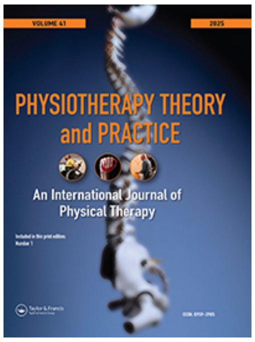

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RESEARCH REPORT

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Effect of adding thoracic manipulation for the management of patients with adhesive capsulitis: a randomized clinical trial

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ABSTRACT

Background: Research is supporting thoracic spine manipulation (TSM) as an intervention in treating adhesive capsulitis (AC) when coupled with physical therapy interventions.
Purpose: To investigate whether TSM improves AC outcomes when combined with physical therapy interventions.
Method: A double-blinded, randomized, controlled trial with 40 patients assigned into two groups. The experimental group (EG) received physical therapy intervention and TSM; the control group (CG) had physical therapy with sham manipulation. Both groups received interventions biweekly for 12 weeks. Outcomes included Visual Analogue Scale (VAS), Shoulder Pain and Disability Index (SPADI), scapular upward rotation, and shoulder passive range of motion conducted at baseline, after 1 session, 6 and 12 weeks.
Results: Both groups improved significantly after 6 and 12 weeks in pain, disability ($p = 0.01$ for both; d = 1.53 and 1.46, respectively), scapular upward rotation, shoulder flexion ($p = 0.02$ for both; d = 2.2 and 0.92, respectively), abduction ($p = 0.04$; d = 0.07), and external rotation ($p = 0.03$; d = 0.7). However, CG showed no significant improvement in pain or disability after one session ($p = 0.14$ and $p = 0.16$, respectively; d = 0.46 for both). Between groups, results favored EG significantly in pain, disability, scapular upward rotation, shoulder flexion, and abduction ($p = 0.02$, $p = 0.01$, $p = 0.02$, $p = 0.05$, and $p = 0.04$, respectively) at 6 weeks (d = 0.81, d = 0.87, d = 0.67, d = 0.64, and d = 0.69, respectively).
Conclusion: The results suggest that adding TSM yielded superior clinical benefits when compared to physical therapy interventions in AC patients. Nevertheless, it is imperative to acknowledge a specific limitation in our study is the omission of passive internal rotation assessment. This aspect represents a notable constraint in our research.
Clinical trial registry number: Pan African clinical trial registry "*PACTR202303495421928*"

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Frozen shoulder; manual therapy; shoulder pain; interventional therapy; rehabilitation

Introduction

Adhesive Capsulitis (AC) is an inflammatory and fibrotic shoulder condition in which there is an excessive formation of scar tissue and adhesions in the glenohumeral joint due to certain pathologies leading to progressive loss in the range of motion of the joint, eventually leading to significant functional limitations. The disease begins with inflammatory cellular infiltration of the capsule, followed by proliferation of these cells and synovitis with the formation of scar tissue and loss of axillary folds (Le, Lee, Nazarian, and Rodriguez, 2017).

Of all intra-articular disease processes that affect the shoulder, AC is often described as the most commonly occurring (Neviaser, 1989). The classification of AC is often divided in the literature into two types, the first being primary or idiopathic AC that occurs on its own, and the second being secondary AC which follows predisposing factors. The literature shows that primary/idiopathic AC is often accompanied by other diseases such as diabetes mellitus, and secondary AC usually occurs after injury or trauma to the shoulder (Tighe and Oakley, 2008).

The progression of AC usually occurs over three distinctive phases according to recent literature. The first phase is characterized by marked pain that is initially worse at night but progresses to be present at rest with an accompanying gradual increase in stiffness. The second phase is described as a gradual decrease in range of motion following a specific capsular pattern, most markedly in external rotation, accompanied by increases in stiffness due to progressed synovitis. The third phase is where there is minimal pain and

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resolution of stiffness with an increased range of motion, although not fully as some adhesions remain. Although the exact pathophysiology of this entire process is yet to be fully understood, this process is thought to be mediated by inflammatory changes causing synovitis and eventually fibrosis of the glenohumeral joint capsule (Sueki, Cleland, and Wainner, 2013).

Although some belief among clinicians is that AC is self-limiting and resolves on its own after the resolution of its 3 phases, the evidence does not support this view where it has been estimated that up to half of the patients suffering from AC have persisting and chronic symptoms that warrant conservative or surgical treatment approaches (Le, Lee, Nazarian, and Rodriguez, 2017). A recent systematic review shows that complete recovery of this condition without treatment is "unfounded" (Wong et al., 2017).

Treatment of AC has included locally applied manual therapy techniques such as range of motion, mobilization, heat and ice, and ultrasound as well as surgical interventions if conservative treatment fails (Cho, Bae, and Kim, 2019) and several other modalities. Most of the available literature addresses AC with interventions such as physical therapy, corticosteroid injection, and manipulation, which is applied locally and directly at the shoulder joint (Bergman et al., 2004; Winters et al., 1997).

A recent focus of contemporary research examines the effectiveness of addressing pain localized at one joint by applying interventions to different joints in accordance with the regional interdependence concept which goes back over two decades (Wainner, Whitman, Cleland, and Flynn, 2007). Regional interdependence states that the patient's primary symptoms may be related to various regions and/or systems with disregard to the actual proximity and closeness with the area over which the primary symptoms reside (Sueki, Cleland, and Wainner, 2013). Hence, treating those impairments can show an effective way of managing the primary deficit (Minkalis et al., 2017; Wainner, Whitman, Cleland, and Flynn, 2007).

The underlying mechanisms of regional interdependence have been explained in various ways. Initially, Steindler proposed what he called a "kinetic chain" that makes up the musculoskeletal system. The kinetic chain concept means that all the joints of the body are interconnected so movement or biomechanical changes in one joint will undoubtedly cause movement and biomechanical changes in the other joint and so on. More recently than that, it was suggested that regional interdependence is a combination of the neurophysiological effect of manual therapy and the biomechanical mechanism proposed earlier. Both of the proposed mechanisms require more evidence to reach conclusiveness, however (Sueki, Cleland, and Wainner, 2013).

Multiple studies have applied this concept to different neck and shoulder conditions using manual therapy directed at the thoracic spine (Boyles et al., 2009; Dunning et al., 2015; Elmelhat, Abdelmagid, Gomaa, and Gad, 2020; McDevitt, Young, Mintken, and Cleland, 2015; Muth, Barbe, Lauer, and McClure, 2012; Strunce, Walker, Boyles, and Young, 2009); however, the majority of the studies did not focus on the AC condition specifically. A retrospective case series investigated a regional interdependence approach and its effect on AC; however, the interventions did not include thoracic spine manipulation (Wong et al., 2018). Nevertheless, all outcome measures reported favorable effect size increases.

