

Research Paper

Tele-rehabilitation Versus In-clinic Exercise Therapy for Shoulder Tendinopathy: A Randomized Clinical Trial

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ABSTRACT

Objectives: Rotator cuff tendinopathy (RCT), affecting 15-27% of adults, is a leading cause of shoulder disability with significant socioeconomic impacts. While exercise therapy remains the first-line treatment, tele-rehabilitation emerges as a potentially cost-effective alternative to clinic-based care. This study aimed to compare the efficacy of tele-rehabilitation versus in-clinic exercise therapy for pain, disability, function, and quality of life (QoL) in patients with RCT.

Methods: This randomized controlled trial compared tele-rehabilitation versus in-clinic exercise therapy in 40 patients with RCT. Both groups received 10 supervised 45-minute sessions over 4 weeks and performed identical Codman pendulum and strengthening exercises. Visual analog scale (VAS), disabilities of the arm, shoulder, and hand (DASH) questionnaire, and brief World Health Organization QoL (WHOQOL-BREF) scale were assessed at baseline, post-intervention, and 2-month follow-up using Generalized linear mixed-effects model (LMM) analysis.

Results: Both groups demonstrated significant reductions in pain and disability ($P < 0.001$), as well as improvements in the DASH questionnaire and the WHOQOL-BREF scale ($P < 0.001$) post-intervention and at 2-month follow-up. However, no significant difference was found between the two groups. Although improvement trends were similar between groups ($P > 0.05$), a significant time-by-group interaction was observed for the DASH questionnaire ($P = 0.008$).

Discussion: Both in-clinic exercise and tele-rehabilitation effectively reduce pain and disability from RCT, improving patients' functional abilities and QoL. Tele-rehabilitation is particularly valuable as a complementary treatment during pandemics or when access to physical therapy is limited, offering convenience, flexibility, and increased patient adherence.

Keywords:

Tendinopathy, Rotator cuff, Tele-rehabilitation, Exercise therapy, Pain

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Highlights

- Both tele-rehabilitation and in-clinic exercise therapy significantly reduce pain and disability in patients with RCT over three months.
- Both tele-rehabilitation and in-clinic exercise therapy significantly improve DASH scores and QoL in patients with RCT over three months.
- No significant differences were found between the two interventions at any time point, indicating that synchronous tele-rehabilitation can produce improvement as much as in-clinic physiotherapy.

Plain Language Summary

Rotator cuff tendinopathy (RCT) is a common cause of shoulder pain that can affect daily activities and quality of life (QoL). Exercise therapy is the mainstay of treatment; however, attending a clinic may be difficult for some people. This study compared a tele-rehabilitation program (exercises performed at home under online supervision) with standard in-clinic exercise therapy in 40 adults with RCT. Both groups improved significantly in pain, disability, symptoms, and QoL over three months, with no meaningful difference between the two approaches. These findings suggest that tele-rehabilitation can be an effective and convenient alternative to clinic-based treatment.

Introduction

Musculoskeletal disorders are a leading cause of years lived with disability worldwide [1]. Shoulder pain ranks as the third most common musculoskeletal complaint, affecting 15–27% of adults, and rotator cuff tendinopathy (RCT) accounts for approximately 70% of these cases [2]. RCT is defined as a clinical condition characterized by pain, tenderness, and often functional impairment arising from degenerative or inflammatory changes in the rotator cuff tendons (supraspinatus, infraspinatus, teres minor, subscapularis) without a complete tear [3, 4]. The pathomechanics of RCT involve a combination of intrinsic factors (tendon vascularity, collagen disorganization, tenocyte apoptosis) and extrinsic factors (subacromial impingement, scapular dyskinesis), leading to altered force transmission and proprioceptive deficits [5]. Consequently, RCT negatively affects motor control of the shoulder complex by disrupting the feedforward activation of rotator cuff muscles and altering scapulohumeral rhythm [6].

Beyond pain, RCT limits activities of daily living and work capacity and can adversely affect mental health and quality of life (QoL) [7]. The economic burden is substantial; average annual costs per patient have been estimated at €4,139 in Sweden [8] and approximately £8,500 in the United States [9]. Up to 40% of patients continue to experience pain and disability one year after diagnosis, emphasizing the need for early, effective intervention [10, 11].

Current clinical guidelines recommend conservative management as first-line treatment, including activity modification, analgesic medication, and a 12-week structured exercise program [12]. Exercise-based therapies in RCT focus on strengthening the rotator cuff and scapular stabilizers, as well as incorporating neuromuscular training (e.g. motor control retraining, proprioception, and functional upper extremity exercises) [12, 13]. Several randomized trials have confirmed that supervised exercise reduces pain and improves function in RCT [11, 14–16].

In parallel, digital health solutions have expanded access to care. Tele-rehabilitation—the delivery of rehabilitation services via online platforms—can improve treatment accessibility, reduce costs, and enhance patient convenience, especially for those in remote areas [17, 18]. Tele-rehabilitation has shown effectiveness comparable to in-clinic physiotherapy for various musculoskeletal conditions [11, 19, 20].

