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Immediate Effects of a Seated versus Supine Upper Thoracic Spine Thrust Manipulation Compared to Sham Manipulation in Individuals with Subacromial Pain Syndrome – A Randomized Clinical Trial

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The Immediate Effects of a Seated versus Supine Upper Thoracic Spine Thrust Manipulation Compared to Sham Manipulation in Individuals with Subacromial Pain Syndrome – A Randomized Controlled Trial

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Approval/Signature Page

We hereby certify that this dissertation, submitted by Jason K. Grimes, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirement for the degree of Doctor of Philosophy in Physical Therapy.

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Abstract

Background: Individuals with Subacromial Pain Syndrome (SPS) often present with a variety of contributing factors. It is possible that a subgroup exists within SPS that has primary impairments of scapular mobility and/or muscle strength. In an attempt to better identify scapular contributions in SPS, the Scapular Assistance Test (SAT) and Scapula Reposition Test (SRT) have been described. Additionally, thoracic spine thrust manipulation has been shown to be effective for shoulder pain. Problem Statement: It is currently unknown whether or not there are impairments in scapulothoracic muscle force generation or scapular mobility in individuals with SPS who have positive results on the SAT and SRT. It also remains unknown whether individuals with SPS respond differently in the immediate effects on scapular motion, scapulothoracic muscle force generation, pain, or function following different manipulation techniques. Methodology: Sixty subjects with shoulder pain were enrolled in the study. Baseline measures were obtained for scapular upward rotation and posterior tilt, scapulothoracic muscle force generation, pectoralis minor muscle length, pain, and function. Participants were randomized to receive a seated thrust manipulation, supine thrust manipulation, or sham manipulation. Measures were reassessed immediately after treatment and the Penn Shoulder Score (PSS) was reassessed at 48 hours. Results: The results indicated no significant differences in scapular upward rotation or posterior tilt, or muscle force generation based on the results of the SAT or SRT. There was a small but significant difference in pectoralis minor muscle length based on the result of the SAT. There were no significant between-group differences in scapular motion, muscle force generation, or pectoralis minor muscle length based on the treatment received. There were no significant differences in 48-hour improvement in pain, function, satisfaction, and total PSS scores. Small but significant within group changes existed on several measures. Discussion: The SAT and SRT may be ineffective in differentiating scapular

movement associated impairments. Thoracic spine thrust manipulation resulted in no greater immediate improvements in scapular motion, strength, pectoralis minor muscle length, pain, or function compared to a sham treatment. The improvements in pain and function are likely not biomechanical in nature and are likely not derived from the manipulative thrust.

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CHAPTER 1: INTRODUCTION

Background

Shoulder pain is a common musculoskeletal problem for which individuals seek medical care, often including physical therapy. The prevalence of shoulder pain in the general population has been reported to be between 7-26%,[1] and as much as 65% of all shoulder pain has been associated with Subacromial Impingement Syndrome (SIS).[2] Typically, the term "shoulder impingement" has been used to describe a number of pathoanatomical conditions including subacromial bursitis, rotator cuff tendinopathy, partial rotator cuff tear, full-thickness rotator cuff tear, long head of biceps tendinopathy, and internal impingement.[3] Although SIS represents the most commonly used shoulder diagnostic label,[3-5] there has been a recent interest in physical therapy in replacing this label.[3,5-9]

There are several reasons behind the suggestion to discontinue the use of "impingement syndrome" as a diagnosis.[4,9] Neer introduced the term "impingement syndrome" in 1972,[10] indicating compression and mechanical abrasion of the rotator cuff and subacromial bursa beneath the anterior portion of the acromion, requiring surgical intervention to increase the subacromial space via an anterior acromioplasty.[4] This proposed mechanism of impingement has been challenged because the presence of a compression mechanism is less common than originally believed and is not likely the predominant etiology of subacromial pain.[3-7,11-13] It appears that impingement is more likely a complex of conditions involving both intrinsic and extrinsic factors and not simply compression of the rotator cuff tendons beneath the acromion.[4] These factors have been said to include alterations in kinematics, weakness or alterations in motor activity, degeneration of tendons or bursae, and capsular tightness or laxity.[13] This consideration supports the concern that SIS has become too broad of a diagnostic label and is thus inconsistently effective in guiding treatment.[3] It also supports the theory that subgroups of patients with impingement likely exist.[4,9] Additionally, it has been reported that uniformity in the clinical criteria used to define the diagnosis of impingement is lacking and a gold standard for diagnosis does not exist.[9]

In recognition of these concerns, the use of "Subacromial Pain Syndrome" (SPS) has been recommended instead.[5,8,13-15] A recently developed classification system promotes the use of SPS as one classification, along with adhesive capsulitis, glenohumeral instability, and 'other' as the remaining categories.[14] In clear appreciation that the main idea behind a diagnostic label is to help guide treatment decisions, this proposed classification system also requires the consideration of tissue irritability and patient-specific impairments in hopes of more effectively doing so.[14] While the label SPS is no more specific than SIS, it is believed to more accurately describe the pathologic condition, support the existence of subgroups within the larger diagnostic category, and foster improved treatment outcomes.[14,15] As a result, SPS will be used for the purposes of this paper.

Patients with SPS often present with a variety of impairments and contributing factors which lead to their limitations in pain-free function. The scapula is believed to play an important role in upper extremity function[16-19] by providing both the necessary stability and mobility to allow the arm to move into a variety of positions and produce complex functional movement. Accordingly, impairments of scapular stability or mobility may be attributed to pain and upper extremity dysfunction.[11,17,20-25] It is therefore necessary for clinicians to have the means to accurately evaluate and determine the relevance of the scapulothoracic region in patients with shoulder pain.