Some evidence has recently focused on studying the effects of thoracic spine manipulation on patients with general shoulder pain based on the concept of regional interdependence. The conclusiveness of these effects is yet to be determined. Another paper studied the effects of thoracic and rib manipulation on subjects with shoulder pain and found that post-treatment the manipulation group had improvements in pain and range of motion when compared to the controls (Strunce, Walker, Boyles, and Young, 2009). On the other hand, a more recent study compared the effect of thoracic spine manipulation with sham manipulation on patients with subacromial pain syndrome, and the results showed no significant differences in terms of pain or range of motion. This leaves the area needing additional investigation and research (Grimes, Puentedura, Cheng, and Seitz, 2019).

Studies that test the idea of regional independence on AC-affected patients are scarce. A single case study investigated the effect of thoracic spine manual physical therapy on an AC-affected individual (McCormack, 2012). In this case report, the investigators created a treatment plan similar to the one performed in this study. The rehabilitation interventions consisted of a range of motion and stretching exercises, coupled with mobilizations as well as manipulations directed to different thoracic spinal segments. Initially, the interventions did not yield much difference; however, after several weeks of performing these interventions, the individual reported significantly decreased levels of pain and increased levels of range of motion, with the latter remaining somewhat limited. The researchers here utilized joint mobilizations as well as high-velocity manipulations in their treatment, and they also highlighted the need for additional compounding research and investigations concerning the effects of adding interventions that are based on the concept of regional interdependence.

Accordingly, this study aims to investigate the effect of adding high-velocity low amplitude thoracic spine manipulation to physical therapy interventions on pain, disability scores, and passive range of motion of the scapula and shoulder in patients with AC.

Method

Design

The authors obtained regional ethics approval from the ethics committee of the Faculty of Physical Therapy, Cairo University, and Code: **P.T.REC/012/004636**. This randomized controlled clinical trial was also prospectively registered at the Pan African Clinical Trials Registry (PACTR) with a registration number: ***PACTR202303495421928.***

All potential participants were recruited from the outpatient clinic at Cairo University and several private physical therapy clinics in Cairo and Giza and were assessed for their eligibility to be included in this study. All patients passing the eligibility assessment and interested in participating were asked to sign written informed consent after providing them with verbal information concerning the study that would not interfere with the proposed blinding methods. Following their consent, baseline measurements and demographic information were taken before and after completion of the study.

Recruitment took place based on a waiting list with no financial incentives given to any of the participants. The patients were then randomly divided into two groups; allocations were sequentially numbered and placed in sealed and opaque envelopes to ensure concealed allocation. After participant enrollment, a baseline assessment was obtained by an independent experienced blinded assessor. Also, the persons responsible for allocation and randomization were different than those screening and assessing the patients for eligibility to minimize bias.

After group allocation, patients underwent two treatment sessions of 30 min per week for a total of 12 weeks with the experimental group receiving a different intervention plan (thoracic spine manipulation vs. sham thoracic spine manipulation). Outcome measures were taken again after the first session (immediately), at 6 weeks, and finally at 12 weeks (follow-up). The outcome assessors were blinded concerning group assignment.

Participants

Sample size calculation

G*POWER© software (ver.3.1.9.2, Heinrich-Heine-University, Düsseldorf, Germany) with a priori testing was used to calculate the adequate sample size for, between and within-group ANOVA, using a significance level of 5%, a power level of 90%, and a medium effect size (dz = 0.25) with two groups (Faul, Erdfelder, Lang, and Buchner, 2007). The mean difference used in this study was 5 degrees of scapular upward rotation (Mohamed et al., 2020; Surenkok, Aytar, and Baltaci, 2009). Based on the assumptions it was estimated that the sample size needed for this study is of minimum 36. This number was increased to 40 with an 11% attrition rate.

Patient recruitment

Patients included in this study were those with AC; aged between 40 and 60 years; diagnosed with primary AC; being diagnosed and confirmed by an orthopedic surgeon with the following criteria: unilateral limitation of both active and passive range of motion with pain that has interfered with daily activities and glenohumeral passive range of motion (ROM) that is limited in multiple directions, with external rotation the most limited (Schultheis, Reichwein, and Nebelung, 2008); with no medical treatment other than analgesics within the past three months; with no history of corticosteroid injections; and limited passive shoulder elevation (scaption) above 90 degrees as recommended in many similar studies (Mohamed et al., 2020; Teys, Bisset, and Vicenzino, 2008). The exclusion criteria were as follows: previous shoulder or thoracic spinal surgery; history of trauma or fracture within the last 3 months; osteoporosis; myelopathy; cervical radiculopathy; serious medical or mental diseases; and/or the presence of any contraindication to manipulation.

In total, 75 patients were screened for eligibility; 35 of these patients were then excluded; 15 of them did not meet one or more of the inclusion criteria for this study; 8 patients declined to participate after knowing the length of the study, and 12 patients declined for other reasons (5 were not willing to try manipulation techniques, 3 had a history of shoulder dislocation, and 4 had negative experience of physical therapy). Thus, 40 patients were eligible and willing to participate in this study. The recruitment started on March 15, 2023 until the end of the study on August 15, 2023. A written consent form was obtained from each participant. Assignment was done randomly equally to either the experimental group containing a total of 20 patients or the control group also containing a total of 20 patients. No patients were lost to follow-up; therefore, a total of 40 patients completed the 12-week length of the trial. The enrollment of the patients is summarized and shown in (Figure 1).

Outcome measures

The outcome measures and assessments were taken at baseline, after the initial session, at 6 weeks, and finally at 12 weeks of therapy.

The following outcome measures were chosen.

Visual analogue scale for shoulder pain

The visual analogue (VAS) scale was used to estimate the pain levels of the patients. The VAS scale is a subjective scale in which the patient rates his/her pain on a scale of 1 to 10. Usually, the score is recorded by pointing out the "level of pain" on a line that is 10 cm long and divided into 1 cm blocks (Delgado et al., 2018). The VAS has a reliability score (Spearman's correlation coefficients) varying between 0.60 and 0.77, and validity between 0.76 and 0.84. VAS has been claimed to possess a moderate to good reliability ratio (Boonstra et al., 2008).

The minimal clinically important difference (MCID) on a visual analogue scale measured in the shoulder pain population receiving rehabilitation is often considered to be around 1.4 to 3 cm on a 0–10 VAS for shoulder pain (Tashjian, Deloach, Porucznik, and Powell, 2009).

