was asked to choose a point on the pain intensity scale that they felt best reflected the current state of pain. Clinical studies often use the VAS because of its responsiveness, validity, and reliability in measuring pain intensity (15).

The Secondary outcomes were

The patient's ankle ROM was measured both before and after the treatment utilizing a standard universal goniometer. The ankle joint's active ROM, which includes dorsiflexion, plantarflexion, inversion, along with eversion, was assessed in standardized positions. For statistical analysis, the mean of three consecutive measurements was taken. Universal goniometry is a valid and reliable way to measure ankle ROM in both research and clinical settings (16).

Biodex Balance System (BBS) measurements of balance performance: Postural stability along with balance were assessed both before and after the treatment. Following a standardized familiarisation session, participants did a 20-second open-eye single-leg posture test on the dynamic platform. After three trials, the average value was taken into consideration for the analysis. The

BBS offers objective assessments of balance performance, such as the OSI, APSI, and MLSI, where higher scores indicate less postural stability. Dynamic balance evaluations using the Biodex Balance System have shown high reliability and validity in patients suffering from ankle instability as well as additional musculoskeletal disorders (17, 18).

The Foot and Ankle Outcome Score (FAOS) was used to evaluate foot and ankle function. This validated patient-reported outcome measure was used both prior to and after the treatment. There are five subscales that make up the FAOS: pain, symptoms, ADL, function in sports and recreation, and quality of life (QOL) related to the foot and ankle. High scores indicate less symptoms and improved foot and ankle function; scores are converted from 5-point Likert scales to a normalized scale from 0 to 100. The FAOS has showed strong reliability, validity, in addition to responsiveness for measuring functional outcomes in those with foot and ankle conditions (19, 20).

Methods for treatment:

1. Control Group (Conventional Treatment): Participants in the control group received a conventional rehabilitation program consisting of a 10-minute dynamic warm-up and stretching exercises followed by progressive dynamic balance training. The stretching program targeted the ankle invertors, evertors, calf muscles, hamstrings, iliotibial band, quadriceps, and hip flexors, with each stretch held for 30 seconds. Dynamic balance training was performed for 20 minutes per session, two times weekly for 8 weeks (16 sessions), and included progressive single-leg balance activities such as hop-to-stabilization, hop-to-stabilization with reach, box drills, in addition to single-limb stance exercises with eyes open then eye closed. Exercise difficulty was progressively increased to enhance postural control, neuromuscular function, and functional ankle stability (21, 22, 23).

2. Treatment Group (Experimental Group): Along with the experimental intervention, individuals in the treatment group also got the control group's standard rehabilitation program. Kinetic control is a retraining approach that teaches patients to regulate their uncontrolled movements, as well as how to retrain their muscles to work together more effectively. Retraining coordination for the UCM location and direction is similar to testing, except that there are more repetitions with the proper pattern. Participation in the retraining was encouraged through the use of visual along with palpatory feedback, unloading, support from clinicians, and verbal modification. Once the subject has grasped the motion or action, they are required to do it without any type of visual or palpatory feedback or verbal criticism. The next step was to apply the positions' growth to more difficult roles (14).

Each treatment session began with single-leg stance training, during which participants maintained a neutral alignment of the trunk, pelvis, hip, knee, as well as foot while standing on the affected limb. Three sets of 30-second holds were performed with a 30-second rest interval between sets. As participants demonstrated improved control, the exercise was progressed by performing it on an unstable surface or with the eyes closed (24).

This was followed by heel-raise exercises to progressively load the Achilles tendon. During the first week, the participants started by raising their heels with both legs, then moved on to raising them with only one leg during the subsequent weeks. Three sets of 12 repetitions were completed using a slow tempo of approximately 2 seconds during the concentric phase and 3 seconds during the eccentric phase, with a 60-second rest between sets. External resistance was added as tolerated while maintaining proper movement quality (24).

