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Influence Of Adding Mulligan Mobilization to Low Level Laser Therapy in Treatment of Patients with Shoulder Adhesive Capsulitis: A Double Blinded, Randomized Controlled Trial

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ABSTRACT:

Purpose: To investigate the influence of adding Mulligan mobilization with movement (MWM) to low level laser therapy (LLLT) on pain intensity, shoulder range of motion (ROM), functional outcomes, and sleep quality in patients with shoulder adhesive capsulitis (AC).

Methods: Sixty-four patients with AC were randomly assigned into two groups: study group (n=32) and control group (n=32). A total of nine treatment sessions were administered to both groups, three times weekly on alternate days for 3 weeks. Patients in the study group received MWM combined with LLLT applied to the affected shoulder in addition to a standardized therapeutic exercise program, while participants in the control group received LLLT alone along with the same standardized therapeutic exercise program. The primary outcome variable was pain intensity assessed using the Visual Analog Scale (VAS). Secondary outcome measures included shoulder ROM (flexion, abduction, and external rotation) assessed using a standard goniometer, shoulder pain and disability assessed using the Shoulder Pain and Disability Index (SPADI), and sleep quality evaluated using the Pittsburgh Sleep Quality Index (PSQI). Measurements were obtained before and after the 3-week intervention period.

Results: After the 3-week intervention, both groups demonstrated significant improvements in all outcome measures compared with baseline values ($p < 0.05$). Nevertheless, the study group exhibited significantly greater improvements than the control group across all outcome measures, with between-group comparisons revealing large effect sizes favoring the study group for pain reduction, functional improvement, and sleep quality enhancement.

Conclusion: The combination of MWM with LLLT and therapeutic exercises was more effective than LLLT alone with therapeutic exercises in reducing pain and disability, improving shoulder ROM, and enhancing sleep quality in patients with AC.

INTRODUCTION

Shoulder Adhesive Capsulitis (AC), commonly referred to as frozen shoulder, is a disabling musculoskeletal condition characterized by progressive pain, stiffness, and significant restriction of both active and passive range of motion (ROM) of the glenohumeral joint **(Allen, 2018)**. It affects approximately 2–5% of the general population and is more prevalent among middle-aged individuals **(Uppal et al., 2015 and Alkhawaldeh et al., 2016)**. The condition typically follows a prolonged course, often lasting up to two to three years, and is associated with substantial functional limitations and reduced quality of life **(Xiao et al., 2017)**.

Despite its self-limiting nature, the prolonged duration and severity of symptoms necessitate effective therapeutic interventions **(Kelley et al., 2009)**. Conservative management remains the first-line approach and commonly includes therapeutic exercises, manual therapy, and electrotherapy modalities **(Lamplot et al., 2018)**. Among these, joint mobilization techniques have demonstrated beneficial effects in improving pain and ROM **(Gupta et al., 2024)**. In particular, Mulligan Mobilization with Movement (MWM) has shown promising outcomes in enhancing shoulder mobility and reducing pain through the application of sustained accessory glide combined with active physiological movement **(Celik et al., 2025)**. The proposed physiological mechanisms of Mulligan mobilization include the correction of minor positional faults within the joint, restoration of normal arthrokinematics, and reduction of mechanical stress on periarticular structures **(Chitale et al., 2022)**. In addition, MWM is thought to induce neurophysiological effects, such as activation of mechanoreceptors, inhibition of nociceptive input at the spinal cord level, and enhancement of proprioceptive feedback, thereby contributing to immediate pain reduction and improved motor control **(Westad et al., 2019)**. However, current evidence regarding Mulligan techniques remains limited and largely based on preliminary or small-scale studies **(Stathopoulos et al., 2019)**.

