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Original Article

Comparative Effects of High-Velocity Low-Amplitude (HVLA) Thrust and Muscle Energy Technique (MET) on Shoulder Mobility and Pain in Patients with Adhesive Capsulitis

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ABSTRACT

Background: Adhesive capsulitis is a painful shoulder disorder characterized by capsular fibrosis, progressive stiffness, and restriction of active and passive glenohumeral range of motion. Manual therapy is commonly used in rehabilitation, but direct comparative evidence between high-velocity low-amplitude thrust manipulation and post-isometric relaxation muscle energy technique remains limited. **Objective:** To compare the short-term effects of HVLA thrust manipulation plus conventional therapy and PIR-MET plus conventional therapy on pain and shoulder range of motion in patients with Stage II–III adhesive capsulitis. **Methods:** Ethical approval of this study was obtained from the Ethics Committee of Green International University under Approval Clinical trial Reg# NCT07600372. This single-center randomized controlled trial included 66 patients with Stage II–III adhesive capsulitis, allocated equally into HVLA + CT and PIR-MET + CT groups. Both groups received 4 weeks of intervention. Pain was assessed using the Visual Analogue Scale, while active and passive shoulder flexion, abduction, external rotation, and internal rotation were measured using a universal goniometer. Between-group and within-group comparisons were analyzed using parametric tests, with effect sizes and 95% confidence intervals reported. **Results:** Baseline characteristics and outcome measures were comparable between groups. Both interventions significantly improved pain and all ROM outcomes after 4 weeks ($p<0.001$). PIR-MET + CT produced greater improvements than HVLA + CT, including larger VAS pain reduction (5.32 cm vs 3.12 cm) and greater active and passive ROM gains across all shoulder movements. Post-intervention between-group comparisons significantly favored PIR-MET + CT for pain and all mobility outcomes ($p<0.001$). **Conclusion:** PIR-MET combined with conventional therapy produced superior short-term pain reduction and shoulder mobility improvement compared with HVLA thrust manipulation combined with conventional therapy in Stage II–III adhesive capsulitis. **Keywords:** Adhesive capsulitis; Frozen shoulder; HVLA; PIR-MET; Manual therapy; Range of motion.

INTRODUCTION

Adhesive capsulitis, commonly referred to as frozen shoulder, is a painful and disabling glenohumeral disorder characterized by progressive shoulder pain, capsular fibrosis, and restriction of both active and passive range of motion. The condition compromises shoulder mobility through synovial inflammation, capsular thickening, periarticular soft-tissue shortening, and adhesions that limit physiological and accessory joint motion. Because the shoulder is essential for reaching, dressing, grooming, lifting, overhead activities, and occupational tasks, adhesive capsulitis produces substantial functional limitation and reduces health-related quality of life, particularly when pain persists at night and restricts sleep (1). The clinical course is usually described in freezing, frozen, and thawing phases, with the frozen and thawing stages being dominated by stiffness, capsular restriction, and incomplete restoration of shoulder mobility. Epidemiological evidence indicates that adhesive capsulitis is more common in middle-aged adults and is associated with metabolic and endocrine comorbidities, particularly diabetes mellitus and thyroid disorders, although idiopathic cases are also frequent (2,3).

The movement limitation in adhesive capsulitis typically follows a capsular pattern, with external rotation often affected earliest and most severely, followed by abduction, flexion, and internal rotation. These restrictions are clinically meaningful because even modest losses in rotation and elevation can interfere with self-care, dressing, grooming, and reaching behind the back. Conservative management therefore aims not only to reduce pain but also to restore capsular extensibility, normalize glenohumeral arthrokinematics, improve active and passive range of motion, and facilitate return to daily function. Physiotherapy remains a central component of conservative care and commonly includes heat therapy, stretching, strengthening, range-of-motion exercises, joint mobilization, manual therapy, patient education, and home exercise programs (4). Systematic reviews have shown that manual therapy and exercise may improve pain and mobility in adhesive capsulitis; however, the strength of evidence remains limited by heterogeneity in intervention type, dosage, treatment duration, comparator selection, and outcome reporting (5-7).

High-velocity low-amplitude thrust manipulation and post-isometric relaxation muscle energy technique represent two clinically distinct manual therapy approaches used to address musculoskeletal restriction. HVLA thrust involves a rapid, controlled, low-amplitude impulse applied near the end range of joint movement, with proposed effects including restoration of joint play, stimulation of mechanoreceptors, modulation of pain, reduction of muscle guarding, and improvement in accessory motion. In contrast, PIR-MET is a patient-assisted technique in which a gentle isometric contraction is followed by relaxation and stretch to a new resistance barrier, potentially reducing muscle tone, improving soft-tissue extensibility, and allowing progressive gains in restricted movement. These mechanistic differences are important in adhesive capsulitis because pain, protective guarding, capsular tightness, and shortened periarticular tissues may respond differently to thrust-based versus contract-relax manual interventions (8-13).

Previous clinical studies have evaluated mobilization techniques, stretching programs, conventional physiotherapy, and muscle energy techniques in patients with adhesive capsulitis, and several have reported improvements in pain, shoulder range of motion, and functional status when MET or mobilization is added to conventional rehabilitation (14-16). More recent evidence has also examined high-intensity home stretching, manual therapy combined with dynamic stretching, extracorporeal shockwave therapy, and other physiotherapy approaches, but conclusions remain constrained by variability in treatment protocols and outcome measures (17-21). Direct comparative evidence between HVLA thrust manipulation and PIR-MET in patients with Stage II–III adhesive capsulitis remains limited, particularly when both interventions are delivered alongside the same conventional physiotherapy program and evaluated using active and passive shoulder range-of-motion outcomes.

