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Effects of Adding Muscle Energy Technique to Joint Mobilization on Pain, Range of Motion, and Shoulder Function After Arthroscopic Rotator Cuff Repair: An Observational Cohort Study

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABC 1 **Cui Xianchao**
A 2 **Zheng Xiuqiong**
BC 1 **Chen Sheng**
BC 1 **Li Wei**
E 1 **Huang Xiaoqun**
AE 1 **Wei Chunxia**

1 Department of Rehabilitation Medicine, Yichang Central People's Hospital, The First College Of Clinical Medical Science, China Three Gorges University, Yichang, Hubei, PR China
2 Department of Rheumatology and Immunology, Yichang Central People's Hospital, The First College Of Clinical Medical Science, China Three Gorges University, Yichang, Hubei, PR China

Corresponding Author: Wei Chunxia, No. 45, Fusui Road, Xiling District, Yichang City, Hubei Province, China, e-mail: weichunxia17@163.com
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Background: Although muscle energy technique (MET) and joint mobilization (JM) are individually used in shoulder rehabilitation, evidence for their combined application following arthroscopic rotator cuff repair (ARCR) remains limited. This study evaluated whether adding MET to JM yields superior outcomes compared with JM in patients after ARCR.

Material/Methods: Forty patients who underwent ARCR were enrolled in this observational cohort study and assigned to either a control group (n = 20) receiving JM or an experimental group (n = 20) receiving MET in addition to the same JM. Shoulder function was assessed using the University of California at Los Angeles (UCLA) shoulder rating scale, pain using the visual analog scale (VAS), and joint range of motion using active range of motion (AROM). Assessments were performed at baseline and after 4 weeks.

Results: Baseline characteristics were comparable between groups (all $P > 0.05$). Both groups improved significantly after the 4-week intervention (all $P < 0.001$). However, the experimental group demonstrated significantly greater gains: lower VAS scores (1.45 ± 0.69 vs 2.35 ± 0.81, $P < 0.001$), greater AROM in all directions (flexion $P = 0.021$; abduction and external rotation both $P = 0.003$; internal rotation $P = 0.006$), and higher UCLA shoulder rating scale scores (23.15 ± 2.03 vs 19.05 ± 2.26, $P < 0.001$).

Conclusions: Combined MET and JM significantly improved shoulder AROM, reduced pain, and enhanced shoulder motor function compared with JM in patients after ARCR.

Keywords: **Rehabilitation • Shoulder Pain • Physical Therapy Modalities • Observational Study**

Abbreviations: **ARCR**, arthroscopic rotator cuff repair; **JM**, joint mobilization; **MET**, muscle energy technique; **UCLA**, University of California at Los Angeles; **AROM**, active range of motion; **VAS**, visual analog scale; **RCI**, rotator cuff injury

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Introduction

Rotator cuff injury (RCI) is a damage to the rotator cuff structure, which is composed of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles [1]. The injuries usually result from trauma, degeneration, or long-term chronic shoulder overuse. These conditions range from acute traumatic tears to chronic degenerative lesions, leading to shoulder pain, decreased range of motion, muscle weakness, and significant limitation in daily activities [1]. If conservative treatment fails or symptoms progress, surgical intervention may be indicated [2].

Arthroscopic rotator cuff repair (ARCR) is a highly effective procedure for RCI, restoring native anatomy, improving patient function, and relieving pain. Long-term follow-up studies demonstrate promising outcomes, including sustained pain relief and motor function improvement [3]. Despite ARCR ensuring structural integrity of the rotator cuff, postoperative rehabilitation remains important and challenging. Pain, muscle weakness, and immobilization following ARCR, if not managed promptly and effectively, can lead to joint adhesions, muscle atrophy, and poor functional recovery, compromising surgical outcomes [4]. Rehabilitation therapy is therefore critical for optimizing postoperative results after ARCR.

Muscle energy technique (MET) and joint mobilization (JM) are among the most promising rehabilitation techniques. MET is a manual therapy method that uses the patient's own isometric muscle contractions, controlled by the therapist, to improve joint range of motion, relieve pain, and improve muscle function [5]. It uses post-contraction relaxation (post-isometric relaxation) to lengthen and stretch soft tissues. In shoulder rehabilitation, MET can reduce periarticular muscle tension and thus provide better conditions for JM. For example, when shoulder stiffness is due to rotator cuff dysfunction, MET can relieve muscle spasm and soft tissue tightness, thereby increasing joint flexibility. JM refers to passive movements performed by therapists within the physiological and accessory range of motion of a joint, which can help improve mobility and reduce pain [6]. It works through stretching and gliding movements on the joint capsule, ligaments, and surrounding soft tissues to restore normal joint biomechanics. Gutierrez-Espinoza et al [7] showed that glenohumeral JM can improve range of motion and reduce pain in patients with rotator cuff disorders. In clinical practice, the combined use of MET and JM has been shown to improve range of motion and reduce pain in patients with adhesive capsulitis of the shoulder [8,9]. This combined approach aims to improve biomechanical movement and relieve muscular rigidity. JM, as a specialized passive manual therapy targeting the joint capsule and periarticular tissues, serves to restore normal joint arthrokinematics, alleviate pain, and enhance mobility [10].