Shoulder pain and disability index for functional disability

The Shoulder Pain and Disability Index (SPADI) was developed to assess both pain and disability of the shoulder joint in an outpatient setting. A recent systematic review reported reliability coefficients of ≥ 0.89 and high internal consistency with Cronbach's α typically exceeding 0.90. The SPADI contains 13 items that assess two domains; a 5-item subscale that measures pain and an 8-item subscale that measures disability (Breckenridge and McAuley, 2011).

The SPADI usually takes around 5 to 10 min to complete with the literature investigating the Arabic version of the SPADI showing high inter-rater agreement, validity, and methodological qualities. It also showed high test-retest reliability and construct validity (Alsanawi et al., 2015; Guermazi et al., 2011).

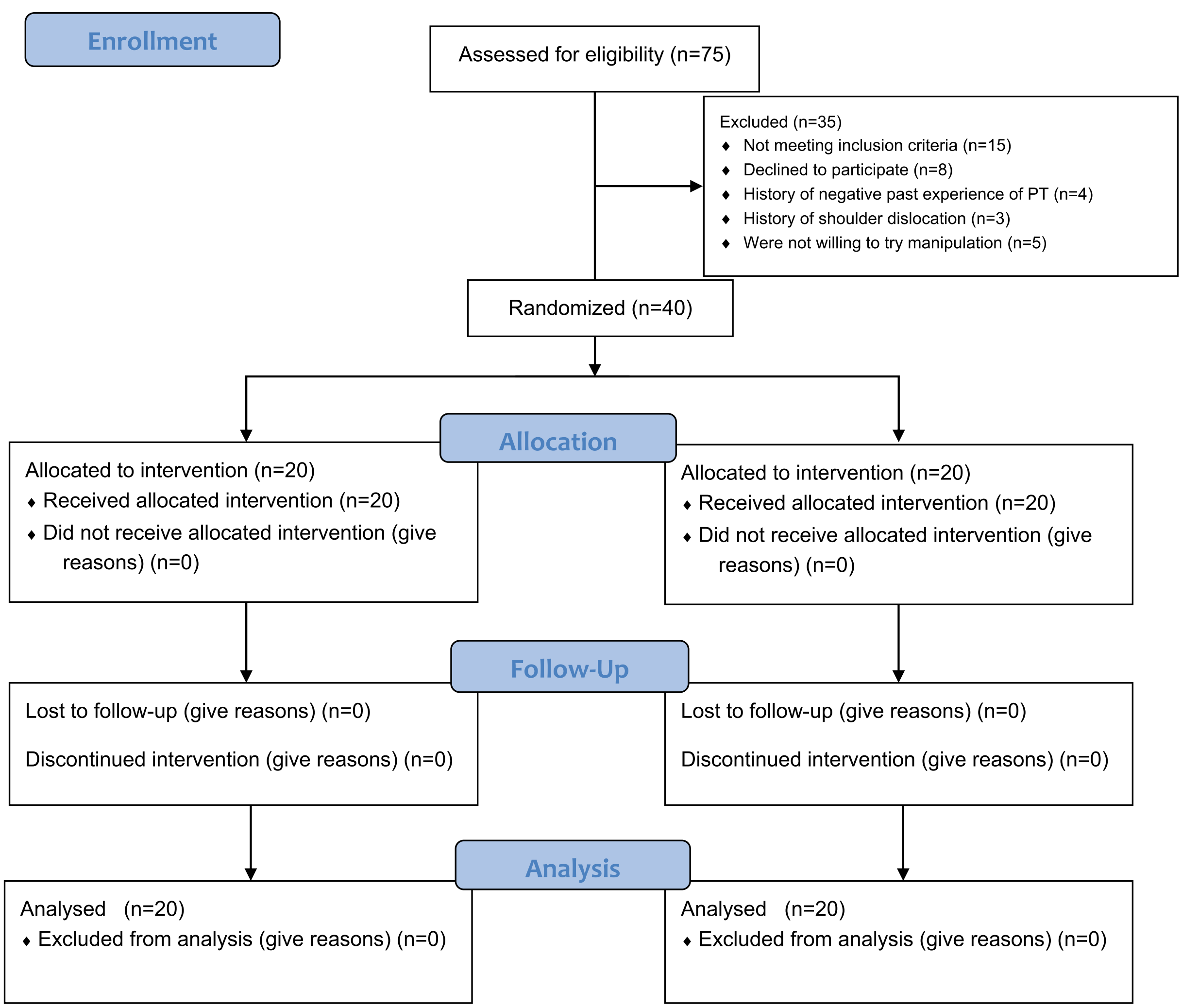

Figure 1. Enrollment of patients.

The patients were instructed to describe the severity of their shoulder problems in the previous week by marking one number on a scale from zero (no pain or disability) to ten (maximum pain and disability) for each item. The results from each subscale were added up and converted to a score out of 100, with a higher final score indicating more severe shoulder pain, impairment, or disability, with a reported minimal clinically important difference (MCID) of 8 to 13 points (Tveitå, Ekeberg, Juel, and Bautz-Holter, 2008).

Scapular Range of motion using an inclinometer

Scapular passive range of motion was measured with the use of two inclinometers, (The Saunders Group, Chaska, MN, USA© ™). One placed on the humeral shaft and the other placed on the spine of the scapula. The participant was standing with the arm initially by the side of the trunk. After placing the inclinometers, they were calibrated so that the starting measurements were fixed and hence minimizing the placement errors that may occur. This was done in accordance with standardized protocols described elsewhere (Watson, Balster, Finch, and Dalziel, 2005).

After that, the participant's shoulder was slowly abducted with the thumb leading upwards and stopped at 90 degrees with the measurements taking place at a maximum of 90 degrees. Patients with limitations above 90 were excluded from the study, with the scapular range being measured by the inclinometer placed at the spine of the scapula.

The literature shows that the bubble inclinometer is a valid and reliable way of assessing scapular upward rotation in all ranges of abduction in the coronal plane (Watson, Balster, Finch, and Dalziel, 2005).

Passive shoulder range of motion using an electronic goniometer

Measurements for passive shoulder range of motion were performed during external rotation, abduction and flexion. Notably, existing evidence suggests, as elucidated by Rundquist, Anderson, Guanche, and Ludewig (2003), that internal rotation may exhibit heightened limitation, particularly in instances where measurements are obtained from shoulder abduction. Thus, a major limitation of this study is the absence of passive internal rotation assessment.

In this trial, passive range of motion measurements for the shoulder was taken and used as an outcome measure. Non-elastic fixation straps were employed to secure the scapula in a neutral position. These straps were carefully adjusted to limit scapular movement while allowing for the necessary GH joint motion during passive range testing. Although clinically applicable, there was a lack of proving the exact figures of validity and reliability concerning this method of isolating glenohumeral movement.