In an attempt to better identify scapular contributions to the presentation of pain in patients with SPS, two symptom modification tests for the scapula have been reported in the literature: the Scapular Assistance Test (SAT)[19,26-28] and the Scapula Reposition Test (SRT).[25,29] These tests require the examiner to assess the magnitude of the patient's symptoms during a provocative clinical test with the scapula in its natural position first. The painful procedure is then repeated while the examiner manually alters scapular position or motion.[25] The SRT[25,29] focuses on correcting scapular position with an emphasis on posterior tilt and external rotation of the scapula, while the SAT (or modified SAT)[19,26-28] focuses on correcting or facilitating scapular motion during dynamic arm elevation. The theory behind these tests is that success in reducing the patient's pain or difficulty during the test may be an indication to include interventions aimed at improving scapular position, motion, or muscle function.[27] Therefore, the outcome of the test may help to direct treatment choices.

This chapter will provide further information behind the current problem and significance of pursuing this study to investigate the results of the SAT and SRT and assess for the presence of impairments in scapular mobility and strength in patients with SPS. This study also utilized thoracic spine thrust manipulation, a treatment approach that has been shown to be beneficial in patients with SPS,[30-36] to examine the immediate effects of two different manipulation techniques on scapular mobility, scapulothoracic muscle strength, and pain in this population.

Statement of the Problem

While many techniques for clinical examination of the scapula have been previously described in the literature,[16,18,25-27,37-41] widespread agreement and acceptance has yet to occur due to a number of issues associated with these methods. Tests that can easily be integrated into clinical practice need to be affordable, easy to perform, reliable, valid, and responsive to change.[23] Asymmetries in scapular position[42,43] and motion[44] within normal subjects, complex kinematics involving small magnitudes of motion, and variability within these motions in normal subjects[45] are just a few of the issues commonly encountered. Assessing motions that are small in magnitude with large degrees of variability can be difficult, frustrating, and often considered irrelevant or unnecessary in clinical practice. In the laboratory setting, expensive and specialized equipment is used to capture this information, making it largely inapplicable to the clinical environment.[23] The difficulties experienced in determining normal from abnormal scapular motion have led to persistent challenges and inadequacies in assessing the true impact of the scapula in the development or perpetuation of shoulder pain and dysfunction. To compound these issues, the prevalence of abnormal scapular movement or control in asymptomatic shoulders is no different than in individuals with shoulder pain.[29,46-49] Thus the relevance of abnormal motion in the treatment or prevention of shoulder injury has been challenged.[50,51]

In response to these issues, authors[19,25,52-54] have described and recommended the utilization of symptom modification tests over static or dynamic motion assessments in examining for scapular involvement in shoulder dysfunction. The ability of the test to immediately alter the patient's symptoms through a change in position or facilitation of motion is the indication that the scapula is likely a contributing factor.[53] This eliminates the need for making the challenging and controversial determination of normal versus abnormal scapular motion using visual assessment.

However, little has been reported on the clinical utilization of the SAT and SRT in examining patients with SPS. It may be helpful to know if impairments in scapular mobility, dynamic control, or scapulothoracic muscle strength are present more commonly in individuals with positive tests. Additionally, based on the theory of regional interdependence[55] and previous literature reporting effects from thoracic manipulation in individuals with shoulder pain,[30-36] it would be helpful to know if any of these scapular impairments change following manipulation to the thoracic spine. Previous literature that has investigated scapular kinematics following thoracic manipulation has been limited to humeral elevation to 120 degrees[32,33,36] and may be missing valuable information. Changes in scapulothoracic muscle strength have been identified in asymptomatic subjects with manual therapy to the thoracic spine, including mobilization[56] and manipulation.[57] However, only one study examining the effects of thoracic manipulation in patients with shoulder pain included any assessment of scapulothoracic muscles, and that evaluated muscle activation using surface EMG.[33] Those results indicated a small but significant increase in middle trapezius activity.[33] Specifically, the effects of thoracic spine thrust manipulation in patients with SPS and the relationship to positive and negative results on the SAT and SRT has not been investigated previously.

This study enhances our understanding of the role of the scapula as a contributor to the production of shoulder pain in patients with SPS by providing impairment-based information from the scapulothoracic joint and examining for relationships with the outcomes on the SAT and SRT. Handheld dynamometry was used to assess strength of the middle trapezius, lower trapezius, and serratus anterior (all muscles believed to play significant roles in providing scapular stabilization and movement).[54,58] Scapular upward rotation and scapular posterior tilt motion with active and passive maximal humeral elevation was measured as change values from the resting position of the scapula with the arm at the side of the body. These results help to provide a better understanding of the possible clinical utility of the SAT and SRT. This information can then be considered as clinicians begin to develop possible subgroupings within SPS that can effectively guide treatment decisions.

Finally, the effects of two different thoracic manipulation techniques commonly used for the treatment of shoulder pain (seated cervicothoracic distraction manipulation and supine upper thoracic manipulation) were assessed and compared to a sham technique in this population to determine if one technique results in greater immediate improvements than the other. While thoracic spine thrust manipulation has been shown to be effective in the management of shoulder pain, previous studies have either performed multiple manipulative techniques on each subject or compared a single technique to sham. While there is a possibility that choice of thoracic spine manipulation technique is irrelevant, it is unknown whether one technique would prove to be more effective than another technique when used in isolation and directly compared.
Changes in pain, function, scapular upward rotation and posterior tilt active and passive ROM, scapulothoracic muscle strength, and pectoralis minor muscle length were examined.

Problem Statement: It is currently unknown whether impairments in scapulothoracic muscle strength or scapular mobility are greater in individuals with SPS who have positive results on the Scapula Reposition Test (SRT) or Scapular Assistance Test (SAT). Additionally, while it has been shown that individuals with SPS benefit from thoracic manipulation, it remains unknown whether these individuals respond differently in the immediate effects on scapular motion, scapulothoracic muscle strength, or pain following a seated upper thoracic manipulation, a supine upper thoracic manipulation, or a sham manipulation.