In a systematic review by Gava et al. (2022) [14], the effects of tele-rehabilitation on pain and disability in individuals with shoulder pain were examined. The review included six randomized controlled trials involving 368 patients. The findings indicated minimal differences in the effectiveness of tele-rehabilitation programs compared to clinic-based physiotherapy or home exercise in improving pain and disability. However, among these six studies, three focused on post-surgical shoulder pain, one on frozen shoulder, and two on chronic shoulder

pain; none specifically addressed RCT. Furthermore, the included studies were low quality, and the overall certainty of evidence was very low. Consequently, because high-quality evidence specifically in the RCT population is lacking, tele-rehabilitation cannot be definitively recommended for these patients. Given this gap in the literature, this study aimed to compare the effects of tele-rehabilitation versus in-clinic exercise therapy on pain, disability, Disabilities of the arm, shoulder, and hand (DASH) scores, and QoL in participants with RCT. This study hypothesizes that tele-rehabilitation is as effective as in-clinic exercise therapy in improving pain, disability, and QoL in individuals with RCT.

Materials and Methods

This prospective, randomized, single-center clinical trial was conducted at the Department of Physical Medicine and Rehabilitation. Individuals referred to the Department of Physical Medicine and Rehabilitation with a diagnosis of shoulder tendinopathy and meeting the inclusion criteria were referred to the Physiotherapy Department, where, upon providing consent to participate in the study, they underwent assessment and received the intervention.

Randomization and blinding

Participants were randomly assigned to two groups: one receiving in-clinic exercise therapy (in-clinic) and the other group receiving tele-rehabilitation exercise therapy (tele-rehab). For the random sequences, block randomization was implemented with block sizes randomly set to two, four, or six. Initially, block sizes were chosen at random. For each block, various permutations were created to ensure equal group sizes, and then one of these permutations was randomly selected. The random numbers were generated using a computer in an independent statistical unit. For concealed allocation, the results of the randomization were sealed in opaque envelopes [21]. Due to the study design, blinding of physicians and participants was not possible; therefore, only assessor blinding was utilized in this study.

Sample size

The sampling method was convenience sampling. Sample size was calculated a priori using G*Power software, version 3.1.9.2 using a two-sided independent t-test for the difference between two independent means. Based on the study by Malliaras et al. [11], the mean and standard deviation values for pain and shoulder disability were 15 ± 9.5 in the tele-rehabilitation group and

32.9 ± 19.9 in the exercise education group. The pooled standard deviation was 15.59, giving a Cohen's d effect size of 1.15. With a type I error (α) of 0.05 and a statistical power of 80%, the required sample size was calculated as 18 participants per group. To account for an anticipated 10% dropout rate, the final sample size was set at 20 participants per group, for a total of 40 participants.

Inclusion and exclusion criteria

The inclusion criteria included adults aged between 18 and 50 years [16, 22, 23]; MRI-confirmed diagnosis of RCT; shoulder pain duration greater than 6 weeks; worst shoulder pain over the past week greater than 3/10 on a numerical rating scale documented by a retrospective pain diary and confirmed by the evaluating physician [16, 23]; and ownership of a smartphone with the ability to use it.

Individuals who had undergone any treatments or surgeries within the past three months [23], exhibited symptoms of cervical radiculopathy, experienced paresthesia, had a complete rotator cuff tear, or had a history of tumors or malignancies in the affected area were excluded from the study [16]. Additionally, participants with active infections in the shoulder joint or surrounding tissues, coagulation disorders, or anticoagulant use were also ineligible. Furthermore, individuals with systemic rheumatological disorders, a history of upper limb fractures, or those who had taken systemic corticosteroids in the past month were excluded from the study [16].

Interventions

Both groups received 10 sessions of exercise therapy (45 minutes each) over 4 weeks (2–3 sessions per week) [24]. The initial session for both groups was held in the clinic under the supervision of a specialist physiotherapist, who provided standardized instruction. All exercises followed a published protocol for rotator cuff and scapular stabilizer strengthening [25].

The exercises included Codman pendulum exercises and strengthening routines targeting the rotator cuff muscles, including the supraspinatus, infraspinatus, teres minor, and subscapularis. Additionally, the program focused on strengthening the scapular stabilizers, which involved the upper, middle, and lower trapezius, rhomboid muscles, levator scapulae, as well as the pectoralis minor and major [13, 25, 26] (A detailed description of each exercise is provided in Table 1 based on the Template for Intervention Description and Replication checklist).