The testing went as follows: When assessing external rotation, the patient laid supine. The shoulder was placed in 90-degree abduction and neutral rotation. The elbow was placed in 90 degrees of flexion. For individuals that could not tolerate this position, the degree of abduction was lowered to 60 or 45 degrees and the measurement was taken from that position which was reliable and tolerable for the patient. The fulcrum was placed on the olecranon process and the arms of the goniometer bisected the forearm, being perpendicular to the floor. The shoulder was then passively and slowly externally rotated until the limit present was reached through the end feel. One arm of the goniometer stayed static while the other moved with the forearm of the patient.

When assessing abduction, the patient way asked to lay supine with the scapula stabilized, the fulcrum was placed on the coracoid process, and arms of the goniometer parallel to the patient's trunk and bisecting the humeral shaft in half. The arm was then passively brought out to abduction in the available range until a limit was presented through the end feel. One arm of the goniometer was kept static while the other moved with the shaft of the humerus.

When assessing flexion, the patient laid supine with the scapula stabilized, the fulcrum was placed in the middle of the humeral head laterally, with the arms of the goniometer parallel to the floor and bisecting the humeral shaft in half. The arm was then passively brought anteriorly to the patient in flexion in the available range until an end feel limit was sensed. One arm of the goniometer stayed static while the other moved with the shaft of the humerus.

Interventions

Patients in both groups received local superficial heat therapy (a form of thermotherapy) by the use of a heating blanket at around 60–63 degrees Celsius for 15–20 min aimed at reducing pain and general stiffness, similar to another study as part of a comprehensive treatment plan for AC (Leung and Cheing, 2008).

In addition, passive and active assisted range of motion techniques were carried out for each participant. The motions of which the patients carried out included flexion, abduction, and external rotation with a hold at the end of the range to create a sustained stretch. The patients were allowed to use their unaffected arm or a wand to aid in the active-assisted movements. An experienced physical therapist performed the passive movements for each participant. This intervention was carried out over three sets, with each set having up to 12 repetitions or as many as tolerated. Researchers investigating the effects of similar exercises had patients to do 4 direction-specific stretches using the unaffected arm and a bar for assistance twice a day and found improvements in pain, range of motion, and shoulder function (Griggs, Ahn, and Green, 2000).

Joint mobilizations were also applied to each participant in the planes of restricted motion with grades varying between grade 3 and grade 4 typically used when stiffness is present; provided anteroposterior mobilization in 20–30 degrees of shoulder flexion as well as caudally directed mobilizations in 20–30 degrees of shoulder abduction (Maricar, Shacklady, and McLoughlin, 2009). The mobilizations were standardized as the same therapist provided the mobilizations in accordance with appropriate end feel and force. The interventions consisted of sets of 12 repetitions or till patient tolerance and were an integral part of AC rehabilitative plans of care in previous research (Vermeulen et al., 2006).

Thoracic spine manipulation

High-velocity low amplitude grade 5 thrusts were utilized targeting the thoracic spine segments T1 to T6. These are manual techniques utilizing fast rotatory force aimed at facet joints to induce decompression and greater mobility.

Prone Extension Technique "Butterfly" Manipulation: This technique targets the upper thoracic region on the lower thoracic and upper lumbar regions. The patient lies prone with the head and neck in a comfortable position and the arms relaxed on each side of the bed. The hypothenar eminence of the right hand is placed on the left transverse process establishing firm contact with the area. Then, the hypothenar eminence of the left hand is placed on the right transverse process also establishing firm contact. Following the hand placement, the patient is asked to inhale deeply and then exhale fully to induce relaxation during which the therapist shifts his center of gravity to be directly perpendicular to the points of contact and applies a downward and rotatory fast grade 5 thrust force through the transverse processes. This prone extension technique is otherwise known as the "Butterfly" technique resembling the shape of hand placement (Strunce, Walker, Boyles, and Young, 2009).

Supine Flexion "Cupping" Manipulation: This technique targets the upper thoracic region on the lower thoracic and upper lumbar regions. The patient lies supine with the head and neck in a comfortable position and the arms crossed over the chest in an overlapping fashion. The therapist stands at the side of the patient and rolls one arm around the shoulder to gently lift the patient's upper half and continues to place the hand in a "cup" fashion with the fingers slightly flexed, having the fingers pressing on one side of the transverse processes and the thenar eminence pressing on the other side with the spinous processes cupped in between. The therapist then establishes firm contact between his/her body and the crossed arms of the patient, slowly returning them to the supine position. As the patient approaches the supine position the therapist leans over them maintaining a downward leverage and introduces a fast grade 5 thrust force toward the hand under the patient.

Patients in both groups received real or sham manipulation 2 sessions per week for 12 weeks according to the group allocation.

For patients in the control group, the sham manipulation technique was applied with the same initial positions for each manipulation technique being taken; however, hand placements were taken with broad and nonspecific contact points and the technique was applied with inadequate low velocity and low amplitude forces (Lynge et al., 2021).

Compliance

The patients consented to the frequency of sessions being twice per week for 12 weeks, totaling 24 sessions for each patient in each of the two groups. In addition, the manipulation techniques were conducted by a certified and experienced physical therapist who was blinded to the purpose and outcomes of this study.

Statistical analysis

A repeated measure analysis of variance (ANOVA) was used to analyze and detect differences within and between the experimental and control groups concerning pain, disability, scapular upward rotation, as well as shoulder external rotation, abduction, and flexion. The models included 1 independent factor (group), 4 repeated measures (time), and an interaction factor (group × time). The significance level was set at $p < 0.05$. SPSS (ver. 25, IBM Inc., Armonk, NY, USA © ™) was used for statistical analysis in this study.

Results

The demographic and general characteristics of patients at baseline are shown in Table 1. There were no differences between both sets of patients in each group with

Table 1. Participant characteristics and their comparisons.