Goals: The first goal of this research was to determine whether the SRT or SAT differentiates impairments in strength of the middle trapezius, lower trapezius, and serratus anterior muscles and impairments in scapular upward rotation and posterior tilt motion in patients with SPS. A second goal was to determine the immediate effects of specific thoracic spine thrust manipulation techniques on pain, self-reported function, impairments in force generation of the middle trapezius, lower trapezius, and serratus anterior muscles, impairments in scapular upward rotation and posterior tilt motion with maximal arm elevation, or impairments in pectoralis minor muscle length in patients with SPS.

Relevance and Significance of the Study

Shoulder pain is a common musculoskeletal disorder encountered by Physical Therapists (PTs) and as much as 65% of all shoulder pain has been associated with SPS.[2] Clinicians commonly encounter patients with SPS that exhibit a variety of impairments in glenohumeral ROM and strength as well as scapulothoracic ROM and strength. One of the greatest difficulties in effectively managing these patients may be determining which patients may benefit from targeted treatment to the scapulothoracic joint to aid in resolving the shoulder pain, loss of function and disability. Providing an assessment method or strategy for examination that can facilitate a better understanding of the scapular contribution may improve physical therapy outcomes for these patients.

It has long been understood that the scapula plays an important role in upper extremity function.[16-19] As the link connecting the arm to the trunk, the scapula provides significant contributions to shoulder range of motion, strength, control, and overall function. Acknowledgement of these roles has led to an understanding that shoulder pain and disability may be associated with deficiencies in scapular stability or mobility. Because of this likelihood, it is important that we have valid and reliable methods of assessing the scapula in these roles. Although a number of techniques for clinical examination of scapular posture and motion have been reported,[11,17,18,21,22,59] they have been met with skepticism and clinicians have been largely reluctant to incorporate them into clinical practice due to unacceptable levels of reliability, validity, lack of responsiveness, or degree of difficulty to perform.[23] As a result, the search continues for a reliable, valid, and efficient means of assessing the contributions from the scapulothoracic joint that are most meaningful to consider in patients with SPS.

As McClure et al stated, "[a] method that can reliably identify people with scapular motion abnormalities and that is suitable for routine clinical use would be of great value...".[11(p1086)] While the clinical examination of scapular position and motion has appeared to offer minimal value due to naturally occurring variability and small magnitudes of differences in movement between normal and abnormal groups, the symptom modification tests appear promising in determining the role of the scapula in the presence of shoulder pain.[19,25,52-54] Therefore, further investigation into the SRT and SAT in patients with SPS may provide information that defines a distinct subgroup of patients with SPS that may benefit from unique treatment. Identifying whether or not impairments in scapular motion or strength are present in patients with positive results on these tests will help provide additional insight behind the mechanism of the tests and may help guide future treatment decisions.

One treatment that has shown benefits in patients with SPS is thoracic spine thrust manipulation.[30-36] While there are a variety of distinct manipulation techniques available for the thoracic spine, the prone posterior-to-anterior,[34,36] supine anterior-to-posterior,[34] and seated distraction[31-33] thrusts are commonly used in clinical practice. This study will utilize the supine and seated thrust manipulations for several reasons. Previous work has reported an increase in strength of the lower trapezius in asymptomatic subjects through use of the supine technique.[57] Knowing if the same results can be obtained in patients with SPS would be informative. Additionally, laboratory studies that used motion sensors to assess scapular kinematics before and after manipulation are often unable to utilize the supine technique due to concerns regarding movement of the sensors. The literature that has reported no significant change in scapular kinematics after thoracic manipulation has yet to include a supine technique.[32,33,36] The influence of thoracic spine thrust manipulation on muscle strength and scapular kinematics will be examined in this study on symptomatic individuals. Therefore, using the supine technique over the prone technique for this study will provide new information and a greater contribution to the literature. Additionally, support for the prone technique has been primarily biomechanical in theory in that it may help to improve thoracic extension mobility. While limitations in thoracic mobility have been linked to shoulder pain[60-62] and altered scapular kinematics,[63] thoracic manipulation has not been shown to have a significant effect on thoracic mobility.[33,36,64] Although this has been reported with the use of techniques in the seated, prone, and supine positions, the conclusions nonetheless question the theoretical support behind the prone technique.

While the seated technique has been used in previous studies,[31-33] the results for scapular kinematic information are inconclusive at this time. One study reported a slight increase in scapular upward rotation[32] while another reported a slight decrease in upward rotation,[33] although both findings were deemed not clinically meaningful. A third study did not examine scapular kinematics.[31] If scapular motion is a contributing problem, the seated technique may potentially offer a stretch to the soft tissues surrounding the scapulothoracic joint or pectoralis minor muscle which may yield a change in scapular mobility or provide other mechanical effects. For this reason, it is believed that the seated technique may produce greater improvements in scapular motion, pectoralis minor muscle length, or scapulothoracic muscle strength when compared to the supine technique.

Limitations of prior studies will be addressed by this study in the area of scapular examination with the use of the SRT and SAT, as well as the selection and possible effects of thoracic spine thrust manipulation for SPS. This knowledge may lead to future research examining the clinical utility of the SRT and SAT in identifying a possible subgroup of patients with SPS, a diagnostic approach that has been suggested in recent systematic reviews and clinical guidelines.[14,65] Future investigations may also be prompted to compare the outcomes of thoracic spine manipulation versus other common treatments, including therapeutic exercise for shoulder motion or strength, motor control training, or other forms of manual therapy, based on the results of the SRT and SAT.

Theories to be investigated

Symptom Modification Tests for Shoulder Pain

A review of the literature demonstrates some inconsistency in findings regarding scapular motion in individuals with normal shoulder function and those with shoulder dysfunction. Multiple sources have reported the importance of scapular upward rotation during upper extremity elevation in healthy individuals.[17,59,66,67] Although the kinematic research has provided conflicting findings in those with SPS,[65] results tend to indicate that decreased scapular upward rotation[17,21,67,68] and decreased scapular posterior tilt[17,21,22] are commonly seen. In theory, insufficient scapular upward rotation or insufficient scapular posterior tilt may lead to a reduction in the subacromial space.[21,27] Alternatively, excessive upward rotation or posterior tilt has been theorized to be a pain-relieving compensation in patients with SPS.[11,69] Scapular dyskinesis[19,38,46,53] may also be found in patients with SPS. It is therefore likely that in a certain subgroup of individuals with shoulder pain, the primary impairments are related to scapular mobility and/or scapulothoracic muscle strength.