Table 1. TIDieR checklist-exercise therapy for RCT (tele-rehab vs in-clinic)

Item	Category	Description
1.	Brief name	Exercise therapy for RCT (in-clinic vs tele-rehab)
2.	Why (rationale)	To compare the effectiveness of tele-rehabilitation versus in-clinic exercise therapy on pain, disability, function, and QoL in patients with RCT.
3.	What (materials)	In-clinic group: printed pamphlet with exercise illustrations and written instructions. Tele-rehab group: smartphone or computer with internet access
4.	What (procedure)	Codman pendulum exercises: Participants stand with affected arm hanging freely, trunk flexed 90° supported by the other arm. Passive glenohumeral motion via trunk movements. Three movement patterns: 1) circumferential (clockwise/counter-clockwise), 2) coronal (abduction-adduction), 3) sagittal (flexion-extension). 3 sets of 10 repetitions per pattern per session. Strengthening routines targeting rotator cuff muscles (supraspinatus, infraspinatus, teres minor, subscapularis) and scapular stabilizers (upper, middle, lower trapezius, rhomboids, levator scapulae, pectoralis minor/major).
5.	Who provided	A specialist physiotherapist. The initial session for both groups was held in the clinic under the same therapist's supervision.
6.	How (mode)	Tele-rehab group: Online sessions via an application. A physiotherapist supervised performance live. Communication via messenger. In-clinic group: Direct, face-to-face supervision by a physiotherapist during each session.
7.	Where (setting)	In-clinic: Department of Physical Medicine & Rehabilitation, Imam Reza Hospital. Tele-rehab: participant's home, initial session in clinic.
8.	When and how much	Total sessions: 10 Duration per session: 45 minutes Frequency: 2–3 sessions per week Total period: 4 weeks Codman pendulum: 3×10 per movement pattern per session Acetaminophen allowed: max 500 mg/day
9.	How well (planned adherence)	Participants were instructed to complete all 10 sessions.

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The Codman pendulum exercise protocol required participants to stand with the affected arm hanging freely while maintaining 90° trunk flexion supported by the contralateral arm. Participants generated passive glenohumeral motion through controlled trunk movements while maintaining complete relaxation of shoulder musculature. The protocol included oscillatory movements in three planes: Circumferential (clockwise/counter-clockwise rotation), coronal (abduction-adduction), and sagittal (flexion-extension) (Figure 1) [27]. Each treatment session comprised 3 sets of 10 repetitions per movement pattern (3×10 repeats) [23, 28].

The 10-session duration was selected because most studies in relevant systematic reviews used 8–12 sessions of therapeutic exercise, which resulted in significant pain reduction and functional improvement in patients with shoulder tendinopathy [29].

The tele-rehab group accessed exercise videos through an available application. During each online session, a physiotherapist supervised the exercise. If participants encountered any issues or had questions, they communi-

cated their concerns to the therapist via messenger. Both the participants and the therapist recorded the methods and duration of the exercises.

In-clinic group participants received the same exercises from the clinic pamphlet and performed them under the direct supervision of a physiotherapist during each session. Participants in both groups were permitted to use acetaminophen at a maximum dose of 500 mg per day.

Process

Participants who met the inclusion criteria were evaluated by a specialist in physical medicine and rehabilitation. Demographic information, including age, gender, height, weight, affected side, limited shoulder range of motion (ROM) (with/without), and duration of pain (more/less than one month), was recorded. Assessments were performed at three time points: Baseline (T0), one month after the final exercise session (T1), and two months after the final session (T2). A blinded assessor conducted all assessments in the same controlled environment.