Participants then performed mini-squats while maintaining correct lower-limb alignment and avoiding excessive foot pronation and knee valgus. Three sets of 10 repetitions were completed, with each repetition held for approximately 3 seconds. Squat depth was progressively increased from approximately 30° to 60° of knee flexion as tolerated (24).

Forward step-down exercises were performed from a 15-cm step to improve eccentric control of the lower limb. Participants completed three sets of 10 repetitions while maintaining appropriate hip, knee, and foot alignment. The step height was increased to 20 cm during the later stages of the program when appropriate (24).

Statistical analysis

Assumptions of normality as well as homogeneity of variance were tested on the data. The data was found to follow a normal distribution ($P>0.05$). No influential outliers were identified. There was also no statistically significant difference ($P>0.05$) when tested for homogeneity of variance using Levene's test. Data met the assumptions of normality and homogeneity of variance; therefore, parametric analyses were performed.

All statistical analysis was carried out using the IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). The demographic data of the patients, as well as the VAS, OSI, FAOS, and ROM variables, are presented quantitatively as means and standard deviations. Quantitative data is presented as the number and frequency of each patient's gender, and a Chi-square test is used to compare the two groups statistically. When comparing two groups' demographic data, an independent t-test is used. use Cohen's d to determine the magnitude of an effect; an effect size of 0.2 is considered small, 0.5 is considered medium, and 0.8 is considered large. Two levels of independent variables (control group versus experimental group) and two levels of outcome measures (VAS, OSI, FAOS, along with ROM) were utilised in the two-way mixed-design repeated-measures MANOVA. The 1st level of independent variables (among subject factors) was the tested group, and the 2nd level of independent variables (within subject factor) was measurement periods. If an F-value was found to be statistically significant from a MANOVA test, the Bonferroni test was used to compare the two sets of data, both within and across groups. The effect size, denoted as partial eta squared (partial $\eta 2$), found in MANOVA tests, may vary from 0 to 1, with bigger values indicating a stronger impact of the predictor. Typically, 0.01, 0.06, and 0.14 are considered small, medium, and large, respectively. At the 0.05 level of probability, all statistical analyses were considered significant.

RESULTS

Participants' baseline demographic and anthropometric characteristics are outlined in Table (1). An overall of 50 participants were enrolled and randomized into either the control group (n = 25) or the experimental group (n = 25). Independent t-tests revealed no statistically significant differences (P>0.05) between the two groups regarding age (P=0.792), weight (P=0.827), height (P=0.288), or BMI (P=0.289). Furthermore, the calculated Cohen's d effect sizes for all continuous variables ranged from negligible to small (d = 0.07 to 0.31), with all 95% confidence intervals crossing zero, confirming that any observed differences at baseline were clinically trivial. Similarly, a Chi-square test revealed that no significant disparity in sex distribution between the control (44.0% male) and experimental (64.0% male) groups (P=0.564).

Table 1. Patient's demographic data in both groups

Items	Groups		Cohen's d (95% CI)	*P*-value
	Control group (n=25)	Experimental group (n=25)		
Age (year)	27.48 ±4.83	27.08 ±5.78	0.07 (-0.48 – 0.62)	0.792
Weight (kg)	71.36 ±7.84	71.96 ± 11.15	0.06 (-0.49 – 0.61	0.827
Height (cm)	164.44 ± 10.11	167.24 ±8.21	0.30 (-0.25 – 0.86)	0.288
BMI (kg/m²)	26.47 ±2.76	25.52 ±3.47	0.31 (-0.24 – 0.86)	0.289
Gender (males: females)	11 (44.00%): 14 (56.00%)	16 (64.00%): 9 (36.00%)		0.564

Quantitative variables data (age, weight, height, and BMI) are reported as mean ±standard deviation and compared by t-independent test.

Qualitative variables data (gender) are reported a frequency (percentage) and compared by Chi-square test

CI: confidence interval; P-value: probability value; P-value > 0.05: non-significant

The within- and between-group comparisons for VAS, OSI, and FAOS are presented in Table (2).