On the other hand, Low-level laser therapy (LLLT), as an electrotherapy modality, has gained attention for its potential to reduce pain and improve tissue healing through photobiomodulation mechanisms **(Hassan et al., 2025)**. It is widely used in musculoskeletal rehabilitation and has shown short-term benefits in improving pain and functional outcomes in patients with AC **(Ordahan et al., 2023)**. LLLT exerts its effects at the cellular level through the absorption of light energy by mitochondrial chromophores, particularly cytochrome c oxidase. This process enhances mitochondrial respiration and adenosine triphosphate (ATP) production, leading to improved cellular metabolism and tissue repair **(Ferraresi et al., 2015)**. Furthermore, LLLT has been shown to modulate inflammatory processes by reducing pro-inflammatory mediators and promoting anti-inflammatory cytokine activity **(Lee et al., 2018)**. It also contributes to analgesia through mechanisms such as decreased nerve conduction velocity, increased release of endogenous opioids, and improved microcirculation, which facilitates tissue oxygenation and healing **(Hagiwara et al., 2007 and de la Barra Ortiz et al., 2025)**.

Although both MWM and LLLT have demonstrated beneficial effects when applied independently, clinical practice often favors multimodal approaches to address the multifactorial nature of AC **(Rill et al., 2011)**. Combining manual therapy with electrotherapy may provide complementary effects by simultaneously targeting mechanical dysfunction and underlying inflammatory processes **(Page et al., 2014)**. Despite this rationale, the current body of literature lacks high-quality evidence examining the synergistic effects of combining specific manual therapy techniques, such as MWM, with LLLT. This gap in the literature highlights the need for well-designed, double-blinded randomized controlled trials to evaluate whether integrating Mulligan mobilization with LLLT provides additional clinical benefits over LLLT alone with the conventional treatment approaches. Therefore, the present study aims to investigate the influence of adding Mulligan mobilization to LLLT on pain, ROM, and functional outcomes in patients with shoulder AC.

METHODS

The present study is a prospective, randomized, parallel-group, double-blinded clinical trial. The study was carried out from May 2023 to October 2024, and approved by the Research Ethics Committee at Faculty of physical therapy, Cairo University (P.T.REC/012/003082). All volunteers were provided with written informed consent to participate in the study after being fully informed of the study's goals and procedures. The participants were recruited from the Outpatient Clinic at the Faculty of Physical Therapy, Cairo University. Every procedure was carried out in conformity with the Helsinki Declaration of 1964 and any subsequent changes. This study was registered in the ClinicalTrials.gov registry, Registration number: NCT04782349.

STUDY POPULATION

A total of sixty-four patients, both male and female who were diagnosed with shoulder AC were enrolled in this study from the Physiotherapy Clinic at Cairo University. Patients were considered eligible for inclusion if they met the following criteria: (1) age between 18 and 65 years; (2) a clinical diagnosis of AC, defined by a limitation of passive external rotation of the affected shoulder to less than 50% compared to the contralateral side **(Atan et al., 2021)**, accompanied by normal radiographic findings; and (3) presence of significant shoulder pain and restricted motion for a duration of at least three months. Patients were excluded if they presented with any of the following conditions: (1) calcific tendinopathy, glenohumeral osteoarthritis, fractures, prior shoulder trauma or surgery, history of malignancy or infection, or inflammatory rheumatic diseases; (2) bilateral AC; (3) recent history of breast, lung, or coronary artery bypass surgery, or radiotherapy; (4) receipt of corticosteroid injection in the affected shoulder within the preceding year; (5) brachial plexus injury or cervical radiculopathy; (6) a history of neuromuscular disorders; or (7) having undergone physical therapy for the same shoulder within the past six months.

Randomization

Based on a simple 1:1 computer-generated randomization ratio (www.randomization.com), participants were randomized to one of the groups after submitting their written informed consent to participate in the trial. The allocation was concealed by using consecutively sealed, numbered, opaque envelopes. Both the evaluator involved in the outcome assessment and patients were blinded to the allocation of treatment. To maintain the double-blind nature of the study, the randomization and allocation sequence were performed by an assistant who was not involved with the subjects' evaluation or therapy. In addition, sessions were scheduled for both groups at different times throughout the day and separately, and participants were instructed not to tell the evaluator what kind of intervention they had been received. Eighty-two patients were investigated for potential eligibility, 64 were ultimately accepted into the experiment, and they were randomly allocated to the study group (n=32), or control group (n=32). The CONSORT flowchart of recruitment and participant retention is seen in Figure 1.