In line with the literature supporting the presence of pathologic scapular kinematics and scapular dyskinesis in individuals with SPS, the symptom modification tests attempt to identify when scapular movement dysfunctions may be providing a significant contribution to the current shoulder dysfunction. Both the SRT and SAT incorporate various degrees of upward rotation and posterior tilt to the involved scapula. In this manner, both tests address the frequently discussed clinical concerns of insufficient scapular upward rotation and insufficient posterior tilt. While both tests provide stability to the scapula, they have significant differences in their primary intentions. The SRT intends to provide a corrected scapular position most commonly during resisted static arm elevation at 90 degrees. The SAT intends to facilitate normal dynamic scapular motion (upward rotation and posterior tilt) during full humeral elevation. Both tests have been reported to have positive findings in individuals with shoulder pathology nearly 50% of the time.[25,26]

Thoracic Spine Manipulation for Shoulder Pain

If impairments in scapular motion or scapulothoracic muscle strength can accurately be identified through use of the SAT and SRT as described, then it would appear that treating those impairments at the scapulothoracic articulation would be the main objective of effective physical therapy treatment for these patients. This concept of examining and treating impairments in a remote anatomical region (i.e., thoracic spine for a patient with shoulder pain) has been termed "regional interdependence".[55,70] The regional interdependence model suggests that many musculoskeletal disorders may respond more favorably to a regional examination and treatment approach.[34] And as the regional interdependence model implies, evidence has shown that interventions focused on the thoracic spine have the potential to alter shoulder symptoms,[30-36,71] with nearly all of these studies utilizing some form of thoracic spine thrust manipulation.[30-36] Previous studies have either utilized multiple manipulative techniques[30,31,34] or only seated techniques.[32,33] However, comparing the effectiveness of a seated vs. supine technique in this patient population has not been examined.

While thoracic thrust manipulation has been shown to reduce shoulder pain,[31-34,36] increase shoulder ROM,[34] and lead to improvements in shoulder function[31,33,36] the exact mechanisms by which it creates these effects remains unclear and largely theoretical at this time. Multiple explanations have been reported, including biomechanical,[31,34] neurophysiological,[33,34] and hypoalgesic.[34] Interaction with a health care professional, passage of time, placebo effects, or the positive effects that could be associated with manual contact have also been suggested.[36]

Biomechanical effects in the scapulothoracic region have been questioned, as multiple studies have shown no significant changes in scapular kinematics following a variety of thoracic manipulation techniques in both symptomatic[32,33,36] and asymptomatic individuals.[72] However, assessment of scapular kinematics was only measured up to 120 degrees of humeral elevation in these studies[32,33,36] and may not be capturing important findings beyond that range. Only one study[33] examined changes in the scapulothoracic muscle activity using surface EMG following manipulation. And finally, the results from the study performed on asymptomatic subjects cannot be generalized to patients with shoulder pain.[72] On the contrary, immediate improvements in shoulder ROM have been reported in one study where the investigator utilized a pragmatic design which allowed for patient-specific interventions; however, scapular kinematics were not examined.[34] Neurophysiological effects have been suggested as a likely mechanism and emerging evidence suggests these effects play an important role.[73]

Potentially, thoracic manipulation techniques that offer a stretch to the soft tissues of the scapulothoracic joint in a seated position may provide other mechanical effects and could be one reason why thoracic manipulation is effective in only some patients with shoulder pain. Therefore, examining changes in pain, scapular motion, and scapulothoracic muscle strength between two different and commonly utilized thrust manipulation techniques may provide additional insight on potential mechanisms. Accordingly, it would be of interest to know if those patients who present with signs and symptoms of SPS demonstrate impairments in active or passive scapular motion, particularly upward rotation and posterior tilt, or scapulothoracic muscle strength. It would also be interesting to know if thoracic spine manipulation can influence those factors, particularly if the seated technique is found to be more effective than the supine technique based on this theory. This information may help us gain a better understanding of the possible mechanisms behind how thrust manipulation in the thoracic region may be effective for subgroups of patients with SPS.

Research Questions:

Research Aim 1:
Questions

1. Are there differences in scapular upward rotation and/or posterior tilt motion during maximal arm elevation in individuals with SPS who test positive vs. negative on the SAT?
2. Are there differences in force generated with manual muscle test positions for the middle trapezius, lower trapezius, and/or serratus anterior muscles in individuals with SPS who test positive vs. negative on the SAT?
3. Are there differences in length of the pectoralis minor muscle in individuals with SPS who test positive vs. negative on the SAT?

4. Are there differences in scapular upward rotation and/or posterior tilt motion during maximal arm elevation in individuals with SPS who test positive vs. negative on the SRT?
5. Are there differences in force generated with manual muscle test positions for the middle trapezius, lower trapezius, and/or serratus anterior muscles in individuals with SPS who test positive vs. negative on the SRT?
6. Are there differences in length of the pectoralis minor muscle in individuals with SPS who test positive vs. negative on the SRT?

Research Aim 2:
Questions

1. Do individuals with SPS experience greater improvements in scapular motion with a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?
2. Do individuals with SPS experience greater improvements in scapulothoracic muscle force generation with a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?
3. Does length of the pectoralis minor muscle, as indicated by a measure of muscle length, change following a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?
4. Do individuals with SPS experience greater improvements in pain and function with a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?

