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Short-Term Effects of Mobilization With Movement, With or Without Exercise, on Pain and Shoulder Range of Motion in Recreational Athletes With Subacromial Impingement Syndrome: A Single-Subject ABAC Withdrawal Study

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Disclosure of Interest
The authors report no competing interests to declare.

Image Contents:
Written informed consent to publish the images associated with study participants was obtained by the principal investigator.

Data Availability:
The data supporting the findings of this study are available in electronic format from the corresponding author upon reasonable request. Raw minute-by-minute active range of motion (AROM) data for all participants across both intervention phases are available in Figure 3 and the attached supporting Excel sheets.

Number of Tables/Figures: 4 Tables, 3 Figures**

ABSTRACT

Background: Mobilization with movement (MWM) and neuromuscular reeducation training are widely utilized interventions to improve range of motion and reduce pain in individuals presenting with subacromial impingement syndrome (SIS). However, limited evidence exists describing how these strategies interact and complement each other within and between treatment sessions.

Objective: To evaluate the effectiveness of a single session of MWM alone compared with MWM combined with rotator cuff neuromuscular reeducation exercise on pain and active shoulder flexion range of motion (AROM) in recreational athletes with SIS.

Methods: A quasi-experimental ABAC single-subject withdrawal design was implemented across four recreational athletes (2 male, 2 female; ages 19–21) diagnosed with SIS. Intervention Phase B consisted of MWM alone, while Phase C consisted of MWM combined with neuromuscular reeducation exercise. Outcome measures included pain-free AROM assessed using a digital inclinometer and self-reported pain using the Global Rating of Change (GROC) scale, with a 5-point change defined as the minimally clinically important difference (MCID). Statistical significance was determined using a two-band standard deviation method.

Results: Statistically significant improvements in AROM were observed in three of four participants following both interventions. The MWM combined with exercise condition produced greater mean increases in AROM (23.2°) compared to MWM alone (8.4°), with longer-lasting effects (mean duration: 25.5 minutes vs. 15 minutes). Clinically meaningful reductions in pain (MCID) were achieved in two participants following MWM alone and in two participants following the combined intervention. Sustained improvements at 24 hours were observed only in the combined intervention condition.

Conclusion: Both MWM alone and MWM combined with neuromuscular reeducation exercise improve pain and AROM in recreational athletes with SIS. The addition of neuromuscular reeducation enhances both the magnitude and duration of these effects. Further research is required to determine generalizability across broader populations.

Keywords: Mobilization with movement (MWM); neuromuscular reeducation; subacromial impingement syndrome (SIS); active shoulder flexion; pain reduction (MCID); single-subject ABAC withdrawal design

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1. INTRODUCTION

Subacromial impingement syndrome (SIS) represents the most common cause of shoulder pain, accounting for approximately 36% of all shoulder pathologies [1,2]. SIS refers to pain and functional limitation associated with structures within the subacromial space [1,2]. Contemporary literature increasingly favors the term “subacromial pain syndrome” (SAPS) to reflect the multifactorial and often non-structural nature of this condition; however, the term SIS is retained in this study for consistency with the diagnostic framework used during participant selection [3].

A primary extrinsic contributor to SIS is altered scapulothoracic rhythm [2]. Scapular upward rotation contributes approximately 30–40% of scapulohumeral rhythm, and reductions in this motion are strongly associated with various shoulder pathologies [4]. Therefore, effective treatment strategies should focus on assessing and correcting scapular positioning and restoring optimal scapulohumeral mechanics [2,4].

Conservative management approaches for SIS include nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections, exercise, rest, and manual therapy interventions [1,8]. A

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systematic review examining these interventions demonstrated low-quality evidence overall; however, corticosteroids, NSAIDs, exercise, and manual therapy showed the strongest support for pain reduction [1]. Notably, manual therapy interventions have been shown to produce immediate effects following a single treatment session [1].