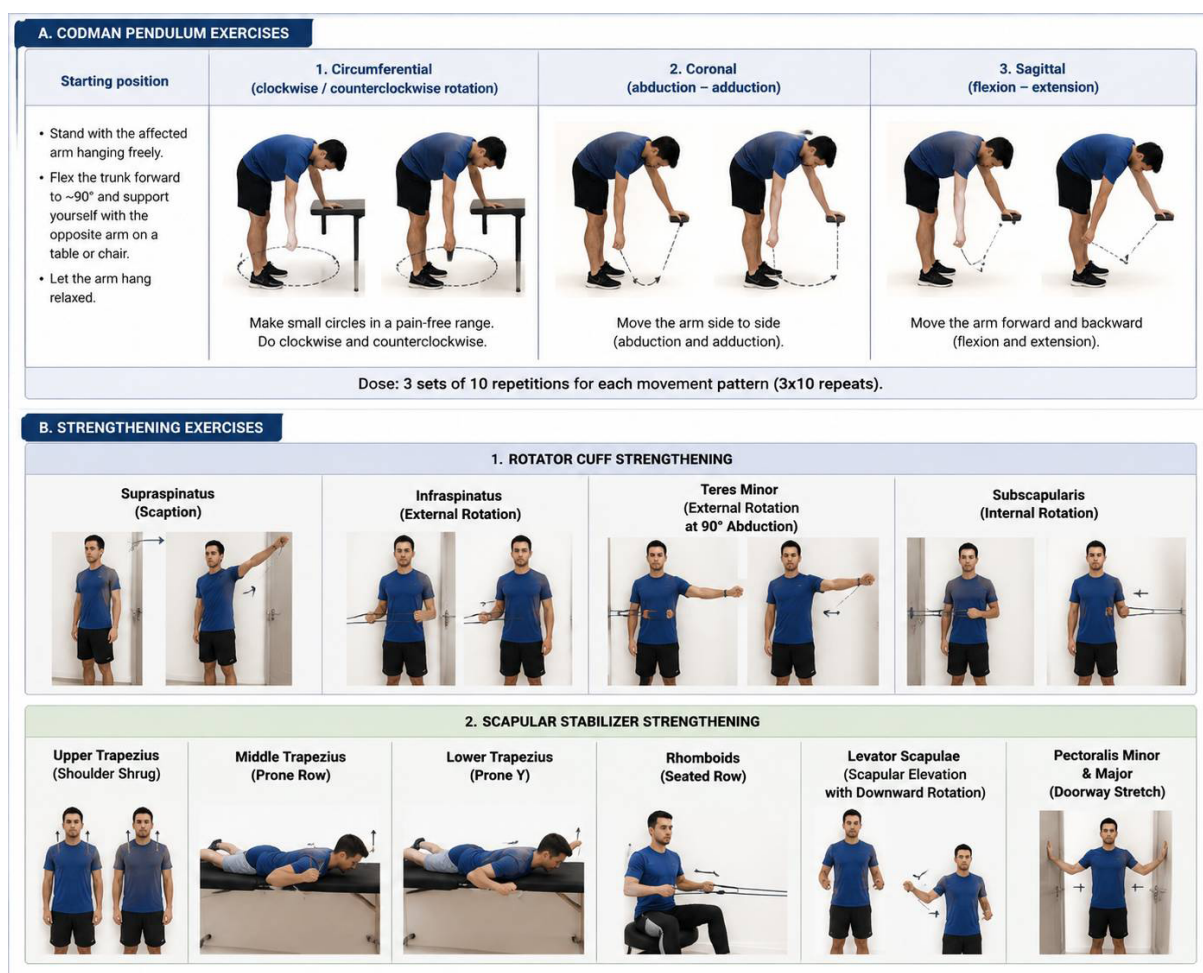


Figure 1. Codman pendulum (three planes) and strengthening exercises for rotator cuff and scapular stabilizers (images generated using artificial intelligence)

Participants' pain and disability were measured using the visual analog scale (VAS). The VAS is a 10-cm horizontal line anchored by "no pain/disability" (0) and "worst imaginable pain/disability" [23, 24, 30]. Participants marked their average pain or disability over the past week [25].

Health-related symptoms were assessed with the DASH questionnaire. The DASH questionnaire is a 30-item tool designed to assess disability and symptoms related to the patient's health status over the past week. It includes questions about the level of difficulty experienced while performing various physical activities due to issues with the arm, shoulder, or hand. Additionally, it evaluates the severity of symptoms such as pain, pain during activities, tingling, weakness, and stiffness. The questionnaire also examines the impact of these problems on social activities, work, sleep, and self-image. Respondents answer each item using a five-point Lik-

ert scale. The final score ranged from 0, indicating no disability, to 100, representing the most severe disability [23-25]. In this study, the total DASH questionnaire score was calculated. The DASH questionnaire has been translated into several languages. It demonstrates high validity and reliability (Cronbach's $\alpha=0.96$, test re-test intraclass correlation coefficient [ICC]=0.92, minimal detectable change=8.7 points, minimal clinically important difference=10.5 points) [31, 32].

Additionally, health-related QoL was evaluated using the brief World Health Organization QoL scale (WHOQOL-BREF) [23]. The WHOQOL-BREF scale is a condensed version of the WHOQOL-100 questionnaire. It consists of 24 items that assess QoL across four dimensions: physical health, mental health, social relationships, and environment. Each item is rated on a five-point Likert scale, where higher scores reflect a better QoL. After calculating the scores, they were linearly transformed

to a scale of 0 to 100. WHOQOL-BREF scale has been translated into several languages and demonstrates high validity and reliability (Cronbach's $\alpha=0.84-0.89$, test re-test ICC=0.86) [33, 34].

Statistical analysis

All analyses were performed using SPSS software, version 26.0. The significance level was set at $\alpha=0.05$ (two-tailed). Data normality was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots. Continuous variables are presented as Mean $\pm$ SD; categorical as frequency (%).

Demographic and clinical characteristics (age, sex, body mass index, affected side, pain duration, baseline VAS, baseline DASH) were compared between groups using independent t-tests for continuous variables and chi-square or Fisher's exact test for categorical variables. No significant differences were found (Table 1), confirming baseline equivalence.

A linear mixed-effects model (LMM) was used. The model included fixed effects of time (T0, T1, T2), group (in-clinic, tele-rehab), and the time $\times$ group interaction. Participants were treated as random effects. For the interaction effects involving additional factors (gender, side, pain duration, ROM limitation), a separate LMM was constructed with group $\times$ factor interaction terms.

Partial eta squared (η^2_p) was calculated for all fixed effects, with interpretation: small ≥ 0.01 , medium ≥ 0.06 , and large ≥ 0.14 .