Although both MET and JM are used for shoulder rehabilitation, evidence supporting their combined use for improving shoulder function after ARCR is limited. It is important to understand how combined treatment can enhance shoulder function, recovery efficiency, and quality of life. In this study, we aimed to investigate whether the addition of MET to JM could enhance shoulder rehabilitation outcomes following ARCR. The primary outcome was pain intensity assessed by the visual analog scale (VAS); secondary outcomes included active range of motion (AROM) in flexion, abduction, and external and internal rotation, as well as overall shoulder function measured by the University of California at Los Angeles (UCLA) shoulder rating scale. The ultimate goals were to establish evidence-based rehabilitation strategies, promote functional recovery, reduce postoperative complications, and enhance quality of life.

Material and Methods

This study was reviewed and approved by the Medical Ethics Committee of Yichang Central People's Hospital (approval No: 2024-293-02), and was conducted in accordance with the principles of the Declaration of Helsinki.

This study was conducted as an observational clinical study and does not constitute a clinical trial. No fees were charged to participants, and reasonable expenses were compensated. The provision of free treatment and compensation in accordance with applicable law was guaranteed in the event of any research-related injury. After ARCR, patients were assigned to either an experimental group (n = 20), which received MET combined with conventional physiotherapy including JM, or to a control group (n = 20), which received conventional physiotherapy including JM alone. This study was conducted in the Department of Rehabilitation Medicine at Yichang Central People's Hospital from September 2024 to June 2025.

Sample size calculation was based on literature on MET and JM in shoulder rehabilitation. Assuming a clinically meaningful difference in UCLA shoulder rating scale score of 3.5 points, a standard deviation of 4.0 [11], alpha = 0.05, and power = 0.80, a minimum of 17 patients per group was required. Accounting for a potential dropout rate of approximately 15%, we enrolled 20 patients per group (40 total). Ten patients were excluded at screening due to not meeting inclusion criteria, yielding a final sample of 40 participants.

Participants

The inclusion criteria of this study were (1) diagnosis of RCI confirmed by magnetic resonance imaging (MRI) according to the American Academy of Orthopedic Surgeons Clinical Practice Guideline for the management of RCI [12]; (2) initial surgical

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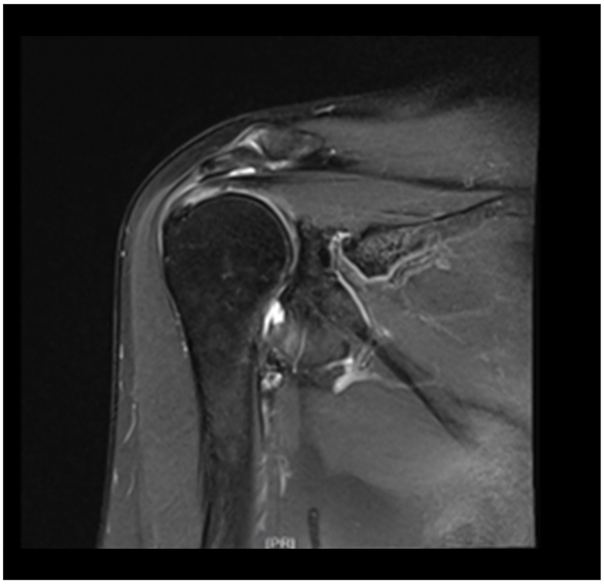

Figure 1. Preoperative imaging of rotator cuff injury. Preoperative coronal oblique T2-weighted fat-suppressed magnetic resonance imaging of the right shoulder from a representative patient. The image demonstrates a full-thickness tear of the supraspinatus tendon. This pattern of injury was representative of the majority of study participants who underwent arthroscopic rotator cuff repair.