Mobilization with movement (MWM) differs from traditional passive joint mobilization techniques (e.g., Maitland, Kaltenborn) in that it incorporates active patient movement during the application of the mobilization [10–14]. MWM has demonstrated superior immediate effects on pain reduction and range of motion compared to passive and sham techniques in peripheral joint conditions [10–14]. However, limited evidence exists evaluating the duration of these effects and the potential additive benefits when combined with neuromuscular reeducation strategies [11,13].

Purpose: The purpose of this study was to evaluate the effects of a single session of MWM alone compared with MWM combined with neuromuscular reeducation exercise on pain, active shoulder flexion range of motion (AROM), and the duration of these outcomes in recreational athletes with subacromial impingement syndrome.

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2. METHODS

2.1 Study Design

This quasi-experimental intervention utilized an ABAC single-subject withdrawal design across four participants, with each participant serving as their own control. Ethical approval was obtained from the Concordia University Wisconsin Institutional Review Board (IRB #1602982-1). All participants provided written informed consent prior to participation.

2.2 Participants

Four recreational athletes (2 males, 2 females; ages 19–21) diagnosed with subacromial impingement syndrome (SIS) were recruited from Concordia University Wisconsin. A recreational athlete was defined as an individual who participates in athletics at a recreational level, trains 1–4 times per week, and does not exceed eight hours per week in a single activity [16].

2.3 Selection Criteria

Participants were included if they were cleared for physical activity and scored between 5 and 10 on the Tegner Activity Level Scale.

Exclusion criteria included:

- Upper extremity or cervical spine surgery within the past year
- Prior diagnosis of adhesive capsulitis, grade III rotator cuff tear, biceps tendon tear, labral tear, or hooked acromion
- Upper extremity fracture within the past year
- History of systemic or neurological disorders, cervical radiculopathy, cancer, active inflammatory disease, or neuromuscular disorders
- Presence of numbness or tingling in the upper extremity

Eligible participants underwent a clinical observation screening using an orthopedic test cluster for SIS, including the Hawkins-Kennedy Test, Neer's Sign, Empty Can Test, Painful Arc Sign, and

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External Rotation Resistance test. This cluster demonstrates a sensitivity of 0.75 and specificity of 0.74, with three or more positive tests indicating impingement [17].

Participants then performed standing active glenohumeral flexion with the thumb oriented upward. If pain was present, passive posterior-to-anterior scapular fixation was applied. Reduction or elimination of pain during fixation was used to infer secondary SIS, allowing inclusion [6]. This diagnostic approach has limitations, as the scapular fixation test lacks established sensitivity and specificity [2], and definitive differentiation from primary impingement requires imaging [18].

2.4 Outcome Measures

Active Shoulder Flexion Range of Motion (AROM):
Pain-free shoulder flexion AROM was measured using an Acumar digital inclinometer, which demonstrates excellent reliability (ICC = 0.90–0.98) [19,20]. Participants were positioned standing, with the inclinometer placed at the midpoint of the humeral shaft. Instructions provided were: *"Stand upright, position your thumb toward the ceiling, and raise your arm forward as far as possible without reaching pain."*

Global Rating of Change Scale (GROC):
Self-reported pain was assessed using a 15-point Global Rating of Change (GROC) scale [21–23]. A change of 5 points was considered the minimally clinically important difference (MCID) [21]. The GROC scale was administered immediately post-intervention and at 24-hour follow-up.

2.5 Interventions

Participants were exposed to both intervention conditions within an ABAC withdrawal design.

Table 1. Global Study Timeline

Baseline A1 (5+ days): Demographic data collection, clinical screening, consent, baseline AROM measurements
Intervention B (1 day): MWM alone, GROC assessment, AROM measured every minute for 30 minutes
Baseline A2 (5+ days): 24-hour GROC, baseline AROM measurements
Intervention C (1 day): MWM plus exercise, GROC assessment, AROM measured every minute for 30 minutes
Follow-up (1 day): 24-hour GROC and AROM measurements

Baseline A1 Phase:
Shoulder flexion AROM was recorded daily for a minimum of 5 consecutive days or until a stable baseline was achieved, defined as measurements remaining within two standard deviations of the mean [24].