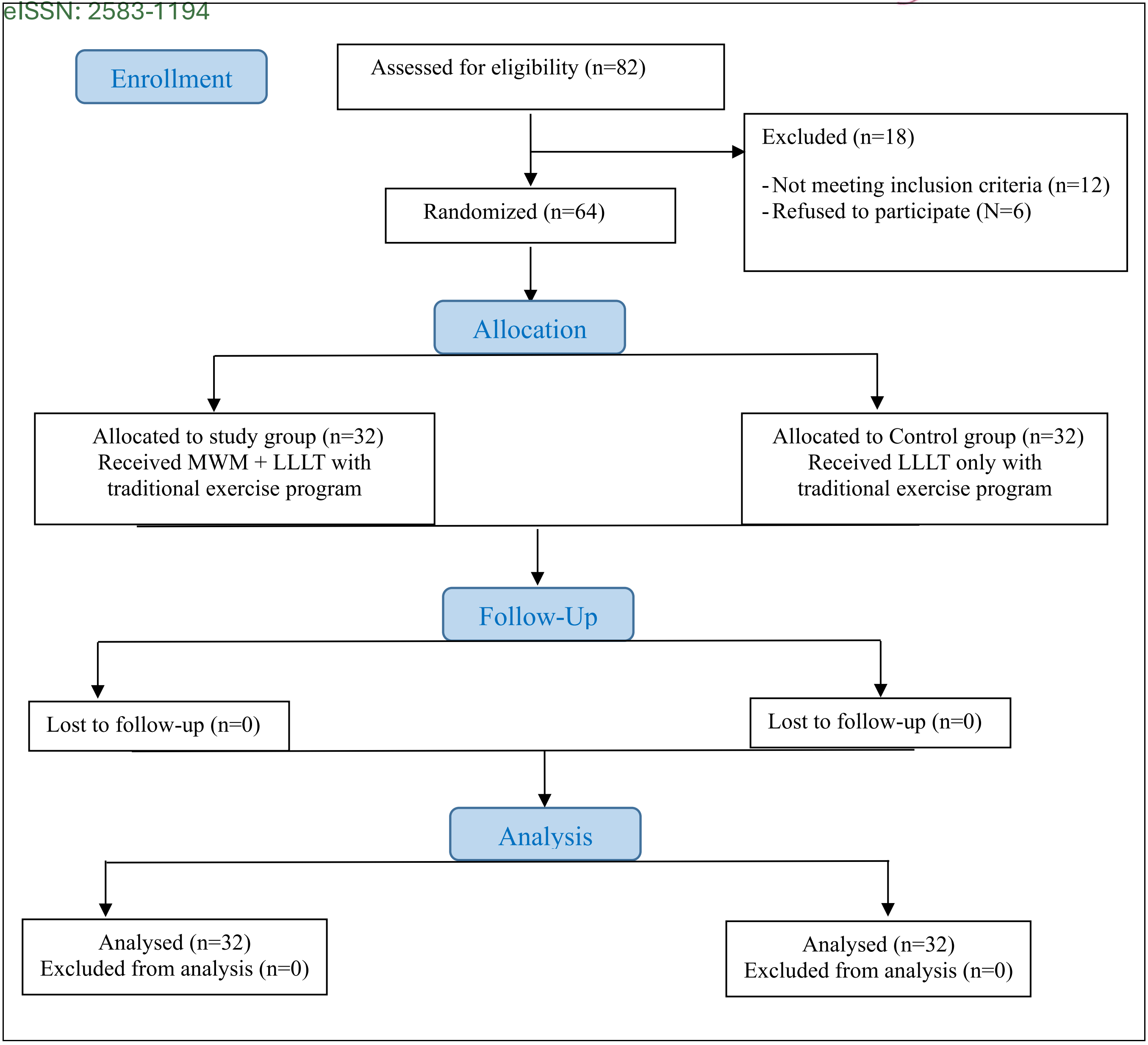

Figure 1: CONSORT flowchart of patients' recruitment and study flow.