Pain intensity (VAS) at baseline, both groups reported moderate-to-severe pain with no significant between-group difference (P= 0.678). Following the intervention, the experimental group provided a significant superior reduction in VAS scores compared with the control group (MD = 1.52, 95% CI: 0.75 – 2.28, P<0.001). While, both groups achieved significant within-group improvements (P<0.05), the experimental group exhibited a substantially greater enhancement percentage (63.97% vs. 37.86%) and a larger effect size (η^2 = 0.460 vs. 0.241), representing that the experimental intervention had a larger clinical effect on pain reduction.

Baseline OSI scores were comparable between groups (P= 0.738). Post-treatment analysis revealed a statistically significant and minimal clinically important difference between-group difference favoring the experimental group (MD = 2.94, 95% CI: 0.86 – 5.03, P= 0.006). Within-group analyses showed significant improvements in both the control (MD = 2.77, P= 0.010) and experimental groups (MD = 5.37, P<0.001). Notably, the experimental group's improvement percentage (61.23%) more than doubled that of the control group (30.37%), with a large effect size (η^2 = 0.214) compared with a moderate effect in the control group (η^2 = 0.068).

Both groups showed significant in FAOS within-group enhancement in functional ability (P<0.001), with large effect sizes (Control: η^2=0.437; Experimental: η^2=0.528). However, contrary to the VAS and OSI results, the between-group difference at post-treatment did not reach statistical significance (MD = 9.51, 95% CI: -11.60 – 30.63, P= 0.374). Although the experimental group showed a numerically higher improvement percentage (36.76%) compared to the control group (29.75%).

Table 2: Within and between group's comparison for VAS, OSI, and FAOS

Variables	Items	Groups (Mean ±SD)		Change (MD)	95% CI	Effect size (η^2)	*P*-value[1]
		Control group (n=25)	Experimental group (n=25)				
VAS	Before-treatment	5.60 ±1.80	5.44 ±1.50	0.16	-0.60 – 0.92	0.002	0.678
	After-treatment	3.48 ±0.92	1.96 ±0.98	1.52	0.75 – 2.28	0.140	<0.001*
	Change (MD)	2.12	3.48				
	95% CI	1.35 – 2.88	2.71 – 4.24				
	Improvement %	37.86%	63.97%				
	Effect size (η^2)	0.241	0.460				
	P-value[2]	<0.001*	<0.001*				
OSI	Before-treatment	9.12 ±4.83	8.77 ±3.96	0.35	-1.73 – 2.43	0.001	0.738
	After-treatment	6.34 ±2.56	3.40 ±1.84	2.94	0.86 – 5.03	0.076	0.006*
	Change (MD)	2.77	5.37				
	95% CI	0.68 – 4.86	3.28 – 7.45				
	Improvement %	30.37%	61.23%				
	Effect size (η^2)	0.068	0.214				
	P-value[2]	0.010*	<0.001*				
FAOS	Before-treatment	308.61 ±40.92	299.75 ±23.72	8.86	-12.25 – 29.98	0.007	0.407
	After-treatment	400.42 ±48.03	409.93 ±33.39	9.51	-11.60 – 30.63	0.008	0.374
	Change (MD)	91.80	110.18				
	95% CI	70.68 – 112.92	89.06 – 131.30				
	Improvement %	29.75%	36.76%				
	Effect size (partial η^2)	0.437	0.528				
	P-value[2]	<0.001*	<0.001*				

Natural Resources for Human Health
eISSN: 2583-1194

Data are reported as mean ± standard deviation (SD); MD: Mean difference; CI: confidence interval; partial η2: partial Eta square P-value: probability value; Significant (P<0.05)

P-value 1: probability value between both groups at pre- and post-treatment and compared statistically by post-hoc pairwise Bonferroni test

P-value 2: probability value between pre- and post-treatment within each group and compared statistically by post-hoc pairwise Bonferroni test