Intervention B Phase (MWM Alone):
Participants completed a single 45-minute session. Pre-intervention GROC assessment involved a standing overhead press using a 5-pound dowel.

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MWM was performed using clinician-applied posterior-to-anterior scapular fixation (Figure 1). Participants performed active glenohumeral flexion using a controlled 4/2/2 tempo (eccentric/isometric/concentric) guided by a 60 BPM metronome.

Protocol:
- 3 sets of 20 repetitions
- 30 seconds rest between sets

Post-intervention, GROC was reassessed and AROM measurements were recorded every minute for 30 minutes. Participants were instructed to avoid excessive overhead activity for 24 hours.

Baseline A2 Phase:
This phase replicated Baseline A1, with the addition of a 24-hour post-intervention GROC assessment. The phase continued until baseline values stabilized or intervention effects dissipated.

Intervention C Phase (MWM + Neuromuscular Reeducation):
Participants completed a single 75-minute session. The MWM protocol was identical to Phase B, followed immediately by neuromuscular reeducation exercises targeting the serratus anterior, pectoralis major/minor, and upper/lower trapezius (Figure 2) [25–27].

Exercises included:
- Forward flexion with horizontal abduction (130°)
- Scaption with horizontal abduction (130°)
- Elevation with external rotation (90°)
- Serratus punch (shoulder protraction)

Protocol:
- 3 sets of 10 repetitions per exercise
- 60 seconds rest between sets
- Tempo: 4/2/2 at 60 BPM
- Equipment: red resistance band [28]

Post-intervention, GROC and AROM were measured every minute for 30 minutes.

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Figure 1. Clinician-applied scapular anterior-to-posterior fixation during MWM demonstrating progressive mechanical positioning.