	Control Group (CG) ($N = 20$)		Experimental Group (EG) ($n = 20$)		
	MEAN	SD	MEAN	SD	P-Value
Age (years)	56.15	7.78	57.95	8.72	0.50
Duration Of Disease (Months)	3.6	1.31	3.25	1.48	0.43
Body Mass Index (BMI)	29.16	5.57	29.96	3.54	0.60
	Number	%	Number	%	P-Value
Gender					
Female	11	55%	10	50%	0.56
Male	9	45%	10	50%	
Diabetic History					
Diabetic	13	65%	11	55%	0.52
Non-Diabetic	7	35%	9	45%	
Lifestyle					
Active	6	30%	8	40%	0.45
Sedentary	14	70%	12	60%	
Patient Tolerance During Shoulder External Rotation ROM					
Tolerate 90 Degrees of Abduction	11	55%	12	60%	0.65
Unable to Tolerate 90 Degrees of Abduction	9	45%	8	40%	

Note. Numerical data expressed as mean ±SD (standard deviation), Categorical data are expressed as number (percentage).
Abbreviations: P-value, probability value; ROM, Range of Motion.
*Statistically significant (P-value <0.05).

respect to age, sex, BMI, duration of disease, lifestyle, and presence of diabetes mellitus ($p > 0.05$ for all).

Within-group comparisons: As shown in Table 2

Pain (visual analogue scale)

Only the experimental group saw a significant difference in pain after one session, after 6 weeks, and after 12 weeks when compared to baseline ($p = 0.01$, $p = 0.01$, and $p = 0.01$, respectively; CI = [0.52,2.67], CI = [2.18, 4.22] and CI = [4.37, 6.13], respectively; d = 0.96, d = 2.01, and d = 3.82, respectively). The control group did not see a significant difference with respect to pain after one session but did have a significant difference after 6 and 12 weeks ($p = 0.16$, 0.01 and 0.01, respectively; CI=[−0.28, 1.68], CI = [1.42, 3.48], and CI = [3.12, 5.38], respectively; d = 0.46, d = 1.53, and d = 2.42, respectively.

Shoulder pain and disability index

The control group only showed a significant difference in SPADI scores after 6 and 12 weeks when compared to baseline ($p = 0.01$ and $p = 0.01$, respectively; CI = [11.58, 29.73], and CI = [25.87, 43.83], respectively; d = 1.46 and d = 2.48, respectively), and showed no significant difference after one session ($p = 0.14$, CI=[−2.39, 16.09], d = 0.47). Within-group comparisons of the experimental group showed a significant difference in all three assessment points after one session, after 6 weeks, and after 12 weeks when compared to baseline ($p = 0.02$, $p = 0.01$, and $p = 0.01$, respectively; CI = [1.33, 18.07], CI = [17.33, 34.37], and CI = [35.99, 49.60], respectively; d = 0.74, d = 1.94, and d = 4.03, respectively).

Scapular upward rotation

Significant differences were seen in all three assessment points when compared to baseline in both the control and experimental group, with the control group achieving $p = 0.01$, $p = 0.01$, and $p = 0.01$, respectively; CI=[−8.77, −1.67], CI=[−18.65, −10.25], and CI=[−26.50, −19.34], respectively; d = 0.94, d = 2.2 and d = 4.1, respectively, while the experimental group achieved $p = 0.01$, $p = 0.01$, and $p = 0.01$, respectively; CI=[−7.93, −1.07], CI=[−22.64, −14.76], and CI=[−30.59, −21.70], respectively; d = 0.84, d = 3.04, and d = 3.77, respectively.

Passive shoulder range of motion

Outcomes with respect to shoulder range of motion were similar to each other across groups, with both the experimental and the control groups showing a significant improvement after 6 and 12 weeks, and no significant differences after one session. For the control group, $p = 0.03$ and $p = 0.01$, respectively; CI=[−13.85, −0.65] and CI=[−18.34, −4.66], respectively; d = 0.7 and d = 1.08, respectively for external rotation, $p = 0.01$ and $p = 0.01$; CI=[−23.76, −7.84] and CI=[−37.69, −10.91], respectively; d = 1.55 and d = 2.72, respectively for abduction, and $p = 0.01$ and $p = 0.01$, respectively; CI=[−19.18, −3.42] and CI=[−32.99, −11.40]; ES = 0.92 and ES = 1.32, respectively for flexion. As for the experimental group, $p = 0.02$ and $p = 0.01$; CI=[−18.01, −2.09] and CI=[−23.63, −8.27], respectively; d = 0.81 and d = 1.33, respectively for external rotation, $p = 0.01$ and $p = 0.01$, respectively; CI=[−36.29, −15.10] and CI=[−54.42, −33.68] respectively; d = 1.55 and d = 1.52 respectively

Table 2. Within group comparisons using ANOVA testing from baseline to after one session, after 6 weeks, and after 12 weeks.

Outcomes	Group	Baseline X± SD	After 1st session X± SD	After 1st session 95% CI	After 1st session d	After 1st session P	6 weeks X± SD	6 weeks 95% CI	6 weeks d	6 weeks P	12 weeks X± SD	12 weeks 95% CI	12 weeks d	12 weeks P
VAS	*CG*	6.95°±1.54	6.25°±1.52	0.7 [−0.28, 1.68]	0.46	0.16	4.50°±1.67	2.45 [1.42, 3.48].	1.53	0.01*	2.70°±1.95	4.25 [3.12, 5.38]	2.42	0.01*
	EG	6.40°±1.64	4.80°±1.71	1.6 [0.52, 2.67]	0.96	0.01*	3.20°±1.54	3.2 [2.18, 4.22]	2.01	0.01*	1.15°±1.04	5.25 [4.37, 6.13]	3.82	0.01*
SPADI (%)	*CG*	64.6°±14.30	57.75°±14.55	6.85 [−2.39, 16.09]	0.47	0.14	43.95°±14.05	20.65 [11.58, 29.73]	1.46	0.01*	29.75°±13.76	34.85 [25.87, 43.83]	2.48	0.01*
	EG	58.05°±13.56	48.35°±12.56	9.7 [1.33, 18.07]	0.74	0.02*	32.20°±13.05	25.85 [17.33, 34.37]	1.94	0.01*	15.25°±6.47	42.8 [35.99, 49.60]	4.03	0.01*
Scapular Upward Rotation	*CG*	10.48°±6.09	15.70°±4.94	−5.22 [−8.77, −1.67]	0.94	0.01*	24.93°±6.99	−14.45 [−18.65, −10.25]	2.2	0.02*	33.40°±5.05	−22.92 [−26.50, −19.34]	4.1	0.02*
	EG	11.60°±4.99	16.10°±5.69	−4.5 [−7.93, −1.07]	0.84	0.01*	30.30°±7.13	−18.7 [−22.64, −14.76]	3.04	0.02*	37.75°±8.46	−26.15 [−30.59, −21.70]	3.77	0.02*
External Rotation	*CG*	38.5°±10.39	41.2°±10.56	−2.7 [−9.40, 4.00]	0.26	0.42	45.75°±10.22	−7.25 [−13.85, −0.65]	0.7	0.03*	50°±10.98	−11.5 [−18.34, −4.66]	1.08	0.03*
	EG	39.15°±11.95	43.05°±11.59	−3.9 [−11.44, 3.64]	0.33	0.30	49.20°±12.89	−10.05 [−18.01, −2.09]	0.81	0.02*	55.10°±12.05	−15.95 [−23.63, −8.27]	1.33	0.01*
Abduction	*CG*	71.95°±11.44	77.70°±13.16	−5.75 [−13.64, 2.14]	0.47	0.15	87.75°±13.36	−15.8 [−23.76, −7.84]	0.07	0.04*	96.25°±27.28	−24.3 [−37.69, −10.91]	0.08	0.04*
	EG	72.95°±14.96	81.50°±13.68	−8.55 [−17.73, 0.63]	0.6	0.07	98.65°±18.013	−25.7 [−36.29, −15.10]	0.08	0.04*	117°±17.36	−44.05 [−54.42, −33.68]	0.09	0.04*
Flexion	*CG*	76.05°±11.35	79.75°±10.82	−3.7 [−10.79, 3.39]	0.33	0.3	87.35°±13.19	−11.3 [−19.18, −3.42]	0.92	0.02*	98.25°±20.98	−22.2 [−32.99, −11.40]	1.32	0.02*
	EG	77.45°±13.51	84.35°±13.23	−6.9 [−15.46, 1.66]	0.52	0.11	97.25°±17.54	−19.8 [−29.82, −9.78]	1.26	0.02*	115.6°±21.09	−38.15 [−49.49, −26.81]	2.15	0.02*