This evidence gap has practical clinical relevance because physiotherapists require comparative data to select manual therapy approaches that are effective, tolerable, reproducible, and suitable for patients with painful capsular restriction. In patients with Stage II–III adhesive capsulitis, where stiffness and restricted mobility predominate, PIR-MET may offer a therapeutic advantage through repeated patient-assisted contraction-relaxation and progressive stretching, whereas HVLA may provide benefit through rapid joint-play facilitation and neurophysiological pain modulation. However, without direct comparison under similar treatment conditions, the relative short-term effects of these two approaches remain uncertain. Therefore, the present randomized controlled trial was conducted to compare the effects of HVLA thrust manipulation plus conventional physiotherapy versus PIR-MET plus conventional physiotherapy on pain intensity and active and passive shoulder range of motion after 4 weeks in patients with Stage II–III adhesive capsulitis. The study hypothesized that PIR-MET combined with conventional physiotherapy would produce greater short-term reductions in pain and greater improvements in shoulder mobility than HVLA thrust manipulation combined with conventional physiotherapy.

MATERIAL AND METHODS

This study was conducted as a single-center, two-arm, randomized controlled trial comparing high-velocity low-amplitude thrust manipulation plus conventional physiotherapy with post-isometric relaxation muscle energy technique plus conventional physiotherapy in patients with Stage II–III adhesive capsulitis. The trial was carried out in the Physical Therapy Department of Johar Poly Child Clinic, Johar Town, Lahore, Pakistan, over a 9-month period after approval of the research synopsis. The design was selected to compare two active manual therapy interventions under similar conventional physiotherapy conditions, allowing estimation of between-group differences in pain intensity and active and passive shoulder range of motion after a 4-week intervention period.

Participants were recruited from patients presenting to the physiotherapy clinic with clinically diagnosed adhesive capsulitis. Eligible participants were adults aged 40–60 years, of either sex, with Stage II or Stage III adhesive capsulitis, shoulder pain and restricted range of motion for more than 3 months, and willingness to provide written informed consent. Patients were excluded if they had a recent shoulder fracture or dislocation, previous shoulder surgery, neurological disorders affecting the upper limb, systemic inflammatory disease such as rheumatoid arthritis, or contraindications to manual therapy including osteoporosis, malignancy, or severe cardiovascular conditions. Adhesive capsulitis was operationally defined as gradual onset shoulder pain and stiffness with clinically meaningful restriction of both active and passive shoulder movement due to capsular inflammation, thickening, fibrosis, and reduced extensibility (22). HVLA thrust was defined as a rapid, controlled, low-amplitude manual impulse applied to a restricted joint segment to improve mobility and reduce stiffness (23). Muscle energy technique was defined as an active manual therapy procedure in which the participant performed an isometric contraction against therapist-applied resistance, followed by relaxation and therapist-assisted stretch to improve mobility and reduce soft-tissue restriction (24).

A total sample of 66 participants was included, with 33 participants allocated to each treatment group. The sample size was based on VAS pain score as the primary outcome, using an expected between-group mean difference of 1.38 points, standard deviation of 2.0, 95% confidence level, 80% power, and 1:1 allocation ratio. Eligible participants were recruited using a non-probability purposive sampling approach from the clinical setting and were then randomly allocated into two intervention groups using a computerized random number generation method. Group A received HVLA thrust manipulation plus conventional physiotherapy, while Group B received PIR-MET plus conventional physiotherapy. Baseline demographic and clinical characteristics were recorded before the start of treatment to assess comparability between groups.

Pain intensity was measured using the Visual Analogue Scale, a 10-cm scale ranging from 0, indicating no pain, to 10, indicating the worst imaginable pain (26). Shoulder mobility was assessed using a universal goniometer and included active and passive shoulder flexion, abduction, external rotation, and internal rotation, recorded in degrees. Shoulder range of motion was operationally defined as the measured glenohumeral movement available during active and passive performance of these motions (25). Outcome measurements were recorded at baseline and after completion of the 4-week intervention. Demographic and clinical variables included age, sex, body mass index, dominant hand, affected shoulder, duration of symptoms, stage of adhesive capsulitis, diabetes mellitus, hypertension, thyroid disorder, and history of trauma or immobilization.

Both groups received the same conventional physiotherapy program to ensure that the comparative effect reflected the added manual therapy technique rather than unequal background treatment. Conventional physiotherapy consisted of moist heat therapy, active and passive shoulder range-of-motion exercises, stretching exercises, and strengthening exercises. Moist heat was applied to the affected shoulder for 10 minutes before exercise to reduce pain, facilitate muscle relaxation, improve local circulation, and increase soft-tissue extensibility. Active and passive range-of-motion exercises included shoulder flexion, abduction, internal rotation, and external rotation, performed for 10 repetitions within the pain-free or tolerable range. Stretching exercises targeted restricted shoulder movements and were performed in three repetitions, with each stretch held for 60 seconds according to participant tolerance. Strengthening exercises were performed using therapist-applied manual resistance in two sets of 10 repetitions to improve shoulder stability, muscle performance, and functional control.

Participants allocated to the HVLA group received HVLA thrust manipulation in addition to conventional physiotherapy. The intervention was applied to restricted shoulder joint movement with the aim of improving glenohumeral joint play, reducing capsular tightness, improving accessory mobility, and decreasing pain. The thrust was delivered as a quick, precise, low-amplitude manual impulse near the restricted end range of shoulder movement by the treating therapist, followed by the same active and passive range-of-motion exercises, stretching, and strengthening protocol used in both groups. An ice pack was applied for 10 minutes when post-treatment soreness, tenderness, or discomfort occurred (27).