Research Hypotheses:

1. Individuals with positive findings on the SAT will be more likely to demonstrate motion deficits in scapular upward rotation than those with negative findings on the SAT.
2. Individuals with positive findings on the SAT or SRT will be more likely to demonstrate motion deficits in scapular posterior tilt than those with negative findings on the SAT or SRT.
3. Individuals with positive findings on the SAT or SRT will be more likely to demonstrate deficits in pectoralis minor muscle length than those with negative findings on the SAT or SRT.
4. Individuals with positive findings on the SRT or SAT will be more likely to demonstrate deficits in force generation in the MMT positions for the middle trapezius, lower trapezius, and/or serratus anterior muscle(s) when compared to patients with negative findings on the SRT or SAT.
5. Individuals with SPS will experience greater improvements in pain, function, scapulothoracic muscle force generation, scapular motion and/or pectoralis minor muscle length following the seated thrust manipulation technique.

Definitions of Terms:

Subacromial Pain Syndrome (SPS) or Subacromial Impingement Syndrome (SIS): pain in the shoulder and/or lateral brachial region which may include pathoanatomic labels such as subacromial impingement, bicipital tendinopathy, rotator cuff tendinopathy and tears, subacromial bursitis, secondary instability, and SLAP lesions[14]

Scapular Assistance Test (SAT): the examiner manually assists the scapula into upward rotation and posterior tilt by pushing superiorly and laterally on the inferior angle and pulling posteriorly on the superior aspect of the scapula as the patient elevates the arm. The test is documented as positive or negative, with a positive test resulting in a decrease in pain of 2 or more points on the verbal numeric rating scale (VNRS) during the SAT compared to active elevation of the arm without the application of the SAT.[26]

Scapula Reposition Test (SRT): the examiner imparts a force to the scapula to encourage posterior tilting and external rotation by grasping the scapula with the fingers contacting the acromioclavicular joint anteriorly and thenar eminence contacting the scapular spine posteriorly, with the forearm placed obliquely across the posterior aspect of the scapula toward the inferior angle. This maneuver is applied during the performance of a clinical test that was previously determined to be painful for the subject, most commonly arm elevation or resisted scaption. The test is documented as positive or negative, with a positive test resulting in a decrease in pain of 2 or more points on the verbal numeric rating scale (VNRS) during the application of the SRT.[25]

Scapular upward rotation: movement of the scapula on the thorax such that the inferior angle of the scapula moves away from the spine and the glenoid fossa turns superiorly

Scapular posterior tilt: movement of the scapula on the thorax such that the superior aspect of the scapula moves posteriorly and the inferior angle moves anteriorly toward the thorax

Thrust manipulation: a passive, high-velocity, low-amplitude mobilization technique applied to a joint complex within its anatomical limit with the intent to restore optimal motion, function, and/or to reduce pain (from the International Federation of Orthopaedic Manipulative Physical Therapists; IFOMPT)

Summary

Given an understanding of the challenges often confronted by clinicians in examining the scapula for contributions to shoulder dysfunction, there are a number of reasons to pursue this research. First of all, gaining an understanding of the presence or absence of strength and motion impairments at the scapula for individuals testing positive or negative on the SRT and SAT may provide evidence to support the utility of these tests. If significant between-group differences do exist in these measures, this information may be used to help guide treatment decisions for patients with SPS. This knowledge may also help to serve as a first step towards defining a subgroup or classification within SPS.

While the literature has revealed benefits from thoracic manipulation for some patients with shoulder pain,[30-34] investigating the comparative effectiveness of a seated vs. supine technique will provide new information for this population. Published studies have either utilized multiple manipulative techniques[30,31,34] or seated techniques only,[32,33] yet we are unaware of anything that has previously compared the immediate effects of a seated technique or supine technique against a sham manipulation for patients with SPS. There is a possibility that the techniques may have different effects on scapular mobility or scapulothoracic muscle strength. One technique may demonstrate to be more effective than the other for individuals with SPS, or one technique may work better for some individuals while the other technique works better for the rest. This information may help us gain a better understanding of the effectiveness of thoracic spine thrust manipulation in this patient population and may help guide treatment decisions for the physical therapy management of SPS.

Chapter 2: Review of the Literature

Introduction

The scapula plays an important role in upper extremity function, providing a necessary balance of stability and mobility to enable normal pain-free functional use. As the link connecting the arm to the trunk, the scapula provides significant contributions to shoulder range of motion (ROM), strength, control, and overall function. Acknowledgement of these roles has led to an understanding that shoulder pain and disability may be associated with deficiencies in scapular stability or mobility.[11,17,20-25] Because of this likelihood, it is important that we have valid and reliable methods of assessing the scapula in these capacities. It would also be important to know if thoracic spine thrust manipulation can result in any immediate changes in scapular mobility or scapulothoracic muscle strength in patients with SPS as it has previously been shown to be effective in reducing shoulder pain and improving function.[31-34,36] The theory of regional interdependence[55,70] is commonly provided as an explanation as to how treatment delivered to the thorax may be helpful in treating shoulder pain.

This chapter will critically appraise the current literature regarding examination of the scapula in an attempt to determine its contribution to the development or perpetuation of shoulder pain and dysfunction. In particular, the assessment of scapular motion and scapulothoracic muscle strength will be discussed. Additionally, an assessment of the literature currently available regarding the use of thoracic spine manipulation for the treatment of shoulder pain will be presented.

Historical Overview

Numerous studies have examined scapular position and motion in healthy individuals as well as various patient populations including those with SPS and frozen shoulder.[11,17,20-22] A number of techniques for clinical examination of scapular posture and motion have been reported.[11,16-18,21,22,37-41,59,74] These techniques have been challenged by commonly encountered side-to-side asymmetries[42-44] and complex kinematics that involve small magnitudes of motion yet present with a large degree of variability across even healthy individuals.[45]

Previous and current methods have included static assessment of the scapula with the arm at rest as well as dynamic assessment of the scapula with elevation of the arm in various planes of movement. The literature surrounding dynamic assessment has largely utilized 3D kinematic motion analysis in laboratory settings with fewer investigations using examination methods commonly available in clinical practice. This section will focus on clinical examination methods for the scapula after summarizing our understanding of normal and abnormal scapular motion, including scapulohumeral rhythm and the knowledge gained from kinematic motion analysis studies.