The within- and between-group comparisons for ankle dorsiflexion, plantar flexion, inversion, as well as eversion are represented in Table (2) and Table (3). Baseline dorsiflexion ROM was comparable between groups (P=0.351). There was a statistically significant difference between the two groups after the intervention, with the experimental group showing larger improvement (MD = 2.68°, 95% CI: 0.03 - 5.33, P=0.42). Both groups achieved significant within-group improvements (Control: MD = 4.48°, P=0.001; Experimental: MD = 5.88°, P<0.001), with the experimental group showing a higher improvement percentage (33.11% vs. 27.18%) and a larger effect size (η^2 = 0.162 vs. 0.101).

No significant baseline differences in plantar flexion were noted (P=0.515). Although both groups showed significant within-group gains (P<0.001), the between-group difference at post-treatment narrowly reached statistical significance (MD = 2.24°, 95% CI: 0.19 – 4.29, P=0.045). The experimental group achieved a greater absolute change (6.40° vs. 4.96°) and a larger effect size (η^2 = 0.222 vs. 0.146), indicating a moderate-to-large treatment effect.

Baseline inversion ROM was similar across groups (P=0.222). Post-treatment analysis revealed a statistically significant between-group difference favoring the experimental group (MD = 1.68°, 95% CI: 0.45 – 2.90, P=0.008). Within-group improvements were significant in both groups (P<0.001), with the experimental group demonstrating a larger effect size (η^2 = 0.286 vs. 0.188) and a greater improvement percentage (21.48% vs. 17.06%).

Baseline eversion ROM was comparable (P=0.246). Critically, the between-group difference at post-treatment was highly significant (MD = 2.28°, 95% CI: 1.05 – 3.50, P<0.001), representing the largest between-group disparity among all ROM measures. While, the experimental group exhibited a substantial within-group improvement (MD = 4.12°, P<0.001) with a large effect size (η^2 = 0.317), the control group's within-group change failed to reach statistical significance (MD = 1.12°, P=0.073) and demonstrated only a small effect (η^2 = 0.033). The experimental group's improvement percentage (34.56%) was nearly four times greater than that of the control group (8.86%), underscoring the specific efficacy of the experimental intervention on ankle eversion mobility.

Table 3: Within and between group's comparison for range of motion

Variables	Items	Groups (Mean ±SD)		Change (MD)	95% CI	Effect size (η^2)	*P*-value[1]
		Control group (n=25)	Experimental group (n=25)				
Dorsi flexion	Before-treatment	16.48 ±5.35	17.76 ±5.17	1.28	-1.42 – 3.98	0.009	0.351
	After-treatment	20.96 ±3.85	23.64 ±4.77	2.68	0.03 – 5.33	0.039	0.042*
	Change (MD)	4.48	5.88				
	95% CI	1.77 – 7.18	3.17 – 8.58				
	Improvement %	27.18%	33.11%				
	Effect size (η^2)	0.101	0.162				
	P-value[2]	0.001*	<0.001*				
Plantar flexion	Before-treatment	31.84 ±7.00	32.64 ±2.49	0.80	-3.23 – 1.63	0.004	0.515
	After-treatment	36.80 ±3.17	39.04 ±3.08	2.24	0.19 – 4.29	0.034	0.045*

	Change (MD)	4.96	6.40				
	95% CI	2.53 – 7.39	3.97 – 8.83				
	Improvement %	15.58%	19.61%				
	Effect size (η^2)	0.146	0.222				
	P-value[2]	<0.001*	<0.001*				
Inversion	Before-treatment	17.12 ±1.85	17.88 ±1.96	0.76	-0.46 – 1.98	0.015	0.222
	After-treatment	20.04 ±2.47	21.72 ±2.38	1.68	0.45 – 2.90	0.071	0.008*
	Change (MD)	2.92	3.84				
	95% CI	1.69 – 4.14	2.61 – 5.06				
	Improvement %	17.06%	21.48%				
	Effect size (η^2)	0.188	0.286				
	P-value[2]	<0.001*	<0.001*				
Eversion	Before-treatment	12.64 ±2.51	11.92 ±2.03	0.72	-0.50 – 1.94	0.014	0.246
	After-treatment	13.76 ±2.22	16.04 ±1.90	2.28	1.05 – 3.50	0.124	<0.001*
	Change (MD)	1.12	4.12				
	95% CI	-0.10 – 2.34	2.89 – 5.34				
	Improvement %	8.86%	34.56%				
	Effect size (partial η^2)	0.033	0.317				
	P-value[2]	0.073	<0.001*				