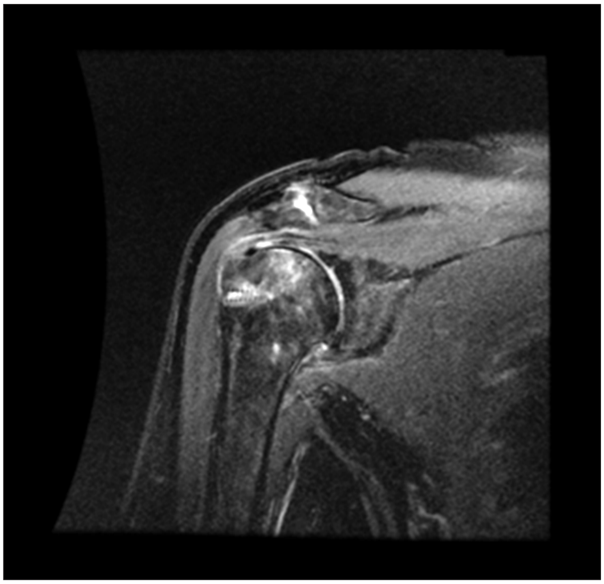

Figure 2. Postoperative imaging of rotator cuff injury in a representative patient. Postoperative coronal oblique T2-weighted fat-suppressed magnetic resonance imaging of the same shoulder obtained following arthroscopic rotator cuff repair. The image demonstrates successful restoration of the supraspinatus tendon continuity with intact suture anchors visible within the greater tuberosity footprint region. This postoperative imaging confirms adequate tension and positioning of the repaired rotator cuff, which is essential for successful rehabilitation outcomes.

treatment (4-8 weeks postoperatively); (3) age 18-65 years; (4) knowledge of and willingness to cooperate actively in rehabilitation therapy; (5) no previous major trauma to disease recovery; and (6) written informed consent to rehabilitation treatment. The exclusion criteria were (1) unhealed upper limb fractures; (2) RCI accompanied by upper limb fractures; and (3) massive rotator cuff tears. The discontinuation and elimination criteria included (1) receipt of other treatments (actively or passively) during the trial period that could influence the study outcomes; (2) occurrence of severe adverse reactions or other safety events necessitating trial termination; and (3) patient's voluntary request to withdraw from the study during the treatment period.

In this study, all enrolled patients underwent ARCR due to failure of conservative treatment (defined as persistent pain and functional limitation after ≥3 months of physical therapy and/or corticosteroid injection) or acute full-thickness tears confirmed on preoperative MRI. Among the enrolled patients, the types of RCI identified by preoperative MRI were classified as follows: Supraspinatus tendon tears were the most common, with 18 isolated supraspinatus tears (45.0%), 10 combined with infraspinatus tear involvement (25.0%), and 12 combined with subscapularis involvement tears (30.0%). According to the Ellman classification system for tear thickness, 8 patients (20.0%) had partial-thickness articular-surface tears (<50% thickness), while 32 patients (80.0%) had full-thickness tears. All patients underwent arthroscopic repair using suture-anchor techniques, with single-row fixation in 26 patients (65.0%) and double-row fixation in 14 patients (35.0%), depending on tear configuration and bone quality. The imaging findings of select patients are shown in **Figures 1 and 2**.

Interventions

The conventional rehabilitation program served as the standard post-arthroscopic physiotherapeutic interventions routinely prescribed following rotator cuff repair [13]. Core components included (1) cryotherapy: intermittent ice application (15-20 minutes per session) to reduce post-exercise inflammation and pain; (2) therapeutic exercise: progressive strengthening of the rotator cuff and scapular stabilizers using resistance bands, isometric contractions, and low-load dynamic movements, advancing in difficulty according to each patient's tolerance; (3) active-assisted and active range-of-motion exercises: pendulum exercises (Codman's maneuver), wall-walking drills, and wand-assisted flexion, abduction, and rotation to progressively restore functional shoulder mobility; and (4) patient education: guidance on activity modification, postural correction, and home-exercise adherence.

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This protocol reflects current clinical practice guidelines and represents the typical standard-of-care pathway in most outpatient rehabilitation settings following ARCR [14]. Both groups received identical conventional rehabilitation.

Patients in the control group received Maitland mobilization therapy and the conventional rehabilitation program. The JM protocol [15,16] included 3 standardized techniques, all performed with the patient in the supine position. (1) Caudal glide: with the affected arm abducted to approximately 70°, the therapist stabilized the medial aspect of the elbow with one hand while applying a graded caudal glide to the proximal humerus with the other. (2) Posterior glide: with the arm relaxed and a small towel placed beneath the scapula for support, the therapist positioned one hand over the humeral head and the other supporting the distal medial humerus, delivering rhythmic posterior glides to the proximal humerus. (3) Rotational mobilization: with the shoulder abducted and the elbow flexed to 90°, the therapist stabilized the humeral head laterally with the upper hand while the lower hand guided internal and external rotation at the forearm. Concurrent inferomedial or superolateral glides were applied to the humeral head via the thumb of the stabilizing hand, corresponding to the direction of rotation. Considering the requirement for tendon-to-bone healing and the need to protect repaired tissues in the early postoperative phase, Grade I and II (pain-modulating) mobilizations were primarily used during the first 2 weeks, with progression to Grade III (stretch-dominated) techniques in weeks 3 and 4 as tissue tolerance permitted. Grade IV oscillations were introduced only in patients who presented with evident capsular restriction without pain provocation. For repairs involving the supraspinatus combined with the subscapularis or infraspinatus, the amplitude of rotational maneuvers was individually titrated to patient tolerance, and their introduction was delayed when clinically indicated. All interventions were administered once daily, 5 days per week, over a 4-week consecutive period. Each treatment session lasted approximately 45 to 60 minutes, of which JM accounted for 15 to 20 minutes; the remaining time was allocated to conventional rehabilitation exercises.