Participants allocated to the PIR-MET group received post-isometric relaxation muscle energy technique in addition to conventional physiotherapy. PIR-MET was applied to restricted shoulder flexion, abduction, internal rotation, and external rotation. For each restricted movement, the shoulder was positioned at the initial resistance barrier, after which the participant performed a gentle isometric contraction against therapist resistance using approximately 20%–30% of maximal effort for 5–7 seconds. After the contraction, the participant relaxed fully, and the therapist gently moved the shoulder to a new resistance barrier. This sequence was repeated 3–5 times for each restricted movement, with approximately 30 seconds of rest between repetitions. The PIR-MET procedure was followed by the same range-of-motion, stretching, and strengthening program provided to the HVLA group. An ice pack was applied for 10 minutes when post-treatment discomfort occurred (28).

Several steps were used to reduce bias and improve consistency of data collection. Eligibility criteria were applied before random allocation, both groups received an equivalent conventional physiotherapy program, outcomes were measured at the same time points, and standardized tools were used for pain and range-of-motion assessment. Treatment procedures were delivered according to predefined protocols, and demographic and baseline clinical variables were compared between groups before evaluating post-intervention outcomes. Potential confounding variables, including sex, affected shoulder, symptom duration, adhesive capsulitis stage, diabetes mellitus, hypertension, thyroid disorder, and history of trauma or immobilization, were documented and compared at baseline.

Ethical approval of this study was obtained from the Ethics Committee of Green International University under Approval Clinical trial Reg# NCT07600372, Data were analyzed using IBM SPSS Statistics version 26. Continuous variables were summarized as mean and standard deviation, while categorical variables were summarized as frequency and percentage. The Shapiro–Wilk test was used to assess normality of continuous outcome variables within each group. Baseline comparability of categorical variables was examined using the chi-square test or Fisher's exact test where expected cell counts were small. Between-group comparisons of continuous outcomes at baseline and 4 weeks were performed using independent-samples t-tests, with Welch's correction applied where equality of variance was violated. Within-group changes from baseline to 4 weeks were evaluated using paired-samples t-tests. Mean differences were reported with 95% confidence intervals, and effect sizes were calculated using Cohen's d for between-group comparisons and Cohen's d_z for within-group change. Statistical significance was set at $p \leq 0.05$. Analyses were conducted using complete outcome data because no participant dropout was reported during the 4-week intervention period.

The study was conducted in accordance with the ethical requirements of Green International University and the participating clinical setting. Written informed consent was obtained from all participants before enrollment. Participants were informed about the purpose of the study, voluntary nature of participation, right to withdraw without penalty, expected benefits, and possible mild risks such as temporary soreness after manual therapy. Participant confidentiality and anonymity were maintained throughout data collection, analysis, and reporting, and identifying information was not disclosed in any study output. Data were recorded using standardized assessment procedures, checked for completeness before analysis, and analyzed according to the prespecified comparison of pain and shoulder range-of-motion outcomes between the two treatment groups.

RESULTS

A total of 66 patients with Stage II–III adhesive capsulitis were enrolled and randomized equally into the HVLA thrust manipulation plus conventional therapy group and the PIR-MET plus conventional therapy group, with 33 participants in each arm. No dropout was reported during the 4-week intervention period; therefore, all randomized participants were included in the final analysis. Baseline demographic and clinical characteristics were broadly comparable between groups, with no statistically significant differences in sex, dominant hand, affected shoulder, symptom duration, disease stage, diabetes mellitus, hypertension, thyroid disorder, or history of trauma/immobilization. This baseline balance supported subsequent comparison of post-intervention pain and shoulder range-of-motion outcomes between the two treatment arms.

Table 1. Baseline Demographic and Clinical Characteristics of Participants by Treatment Group

Variable	Category	HVLA + CT (n=33), n (%)	PIR-MET + CT (n=33), n (%)	Total (N=66), n (%)	Test Statistic	p-value
Sex	Male	14 (42.4)	17 (51.5)	31 (47.0)	χ^2=0.547	0.459
	Female	19 (57.6)	16 (48.5)	35 (53.0)		
Dominant hand	Right	30 (90.9)	27 (81.8)	57 (86.4)	χ^2=1.158	0.475[a]
	Left	3 (9.1)	6 (18.2)	9 (13.6)		
Affected shoulder	Right	18 (54.5)	15 (45.5)	33 (50.0)	χ^2=0.616	0.749[a]
	Left	13 (39.4)	15 (45.5)	28 (42.4)		
	Bilateral	2 (6.1)	3 (9.1)	5 (7.6)		
Symptom duration	3–6 months	12 (36.4)	15 (45.5)	27 (40.9)	χ^2=0.667	0.717
	6–12 months	15 (45.5)	12 (36.4)	27 (40.9)		
	>12 months	6 (18.2)	6 (18.2)	12 (18.2)		
Adhesive capsulitis stage	Stage II	20 (60.6)	17 (51.5)	37 (56.1)	χ^2=0.554	0.457
	Stage III	13 (39.4)	16 (48.5)	29 (43.9)		
Diabetes mellitus	No	25 (75.8)	22 (66.7)	47 (71.2)	χ^2=0.665	0.415
	Yes	8 (24.2)	11 (33.3)	19 (28.8)		
Hypertension	No	26 (78.8)	23 (69.7)	49 (74.2)	χ^2=0.713	0.398
	Yes	7 (21.2)	10 (30.3)	17 (25.8)		
Thyroid disorder	No	29 (87.9)	27 (81.8)	56 (84.8)	χ^2=0.471	0.492
	Yes	4 (12.1)	6 (18.2)	10 (15.2)		
Trauma/immobilization history	No	30 (90.9)	27 (81.8)	57 (86.4)	χ^2=1.158	0.475[a]
	Yes	3 (9.1)	6 (18.2)	9 (13.6)		

[a] Fisher's exact test used because expected cell counts were small. CT = conventional therapy; HVLA = high-velocity low-amplitude thrust; PIR-MET = post-isometric relaxation muscle energy technique.