For any significant main effect of time or time $\times$ group interaction, pairwise comparisons were performed using Bonferroni-corrected t-tests. Specifically, within each group, comparisons were made between T0 vs T1, T0 vs T2, and T1 vs T2. Between-group comparisons were performed at each time point.

Table 2. Baseline participants' characteristics

Characteristics		Clinical PT	Tele-rehabilitation	Total	P
Age (y)		34.5 $\pm$ 3.19	32.6 $\pm$ 4.16	33.5 3.7	0.81
BMI (kg/m ²)		25.89 $\pm$ 2.14	26.08 $\pm$ 2.5	25.98 $\pm$ 2.32	0.25
Sex	Female/male	10.1	9.11	19.21	0.21
Side	Right/left	14.6	14.6	28.12	0.51
Primary ROM	With/without	6.14	7.13	13.27	0.7
Pain time	Under/over one year	12.8	11.9	23.17	0.64

Abbreviations: BMI: Body mass index; ROM: Range of motion; PT: Physical therapy.

Results

Of the 58 patients evaluated, 40 met the inclusion criteria and were randomly divided into two groups, with no participants dropping out of the study over the three months (Figure 2). Among these patients, 52.5% (21 patients) were male, and their ages ranged from 20 to 42 years, with a mean age of 33.5 $\pm$ 3.7 years. Demographic data did not differ significantly between the two groups (Table 2).

Pain (VAS)

Time had a significant main effect on pain scores ($F_{(2, 76)}=45.3$, $P<0.001$, $\eta^2_p=0.54$). The main effect of group was not significant ($F_{(1, 38)}=2.4$, $P=0.128$, $\eta^2_p=0.06$), and the time $\times$ group interaction was also not significant ($F_{(2, 76)}=0.54$, $P=0.587$, $\eta^2_p=0.01$).

Pain decreased significantly from T0 (5.77 $\pm$ 1.02) to T1 (4.12 $\pm$ 1.06; mean difference [MD]=1.65, 95% confidence interval [CI], 1.24%, 2.06%, $P<0.001$) and from T0 to T2 (3.32 $\pm$ 1.09; MD=2.45, 95% CI, 2.04%, 2.86%, $P<0.001$). A significant reduction was also observed from T1 to T2 (MD=0.80, 95% CI, 0.39%, 1.21%, $P<0.001$).

Between-group comparisons at each time point revealed no significant differences (T0: $P=0.75$; T1: $P=0.34$; T2: $P=0.29$) (Tables 3 and 4).

Disability (VAS)

Time had a significant effect on disability scores ($F_{(2, 76)}=38.7$, $P<0.001$, $\eta^2_p=0.50$). No significant group effect ($F_{(1, 38)}=0.44$, $P=0.51$, $\eta^2_p=0.01$) or time $\times$ group interaction ($F_{(2, 76)}=0.24$, $P=0.79$, $\eta^2_p=0.01$) was found.

Table 3. The between-group analysis of outcome measures

Outcome Measure		Mean±SD			P	
		Before Intervention	After Intervention	After 2-Month Follow-up	Group Effect	Time×Group Interaction
Pain	In-clinic PT	5.9±1.16	4.1±1.16	3.45±1.19	0.12	0.58
	Tele-rehabilitation	5.65±0.87	4.15±0.98	3.2±1		
Disability	In-clinic PT	6.35±0.87	4.25±0.85	3.75±0.78	0.51	0.79
	Tele-rehabilitation	6.3±1.08	4.3±0.86	3.9±1.02		
DASH	In-clinic PT	68.25±4.78	43.85±6.89	42.95±7.32	0.25	0.008
	Tele-rehabilitation	65.35±6.05	47.85±7.35	45.9±5.83		
QoL	In-clinic PT	44.3±6.42	58.2±7.65	56.8±7.75	0.78	0.40
	Tele-rehabilitation	44±7.66	54.35±10.6	53.9±11.36		

DASH: Disabilities of the arm, shoulder, and hand.

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Disability improved from T0 (6.32±0.97) to T1 (4.27±0.84; MD=2.05, 95% CI, 1.68%, 2.41%, $P<0.001$) and from T0 to T2 (3.82±0.09; MD=2.50, 95% CI, 2.13%, 2.86%, $P<0.001$). A smaller but significant improvement was also seen from T1 to T2 (MD=0.45, 95% CI, 0.09%, 0.81%, $P=0.009$). No significant between group differences were observed at any time point (all $P>0.05$) (Tables 3 and 4).

Disabilities of the arm, shoulder, and hand

The analysis showed a significant main effect of time ($F_{(2, 76)}=52.1$, $P<0.001$, $\eta_p^2=0.58$) and a nonsignificant group effect ($F_{(1, 38)}=1.35$, $P=0.25$, $\eta_p^2=0.03$). Importantly, the time×group interaction was significant ($F_{(2, 76)}=5.28$, $P=0.008$, $\eta_p^2=0.12$), indicating that the change in DASH scores over time differed between the two groups.