Data expressed as **X± SD** (mean ±standard deviation); 95% **CI** (confidence interval); **d** (Effect size); **P** (P-value). ***CG***, Control group; ***EG***, Excremental group; ***VAS***, Visual Analogue Scale.
SPADI, Shoulder Pain and Disability Index; **ANOVA**: Analysis of Variance; °: Degrees.
*Statistically significant ($p < 0.05$), Compared with before intervention.

for abduction, and $p = 0.01$ and $p = 0.01$, respectively; CI=[−29.82, −9.78] and CI=[−49.49, −26.81], respectively; d = 1.26 and d = 2.15, respectively for flexion.

Between group comparisons

The between-group comparisons are shown in Table 3 and summarized in charts showing progress over time periods (Figure 2).

Pain (visual analogue scale)

There were no significant differences between the two groups at baseline ($p = 0.28$; CI=[−0.47, 1.57]; d = 0.35); however, there was a significant difference recorded after one session ($p = 0.01$; CI = [0.41, 2.49]; d = 0.9), 6 weeks ($p = 0.02$; CI = [0.27, 2.33]; d = 0.81), and after 12 weeks ($p = 0.01$; CI = [0.55, 2.55]; d = 0.99) favoring the experimental group that had a lower average of pain scores than the control group at each stage (3.20 and 1.15, respectively).

Shoulder pain and disability index

There was no significant between-group difference in SPADI scores at baseline. However, significant differences were achieved as early as after the first session, as well as after 6 and 12 weeks ($p = 0.03$; CI = [0.69, 18.10]; d = 0.69, $p = 0.01$; CI = [3.07, 20.43]; d = 0.87, and $p = 0.01$; CI = [7.62, 21.38]; d = 1.35, respectively). Similarly, to pain scores, these results also favor the experimental group that attained a lower average of disability scores across all three assessment points.

Scapular upward rotation

The only between-group difference in scapular upward rotation was seen after 6 weeks and 12 weeks, favoring the experimental group ($p = 0.02$; CI=[−9.89, −0.85]; d = 0.76, and $p = 0.05$; CI=[−8.81, 0.11]; d = 0.62). There was no significant between-group difference in this measure at baseline, and after the first session ($p = 0.5$; CI=[−4.68, 2.44]; d = 0.2, and $p = 0.81$; CI= [−3.81, 3.01]; d = 0.08, respectively).

Passive shoulder range of motion

For external rotation, there was no significant between-group difference found for any time point with a $p > 0.05$ at baseline, after the first session, after 6 weeks, and after 12 weeks. Abduction and flexion showed similar results. A significant difference emerged after 6 and 12 weeks ($p = 0.04$; CI=[−21.0519, −0.7481]; d = 0.69, and $p = 0.01$; CI=[−35.3871, −6.1129]; d = 0.91, respectively for abduction, and $p = 0.05$; CI=[−19.83, 0.034]; d = 0.64 and $p = 0.01$; CI=[−30.82, −3.8 = 0.82, respectively for flexion) favoring the experimental group that had a higher average of range obtained in each assessment point.

Discussion

Concerning pain and disability, the between-group results showed a significant difference favoring the experimental group receiving the thoracic spine manipulation which resulted in lower averages of pain and disability scores on the VAS and SPADI instruments even after one session. These immediate and sustained reductions in pain and disability could be attributable to the physiological effects of spinal manipulation.

The evidence suggests that spinal manipulation can play a role in increasing pain tolerance and increasing pain thresholds. A potential mechanism for this is that when a patient undergoes a manipulation technique, sub-threshold mechanical and chemical stimuli are removed from the paraspinal tissue, altering the central processing of pain in these individuals. This, coupled with a reflexive stimulation that affects muscle and visceral organs and changes the neural output and excitability could result in immediate and possibly sustained changes in pain levels (Pickar, 2002). More recent evidence supports these mechanisms through similar findings. For example, it was found that spinal manipulative therapy operates on neurological reflex pathways that are segment related causing changes in pain threshold (Nim, Kawchuk, Schiøttz-Christensen, and O'Neill, 2020). Another study found that hypoalgesia as well as improved pain at both local and remote sites of areas are targeted with spinal manipulative therapy (Bond, Kinslow, Yoder, and Liu, 2020). Although this study did not focus on regional interdependence, the latter could provide an explanation as to why the findings were both local and remote. Finally, it has been concluded that a "potential central nervous system mechanism" could be present when the results showed increased pressure pain thresholds at remote sites of application (Coronado et al., 2012).

This would be in accordance with the neurophysiological mechanism proposed for regional interdependence, since when the central processing of pain is altered through interventions used on the thoracic spine the overall pain felt by the patient from the shoulder would decrease.

Another mechanism cited by others is that upon application of mechanical pressure to the spinal segments such as occurs in spinal manipulation, mechanoreceptors in the region are stimulated, which causes a general relaxation that can contribute to lowered pain and a subsequent increase in functional levels (da Silva, Santos, de Godoy Marques, and Marques, 2019; Pickar, 2002). In addition,

Table 3. Between-group comparisons using ANOVA testing at baseline, after one session, after 6 weeks, and after 12 weeks.