The overall sample included 31 males (47.0%) and 35 females (53.0%), with similar sex distribution between the HVLA + CT group and the PIR-MET + CT group (p=0.459). Right-hand dominance was common in both groups, affecting 30 participants (90.9%) in the HVLA + CT group and 27 participants (81.8%) in the PIR-MET + CT group, with no significant difference (p=0.475). Affected shoulder laterality was also balanced, with right shoulder involvement in 18 HVLA participants (54.5%) and 15 PIR-MET participants (45.5%), left shoulder involvement in 13 (39.4%) and 15 (45.5%), and bilateral involvement in 2 (6.1%) and 3 (9.1%), respectively. Symptom duration was similarly distributed across treatment arms, and chronic symptoms lasting more than 12 months were present in exactly 6 participants (18.2%) in each group. Stage II adhesive capsulitis was slightly more frequent in the HVLA + CT group than in the PIR-MET + CT group, but the difference was not statistically significant (60.6% vs 51.5%; p=0.457). Comorbidities were also comparable: diabetes mellitus was present in 24.2% versus 33.3% of participants, hypertension in 21.2% versus 30.3%, and thyroid disorder in 12.1% versus 18.2% in the HVLA + CT and PIR-MET + CT groups, respectively, with all p-values exceeding 0.05.

Normality testing using the Shapiro–Wilk test showed that most continuous outcome distributions were approximately normal. Of the 36 tested distributions across pain and range-of-motion outcomes, four showed statistically significant departures from normality: active abduction at baseline in the PIR-MET group, active internal rotation at baseline in the HVLA group, passive abduction at baseline in the PIR-MET group, and passive internal rotation at 4 weeks in the PIR-MET group. Given that the majority of distributions were normal, group sizes were equal, and each group included 33 participants, parametric comparisons were retained for the main analysis.

Table 2. Shapiro–Wilk Normality Testing for Pain and Shoulder Range-of-Motion Outcomes

Outcome	Time Point	HVLA + CT W (p-value)	PIR-MET + CT W (p-value)
VAS pain	Baseline	0.977 (0.697)	0.961 (0.284)
	4 weeks	0.969 (0.458)	0.955 (0.185)
Active flexion	Baseline	0.982 (0.855)	0.954 (0.175)
	4 weeks	0.955 (0.181)	0.975 (0.639)
Active abduction	Baseline	0.957 (0.208)	0.928 (0.031)*
	4 weeks	0.964 (0.340)	0.954 (0.178)
Active external rotation	Baseline	0.983 (0.875)	0.945 (0.092)
	4 weeks	0.946 (0.101)	0.955 (0.185)
Active internal rotation	Baseline	0.933 (0.042)*	0.958 (0.228)
	4 weeks	0.954 (0.177)	0.969 (0.450)
Passive flexion	Baseline	0.979 (0.759)	0.970 (0.470)
	4 weeks	0.946 (0.101)	0.955 (0.184)
Passive abduction	Baseline	0.949 (0.122)	0.929 (0.032)*
	4 weeks	0.977 (0.677)	0.968 (0.417)
Passive external rotation	Baseline	0.986 (0.935)	0.954 (0.170)
	4 weeks	0.953 (0.163)	0.943 (0.086)
Passive internal rotation	Baseline	0.957 (0.211)	0.958 (0.226)
	4 weeks	0.960 (0.258)	0.917 (0.015)*

p<0.05 indicates departure from normality. W = Shapiro–Wilk statistic; VAS = Visual Analogue Scale.

At baseline, pain and shoulder range-of-motion outcomes were statistically comparable between groups, with all baseline p-values greater than 0.05. After 4 weeks of treatment, both groups improved; however, the PIR-MET + CT group demonstrated significantly superior post-intervention outcomes across pain and all active and passive shoulder mobility measures.

VAS pain at 4 weeks was lower in the PIR-MET + CT group than in the HVLA + CT group, with a mean difference of 2.00 cm and a very large between-group effect size. Similarly, PIR-MET + CT produced greater post-intervention active ROM than HVLA + CT, with between-group differences of 20.41° for active flexion, 22.71° for active abduction, 16.64° for active external rotation, and 16.66° for active internal rotation. Passive ROM outcomes followed the same pattern, with PIR-MET + CT exceeding HVLA + CT by 20.47° in passive flexion, 22.65° in passive abduction, 15.58° in passive external rotation, and 16.41° in passive internal rotation. All post-intervention between-group comparisons favored PIR-MET + CT with p<0.001.

Table 3. Between-Group Comparison of Pain and Shoulder Range-of-Motion Outcomes at Baseline and 4 Weeks

Outcome	Time Point	HVLA + CT Mean ± SD	PIR-MET + CT Mean ± SD	Mean Difference (95% CI)	t (df)	p-value	Cohen's d
VAS pain (cm)	Baseline	7.45 ± 0.61	7.65 ± 0.63	−0.199 (−0.504, 0.106)	−1.304 (64)	0.197	−0.32
	4 weeks	4.33 ± 0.47	2.33 ± 0.36	2.004 (1.798, 2.211)	19.406 (59.80)[a]	<0.001	4.78
Active flexion (°)	Baseline	106.36 ± 8.23	106.98 ± 8.14	−0.624 (−4.648, 3.399)	−0.310 (64)	0.758	−0.08