In the in-clinic group, DASH scores decreased from T0 (68.25±4.78) to T1 (43.85±6.89; MD=22.9, $P<0.001$) and remained stable at T2 (42.95±7.32; MD from T0=24.3, $P<0.001$), with no significant change between T1 and T2 (MD=1.4, $P=0.66$).

In the tele-rehab group, DASH scores decreased from T0 (65.35±6.05) to T1 (47.85±7.35; MD=19.0, $P<0.001$) and to T2 (45.9±5.83; MD=20.9, $P<0.001$), with no difference between T1 and T2 (MD=1.9, $P=0.54$).

Between-group comparisons: At T1, the in-clinic group had lower DASH scores than the tele-rehab group (MD=-3.3, uncorrected $P=0.048$), but after Bonferroni correction for three comparisons, the difference was not significant ($P=0.144$). At T2, no significant between-group difference was observed ($P=0.23$) (Tables 3 and 4).

Table 4. The intergroup analysis of outcome measures

Score	MD/95% CI/P		
	Before Intervention to After Intervention MD (95%CI)	Before Intervention to After 2-Month Follow-up	After Intervention to After 2-Month Follow-up
Pain	1.65/(1.24-2.06)/<0.001	2.45/(2.04-2.86)/<0.001	0.8/(0.39-1.21)/<0.001
Disability	2.05/(1.68-2.41)/<0.001	2.50/(2.13-2.86)/<0.001	0.45/(0.089-0.811)/0.009
DASH	20.95/(18.11-23.78)/<0.001	22.37/(19.53-25.21)/<0.001	1.42/(-1.41-4.26)/0.66
QoL	12.12/(8.81-15.43)/<0.001	11.20/(7.88-14.51)/<0.001	-0.92/(-2.38-4.23)/>0.05

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Abbreviations: DASH: Disabilities of the arm, shoulder, and hand; CI: Confidence interval; MD: Mean difference.

Brief World Health Organization quality of life

Time had a significant effect on QoL scores ($F_{(2, 76)}=29.4$, $P<0.001$, $\eta_p^2=0.44$). The group effect was not significant ($F_{(1, 38)}=0.08$, $P=0.78$, $\eta_p^2=0.002$), and the time $\times$ group interaction was also not significant ($F_{(2, 76)}=0.93$, $P=0.40$, $\eta_p^2=0.02$).

QoL improved from T0 (44.15 ± 6.98) to T1 (56.27 ± 9.33 ; MD=12.12, 95% CI, 8.81%, 15.43%, $P<0.001$) and from T0 to T2 (55.35 ± 9.71 ; MD=11.2, 95% CI, 7.88%, 14.51%, $P<0.001$). The change from T1 to T2 was not significant (MD=-0.92, 95% CI, -2.38%, 4.23%, $P=1.00$). No significant between group differences were found at any time point (all $P>0.05$) (Tables 3 and 4).

Interaction effects with other baseline factors

The interaction between group and gender, side of involvement, presence of limited shoulder ROM, and duration of pain (under or over one year) was examined for each outcome. As presented in Table 5, no significant interaction effects were observed for pain, disability, or QoL (all $P>0.10$). For the DASH score, a significant interaction was found with side of involvement ($F_{(2, 30)}=3.69$, $P=0.037$); however, this single significant finding among multiple tests should be interpreted with caution.

Discussion

This study assessed the effectiveness of a tele-rehab exercise therapy compared to in-clinic exercise therapy for individuals with RCT. Forty participants with this condition took part in the study. The results indicated that both the in-clinic and the tele-rehab groups experienced reductions in pain and disability over three months, along

with improvements in symptoms and QoL. No significant differences emerged between the two groups at any time point before the intervention, after the one-month intervention, or at the two-month follow-up. Additionally, the interaction effect of time and group was insignificant, except for disability severity, suggesting that the improvement process over time was similar for both treatment groups.

Several established biomechanical and neuromuscular mechanisms may explain the improvement observed in both groups. Therapeutic exercise has been shown to promote tendon remodeling by stimulating collagen synthesis and improving tendon function [35, 36]. In addition, RCT is associated with altered motor control, including delayed activation of the rotator cuff muscles and compensatory overactivity of the deltoid muscle. The prescribed exercises, including rotator cuff strengthening and scapular stabilization, may help restore coordinated scapulothoracic and glenohumeral motion, improve muscle recruitment patterns, and reduce sub-acromial mechanical stress [37, 38]. Furthermore, pendulum exercises may reduce pain through gentle passive mobilization and minimal rotator cuff muscle activation, thereby facilitating subsequent pain-free shoulder movement and exercise performance [39].