Interventions

A total of nine sessions of treatment were applied to both groups, three times a week on alternate days for 3 weeks by the same physiotherapist. Patients in study group (n=32) were treated with MWM combined with LLLT applied to the affected shoulder in addition to a standardized therapeutic exercise program, while participants assigned to the control group (n=32) received LLLT alone along with the same standardized therapeutic exercise program as the study group. During the course of treatment, the participants were provided with specific instructions to refrain from using analgesic or anti-inflammatory medications, as well as participating in painful activities of daily living that involved the shoulder that was affected.

Mulligan mobilization with movement

Mobilization with Movement according to Mulligan (2010) was applied in this study. All treatment sessions were conducted by physical therapists who were certified in the Mulligan Concept, ensuring standardized and competent application of the technique. The technique is pain free and delivered in three sets of ten repetitions, with a one-minute rest interval between sets during each treatment session.

To improve shoulder flexion ROM: Subject was in supine lying position. Therapist was standing at the head of the plinth; the therapist grasped the humerus with one hand and the forearm with the other, on the affected side. A downward force was applied along the shaft of the humerus as the patient tried to raise his/her affected arm up to the end of a pain-free range and released after returning to the starting position.

To improve shoulder abduction ROM: The patient was in relaxed sitting position. A belt was placed around the therapist's hips and the head of the humerus to glide the humeral head appropriately, as the therapist's hand was used over the appropriate aspect of the head of the humerus. A counter pressure was also applied to the scapula with the therapist's other hand. The glide was sustained during slow active shoulder movements to the end of the pain-free range and released after returning to the starting position.

To improve shoulder external rotation ROM: Subject is in supine position. Therapist was in standing position at the head of the plinth on the affected side. A belt was placed around the bottom of the therapist's foot and just inferior to the head of the humerus to glide the humeral head appropriately, as the therapist's hand is used over the appropriate aspect of the head of the humerus. A downward force was applied along the shaft of the humerus as the patient tries to rotate his/her affected arm up to the end of a pain-free range and released after returning to the starting position.

Low level laser therapy

For LLLT, laser treatment was applied using gallium–aluminum–arsenide infrared diode laser (Chattanooga, Mexico, USA) at a wavelength of 904 nm, a frequency of 5000 Hz and output power of 240 Mw. The spot area is about 0.5 cm^2. A total of 9 points were irradiated along the glenohumeral joint, with a power intensity of 3 J/cm^2 at each point. The application time was 50 seconds for each point. The total dose per shoulder was 27 J per treatment. Three sessions of LILT therapy per week were administered over a 3-week period. These parameters complied with the World Association for Laser Therapy recommendation for AC. During the irradiation, both the physiotherapist and the patient wore laser goggles; and the position of the patients was sitting with arm supported on table.

Exercise program

All patients were given the same exercise program which consisted of shoulder stretching and strengthening exercises. All patients started their treatment sessions with three sets of posterior shoulder capsule stretches, with 30 seconds of hold along with 10 seconds of rest in between each set. Furthermore, the regimen incorporates Thera-elastic band exercises that specifically target the enhancement of serratus anterior strength, shoulder scaption, shoulder external rotation, as well as scapular retraction. A total of three sets, each consisting of 10 repetitions, were performed for each exercise. A rest time of 1 minute was taken between each set. Patients were directed to perform the exercise within their maximum ROM, while minimizing shoulder pain. The resistance level was modified and regulated by altering the Thera-band intensity. The patient was permitted to progress to the stronger band, which is color-coded from orange to blue, and ordered from light to strong resistance, once they were able to complete three sets of ten repetitions with little to no pain.

Outcome measures

All measurements were taken by the same assessor with more than 20 years of clinical experience as a physical therapist. The assessor was not involved in the study's treatments and was blind to the grouping of each patient.

The primary variable was pain intensity that was assessed using a validated visual analog scale (VAS), while the secondary variables were shoulder ROM (flexion, abduction, and external rotation), shoulder pain and disability index (SPADI), and sleep quality.

The severity of shoulder pain was assessed using visual analog scale (VAS: 0-10cm, where 0 indicates no pain and 10 indicates severe pain) which has a high intra and inter-rater reliability to measures of pain severity **(Haefeli & Elfering, 2006)**.