Outcome	Time Point	HVLA + CT Mean ± SD	PIR-MET + CT Mean ± SD	Mean Difference (95% CI)	t (df)	p-value	Cohen's d
	4 weeks	137.22 ± 9.90	157.63 ± 9.93	−20.412 (−25.288, −15.536)	−8.363 (64)	<0.001	−2.06
Active abduction (°)	Baseline	99.27 ± 7.78	99.97 ± 7.58	−0.703 (−4.481, 3.075)	−0.372 (64)	0.711	−0.09
	4 weeks	130.08 ± 9.96	152.79 ± 8.02	−22.706 (−27.154, −18.258)	−10.197 (64)	<0.001	−2.51
Active external rotation (°)	Baseline	36.33 ± 6.82	37.16 ± 6.38	−0.833 (−4.081, 2.414)	−0.513 (64)	0.610	−0.13
	4 weeks	58.70 ± 8.71	75.34 ± 8.51	−16.636 (−20.871, −12.402)	−7.849 (64)	<0.001	−1.93
Active internal rotation (°)	Baseline	41.32 ± 6.21	42.42 ± 5.69	−1.094 (−4.022, 1.834)	−0.746 (64)	0.458	−0.18
	4 weeks	61.58 ± 5.56	78.24 ± 7.29	−16.658 (−19.846, −13.469)	−10.437 (64)	<0.001	−2.57
Passive flexion (°)	Baseline	111.93 ± 8.58	113.28 ± 8.57	−1.348 (−5.566, 2.869)	−0.639 (64)	0.525	−0.16
	4 weeks	143.74 ± 10.14	164.21 ± 9.46	−20.470 (−25.292, −15.647)	−8.480 (64)	<0.001	−2.09
Passive abduction (°)	Baseline	105.11 ± 7.98	106.48 ± 8.04	−1.373 (−5.313, 2.567)	−0.696 (64)	0.489	−0.17
	4 weeks	137.07 ± 10.42	159.72 ± 8.75	−22.648 (−27.381, −17.916)	−9.561 (64)	<0.001	−2.35
Passive external rotation (°)	Baseline	41.79 ± 7.40	42.15 ± 6.45	−0.361 (−3.775, 3.054)	−0.211 (64)	0.834	−0.05
	4 weeks	64.08 ± 9.32	79.66 ± 7.96	−15.582 (−19.844, −11.320)	−7.304 (64)	<0.001	−1.80
Passive internal rotation (°)	Baseline	46.06 ± 6.09	47.17 ± 6.01	−1.109 (−4.085, 1.867)	−0.745 (64)	0.459	−0.18
	4 weeks	66.75 ± 5.97	83.16 ± 6.10	−16.406 (−19.374, −13.438)	−11.041 (64)	<0.001	−2.72

[a] Welch's correction applied because equality of variance was violated. Negative mean differences for ROM indicate higher values in the PIR-MET + CT group. CT = conventional therapy; HVLA = high-velocity low-amplitude thrust; PIR-MET = post-isometric relaxation muscle energy technique; VAS = Visual Analogue Scale.

The pain findings demonstrated a clear post-intervention advantage for PIR-MET + CT. Baseline VAS pain was severe and comparable between groups, with mean scores of 7.45 ± 0.61 cm in the HVLA + CT group and 7.65 ± 0.63 cm in the PIR-MET + CT group (p=0.197). At 4 weeks, VAS pain decreased to 4.33 ± 0.47 cm in the HVLA + CT group and to 2.33 ± 0.36 cm in the PIR-MET + CT group, producing a between-group mean difference of 2.00 cm (95% CI: 1.80 to 2.21; p<0.001). The effect size for post-intervention pain was very large (Cohen's d=4.78), indicating a substantially greater short-term analgesic effect in the PIR-MET + CT group.

Active shoulder mobility improved more prominently in the PIR-MET + CT group across all measured directions. At 4 weeks, active flexion reached 157.63 ± 9.93° in the PIR-MET + CT group compared with 137.22 ± 9.90° in the HVLA + CT group, a difference of 20.41° (95% CI: 15.54 to 25.29; p<0.001). Active abduction showed the largest between-group active ROM difference, with PIR-MET + CT achieving 152.79 ± 8.02° compared with 130.08 ± 9.96° in HVLA + CT, corresponding to a 22.71° advantage (95% CI: 18.26 to 27.15; p<0.001). Active external rotation and active internal rotation also favored PIR-MET + CT by 16.64° and 16.66°, respectively, both with p<0.001 and very large effect sizes.

Passive shoulder mobility showed a parallel pattern of improvement favoring PIR-MET + CT. Passive flexion increased to 164.21 ± 9.46° in the PIR-MET + CT group versus 143.74 ± 10.14° in the HVLA + CT group, yielding a 20.47° between-group advantage (95% CI: 15.65 to 25.29; p<0.001). Passive abduction demonstrated a 22.65° advantage for PIR-MET + CT, with post-intervention means of 159.72 ± 8.75° versus 137.07 ± 10.42° (p<0.001).

Rotational passive movements also improved more in the PIR-MET + CT group, with passive external rotation reaching 79.66 ± 7.96° versus 64.08 ± 9.32° and passive internal rotation reaching 83.16 ± 6.10° versus 66.75 ± 5.97°, respectively. The largest passive ROM effect size was observed for passive internal rotation (Cohen's d=−2.72), suggesting a particularly strong treatment contrast in rotational recovery.

Within-group analysis showed statistically significant improvements from baseline to 4 weeks in both treatment groups across all pain and ROM outcomes. In the HVLA + CT group, VAS pain decreased by 3.12 cm, representing a 41.9% reduction from baseline. Active ROM gains ranged from 20.26° for active internal rotation to 30.86° for active flexion, while passive ROM gains ranged from 20.69° for passive internal rotation to 31.96° for passive abduction. All within-group changes in the HVLA + CT group were statistically significant at p<0.001 and were associated with large within-subject effect sizes.