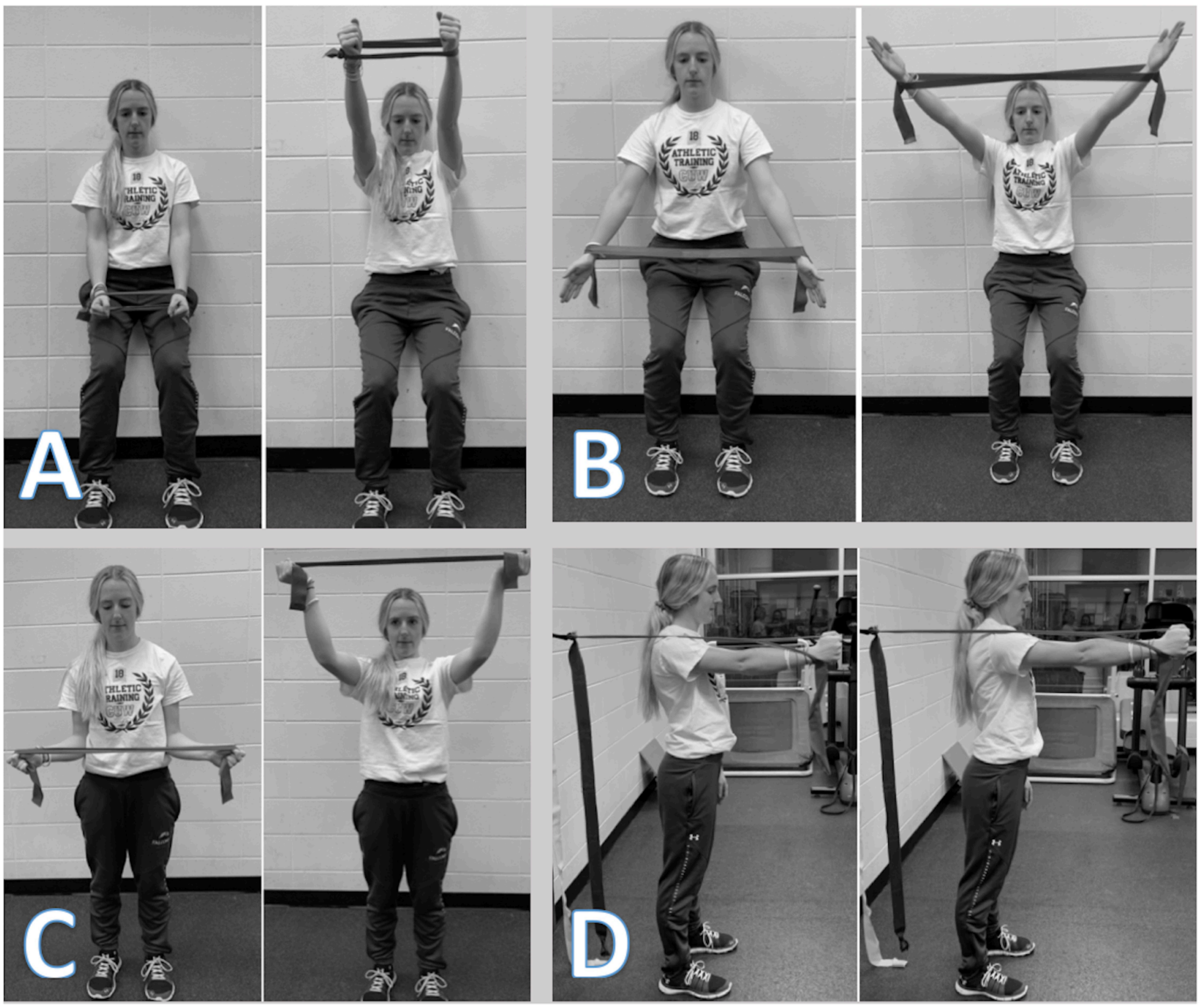

Figure 2. Neuromuscular Reeducation Exercises. (A) Forward flexion with horizontal abduction. (B) Scaption with horizontal abduction. (C) Elevation plus external rotation. (D) Serratus punch.

Follow-Up:
Final GROC and AROM measurements were obtained 24 hours after Intervention C.

2.6 Statistical Analysis

Statistical analysis was performed using a two-band standard deviation method to evaluate trends within the time-series data [30]. A statistically significant change was defined as two consecutive data points falling outside the upper and lower two-standard-deviation bands.

“Return to baseline” was defined as the first time point at which two consecutive AROM measurements fell within the baseline standard deviation range.

Standard deviation values were:
- Participant 1: ±12.15°

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• Participant 2: ±3.15°
• Participant 3: ±7.05°
• Participant 4: ±5.95°

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3. RESULTS

A total of nine participants were initially recruited for the study. Of these, three did not meet the inclusion criteria during the clinical screening, and two participants withdrew due to external conflicts. Four participants completed the study and were included in the final analysis