Scapulohumeral Rhythm

Inman, Saunders, and Abbott[75] were the first to describe scapulohumeral rhythm as what has become the classic understanding of the motion contribution from the scapula during arm elevation. They expressed a 2:1 ratio of glenohumeral elevation to scapular upward rotation. This description led to the understanding that the total 180 degree arc of motion during upper extremity elevation is the result of 120 degrees of elevation at the glenohumeral joint and 60 degrees of upward rotation from the scapula. This 2:1 ratio has commonly been reported, although more recent research has indicated a lesser contribution from the scapula and a ratio more likely between 2.9:1 and 4.4:1, depending on the plane of elevation.[76] These ratios would lead to an expectation of between 33 and 46 degrees of scapular upward rotation, which is considerably less than the original description of 60 degrees. This creates a fundamental question of what the normal range of scapular upward rotation truly is. Despite conflicting evidence regarding the ratio of motion occurring at the glenohumeral joint and scapulothoracic joint, it is understood that the motion contribution from the scapula is critical for normal pain-free UE function.

Appreciating the importance and complexity of the contributions from the scapula, McClure and colleagues defined normal scapulohumeral rhythm in greater detail as follows: "The scapula is stable with minimal motion during the initial 30° to 60° of humerothoracic elevation, then smoothly and continuously rotates upward during elevation and smoothly and continuously rotates downward during humeral lowering. No evidence of winging is present.".[38(p162)] While a definitive ratio of glenohumeral to scapular motion is not included in this description, the statement provides a better description of how the coordinated motion between these regions should occur.

While the concept of scapulohumeral rhythm captures the motion of scapular upward rotation, it does not reflect other motions of the scapula that are occurring in other planes. A closer look at scapular kinematics indicates that the scapula moves through small, but important, amounts of motion in the sagittal and transverse planes as the arm is moved through space.

3-D Scapular Kinematic Motion Analysis

In 1996, Ludewig et al[59] reported on the three-dimensional scapular orientation with elevation of the arm. In a sample of asymptomatic individuals, they discovered a pattern of "progressive upward rotation, decreased internal rotation, and movement from an anteriorly to a posteriorly tipped position as humeral elevation angle increased."[59(p64)] This combination of scapular upward rotation, posterior tilting, and external rotation with humeral elevation in unimpaired shoulders has been reported by multiple sources.[17,22,51,58,59,66,77] Ludewig & Reynolds[17] confirm that upward rotation is the predominant motion at the scapula during elevation of the arm while internal rotation of the scapula appears quite variable across individuals. Given this information, a recommendation is made for careful assessment of scapular anterior tipping (or tilting) and internal rotation, in addition to the more commonly recognized importance of upward rotation.

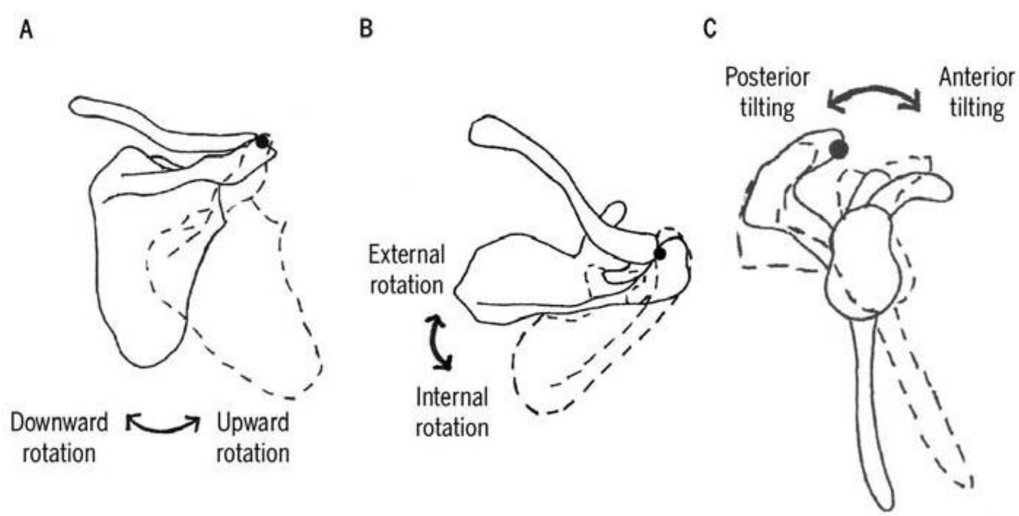


Figure 2-1: Scapular motions (From Ludewig & Reynolds, 2009[17])

Despite the clear pattern of scapular motions with humeral elevation, Ludewig et al[59] reported that variability was evident within both kinematic and EMG measures. This supports what has been discussed earlier in this chapter from previous research describing the clinical assessment of scapular position and motion.[42-44,46,76,78] Naturally occurring variability is common among healthy subjects and makes it difficult to determine normal from abnormal motion. This must be taken into account if one expects to consider scapular kinematics in the diagnosis and/or treatment of shoulder dysfunction. Attempting to identify abnormal in the absence of an accepted norm has been described as a "fundamental flaw" by Willmore and Smith[79] and requires further investigation.

Significance of Scapular Upward Rotation and Posterior Tilt in SPS

With an appreciation for natural variability amongst individuals, the literature has presented a pattern of what is believed to represent normal scapular kinematics. With consideration of this, the literature to date has also attempted to present an understanding of scapular kinematics in the presence of shoulder dysfunction. In a study published in 2000, Ludewig and Cook[21] reported decreased scapular upward rotation, increased anterior tilting, and increased internal rotation through various portions of scapular plane humeral elevation in patients with shoulder impingement. Other studies have reported similar findings. Lawrence et al[68] reported a significant reduction in upward rotation at lower angles of humeral elevation (30° and 60°) and reduced posterior rotation from the SC joint throughout humeral elevation. Ohl et al[80] also described a significant reduction in upward rotation during arm elevation for individuals with impingement.