Data are reported as mean ± standard deviation (SD); MD: Mean difference; CI: confidence interval; partial η2: partial Eta square P-value: probability value; Significant (P<0.05)

P-value 1: probability value between both groups at pre- and post-treatment and compared statistically by post-hoc pairwise Bonferroni test

P-value 2: probability value between pre- and post-treatment within each group and compared statistically by post-hoc pairwise Bonferroni test

DISCUSSION

This study was done to evaluate the effectiveness of adding Kinetic Control training to a conventional rehabilitation program in subjects with AT. Outcome measures, including pain intensity measured by the VAS, ankle ROM, dynamic balance assessed using the OSI, and foot and ankle function evaluated by the FAOS, were assessed at baseline and after termination of the 8-week treatment program. The collected data were subsequently analyzed to examine the impacts of the treatment on pain, ankle mobility, balance, and functional performance.

The findings demonstrated that both groups showed significant improvements following treatment. However, participants who received Kinetic Control training achieved significantly greater reductions in pain, improvement in ankle ROM, and dynamic balance compared to the conventional rehabilitation group. Although FAOS improved significantly within both groups, the between-group difference did not reach statistical significance.

The study demonstrated a significantly greater reduction in pain intensity in the Kinetic Control group compared to the conventional treatment group. This finding may be attributed to the emphasis of Kinetic Control training on correcting faulty

movement patterns and optimizing lower-limb alignment during functional activities, thereby reducing excessive mechanical loading and compressive stress on the Achilles tendon. Malliaras et al. (2013) reported that progressive loading programs improve tendon capacity and alleviate symptoms by restoring the mechanical characteristics of the tendon, while Rio et al. (2015) suggested that exercise-induced improvements in neuromuscular function contribute to pain modulation and enhanced motor performance. Therefore, the superior reduction in pain observed in the present study supports the integration of Kinetic Control training as an effective adjunct to conventional rehabilitation for individuals with Achilles tendinopathy (25, 26).

The present study demonstrated significant improvements in ankle ROM, such as dorsiflexion, plantarflexion, inversion, along with eversion, in both groups following the intervention. However, participants who received Kinetic Control training exhibited significantly greater improvements than those who received conventional rehabilitation alone. The enhanced ROM found in the experimental group may be related to the reduction in pain, which likely diminished protective muscle guarding and enabled participants to move the ankle through a greater pain-free range. Among the ROM variables, ankle eversion demonstrated the greatest improvement following Kinetic Control training. This finding may be explained by the program's emphasis on improving foot alignment, and enhancing neuromuscular control of the peroneal muscles, which are essential for dynamic ankle stability and subtalar joint motion. Improved sensorimotor control during weight-bearing activities may also have reduced compensatory movement patterns and facilitated restoration of normal eversion mobility. These results are supported by Brumann et al. (2014), who reach a conclusion that rehabilitation programs incorporating progressive functional exercises improve ankle mobility and movement quality following Achilles tendon disorders. Similarly, Silbernagel et al. (2007) demonstrated that progressive loading exercises effectively restore tendon function and improve lower-limb mobility while reducing symptoms in patients with Achilles tendinopathy (27, 28).