The standard goniometer was utilized to evaluate the ROM of the shoulder joint (flexion, abduction, as well as external rotation). The standard goniometer demonstrated excellent reliability with an intra-class correlation coefficient (ICC ranging from 0.85 to 0.99) **(Cools et al., 2014)**. During evaluation, the goniometer was positioned at the acromion for measuring abduction, at the greater tubercle for measuring flexion, as well as at the olecranon for measuring external rotation. These measurements were taken at a shoulder abduction angle of 90˚ and elbow flexion. Measurements were performed three times, and the average values were used for the analysis.

The shoulder disability was assessed via the Shoulder Pain and Disability Index (SPADI), a validated tool that measures both the subjective experience and the extent of shoulder pain as well as disability **(Paul et al., 2004)**. This questionnaire is designed to be self-administered and comprises two subscales: disability as well as pain. The pain subscale comprises 5 items, whereas the disability subscale comprises 8 items. Patients were instructed to rate each item via a 0-100 mm VAS. The potential range of scores for the SPADI assessment is from 0 to 100. Higher scores indicated increased levels of pain as well as disability **(Roach et al., 1991)**. SPADI has been evidenced as a valid and reliable shoulder pain and function questionnaire with ICC ranging from 0.84 to 0.95 **(Angst et al., 2011)**.

The Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep dysfunction. The PSQI comprises seven components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disorder, drug usage for sleep as well as functional disorder in the morning. The total PSQI score is calculated by summing the individual values from the 7 components, resulting in a range of 0 to 21. Poor sleep quality is considered to be indicated by a score of six or above. The Arabic version of PSQI has been validated and shows acceptable reliability. The Cronbach's alpha coefficient for the Arabic PSQI is 0.77, indicating good internal consistency **(Suleiman et al., 2010)**.

Sample size calculation

The required sample size and statistical power were calculated using G*Power software (version 3.1.9.2; Düsseldorf, Germany). Based on the results of a pilot study, it was estimated that a minimum of 26 participants per group would be required to detect a standardized mean difference (Cohen's d = 0.35) in VAS scores, assuming a standard deviation of 0.5 for the primary outcome measure. This calculation was performed with a statistical power of 80% and a significance level (α) of 0.05. To account for an anticipated attrition rate of 20%, the sample size was increased to 32 participants per group, resulting in a total sample size of 64 participants.

Statistical analysis

Shapiro-Wilk test was used to assess the normality of the data. All variables, including age, body Mass index, VAS, shoulder ROM, SPDI, and sleep quality were normally distributed, so parametric tests were used. Baseline comparability between groups was assessed using the independent-samples t test and the χ^2 test for categorical variables. The outcome measures (VAS, shoulder ROM, SPDI, and sleep quality) were analyzed using a two-way multivariate analysis of variance (MANOVA) to detect the effect of treatment on all measured variables and elucidate the interaction between time and treatment and finally the effect of time. Regarding the adjustment for multiple comparisons, the Bonferroni test was used to investigate the difference within each group and between groups at pretreatment and post-treatment. The size of the difference between both groups determined partial η^2. $P< 0.05$ was used as the significance level for all statistical tests. All statistical analysis was conducted using SPSS version 22 for Windows (IBM SPSS, Chicago, Illinois, United States).

RESULTS

As shown in Table (1), there was no substantial difference in the participants' characteristics, that comprise age, sex, BMI, disease duration, as well as the affected side $P > 0.05$.

Table 1. Comparison of subject characteristics between study and control groups

	Study Group $\bar{X}\pm$ SD	Control Group $\bar{X}\pm$ SD	F-value	p-value
Age (years)	46.7± 11.69	47.64± 12.26	0.10	0.91
BMI (kg/m²)	23.7± 1.1	24.5± 2.23	3.31	0.08
Disease duration (month)	4.6± 0.98	4.4± 0.76	0.83	0.36
Sex, n (%)				
Male	14(43.8%)	17(53.1%)		0.45

	Female	18(56.2%)	15(46.9%)	
Affected side, n (%)				
	Right	12(37.5%)	14(43.8%)	0.61
	Left	20(62.5%)	18(56.2%)	

$\bar{X}$: Mean, SD: Standard deviation, p-value: Probability value, *: significance, BMI: Body Mass Index.