The experimental group received MET [17,18] in addition to the identical conventional rehabilitation and Maitland JM regimen administered to the control group. Within each treatment session, MET was performed sequentially following JM. It should be noted that MET and Maitland JM are distinct modalities: whereas JM addresses passive accessory motion and articular neuro modulation through therapist-driven oscillations, MET engages voluntary isometric contraction to utilize post-isometric relaxation and reciprocal inhibition mechanisms. The MET protocol consisted of 3 standardized procedures, all performed with the patient in the supine position. (1) MET for shoulder flexion: the affected shoulder was passively flexed to its end-range of motion within the patient's pain tolerance. The therapist stabilized the scapula with one hand while holding the patient's elbow with the other, applying a gentle graded traction force at the elbow. The patient was instructed to resist this traction with approximately 30% of maximal voluntary effort for 10 seconds. Following complete muscular relaxation, the shoulder was passively moved to the newly acquired motion barrier. This contraction-relaxation cycle was repeated 3 to 5 times or until no further range gain was observed. (2) MET for shoulder abduction: the affected arm was passively abducted to its restrictive barrier. The therapist grasped the elbow with one hand while applying a caudal glide to the humeral head with the other. The patient was instructed to resist the caudal glide at approximately 30% of maximal force for 10 seconds. After relaxation, the abduction angle was increased to the new motion barrier. The procedure was repeated 3 to 5 times. (3) MET for internal and external rotation: the shoulder was passively rotated (internally or externally) to its end-range. The therapist stabilized the elbow with one hand while holding the wrist with the other to apply a gentle rotational force. The patient resisted this rotation at approximately 30% of maximal effort for 10 seconds. Upon relaxation, the limb was repositioned to the new motion barrier. The procedure was performed 3 to 5 times for each direction. Session parameters were consistent with those of the control group: once daily, 5 days per week, over 4 consecutive weeks, with each full session lasting approximately 45 to 60 minutes (**Figure 3**).

Outcome Assessments

All outcomes were assessed by the same blinded rehabilitation therapist at baseline and after the 4-week intervention. The following validated outcome measures were used.

The UCLA shoulder rating scale was used to assess shoulder joint function and is widely used for evaluating outcomes in shoulder surgery and related pathological research. The total UCLA score is 35 points. The scores were interpreted as follows: excellent (34-35 points), good (29-33 points), and poor (<29 points). A higher score indicates better recovery of shoulder joint function [19].

The VAS was used to measure shoulder pain. A 10-cm horizontal line was drawn on paper, with (0), indicating "no pain" and the endpoint (10) indicating the "most severe pain". The patient marked the line at a point corresponding to their perceived level of pain, which was then recorded. The scores were interpreted as follows: 0, no pain; 1-3, mild pain (tolerable); 4-6, moderate pain (affecting sleep, but still tolerable); and 7-10, severe pain (intolerable, affecting sleep quality and appetite) [20].

The score for AROM was evaluated by using a standard goniometer to measure active flexion, abduction, internal rotation,