The experimental group additionally reported superior enhancement in dynamic balance, as demonstrated by the greater reduction in the OSI compared with the conventional treatment group. This improvement may be attributed to the ability of Kinetic Control training to enhance proprioception, sensorimotor integration, and neuromuscular control through repetitive, task-specific movement retraining. By emphasizing correct lower-limb alignment and controlled weight-bearing activities, the program likely improved the ankle strategy used to preserve postural stability during functional tasks. These results are in line with those of McKeon et al. (2008), who showed that those with chronic ankle instability benefit from balance training in terms of sensorimotor function along with postural control. Similarly, Gribble et al. (2016) highlighted the importance of proprioceptive and neuromuscular rehabilitation in restoring dynamic balance and preventing recurrent lower-limb dysfunction. In addition, Han et al. (2015) reported that exercise programs incorporating movement control and balance training significantly improve postural stability and functional performance by enhancing proprioceptive feedback and neuromuscular coordination. Therefore, the superior improvements in dynamic balance observed in the present study suggest that the inclusion of Kinetic Control training into traditional rehabilitation effectively restores postural control mechanisms and functional stability in those with AT (29, 30, 31).

Although both groups demonstrated significant improvements in the FAOS following the intervention, no statistically significant difference was detected among between the Kinetic Control and conventional rehabilitation groups. Several factors may explain this finding. The FAOS is a patient-reported outcome measure that reflects the individual's level of pain, symptoms, daily activities, sports function, in addition to QOL, which may be influenced by subjective factors and may not fully capture early changes in physical performance. In addition, the conventional rehabilitation program, which included stretching and progressive balance training, was effective in improving foot and ankle function, thereby reducing the likelihood of detecting significant between-group differences. These findings agree with Malliaras et al. (2013), who reported that meaningful functional recovery in Achilles tendinopathy generally requires prolonged progressive loading programs, and with Martin et al. (2018), who emphasized that improvements in patient-reported outcomes often occur gradually and may not parallel early changes in pain or physical performance (25, 32).

The superior outcomes found in the Kinetic Control group may be clarified by the underlying principles of the intervention, which focus on optimizing movement quality rather than simply increasing muscle strength. Kinetic Control training emphasizes the identification and correction of faulty movement patterns through task-specific movement retraining, enabling patients to perform functional activities with improved lower-limb alignment and more efficient load distribution across the kinetic chain. Restoring appropriate alignment of the foot, ankle, knee, and hip reduces excessive mechanical stress on the Achilles tendon and minimizes compensatory movement strategies that may contribute to persistent symptoms. Furthermore,

repeated practice of controlled functional movements promotes motor learning, allowing patients to develop more efficient and automatic movement patterns during daily and sporting activities (24).

These findings suggest that incorporating Kinetic Control exercises into traditional rehabilitation may enhance pain relief, improve dynamic balance, and restore ankle mobility in patients suffering from AT. Clinicians may therefore consider Kinetic Control as an adjunctive intervention during conservative management.

Various limitations of this study should be acknowledged. First, no long-term following-up was conducted; therefore, the persistence of treatment effects beyond the intervention period remains unknown. In addition, the study was performed at a single rehabilitation center, that may reduce the external validity of the findings.

Future studies should involve objective measures of tendon structure, such as musculoskeletal ultrasonography or magnetic resonance imaging, together with assessments of calf muscle strength, gait biomechanics, and lower-limb kinematics for better understanding the mechanisms of recovery.

CONCLUSION

Both the conventional rehabilitation program and the addition of Kinetic Control training significantly improved pain, dynamic balance, ankle ROM, and foot and ankle function in individuals with AT. However, participants who received Kinetic Control training provided a significantly larger enhancement in pain intensity, dynamic balance, and ankle ROM than those receiving conventional rehabilitation alone. Both groups had significant improvements in foot and ankle function, but there was no significant difference was found between them. These findings suggest that integrating Kinetic Control exercises into conventional rehabilitation provides additional clinical benefits by enhancing movement quality, neuromuscular control, and lower-limb function. Therefore, Kinetic Control training may be considered an effective adjunct to conservative rehabilitation for patients suffering from AT.

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