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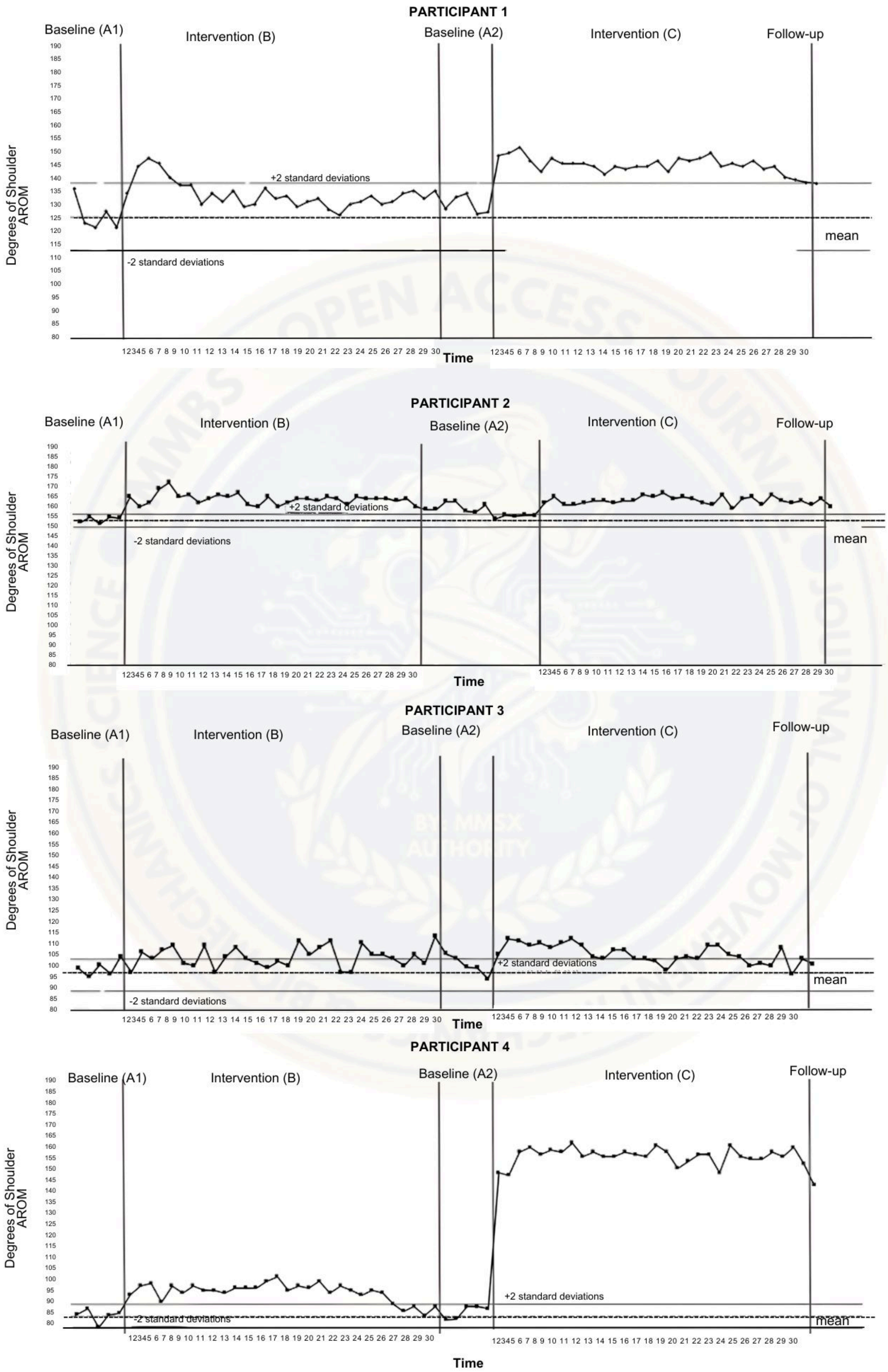

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Figure 3: Minute-by-minute shoulder flexion AROM values across baseline and intervention phases with two-band standard deviation limits. (Note: Figure recreated by JMMBS for enhanced visual clarity.)

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Table 1. Global Study Timeline

Phase	Procedure
Baseline A1 (5+ days)	-Demographic Information -Clinical Observation Screen -Consent Forms -Baseline AROM measurements
Intervention B (1 day)	-Mobilization with Movement -GROC scale -Repeated AROM measured by the minute for 30 minutes
Baseline A2 (5+ days)	-24-hour post-intervention GROC scale -Baseline AROM measurements
Intervention C (1 day)	-Mobilization with movement + exercise -GROC scale -Repeated AROM measured by the minute for 30 minutes
Follow-up (1 day)	-24-hour post-intervention GROC scale -24-hour post-intervention AROM

Baseline (A1) Phase. The first visit included the initial evaluation, demographic

Table 2. Participant Demographics

Participant	Age	Gender	Height	Weight	Involved Arm
1	20	Male	5'0"	123	Right
2	21	Female	5'7"	155	Left
3	19	Female	5'7"	145	Right
4	19	Male	6'1"	178	Left
Mean	19.75	50% Male	5'6"	150.25	50% Right

Global Rating of Change (GROC) Results (Table 3):
Clinically meaningful improvements in pain (MCID ≥5 points) were observed in Participant 1 following the MWM-alone intervention and in Participants 1 and 4 following the MWM-plus-exercise intervention. At 24-hour follow-up, sustained improvement was observed only in Participant 4 following the combined intervention.