Pain intensity and shoulder joint range of motion

As indicated in Table (2), there were no statistically significant differences between groups at baseline regarding VAS scores ($p > 0.05$). Within-group analysis showed a statistically significant reduction in VAS scores in both groups after the intervention period ($p < 0.05$). Between-group comparisons demonstrated a statistically significant reduction in pain intensity in favor of the study group compared with the control group (MD = -1.10; 95% CI: -1.70 to -0.50; $p < 0.05$; $\eta p^2 = 0.17$).

Regarding shoulder ROM (flexion, abduction, and external rotation), there were no statistically significant differences between groups at baseline regarding (all $p > 0.05$), indicating that the groups were comparable before treatment. Within-group analysis revealed statistically significant improvements in all ROM parameters (flexion, abduction, and external rotation) in both groups following the intervention period (all $p < 0.05$). After 3 weeks of treatment, between-group comparisons demonstrated that the study group showed significantly greater improvements in shoulder flexion compared with the control group (MD = 17.1; 95% CI: 14.2 to 20.0; $p < 0.05$; $\eta p^2 = 0.66$). Similarly, significant differences were observed in shoulder abduction in favor of the study group (MD = 16.5; 95% CI: 13.6 to 19.4; $p < 0.05$; $\eta p^2 = 0.63$). Moreover, external rotation showed a statistically significant improvement in the study group compared with the control group (MD = 14.2; 95% CI: 12.4 to 16.0; $p < 0.05$; $\eta p^2 = 0.81$, table (2).

Table 2. Pain intensity and shoulder joint range of motion measurements comparison within and between groups.

		Study Group $\bar{X}\pm$ SD	Control Group $\bar{X}\pm$ SD	MD (95% CI)	P-value	ηp^2
VAS (cm)						
	Pre-Treatment	7.4±2.1	6.9± 1.9	0.50(-0.50 to 1.50)	0.32	
	Post-Treatment	3.2± 1.1	4.3± 1.3	-1.10(−1.70 to −0.50)	P<0.05*	0.17
		P<0.05*	P<0.05*			
ROM (degrees)						
Flexion						
	Pre-Treatment	121.4±10.9	125.9± 8.2	-4.5(-9.9 to 0.9)	0.10	
	Post-Treatment	173.2± 6.6 P<0.05*	156.1± 5.1 P<0.05*	17.1(14.2 to 20.0)	P<0.05*	0.66
Abduction						
	Pre-Treatment	107.3± 6.7	104.6± 5.4	2.7(-0.3 to 5.7)	0.078	
	Post-Treatment	162.2± 5.3 P<0.05*	145.7± 6.1 P<0.05*	16.5(13.6 to 19.4)	P<0.05*	0.63
External rotation						
	Pre-Treatment	54.1± 8.6	52.4± 3.7	1.7(-1.6 to 5.0)	0.31	
	Post-Treatment	81.7± 2.5 P<0.05*	67.5± 4.5 P<0.05*	14.2(12.4 to 16.0)	P<0.05*	0.81

$\bar{X}$: Mean, SD: Standard deviation, CI: Confidence interval, p-value: Probability value, ηp²: partial eta squared, *: significance, VAS: Visual Analog Scale, ROM: Range of Motion.

Shoulder pain and disability

As indicated in Table (3), there were no statistically significant differences between groups at baseline regarding SPADI (pain, disability, and total) scores (all $p > 0.05$), indicating that the groups were comparable before treatment. Within-group analysis showed statistically significant improvements in all SPADI components (pain, disability, and total) in both groups after the intervention period (all $p < 0.05$). After 3 weeks of treatment, between-group comparisons revealed that the study group demonstrated significantly greater improvements in SPADI pain scores compared with the control group (MD = -18.84; 95% CI: -24.04 to -13.64; $p < 0.05$; $\eta p^2 = 0.46$). Similarly, significant differences were observed in SPADI disability scores in favor of the study group (MD = -16.0; 95% CI: -20.1 to -11.9; $p < 0.05$; $\eta p^2 = 0.43$). Moreover, SPADI total scores showed a statistically significant improvement in the study group compared with the control group (MD = -38.0; 95% CI: -41.8 to -34.2; $p < 0.05$; $\eta p^2 = 0.76$).