In the PIR-MET + CT group, the magnitude of within-group improvement was larger across every outcome. VAS pain decreased by 5.32 cm, representing a 69.6% reduction from baseline. Active ROM gains ranged from 35.82° for active internal rotation to 52.82° for active abduction, while passive ROM gains ranged from 35.99° for passive internal rotation to 53.24° for passive abduction. All within-group changes in the PIR-MET + CT group were statistically significant at $p<0.001$, with very large within-subject effect sizes.

Table 4. Within-Group Changes in Pain and Shoulder Range of Motion from Baseline to 4 Weeks

Group	Outcome	Baseline Mean ± SD	4 Weeks Mean ± SD	Mean Change ± SDdiff	95% CI of Change	t (df=32)	p-value	Cohen's dz	% Change
HVLA + CT	VAS pain (cm)	7.45 ± 0.61	4.33 ± 0.47	−3.121 ± 0.614	−3.338 to −2.903	29.181	<0.001	5.08	−41.9
	Active flexion (°)	106.36 ± 8.23	137.22 ± 9.90	30.861 ± 5.050	29.070 to 32.651	35.103	<0.001	6.11	29.0
	Active abduction (°)	99.27 ± 7.78	130.08 ± 9.96	30.815 ± 4.953	29.059 to 32.571	35.742	<0.001	6.22	31.0
	Active external rotation (°)	36.33 ± 6.82	58.70 ± 8.71	22.370 ± 4.787	20.672 to 24.067	26.843	<0.001	4.67	61.6
	Active internal rotation (°)	41.32 ± 6.21	61.58 ± 5.56	20.258 ± 4.771	18.566 to 21.949	24.389	<0.001	4.25	49.0
	Passive flexion (°)	111.93 ± 8.58	143.74 ± 10.14	31.806 ± 5.573	29.830 to 33.782	32.785	<0.001	5.71	28.4
	Passive abduction (°)	105.11 ± 7.98	137.07 ± 10.42	31.961 ± 5.650	29.957 to 33.964	32.498	<0.001	5.66	30.4
	Passive external rotation (°)	41.79 ± 7.40	64.08 ± 9.32	22.294 ± 5.307	20.412 to 24.176	24.132	<0.001	4.20	53.4
	Passive internal rotation (°)	46.06 ± 6.09	66.75 ± 5.97	20.694 ± 5.189	18.854 to 22.534	22.910	<0.001	3.99	44.9
PIR-MET + CT	VAS pain (cm)	7.65 ± 0.63	2.33 ± 0.36	−5.324 ± 0.755	−5.592 to −5.056	40.500	<0.001	7.05	−69.6
	Active flexion (°)	106.98 ± 8.14	157.63 ± 9.93	50.648 ± 5.906	48.554 to 52.743	49.265	<0.001	8.58	47.3
	Active abduction (°)	99.97 ± 7.58	152.79 ± 8.02	52.818 ± 4.629	51.177 to 54.459	65.552	<0.001	11.41	52.8
	Active external rotation (°)	37.16 ± 6.38	75.34 ± 8.51	38.173 ± 4.762	36.484 to 39.861	46.050	<0.001	8.02	102.7
	Active internal rotation (°)	42.42 ± 5.69	78.24 ± 7.29	35.821 ± 4.745	34.139 to 37.504	43.372	<0.001	7.55	84.4
	Passive flexion (°)	113.28 ± 8.57	164.21 ± 9.46	50.927 ± 5.923	48.827 to 53.027	49.396	<0.001	8.60	45.0
	Passive abduction (°)	106.48 ± 8.04	159.72 ± 8.75	53.236 ± 5.186	51.398 to 55.075	58.972	<0.001	10.27	50.0
	Passive external rotation (°)	42.15 ± 6.45	79.66 ± 7.96	37.515 ± 5.067	35.718 to 39.312	42.528	<0.001	7.40	89.0
	Passive internal rotation (°)	47.17 ± 6.01	83.16 ± 6.10	35.991 ± 4.575	34.369 to 37.613	45.195	<0.001	7.87	76.3

CT = conventional therapy; HVLA = high-velocity low-amplitude thrust; PIR-MET = post-isometric relaxation muscle energy technique; VAS = Visual Analogue Scale; SDdiff = standard deviation of paired difference.

Comparison of change scores showed that PIR-MET + CT produced larger absolute improvements than HVLA + CT across all outcomes. Pain reduction was 2.20 cm greater in the PIR-MET + CT group than in the HVLA + CT group, corresponding to a 69.6% reduction from baseline compared with 41.9% in the HVLA + CT group. Active ROM improvements were also consistently larger with PIR-MET + CT, exceeding HVLA + CT by approximately 19.79° for active flexion, 22.00° for active abduction, 15.80° for active external rotation, and 15.56° for active internal rotation. Passive ROM improvements showed a similar treatment gradient, with PIR-MET + CT exceeding HVLA + CT by approximately 19.12° for passive flexion, 21.28° for passive abduction, 15.22° for passive external rotation, and 15.30° for passive internal rotation.

Table 5. Comparative Magnitude of Improvement from Baseline to 4 Weeks

Outcome	HVLA + CT Mean Change	PIR-MET + CT Mean Change	Improvement with PIR-MET + CT
VAS pain (cm)	−3.121	−5.324	−2.203
Active flexion (°)	30.861	50.648	19.787°
Active abduction (°)	30.815	52.818	22.003°
Active external rotation (°)	22.370	38.173	15.803°
Active internal rotation (°)	20.258	35.821	15.563°
Passive flexion (°)	31.806	50.927	19.121°
Passive abduction (°)	31.961	53.236	21.275°
Passive external rotation (°)	22.294	37.515	15.221°
Passive internal rotation (°)	20.694	35.991	15.297°

The overall pattern of findings indicates that both interventions were effective over 4 weeks, but PIR-MET + CT produced consistently larger and clinically meaningful improvements in pain and shoulder mobility. The strongest comparative advantage of PIR-MET + CT was observed for pain reduction and abduction recovery, with an additional 2.20-cm reduction in VAS pain, 22.00° greater active abduction gain, and 21.28° greater passive abduction gain compared with HVLA + CT. Rotational outcomes also favored PIR-MET + CT, with additional gains of approximately 15°–16° in both active and passive external and internal rotation. These findings suggest that, within the short-term treatment period studied, PIR-MET added to conventional therapy produced broader and larger improvements than HVLA thrust manipulation added to the same conventional therapy program.