		Baseline				After 1st session				6 weeks				12 weeks			
Outcomes	Group	X± SD	95% CI	d	P	X± SD	95% CI	d	P	X± SD	95% CI	d	P	X± SD	95% CI	d	P
VAS	CG	6.95°± 1.54	0.55	0.35	0.28	6.25°±1.52	1.45	0.9	0.01*	4.50°±1.67	1.3	0.81	0.02*	2.70°± 1.95	1.55	0.99	0.01*
	EG	6.40°± 1.64	[−0.47, 1.57]			4.80°±1.71	[0.41, 2.49]			3.20°±1.54	[0.27, 2.33]			1.15°± 1.04	[0.55, 2.55]		
SPADI (%)	CG	64.6°± 14.30	6.55	0.47	0.15	57.75°±14.55	9.4	0.69	0.03*	43.95°±14.05	11.75	0.87	0.01*	29.75°± 13.76	14.5	1.35	0.01*
	EG	58.05°± 13.56	[−2.37, 15.47]			48.35°±12.56	[0.69, 18.10]			32.20°±13.05	[3.07, 20.43]			15.25°± 6.47	[7.62, 21.38]		
Scapular Upward Rotation	CG	10.48°± 6.09	−1.12	0.2	0.5	15.70°± 4.94	−0.4	0.08	0.81	24.93°±6.99	−5.37	0.76	0.02*	33.40°± 5.05	−4.35	0.62	0.05*
	EG	11.60°± 4.99	[−4.68, 2.44]			16.10°±5.69	[−3.81, 3.01]			30.30°±7.13	[−9.89, −0.85]			37.75°± 8.46	[−8.81, 0.11]		
External Rotation	CG	38.5°± 10.39	−0.65	0.06	0.85	41.2°±10.56	−1.85	0.17	0.60	45.75°±10.22	−3.45	0.3	0.35	50°± 10.98	−5.1	0.44	0.17
	EG	39.15°± 11.95	[−7.82, 6.52]			43.05°±11.59	[−8.95, 5.25]			49.20°±12.89	[−10.89, 3.99]			55.10°± 12.05	[−12.5, 2.28]		
Abduction	CG	71.95°± 11.44	−1	0.08	0.81	77.70°±13.16	−3.8	0.28	0.38	87.75°±13.36	−10.9	0.69	0.04*	96.25°± 27.28	−20.75	0.91	0.01*
	EG	72.95°± 14.96	[−9.53, 7.53]			81.50°±13.68	[−12.397, 4.7927]			98.65°±18.013	[−21.05, −0.7481]			117°± 17.36	[−35.3, −6.1]		
Flexion	CG	76.05°± 11.35	−1.4	0.11	0.72	79.75°±10.82	−4.6	0.38	0.23	87.35°±13.19	−9.9	0.64	0.05*	98.25°± 20.98	−17.35	0.82	0.01*
	EG	77.45°± 13.51	[−9.39, 6.59]			84.35°±13.23	[−12.34, 3.14]			97.25°±17.54	[−19.83, 0.034]			115.6°± 21.09	[−30.8, −3.8]		

Abbreviations: X± SD (mean ±standard deviation); *CI,* confidence interval; *P-value*, probability value; *d*, Effect size; *CG*, Control group; *EG*, Excremental group; *VAS*, Visual Analogue Scale; SPADI, Shoulder Pain and Disability Index.; ANOVA: Analysis of Variance; °: Degrees.

*Statistically significant ($p < 0.05$), Compared between-groups.

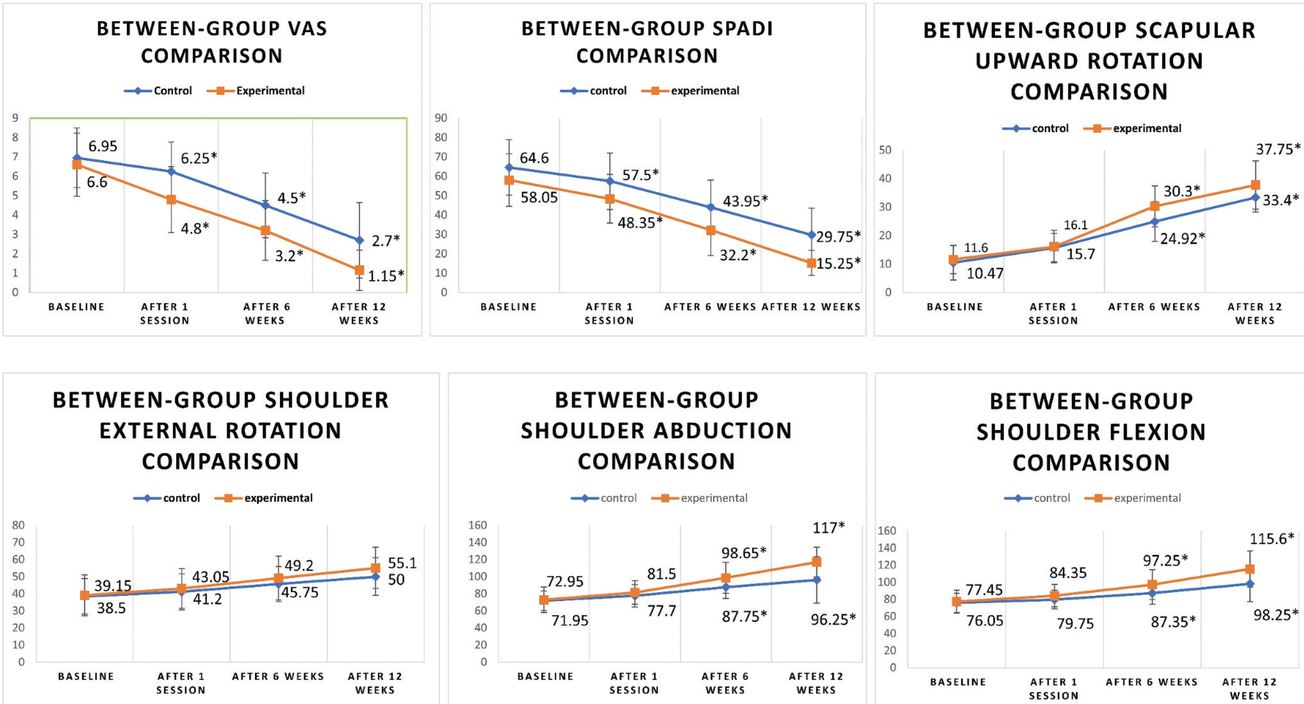

Figure 2. Line charts showing between group comparisons of VAS (visual analogue scale), SPADI (shoulder pain and Disability Index), scapular upward rotation, passive shoulder external rotation, passive abduction, and passive flexion at baseline, after 1 session, after 6 weeks, and after 12 weeks.
*Indicates a significant difference between the values at this time point.

faulty biomechanical properties of thoracic segments have been found to contribute to shoulder and cervical pain (Norlander, Aste-Norlander, Nordgren, and Sahlstedt, 1996), and thus, corrections of these faults would result in decreased levels of pain.