These findings align with previous studies that have confirmed physiotherapy exercises as an independent and effective treatment option for shoulder tendinopathies [33, 34, 40]. In comparing physiotherapy interventions with other treatment modalities, a review by Lazzarini et al. (2025) [40] indicated that corticosteroid injections were not significantly more effective than physiotherapy unless combined with other physiotherapy interventions. Additionally, a study by Magalhães et

Table 5. Interaction effects of group with gender, side of involvement, duration of initial pain, and limited shoulder rom over time (repeated measures)

Score		Gender	Side	Limited Shoulder ROM	Pain Time
Pain	df	2,30	2,30	2,30	2,30
	F	1.58	2.04	0.49	1.24
	P	0.22	0.14	0.61	0.30
Disability	df	2,30	2,30	2,30	2,30
	F	1.26	0.12	1.43	3.24
	P	0.29	0.88	0.25	0.053
DASH	df	2,30	2,30	2,30	2,30
	F	0.07	3.69	1.57	0.25
	P	0.93	0.037	0.22	0.77
QoL	df	2,30	2,30	2,30	2,30
	F	1.52	1.80	1.61	3.49
	P	0.23	0.18	0.21	0.70

DASH: Disabilities of the arm, shoulder, and hand; ROM: Range of motion.

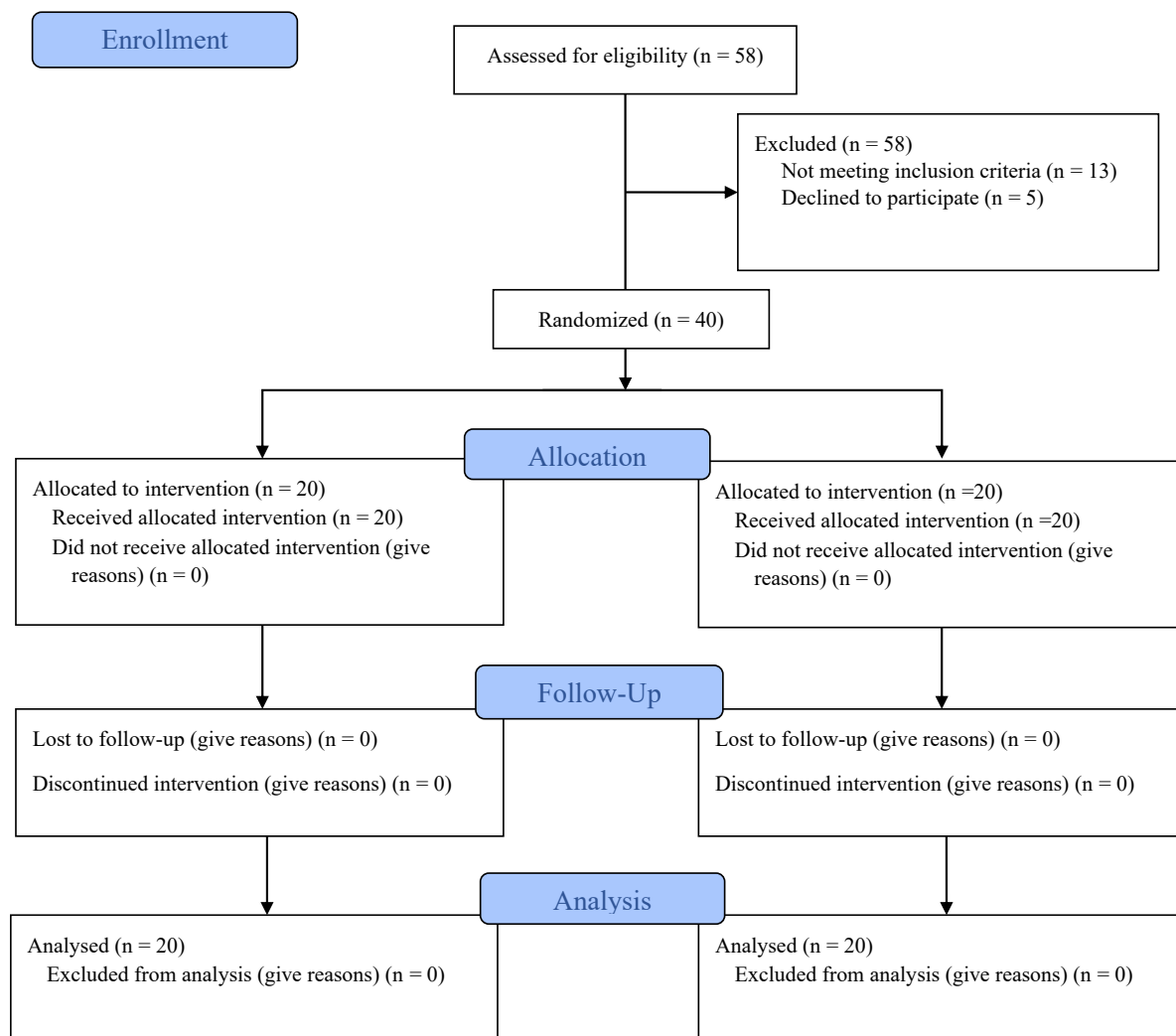


Figure 2. CONSORT flow diagram

al. (2024) [34] found that intrathecal microelectrolysis associated with exercises did not have a greater impact on pain intensity and disability in individuals with RCT than therapeutic exercises alone. These results highlight that physiotherapy can serve as a safe and independent treatment option for managing RCT.