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Table 3. Global Rating of Change Results (15-point scale)

Participant	Post-MWM Alone	24h Post-MWM Alone	Post-MWM + Exercise	24h Post-MWM + Exercise
1	5*	2	5*	4
2	2	1	2	-1
3	2	2	3	2
4	4	0	6*	5*

*MCID defined as ≥5-point change [21]

Active Shoulder Flexion Range of Motion (AROM) Results (Table 4):
Statistically significant increases in AROM were observed in Participants 1, 2, and 4 following both intervention conditions. The MWM-plus-exercise condition produced greater average increases in AROM (23.2°) compared to MWM alone (8.4°), along with longer-lasting effects (mean duration: 25.5 minutes vs. 15 minutes).

Participant 3 demonstrated no measurable duration of improvement for either intervention. Participants 2 and 4 maintained improvements beyond 30 minutes, with extended effects observed at the 24-hour follow-up following the combined intervention.

Table 4. Active Shoulder Flexion Range of Motion Data

Measure	Participant 1	Participant 2	Participant 3	Participant 4
Baseline A1 Mean (±SD)	125.7° (±12.15)	151.7° (±3.15)	97.9° (±7.05)	89° (±5.95)
Post-MWM Alone (B)	134°	163°	96°	98°
% Change from A1	6.6%	7.4%	-1.9%	10.1%
Duration (minutes)	4	30	0	25
Baseline A2 Mean (±SD)	129.7° (±12.15)	156° (±3.15)	99.2° (±7.05)	90.6° (±5.95)
Post-MWM + Exercise (C)	148°	160°	104°	151°*
% Change from A2	14.1%	2.6%	4.8%	66.7%
Duration (minutes)	30	30+ (24h)	0	30+ (24h)

*Statistically significant (two consecutive points outside two-band SD) [30]

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4. DISCUSSION

This study provides novel insight into the standalone and combined effects of mobilization with movement (MWM) and neuromuscular reeducation in recreational athletes with subacromial impingement syndrome. Both intervention strategies resulted in improvements in pain and range of motion; however, the combined MWM-plus-exercise condition produced superior outcomes in both magnitude and duration. Substantial inter-participant variability was observed, emphasizing the importance of individualized treatment strategies.

4.1 Patient-Reported Pain

This study represents the first investigation utilizing the Global Rating of Change (GROC) scale to evaluate the effectiveness of MWM in individuals with SIS. Previous research has predominantly relied on visual analog scales (VAS), numerical pain rating scales (NPRS), and pressure pain threshold (PPT), limiting direct comparability [31–34].

The present findings support the use of GROC as a meaningful tool for capturing short-term patient-perceived changes. Clinically meaningful improvements (MCID) were observed in select participants, indicating that both interventions can produce perceptible reductions in pain. The slight decline observed in Participant 2 at 24 hours following the combined intervention may be attributed to delayed-onset muscle soreness, central sensitization, or suboptimal scapular repositioning.

From a mechanistic perspective, MWM may induce hypoalgesic effects through peripheral mechanoreceptor stimulation and modulation of nociceptive input via gate control mechanisms [35]. The incorporation of active movement may facilitate neuromuscular reorganization and improved proprioceptive mapping, while scapular repositioning may optimize force-couple relationships and reduce subacromial compression [36]. The addition of exercise likely reinforces these neuromuscular adaptations.