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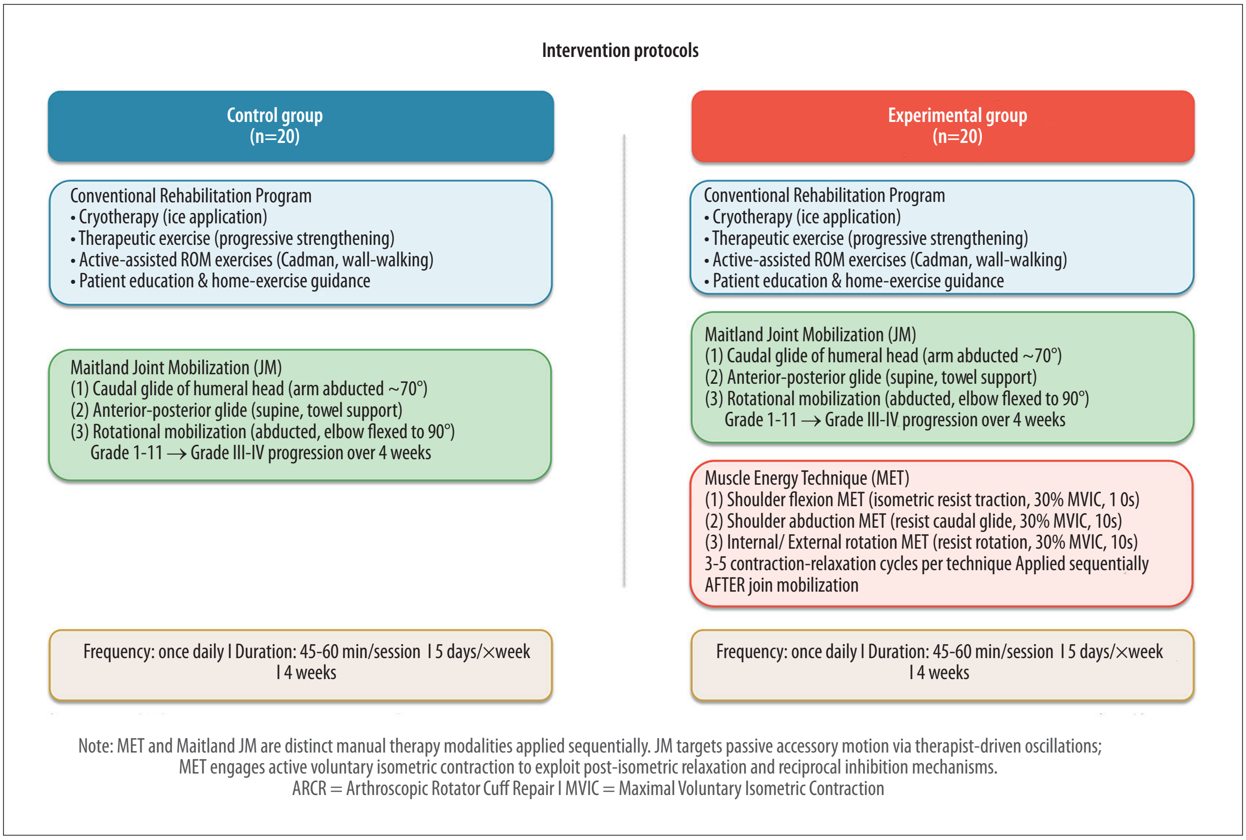

Figure 3. Intervention protocol.

and external rotation of the effected shoulder. A higher range of motion signifies improved function of the shoulder joint [21].

Statistical Analysis

Statistical analyses were conducted using SPSS version 27.0 (IBM Corp, Armonk, NY, USA). Categorical variables were expressed as frequencies and proportions and compared using the chi-square test. Continuous variables were expressed as mean±standard deviation (SD). The normality of continuous data was assessed using the Shapiro-Wilk test. For normally distributed data, paired-sample *t* tests were used for within-group comparisons, and independent-sample *t* tests were used for between-group comparisons. For non-normally distributed data, the Wilcoxon signed-rank test was used for within-group comparisons, and the Mann-Whitney U test was used for between-group comparisons. A *P* value <0.05 was considered statistically significant for all analyses.

Results

A total of 40 patients (16 men and 24 women) met the inclusion criteria and were enrolled in this study. The mean age of the patients was 55.12 ± 6.00 years. Patients were randomly allocated to either the experimental group or the control group (20 per group). No adverse events were recorded during the study period. Baseline demographic and clinical characteristics were comparable between groups ($P > 0.05$), as shown in **Table 1**.

Pain Intensity (VAS)

Pain levels declined substantially in both groups. In the control group, VAS scores decreased from a mean of 4.65 ± 0.99 at baseline to 2.35 ± 0.81 after intervention, whereas the experimental group experienced an even more pronounced reduction—from 4.75 ± 0.79 to 1.45 ± 0.69. The between-group comparison after intervention revealed that participants receiving MET combined with JM reported significantly lower pain scores than those in the control condition ($t = 3.78$, $P < 0.001$). This represents not only a meaningful clinical difference but also suggests that the addition of MET conferred a distinct analgesic benefit beyond conventional rehabilitation alone, as shown in **Figure 4**.

Active Range of Motion

Within-group improvements in AROM were robust and statistically significant across all 4 planes of shoulder motion for

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Table 1. Characteristics of all participants.