The results of Villa Muñoz et al. [33] showed that both therapeutic exercise and myofascial trigger point therapy effectively improve pain and ROM in individuals with shoulder tendinopathy. Additionally, therapeutic exercise can serve as a viable alternative to manual therapy, offering cost-effective benefits, particularly in remote care and group sessions. This highlights the broader application of therapeutic exercise in physiotherapy. In this study, a combination of Codman and rotator cuff muscle-strengthening exercises was implemented, enabling tele-rehabilitation.

Tele-rehabilitation is an innovative approach with significant potential to enhance accessibility, convenience, and flexibility for patients [41]. It fosters greater patient engagement by incorporating tools, such as continuous monitoring, exercise biofeedback, gamification, and communication via video or telephone [22, 42]. Review studies indicated that tele-rehabilitation is more effective than traditional home exercise in improving ROM, functional outcomes, and QoL for patients with shoulder disorders [14, 18]. The results of this study indicate that tele-rehabilitation can be as effective as in-clinic exercise, particularly in improving patients' pain, function, symptoms, and overall QoL. These findings align with those of Türkmen et al. (2020) [43], who compared video-based rehabilitation programs with traditional physiotherapy. They also concluded that tele-rehabilitation can serve as an effective and cost-efficient option for the conservative treatment of minor rotator cuff tears.

Evidence on the effectiveness of tele-rehabilitation is still developing. Some studies, including a systematic review by Gava et al. (2022) [14], have indicated no significant difference between tele-rehabilitation and in-clinic physiotherapy or home exercise programs in improving pain and disability. These findings suggest that while tele-rehabilitation may be a promising option, there is not yet sufficient high-quality evidence to fully endorse it as a standalone treatment.

Adhering to physical therapy is crucial for improving outcomes and preventing exacerbations. Tele-rehabilitation may enhance adherence. A study by Malliaras et al. (2020) [11] demonstrated that adherence to tele-rehabilitation programs can be higher than with traditional methods, which may lead to improved treatment outcomes. In our study, treatment adherence was similar in both the tele-rehabilitation and in-clinic physiotherapy groups, with all participants completing their treatment sessions.

Several similar studies have noted gender imbalances in the sample, which may impact the generalizability of the results [11]. In contrast, this study achieved approximately equal representation of both sexes among participants, enhancing the generalizability of its findings. Although the study design did not allow participant blinding, the assessor was not aware of which group participants belonged to.

Limitations and future research recommendations

Several limitations should be acknowledged. First, the follow-up period was only two months after intervention; longer-term outcomes (e.g. 6 or 12 months) are needed to evaluate symptom recurrence and the need for additional interventions. Second, we did not assess neuromuscular outcomes directly (e.g. surface EMG of rotator cuff muscles, corticospinal excitability), which would have provided insights into the biological mechanisms underlying the clinical improvements. Future studies should incorporate EMG and strength measurements (e.g. isokinetic dynamometry of shoulder rotators) to determine whether tele-rehabilitation and in-clinic therapy produce similar neuromuscular adaptations. Third, we did not measure shoulder ROM or muscle strength; future trials should include these variables to obtain a more comprehensive functional profile. Fourth, participants were relatively young (mean 33.5 years) and all owned smartphones, limiting generalizability to older adults or those with low digital literacy. Fifth, while assessor-blinding was maintained, participants could not be blinded, which may introduce performance bias.

Clinicians can confidently prescribe tele-rehabilitation for motivated patients with RCT, especially when access to a clinic is limited. Future research should focus on (a) identifying predictors of response to tele-rehabilitation, (b) comparing different tele-rehabilitation formats (synchronous vs. asynchronous), and (c) evaluating cost-effectiveness from a societal perspective.

Conclusion

This study, in conjunction with existing evidence, confirms that both in-clinic physiotherapy and tele-rehabilitation effectively reduce pain, decrease disability, and improve functional outcomes and QoL in patients with RCT. Tele-rehabilitation, in particular, offers distinct advantages including broader accessibility, scheduling flexibility, and potentially improved patient adherence, positioning it as a viable complementary or alternative treatment pathway.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Research Ethics Committee of [Aja University of Medical Sciences](#), Tehran, Iran (Code: IR.AJAUMS.REC.1403.073), and was registered by the [Iranian Registry of Clinical Trials \(IRCT\)](#), Tehran, Iran (Code: IRCT20180416039323N5). This study was conducted in accordance with the guidelines of the Declaration of Helsinki. Informed consent was obtained from all participants after they received a thorough explanation of the study's objectives. Informed consent was obtained from all participants.

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Authors' contributions

Data collection, and data analysis: Reza Kazempour-Mofrad; Investigation: Siros Azizi; Intervention: Afshaneh Dadarkhah; Patient referral: Zahra Rezasoltani, Siros Azizi, and Reza Kazempour-Mofrad; Methodology: Masumeh Bagherzadeh Cham; Writing: All authors; Supervision: Reza Kazempour-Mofrad;

Conflict of interest

The authors declared no conflict of interest.

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