Table 3. Shoulder pain and disability index comparison within and between groups.

Variables	Study Group $\bar{X}\pm$ SD	Control Group $\bar{X}\pm$ SD	MD (95% CI)	P value	ηp²
SPADI (pain) %					
Pre-Treatment	72.33± 16.6	67.75± 14.3	4.58 (-2.8 to 12.4)	0.22	
Post-Treatment	33.8± 9.2	52.64± 11.5	-18.84 (-24.04 to -13.64)	P<0.05*	0.46
	P<0.05*	P<0.05*			
SPADI (disability) %					
Pre-Treatment	56.8± 5.9	57.9± 8.3	-1.1 (-4.7 to 2.5)	0.54	
Post-Treatment	31.1± 4.2	47.1± 9.2	-16.0 (-20.1 to -11.9)	P<0.05*	0.43
	P<0.05*	P<0.05*			
SPADI (total) %					
Pre-Treatment	125.2± 12.3	123.6± 10.3	1.6 (-3.7 to 6.9)	0.56	
Post-Treatment	63.7± 5.3	101.7± 8.2	-38.0 (-41.8 to -34.2)	P<0.05*	0.76
	P<0.05*	P<0.05*			

$\bar{X}$: Mean, SD: Standard deviation, CI: Confidence interval, p-value: Probability value, ηp²: partial eta squared, *: significance, SPADI: Shoulder Pain and Disability Index.

Sleep quality

As indicated in Table (4), there were no statistically significant differences between the groups at baseline regarding PSQI (total) scores ($p > 0.05$), indicating that the groups were comparable before treatment. Within-group analysis showed a statistically significant improvement in PSQI (total) scores in both groups after the intervention period ($p < 0.05$). After the treatment period, between-group comparisons demonstrated a statistically significant improvement in PSQI (total) scores in favor of the study group compared with the control group (MD = -1.6; 95% CI: -1.8 to -1.4; $p < 0.05$; $\eta p^2 = 0.78$).

Table 4. Pittsburgh sleep quality index comparison within and between groups.

Variables	Study Group $\bar{X}\pm$ SD	Control Group $\bar{X}\pm$ SD	MD (95% CI)	P value	ηp²
PSQI (total) %					
Pre-Treatment	7.8± 0.6	6.9± 0.8	0.2(-0.1 to 0.5)	0.20	
Post-Treatment	3.6± 0.5	5.2± 0.4	−1.6(-1.8 to -1.4)	P<0.05*	0.78
	P<0.05*	P<0.05*			

$\bar{X}$: Mean, SD: Standard deviation, CI: Confidence interval, p-value: Probability value, ηp^2: partial eta squared, *: significance, PSQI: Pittsburgh Sleep Quality Index.

DISCUSSION

The present study was conducted to investigate the effectiveness of adding MWM to LLLT in patients with shoulder AC. The results demonstrated that the combined intervention produced significantly greater improvements in all outcome measures, including pain, shoulder ROM, functional disability, and sleep quality, compared with LLLT alone. These findings support the superiority of combining manual therapy techniques with photobiomodulation modalities to address both mechanical and biological components of AC **(Canelada et al., 2022)**.

The significant reduction in pain and improvement in function observed in the study group can be explained by the complementary mechanisms of both interventions. LLLT acts primarily at the cellular level through photobiomodulation effects, stimulating fibroblast activity, enhancing collagen synthesis, and improving tissue repair. In addition, it reduces inflammatory mediators such as cyclooxygenase-2 and prostaglandin E2, which contributes to pain modulation **(Prianti et al., 2014)**. It also enhances ATP production, improving cellular metabolism and accelerating recovery in periarticular tissues **(Al Balah et al., 2025)**. These mechanisms have been supported by **Ordahan et al. (2023)**, who reported that LLLT is effective in reducing pain and improving functional outcomes in AC patients through anti-inflammatory and bio-stimulatory effects.