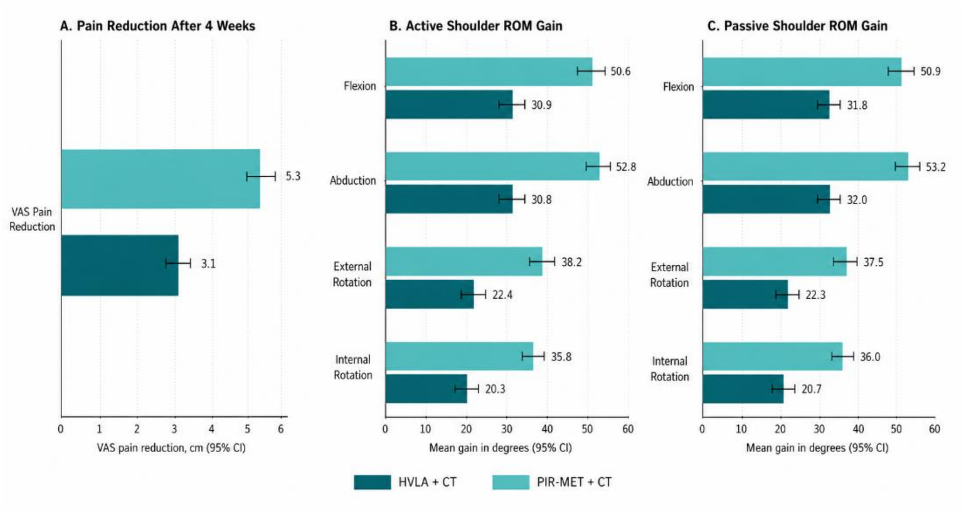

Figure 1. Comparative Short-Term Treatment Response in Adhesive Capsulitis

The panelled figure demonstrates consistently greater 4-week improvement with PIR-MET plus conventional therapy compared with HVLA plus conventional therapy across pain and shoulder mobility outcomes. Pain reduction was larger with PIR-MET + CT than HVLA + CT, with VAS decreasing by 5.32 cm versus 3.12 cm. Active ROM gains also favored PIR-MET + CT across flexion, abduction, external rotation, and internal rotation, with additional improvements of approximately 15.6°–22.0° compared with HVLA + CT. Passive ROM showed the same treatment-response gradient, with PIR-MET + CT producing 35.99°–53.24° gains compared with 20.69°–31.96° in the HVLA + CT group. The largest mobility advantages were observed for abduction, where PIR-MET + CT exceeded HVLA + CT by 22.00° in active abduction and 21.28° in passive abduction, indicating a clinically meaningful superiority of PIR-MET for short-term restoration of shoulder elevation and capsular mobility.

DISCUSSION

This randomized controlled trial compared the short-term effects of high-velocity low-amplitude thrust manipulation plus conventional therapy with post-isometric relaxation muscle energy technique plus conventional therapy in patients with Stage II–III adhesive capsulitis. The findings showed that both interventions produced statistically significant improvements in pain intensity and shoulder range of motion after 4 weeks; however, the magnitude of improvement was consistently greater in the PIR-MET group across all measured outcomes. Pain reduction was larger with PIR-MET + CT than HVLA + CT, with VAS scores decreasing by 5.32 cm compared with 3.12 cm, respectively. Similarly, active and passive shoulder mobility improved more substantially in the PIR-MET group, with active ROM gains ranging from 35.82° to 52.82° and passive ROM gains ranging from 35.99° to 53.24°, compared with active gains of 20.26° to 30.86° and passive gains of 20.69° to 31.96° in the HVLA group. These findings suggest that PIR-MET, when added to conventional physiotherapy, may offer a stronger short-term therapeutic effect than HVLA thrust manipulation for reducing pain and improving shoulder mobility in patients with adhesive capsulitis.

The greater reduction in pain observed in the PIR-MET group may be explained by the physiological effects of post-isometric relaxation, including reduced muscle guarding, improved tolerance to stretch, modulation of neuromuscular tone, and progressive lengthening of restricted periarticular tissues. Adhesive capsulitis is characterized not only by capsular fibrosis and restricted arthrokinematics but also by pain-related guarding and protective limitation of movement. A patient-assisted contract-relax technique may therefore be particularly useful because it allows repeated movement toward a new resistance barrier while maintaining patient control and minimizing perceived threat. Previous evidence on Spencer muscle energy technique and proprioceptive neuromuscular facilitation in adhesive capsulitis has similarly indicated that neuromuscular facilitation-based approaches can reduce pain and improve shoulder movement when integrated into rehabilitation programs (29). The current findings extend this therapeutic rationale by showing that PIR-MET produced a larger analgesic response than HVLA when both were delivered alongside the same conventional therapy program.

The improvement in shoulder mobility was clinically meaningful because the largest gains occurred in movements commonly restricted in adhesive capsulitis, including abduction and rotation. In the present trial, PIR-MET produced an additional 22.00° improvement in active abduction and 21.28° improvement in passive abduction compared with HVLA, while rotational outcomes also favored PIR-MET by approximately 15°–16°. Restoration of abduction and rotation is particularly relevant because these movements are essential for dressing, grooming, reaching overhead, reaching behind the back, and other daily functional activities. Comparative literature on mobilization and muscle energy approaches supports the view that manual therapy can improve ROM in adhesive capsulitis, although the relative superiority of specific techniques remains uncertain due to variations in protocols and outcome measures (30,31). The present findings provide direct comparative evidence suggesting that PIR-MET may be more effective than HVLA for short-term ROM restoration in Stage II–III adhesive capsulitis.