Ludewig and Cook[21] concluded that posterior tilt of the scapula may be more critical than upward rotation for clearance of the rotator cuff tendons in the subacromial space by elevating the anterior aspect of the acromion.[21] Lukasiewicz et al[22] reported discovering significantly less posterior tilt of the scapula in subjects with shoulder impingement during scapular plane elevation. They also demonstrated a greater degree of scapular elevation in the shoulder impingement group. These investigators did not discover a reduction in scapular upward rotation, as reported by Ludewig and Cook.[21] The findings from Lukasiewicz et al[22] need to be interpreted cautiously as the subjects in the impingement group were an average of 11.5 years older than the healthy group and age has been reported to effect scapular kinematics. Hebert and colleagues[20] also presented evidence supporting the importance of posterior tilt of the scapula. While they found no significant differences in scapular motions between symptomatic and asymptomatic shoulders in subjects with unilateral shoulder impingement, asymmetry was noted with sagittal plane tipping between the symptomatic and contralateral shoulder. They also discovered that both scapulae of the subjects with unilateral shoulder impingement demonstrated a similar behavior which was different from that of healthy subjects. The serratus anterior is believed to have the best ability to produce posterior tilt of the scapula[21,54] and may be a key factor to consider. This information indicates that a method to accurately assess posterior tilt motion in the clinical environment can be of major importance in terms of preventing, reducing or eliminating shoulder impingement.

Ludewig and Reynolds[17] state that the evidence supporting alterations in scapular kinematics is substantial, with 9 of 11 cited studies identifying a significant group difference in at least one scapular kinematic variable (upward/downward rotation, posterior/anterior tipping, or external/internal rotation) in subjects with impingement or rotator cuff dysfunction. Despite some discrepancies in the reported findings, 4 of 9 studies found decreased upward rotation and 4 of 7 found decreased posterior tilt.[17]

Evidence does exist that conflicts with the substantial body of literature demonstrating reductions in scapular upward rotation, posterior tilting, and external rotation in individuals with shoulder impingement. In 2006, McClure et al[11] investigated scapular kinematics in people with and without impingement. Both groups demonstrated the frequently reported pattern of scapular posterior tilt, upward rotation, and external rotation with increasing humeral elevation. However, subjects with impingement actually demonstrated a slightly greater amount of scapular upward rotation with shoulder flexion and slightly greater posterior tilt with humeral elevation in the scapular plane compared with the control group. The authors proposed a number of possible explanations for these discrepancies from previously published work, one of which was a consideration that scapular motion in individuals with impingement may be highly variable due to both patient and measurement factors. A study by Rundquist[69] examining scapular motions in subjects with idiopathic loss of shoulder ROM also revealed a greater degree of upward rotation on the involved side. However, this finding is not surprising when considering the likelihood of a compensatory strategy from the scapulothoracic joint for motion loss at the glenohumeral joint.

A recent systematic review by Ratcliffe et al[65] concluded that there is insufficient evidence to support that the scapula adopts a common and consistent posture in individuals with SPS. Further, the authors state that any observed deviations may not be contributory to SPS but rather normal variations. They also conclude that rehabilitation aimed at restoring the scapula to an idealized normal posture is not supported by the literature. These arguments tend to indicate the need for a change when it comes to evaluating the scapula in patients with SPS, and the utilization of the symptom modification tests may provide a better alternative.

Clinical Examination Methods: Assessment of Scapular Position

The emphasis for assessment of the scapula at rest and in various static positions has been to provide efficient, practical, and reliable means of describing or quantifying scapular position or motion. Clinicians often start by examining the position of the scapula on the thorax with the arm at rest, however remain limited with techniques to measure or accurately detect faulty postural alignment that may contribute to dysfunction. In 1990, DiVeta et al[37] discussed using a piece of string as a means to measure the distance from the third thoracic vertebrae to the inferior aspect of the acromion process of the scapula while the arm is at rest along the side of the body. Similarly, Kibler's[16] Lateral Scapular Slide Test involved the use of a tape measure to assess the distance between the inferior angle of the scapula and the spinous process of the nearest thoracic vertebrae in three different positions of humeral elevation.

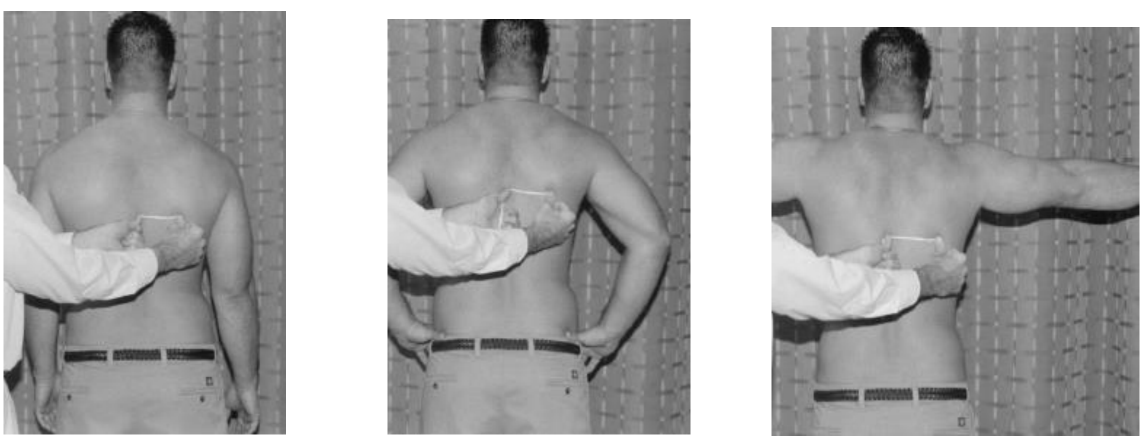


Figure 2-2: Kibler's Lateral Scapular Slide Test (From Odom et al, 2001[81])

Although both techniques demonstrated good reliability with ICCs generally > 0.80,[16,37] they present a number of limitations and concerns with validity. Gibson and colleagues[78] discovered consistently larger means for the measures obtained on the dominant side compared to the nondominant side for both of these measures in their sample of healthy, non-athletic subjects. Additionally, both techniques rely on accurate bony palpation by the examiner, are limited to the static position being measured, and only assess the scapula in a single plane. Furthermore, the Lateral Scapular Slide Test relies on a linear measurement of distance to indicate the amount of angular displacement of the scapula.