	Control group (n = 20)	Experimental group (n = 20)	*t/χ²/Z*	*P*
Sex (Male/Female)	9/11	7/13	0.42	0.519
Age (years)	54.70 ± 5.22	55.55 ± 6.79	-0.44	0.66
Postoperative (days)	38.95 ± 3.94	39.15 ± 2.46	-0.19	0.848
Affected shoulder (right/left)	16/4	15/5	0	1

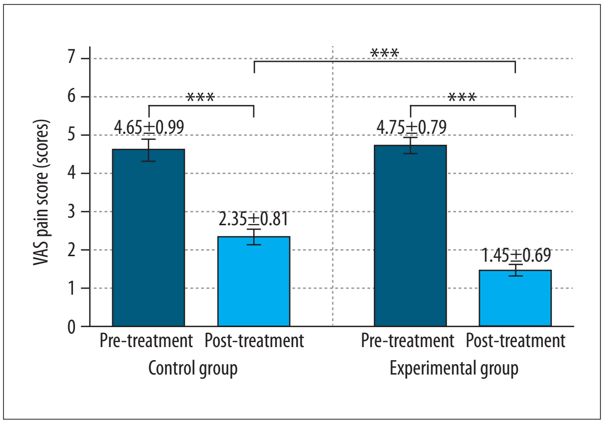

Figure 4. Within-group and between-group comparison of visual analog scale (VAS) scores before and after intervention. Bars represent mean ± SD (n = 20 per group). *** $P < 0.001$.

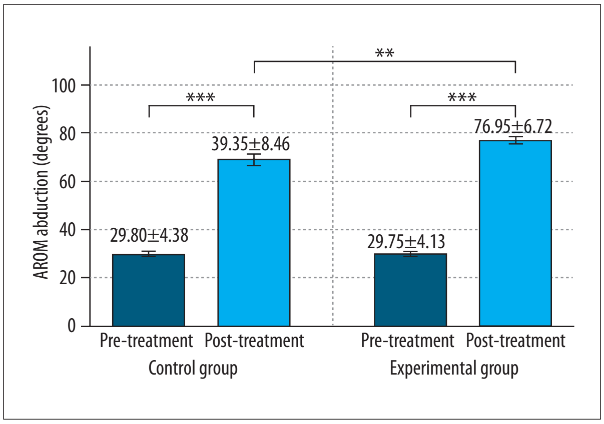

Figure 6. Within-group and between-group comparison of active range of motion (AROM) in shoulder abduction before and after intervention. Bars represent mean ± SD in degrees (n = 20 per group). ** $P < 0.01$; *** $P < 0.001$.

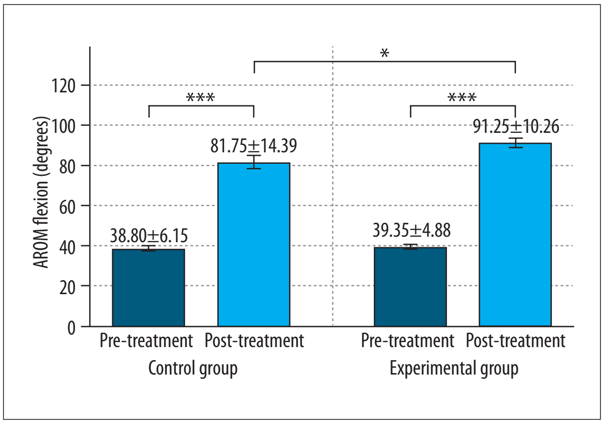

Figure 5. Within-group and between-group comparison of active range of motion (AROM) in shoulder flexion before and after intervention. Bars represent mean ± SD in degrees (n = 20 per group). * $P < 0.05$; *** $P < 0.001$.

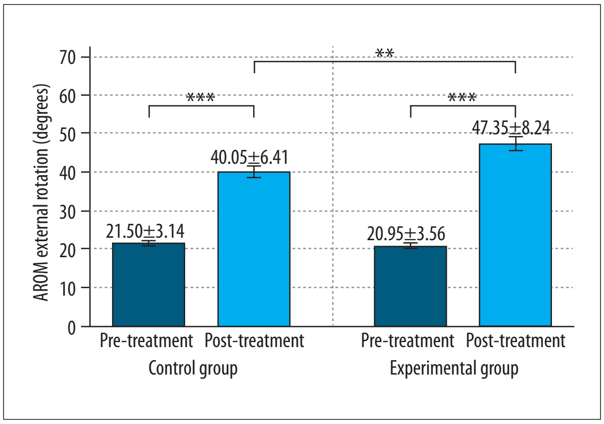

Figure 7. Within-group and between-group comparison of active range of motion (AROM) in external rotation before and after intervention. Bars represent mean ± SD in degrees (n = 20 per group). ** $P < 0.01$; *** $P < 0.001$.

both cohorts (all $P < 0.001$). However, the experimental group consistently achieved superior outcomes at the post-intervention assessment. In flexion, the experimental group attained a mean AROM of 91.25° ± 10.26° compared with 81.75° ± 14.39° in the control group ($P = 0.021$) (**Figure 5**). Abduction yielded an even more marked difference: 76.95° ± 6.72° vs 69.35° ± 8.46° ($P = 0.003$) (**Figure 6**). External rotation and internal rotation followed a similar pattern, with between-group differences favoring the experimental protocol by approximately 7° to 7.5° on average, with external rotation of 47.35° ± 5.89° vs 40.05° ± 7.12° ($P = 0.003$) (**Figure 7**), and internal rotation of 52.05° ± 6.27° vs 44.95° ± 7.33° ($P = 0.006$) (**Figure 8**).