However, while LLLT primarily addresses tissue healing and pain modulation, it does not directly correct mechanical joint restrictions. This may explain why the addition of Mulligan's MWM technique resulted in superior outcomes in the present study. MWM works by restoring normal arthrokinematics through the application of sustained accessory joint glides combined with active physiological movement **(Vermeulen et al., 2006 and Weleslassie et al., 2021)**. This technique is believed to correct positional faults, reduce capsular tightness, and immediately restore pain-free movement **(Alqallaf et al., 2025)**. These mechanical improvements likely contributed to the greater increases in ROM observed in the present study.

The superiority of Mulligan-based techniques in shoulder AC has been well documented in previous literature. **Doner et al. (2013)** conducted a randomized controlled trial on 40 patients with frozen shoulder and found that the group receiving Mulligan mobilization demonstrated significantly greater improvements in pain, ROM, shoulder function, and patient satisfaction compared with conventional therapy. These findings are consistent with the current study, reinforcing the effectiveness of MWM in improving shoulder mobility and functional outcomes in AC. Further support is provided by systematic review evidence, which reported that MWM techniques result in clinically and statistically significant improvements in shoulder ROM, ranging from 12.30° to 26.09° across all movement planes **(Stathopoulos et al., 2019)**. These improvements are thought to result from neurophysiological mechanisms such as activation of mechanoreceptors, inhibition of nociceptive input, and normalization of motor control, in addition to mechanical joint correction **(Hing et al., 2008)**.

Interestingly, similar synergistic effects of combining Mulligan techniques with physical modalities have been observed in other musculoskeletal conditions. **Seo et al. (2020)** reported that the combination of Sustained Natural Apophyseal Glides (SNAGs), a Mulligan concept technique, with LLLT in patients with chronic low back pain resulted in superior outcomes compared with SNAGs alone. The combined group demonstrated greater pain reduction and functional improvement, exceeding the minimal clinically important difference.

The findings of the present study can be explained as an interaction between immediate pain reduction and improved movement tolerance **(Bialosky et al., 2009)**. Manual therapy and MWM are described as producing short-term pain inhibition and improved mobility, which can then facilitate freer active movement and participation in rehabilitation **(Satpute et al., 2022)**. LLLT reduces tissue inflammation and pain sensitivity, which may allow patients to tolerate mobilization more effectively. Once pain is reduced, MWM can be performed more effectively, enabling immediate improvements in joint mobility. This synergistic interaction likely explains the large effect sizes observed across all outcome measures in the combined treatment group.

Regarding sleep quality, the significant improvement in sleep quality in the study group than the control group may be indirectly attributed to reductions in pain and nocturnal discomfort. This interpretation is supported by previous evidence showing that patients with AC commonly experience nocturnal pain and poor sleep quality, and that sleep disturbance is moderately related to pain severity **(Mulligan et al., 2015)**. Furthermore, this interpretation is supported by another study on AC found that sleep disturbance was moderately related to pain and functional disability, supporting the idea that reducing night pain may improve sleep **(Bhagade & Sreeraj, 2018)**. Overall, the results of this study are consistent with previous evidence supporting both LLLT and Mulligan mobilization as effective interventions for AC. However, the present findings provide additional evidence that combining these two modalities produces superior clinical outcomes. This highlights the importance of a multimodal rehabilitation approach that targets both the biological and mechanical aspects of shoulder dysfunction.

The main strength of the study is that it is a randomized, double-blinded, prospective study. A calculated sample size is considered as additional strength point for this study. However, there are some issues in the current study that need to be addressed. The first is that the study was conducted for a short-term duration without patient follow-up. So, there is a need for further studies with long follow-up periods. The second one is that our sample size was relatively small. Therefore, future studies are required with large sample sizes.

CONCLUSION

The addition of MWM to LLLT significantly enhance treatment outcomes in patients with AC. This combined approach is more effective than LLLT alone in improving pain, function, ROM, and sleep quality, supporting its use as a comprehensive rehabilitation strategy.

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Data availability

The corresponding author can provide data supporting this study's results, given a reasonable request.

Compliance with ethical standards

The protocol underwent registration and received approval from the Institutional Ethics Committee (P.T.REC/012/003082). All patients signed a written consent form. The study's registration was completed at ClinicalTrials.gov (ID: NCT04782349).

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