This concept is in accordance with the biomechanical explanation of the "kinetic chain" of regional interdependence. Anatomically speaking, the scapula is near the upper thoracic segment of the spine, and through the scapulothoracic joint is directly connected to it. Studies have shown that correcting kyphotic posture increases the range of motion of the shoulder joint in an acute timeline (Barrett et al., 2016). Thus, when applying biomechanical changes at the thoracic spine through manipulation, the biomechanical kinetic chain connection would extend to the scapulo-thoracic joint, then the scapula, and subsequently yield positive effects on the shoulder.

The literature supports these findings, with several studies highlighting a decrease in pain and disability following spinal manipulation. One systematic review encompassed several studies that included spinal manipulation as an intervention and concluded that studies "consistently reported pain reduction" however some were comparable to sham interventions (Rist et al., 2019). Another study investigated the effects of spinal manipulation on patients with rotator cuff tendinopathy, after which subjects showed decreased pain levels when performing provocative special tests, as well as decreased pain during shoulder flexion of the affected limb and subsequent increases in function (Muth, Barbe, Lauer, and McClure, 2012).

Moreover, a study investigating the effects of thoracic spine manipulation on shoulder pain found decreases in pain and disability levels as well (da Silva, Santos, de Godoy Marques, and Marques, 2019). Concerning AC particularly, evidence suggests similar patterns of decreased pain and disability shown in studies such as others (McCormack, 2012).

Concerning scapular and shoulder passive range of motion, a significant difference was found in scapular upward rotation, as well as shoulder flexion and abduction. These results were also in favor of the experimental group receiving manipulation, as this group scored higher averages of degrees gained across all three assessment points including immediately after the first session, and a sustained improvement across 6 and 12 weeks. However, these results cannot be hastily generalized to the outer population as the inclusion criteria to be met were individuals with limitations of shoulder passive range of motion beyond 90 degrees of elevation (scaption). So to apply valid generalization, the population should be similar to the one included in this study.

A possible mechanism for these improvements might be stimulation of the muscles that affect and aid scapular upward rotation, and in turn permit increased shoulder elevation in the form of flexion or abduction – specifically, the trapezius muscle coupled with the serratus anterior. This is also supported by the literature, where one study showed that the trapezius muscle produced stabilizing function for the scapula and helped with shoulder elevation, whereas the serratus anterior mainly produced scapular upward elevation and external rotation further assisting with shoulder range of motion (Phadke, Camargo, and Ludewig, 2009).

The concept of thoracic spine manipulation increasing force output in these particular muscles is also supported by research. A recent study examining the effects of spinal manipulation on the upper, middle, and lower fibers of the trapezius as well as the serratus anterior, deltoid, and infraspinatus showed that there was increased neuromuscular drive and output during arm ascent, otherwise known as shoulder elevation, following the manipulation techniques. The study also showed specific increases in the serratus anterior, which was suggested to be the cause of the improvement in clinical shoulder outcomes (Hegarty et al., 2021).

These mechanisms are in accordance with the combined explanation of regional interdependence connecting the biomechanical and neurophysiological aspects. The activation of muscles that connect the thoracic spine to the shoulder through their origins and insertions and increasing their activation rate would logically target the shoulder to which they are connected as well and would not be localized only to the area undergoing the intervention. In other words, targeting a primary symptom through an area that is distant but biomechanically linked through neurophysiological and mechanical mechanisms would yield an effect on all areas connected. This in turn is what the recent definition of regional interdependence is.

External rotation of the shoulder increased significantly within the experimental and control groups, but the comparison was not significant between them. This can be attributed to the fact that AC results in fibrosis of the glenohumeral joint capsule, which affects the anterior portion of the capsule resulting in affection and decrease in external rotation ranges of motion (Le, Lee, Nazarian, and Rodriguez, 2017). Although the intervention program received by both groups is effective in handling this, the thoracic spine manipulation's neurophysiological effects do not extend to the joint capsule and thus would not show significant changes such as those seen in shoulder elevation or in pain and disability which were owed to biomechanical and central effects that manipulation can directly alter. It is essential to underscore that the omission of internal rotation assessment represents a notable limitation in the methodology of this study. It introduces a constraint on the comprehensive understanding of the studied phenomenon. Consequently, the generalizability of the study's findings may be constrained, as the population characteristics may not be fully captured without a comprehensive evaluation of internal rotation. Recognizing and addressing this limitation is crucial for interpreting the study results with the appropriate context and caution.

Limitations

One of this study's limitations is that only two thoracic spine manipulation techniques were chosen based on the patient's comfort and position which could prove an obstacle in terms of generalizability. In addition, no assessment of thoracic intervertebral movement was done before conducting the interventions which could affect the results. An additional limitation of this study lies in the omission of an assessment of internal rotation range of motion despite existing evidence, as reported in the study by Rundquist, Anderson, Guanche, and Ludewig (2003) indicating that internal rotation may be more susceptible to limitations than other planes of the shoulder. It is imperative to acknowledge this limitation and recognize the potential influence of internal rotation on shoulder function. Therefore, future investigations are warranted to comprehensively assess internal rotation range of motion. This would contribute to a more comprehensive understanding of the multifaceted impact on shoulder kinematics within the studied population.

Similarly, the inclusion criteria focused on shoulder passive elevation limitation beyond 90 degrees which hinders the study's external validity in terms of generalizing to the AC population. Individuals who could not reach 90 degrees of shoulder abduction to assess external rotation were also not isolated in terms of statistical analysis. Lastly, the method for scapular stabilization during range of motion assessment has not been shown to be valid or reliable and therefore may have influenced the results.

The dearth of research in this topic area signifies the need for further research. Future studies with a similar area of focus must utilize longer follow-up period, with efforts made to better apply generalizability in terms of population recruitment.

Conclusion

The addition of thoracic spine manipulation to conservative treatment programs of AC showed an immediate and sustained improvement in pain and disability. In addition, more sustained effects included significant improvements in shoulder flexion and abduction as well as scapular upward rotation, which would improve the overall clinical outcome of AC patients. This shows that thoracic spine manipulation could be added to AC patients' plan of care to better solidify clinical improvements while relying based on regional interdependence.

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