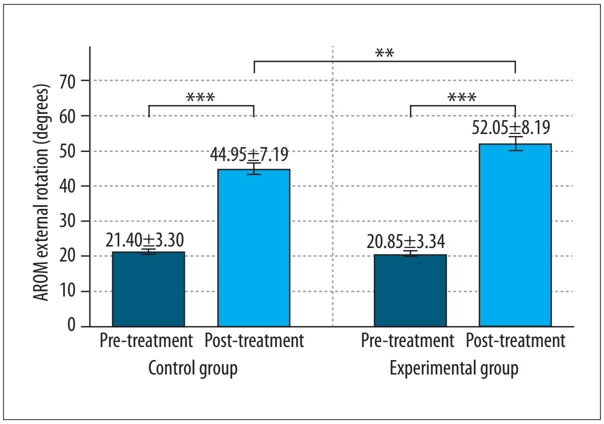

Figure 8. Within-group and between-group comparison of active range of motion (AROM) in internal rotation before and after intervention. Bars represent mean ± SD in degrees (n = 20 per group). ** $P<0.01$; *** $P<0.001$.

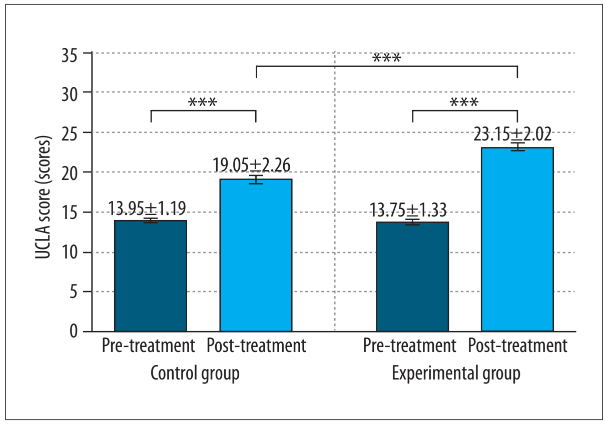

Figure 9. Within-group and between-group comparison of UCLA shoulder rating scale scores before and after intervention. Bars represent mean ± SD (n = 20 per group; maximum score = 35). *** $P<0.001$.

UCLA Shoulder Rating Scale

The most striking between-group difference was with the composite UCLA shoulder rating scale score. Although both groups improved significantly from their respective baselines, the experimental group's post-intervention score of 23.15° ± 2.03° substantially exceeded that of the control group's score of 19.05° ± 2.26°, yielding a significant between-group effect ($P<0.001$). This nearly 4-point difference on a 35-point scale reflects clinically meaningful improvements in pain relief, function, and overall shoulder satisfaction among patients treated with MET plus JM (**Figure 9**).

Discussion

The study aimed to examine the effect of integrating MET with JM on pain severity, AROM, and functional results in patients who had undergone ARCR. Findings revealed that following a 4-week intervention, the experimental group showed notably superior enhancements in UCLA shoulder rating scale scores, VAS rating, and AROM compared with the control group.

After 4 weeks of the combined use of MET and JM, patients who had undergone ARCR experienced a significant reduction in pain intensity. This is consistent with the results of other studies [9,22,23], in which the combination of MET and JM helped relieve shoulder pain. MET reduces periscapular tension by relaxing the periarticular soft tissue. This makes it more suitable to apply JM after that, providing safer and more effective expansion of joint range of motion and reduction in pain. For example, MET relaxation of the rotator cuff muscles (supraspinatus and infraspinatus) before performing JM may reduce protective muscle tension. This step may allow JM to achieve a deeper and more therapeutic effect [24]. In adhesive capsulitis after ARCR, MET using methods such as post-isometric relaxation [25] reduces hypertonicity in the rotator cuff and associated muscles. This leads to increased shoulder range of motion and decreased pain [26]. Rhythmic oscillations in JM can also promote synovial fluid flow [24]. Physical pressure and movement stimulate mechanoreceptors (eg, Ruffini end, Pacinian body) in the periarticular muscles, joint capsule, and ligaments activating inhibitory interneurons in the spinal cord, which may trigger endogenous modulators (eg, release of neurotransmitters such as gamma-aminobutyric acid, endogenous opioids (endorphins) that inhibit the ascending transmission of nociceptive signals. This inhibits the transmission of pain signals at the spinal and brain, raises the pain threshold, and thus relieves pain [27].