4.2 Inter-Participant Variability

Variability in response to treatment was evident across participants. Participant 3, who demonstrated minimal response, may have exhibited greater structural contributions to impingement that are less responsive to scapular repositioning strategies. Additional contributing factors may include baseline differences in scapular mechanics, rotator cuff strength, joint mobility, and psychological influences such as fear-avoidance or pain perception. Future studies should incorporate these variables to better differentiate responders from non-responders.

4.3 Glenohumeral Range of Motion

This study is the first to evaluate the short-term duration of MWM effects on pain-free glenohumeral flexion AROM. The observed immediate improvements are consistent with previous literature [11,13,37,38]. However, the temporal persistence of these effects cannot be directly compared to prior studies, as most existing research has focused solely on immediate post-intervention outcomes. Additionally, this study represents the first application of a single-subject design to investigate MWM effects in the shoulder, whereas prior research has predominantly utilized randomized controlled trials.

4.4 Comparison of Treatment Strategies

The combined MWM-plus-exercise intervention demonstrated superior outcomes in both AROM improvement and duration of effect compared to MWM alone. While one prior study has examined this combination, it was limited to immediate effects within a randomized controlled design [13].

In the present study, the single-subject design allowed for individualized comparisons. With the exception of Participant 2, all participants demonstrated greater improvements following the combined intervention. The observed superiority of MWM-plus-exercise may be attributed to enhanced neuromuscular activation and improved mechanical alignment.

This temporal response is illustrated in Figure 3, where sustained deviation beyond baseline variability bands reflects improved mechanical consistency, optimized force-vector control, and enhanced regulation of joint loading across intervention phases.

4.5 Clinical Implications

Both interventions were effective; however, variability highlights the necessity of individualized clinical decision-making. Clinicians should perform comprehensive assessments to identify the underlying contributors to dysfunction and tailor interventions accordingly.

On average, MWM alone resulted in an increase of 8.4° in pain-free AROM with a duration of approximately 15 minutes, whereas MWM-plus-exercise resulted in an increase of 23.2° with a duration of approximately 25.5 minutes. These findings suggest that the addition of neuromuscular reeducation may enhance both the magnitude and persistence of treatment effects. However, these results should be interpreted cautiously due to the small sample size and variability across participants.

Mechanical Interpretation:

These findings may reflect improved scapulothoracic force coupling and more efficient distribution of muscular torque across the shoulder complex during dynamic elevation.

The application of mobilization with movement (MWM), particularly when combined with neuromuscular reeducation, may contribute to improved force-vector alignment and reduction in aberrant joint loading patterns, thereby decreasing subacromial compressive stress.

From a mechanical perspective, improved coordination between the rotator cuff and scapular stabilizers may enhance moment arm efficiency ($\tau = r \times F$), facilitating more controlled and efficient force transfer throughout the kinetic chain.

4.6 Limitations

Several limitations should be acknowledged. First, there is a lack of prior research examining the duration of MWM effects in SIS, limiting comparative interpretation. Second, definitive differentiation between primary and secondary impingement was not possible without imaging. Third, participant adherence to activity restrictions outside the study could not be fully controlled. Lastly, individual variability in physiological and psychological responses may have influenced outcomes.

4.7 Future Research

Future studies should investigate the long-term effects of repeated MWM and neuromuscular reeducation interventions, explore applications in other anatomical regions and conditions, and utilize randomized controlled designs to establish generalizability to broader populations.

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5. CONCLUSION

This single-subject ABAC withdrawal study provides scientific support for the use of mobilization with movement (MWM), both as a standalone intervention and in combination with neuromuscular reeducation exercise, in the management of recreational athletes presenting with secondary subacromial impingement syndrome (SIS).

The addition of neuromuscular reeducation exercise was associated with greater improvements in both the magnitude and duration of pain reduction and active range of motion (AROM) gains.

However, notable inter-individual variability was observed, indicating that treatment responses are highly subject-specific and reinforcing the importance of individualized clinical decision-making.

Further research with larger sample sizes and controlled study designs is warranted to validate these findings and establish broader clinical applicability.

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