The superiority of PIR-MET over HVLA may also relate to the active participation required during treatment. Unlike thrust manipulation, which is primarily therapist-driven, PIR-MET requires the participant to perform controlled isometric contractions followed by relaxation and assisted stretch. This active component may enhance proprioceptive input, reduce apprehension, improve neuromuscular control, and allow gradual exposure to restricted movement. Prior studies comparing muscle energy technique with other mobilization-based approaches have reported favorable effects of MET on pain, ROM, and disability in adhesive capsulitis, supporting its role as an adjunct to conventional physiotherapy (32,33). In the present study, the consistent treatment advantage across both active and passive ROM outcomes suggests that PIR-MET may influence both voluntary movement performance and passive capsular or soft-tissue extensibility.

Although PIR-MET demonstrated superior outcomes, HVLA + CT was also associated with significant improvement in pain and ROM. Pain decreased by 41.9% in the HVLA group, while ROM improved across all active and passive shoulder movements. These improvements may reflect the combined effects of HVLA thrust manipulation and the standardized conventional physiotherapy program, including moist heat, active and passive range-of-motion exercises, stretching, and strengthening. HVLA may contribute through mechanoreceptor stimulation, joint-play facilitation, short-term pain modulation, and reduction of movement-related guarding. However, adhesive capsulitis involves capsular contracture and progressive soft-tissue restriction, which may require repeated, graded stretching and patient-assisted mobilization rather than a primarily thrust-based approach. Evidence from rehabilitation-focused reviews indicates that multiple conservative interventions can be beneficial in adhesive capsulitis, but the optimal manual therapy dosage and technique selection remain unresolved (34,35).

The present findings are consistent with studies reporting beneficial effects of manual therapy, mobilization, and MET-based interventions in adhesive capsulitis. Comparative work on proprioceptive neuromuscular facilitation, Spencer MET, Mulligan mobilization, and end-range mobilization has shown that structured manual therapy can reduce pain and improve ROM, particularly when combined with exercise-based rehabilitation (36,37). Mallick et al. reported that muscle energy technique improved pain and ROM in frozen shoulder, while Naureen et al. found favorable effects of PIR-MET compared with high-grade Maitland mobilization for pain, ROM, and functional status (38,39). These findings align with the present trial, in which PIR-MET produced broader and larger short-term improvements than HVLA across pain and mobility outcomes. However, direct comparison across studies should be cautious because treatment frequency, duration, patient staging, comparator interventions, and outcome instruments differ substantially.

From a clinical perspective, PIR-MET may be considered a useful adjunct to conventional physiotherapy for patients with Stage II–III adhesive capsulitis, particularly when the therapeutic goal is short-term pain reduction and restoration of shoulder elevation and rotation. Its advantages include patient participation, graded application, low equipment requirement, and compatibility with routine physiotherapy practice. Prior evidence also supports the clinical utility of MET and movement-with-mobilization approaches in adhesive capsulitis, but the present findings suggest that PIR-MET may be especially valuable where pain-related guarding and soft-tissue restriction coexist (40). Nevertheless, the results should be interpreted within the limits of the study design rather than as definitive evidence of long-term superiority.

Several limitations should be considered. First, the follow-up period was limited to 4 weeks, so the durability of treatment effects beyond the immediate post-intervention period remains unknown. Second, the study did not include functional disability measures such as the Shoulder Pain and Disability Index or Disabilities of the Arm, Shoulder and Hand questionnaire, which limits interpretation of how ROM and pain gains translated into functional recovery. Third, the trial was conducted in a single clinical setting with a modest sample size, which may limit generalizability. Fourth, participant blinding is difficult in manual therapy trials because HVLA and PIR-MET are perceptibly different interventions; therefore, performance and expectation bias cannot be excluded. Fifth, the analysis involved multiple pain and ROM outcomes, and although all comparisons consistently favored PIR-MET, future trials should define a primary endpoint, use baseline-adjusted models, and apply an appropriate strategy for multiple comparisons. Finally, home exercise adherence, psychosocial factors, adverse events, and long-term recurrence were not evaluated, although these factors may influence recovery in adhesive capsulitis.

Future research should include multicenter randomized controlled trials with larger sample sizes, longer follow-up periods, assessor blinding, trial registration, and standardized reporting of adverse events. Future studies should also include functional outcomes, quality-of-life measures, patient global impression of change, and subgroup analyses based on disease stage, symptom duration, diabetes status, and baseline stiffness severity. Further comparison of PIR-MET with other manual therapy techniques, dosage schedules, home exercise programs, and multimodal rehabilitation protocols would help clarify its optimal clinical role. Evidence from recent comparative and rehabilitative studies supports the need for more rigorous trials with standardized protocols and clinically meaningful endpoints (41).

CONCLUSION

PIR-MET combined with conventional therapy produced greater short-term improvements than HVLA thrust manipulation combined with conventional therapy in patients with Stage II–III adhesive capsulitis. Both interventions significantly reduced pain and improved active and passive shoulder range of motion after 4 weeks, but PIR-MET demonstrated consistently larger improvements across all measured outcomes, including VAS pain reduction, shoulder flexion, abduction, external rotation, and internal rotation. These findings support PIR-MET as a promising adjunct to conventional physiotherapy for short-term pain relief and mobility restoration in adhesive capsulitis, although longer-term, multicenter trials with functional outcomes and stronger bias-control procedures are required before definitive clinical superiority can be established.

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