The results of the present study showed that the experimental group had significantly improved AROM of shoulder flexion, abduction, internal rotation, and external rotation. Abbas et al [28] reported improved shoulder AROM after 6 weeks with MET and JM. A systematic review also showed that MET and JM can significantly improve shoulder AROM (angles of flexion, external rotation, internal rotation, and abduction) [29]. Patients after ARCR typically need an abduction brace for 6 weeks to protect repaired tissues and allow tendon-to-bone healing [30]. Long immobilization leads to tightness of the periarticular shoulder muscles. MET addresses this problem by engaging the patient to precise, controlled voluntary muscle contractions of specific direction and intensity. This helps to relieve tension in the periarticular muscles, increase extensibility of periarticular tissues, restore normal muscle function, and restore physiological movement patterns of the shoulder joint [31]. In addition to muscle tension, the muscle tension generated by isometric contraction can induce local heat accumulation in tissues. This thermal effect can cause temporary changes in the molecular structure of collagen and elastic

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fibers of soft tissue, decreasing tissue adhesiveness and viscoelasticity and thus improving range of motion [32]. JM effectively addresses postoperative joint stiffness and restricted mobility, which are common problems, especially in early ARCR [33]. By improving the flexibility of the joint capsule and ligaments, JM provides favorable conditions for the effective use of MET. Combining these 2 techniques can allow for faster restoration of the normal AROM of the shoulder.

Our results showed that MET combined with JM was effective in improving UCLA shoulder rating scale scores. This finding is consistent with prior evidence from similar populations. Mallick et al [34], for instance, reported that patients with adhesive capsulitis treated with combined MET and JM demonstrated marked gains in activities of daily living. Although adhesive capsulitis and post-ARCR rehabilitation differ in their primary pathology, the consistency of findings across these distinct cohorts suggests that the MET-JM synergy may operate through mechanisms that are fundamentally neuromuscular rather than disease-specific. While JM has established efficacy in restoring passive accessory motion, emerging evidence indicates that mobilization-alone protocols may yield incomplete functional recovery. Passive gains in joint arthrokinematics do not necessarily translate into stable AROM if periscapular and rotator cuff muscles remain inhibited or weak—a condition frequently encountered after ARCR due to postsurgical reflexive inhibition and disuse atrophy. The present results suggest that supplementing JM with MET addresses this gap: MET leverages voluntary isometric contractions (typically at 20%-50% of maximal effort) to engage spinal reflex arcs (autogenic inhibition via Golgi tendon organs and reciprocal inhibition of antagonists), promote motor unit recruitment, and facilitate the re-education of coordinated muscle activation patterns [35]. Because rotator cuff re-strengthening and timely activation constitute the cornerstone of post-ARCR functional recovery, MET provides a direct means of targeting these muscles during the early rehabilitative phase. Moreover, the sequential or integrated application of JM and MET may confer advantages beyond what either technique could achieve independently. JM preferentially stimulates capsular and ligamentous mechanoreceptors, enhancing afferent input related to joint position sense. MET, by contrast, engages muscle spindle and tendon organ pathways through active contraction, adding a layer of efferent-afferent integration that passive techniques cannot replicate. This complementary stimulation of multiple proprioceptive sources, for example, capsular, ligamentous, and muscular, may accelerate sensorimotor recalibration of the glenohumeral joint, improve scapulohumeral coordination, and ultimately support more durable functional recovery [36].

This study has several limitations. First, the sample size was relatively small (n = 40), which can limit the generalizability and statistical power of the findings. Second, the optimal frequency and duration of MET and JM for rehabilitation after ARCR remain unclear, as limited comparable studies exist in this specific population. Third, this study assessed outcomes only at 4 weeks after intervention, and the absence of long-term follow-up prevents us from drawing conclusions about sustained treatment effects. Fourth, as a single-center study, referral bias cannot be excluded. Future research should include larger, multicenter samples, standardized protocols, and extended follow-up periods to validate these findings and optimize treatment parameters.

Conclusions

The combination of MET and JM significantly improved shoulder AROM, reduced pain, and enhanced shoulder motor function compared with JM in patients after ARCR. Based on these findings, this combined rehabilitation approach may be recommended for clinical use in post-ARCR rehabilitation. However, the long-term efficacy and optimal treatment parameters of this combination require further validation in larger-scale, multicenter randomized studies.

Acknowledgments

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Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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