A systematic review by Larsen et al[82] in 2014 concluded that assessments of scapular positioning or posture demonstrate acceptable levels of intra- and inter-rater reliability, whereas semi-dynamic positioning assessments like the Lateral Scapular Slide Test demonstrate acceptable levels of intra-rater reliability but varied and less reliable results for inter-rater reliability.

More recently, an additional linear measure using a protractor has been described to measure the vertical position of the scapula on the thorax.[83] This method involves measuring the vertical distance between the C7 spinous process and the superior margin of the medial aspect of the scapular spine and the T8 spinous process and inferior angle of the scapula.[83] The results indicated good reliability and acceptable validity. This method, similar to those described by DiVeta et al[37] and Kibler,[16] still relies on accurate bony palpation by the examiner, is limited to the static position being measured, and only assesses the scapula in a single plane. Future research is needed to assess the validity of this method with movement or in different positions or planes.

Despite finding good reliability for the three scapular position tests they investigated (Lateral Scapular Slide Test, distance between the posterior border of the acromion and the table, and distance from the medial scapular border and the fourth thoracic spinous process), Nijs and colleagues[24] were unable to differentiate between symptomatic and asymptomatic sides when using those tests in subjects with unilateral shoulder pain. Based on the lack of correlation with self-reported function, Nijs et al[24] questioned the clinical importance of these scapular measures. Similar findings were also reported by Hebert et al[20] in subjects with unilateral shoulder impingement. The authors commented on the inherent inaccuracies and limitations associated with assessing three-dimensional scapular motion in a linear fashion. This should also be a concern for clinical practice.

Although scapular position has been linked to shoulder impingement and rotator cuff dysfunction and scapular asymmetry can be expected between symptomatic and asymptomatic shoulders,[83] postural asymmetry has also been commonly reported in pain free subjects.[43,79,84] Further, conflicting evidence exists that reports no significant differences in scapular orientation with the arm at rest when comparing individuals with rotator cuff tear or impingement to healthy controls.[80] Oyama et al[43] also reported side-to-side differences in scapular position at rest in a sample of healthy overhead athletes (including baseball pitchers, volleyball players, and tennis players), with increased scapular internal rotation and anterior tipping on the dominant side. Naturally occurring side-to-side differences are commonly observed in individuals due to hand-dominance, occupational demands, or participation in athletics.[43] This discovery represents a major limitation to using the assessment of scapular position diagnostically.

Natural asymmetry frequently seen in healthy subjects has been observed with scapular motion as well, often making it difficult to determine meaningful differences in scapular mobility between healthy subjects and those with shoulder dysfunction. Uhl et al[46] reported finding a high prevalence of asymmetric scapular motions in both symptomatic and asymptomatic subjects. Morais & Pascoal[42] found that scapulae were not symmetrical between sides during arm elevation in 14 healthy subjects. Schwartz et al[44] also reported asymmetries between dominant and non-dominant arms in healthy subjects, with the dominant-side scapula displaying greater upward rotation. Conversely, Crosbie et al[76] reported finding greater amounts of upward rotation on the non-dominant side. Regardless, the finding of side-to-side differences within individuals has been supported by multiple authors.[42-44,46,76,78] Therefore, evidence exists to inform us that side-to-side differences in scapular position or motion in individuals should not be used diagnostically as a sign of clinical significance. Rather, abnormal scapular motion may simply represent normal kinematic variability.[85] This is a challenge clinicians often encounter when attempting to determine the importance or relevance of scapular position and motion when examining patients with shoulder dysfunction.

Clinical Examination Methods: Assessment of Scapular Motion

In consideration of the limitations previously mentioned regarding static assessment, many investigators and clinicians have focused more closely on dynamic assessment of the scapula. Not surprising however, a familiar concern arises with our ability to accurately and reliably measure such complex and often subtle motion.

Discussions surrounding scapular motion have placed an emphasis on the role of upward rotation. Two separate studies by Johnson et al[39] and Watson et al[41] assessed the use of inclinometers for the measurement of scapular upward rotation in an attempt to make such an assessment more practical for clinical practice. By comparing the data obtained from a modified digital inclinometer placed on the scapular spine to that obtained from a magnetic tracking device, Johnson et al[39] demonstrated good to excellent intrarater reliability (ICCs from 0.89-0.96) and validity with the inclinometer. These findings were then confirmed by Watson et al[41] who reported good to excellent reliability and an SEM of 5° with the use of a gravity inclinometer placed on the scapular spine. While the study by Johnson et al[39] examined elevation in the scapular plane with healthy and symptomatic subjects, Watson et al[41] utilized frontal plane abduction for subjects with shoulder pathology. The two papers together demonstrate that an inclinometer can be used to reliably measure scapular upward rotation in multiple planes of motion with both symptomatic and asymptomatic individuals. The results of a recent systematic review also indicate that this measurement could be deemed appropriate for clinical use based on the available evidence.[82]

Multiple studies have obtained measurements of scapular upward rotation with humeral elevation, allowing comparisons to be made across papers in an attempt to determine the normal range of upward rotation motion and provide clarity to the description of scapulohumeral rhythm. Clinicians might then be able to more confidently conclude whether or not an apparent restriction in scapular upward rotation is contributing to a patient's shoulder dysfunction. In general, the work from Borsa et al[18] reported smaller values for upward rotation ROM than most other studies, with a mean (SD) of 18.12° (5.8°) for humeral elevation up to 120°, while Johnson et al[39] reported 39.1° (8.4°) for that same range of humeral elevation. Watson et al[41] reported mean values between 41-45° at 135° of elevation and 55-57° at the end-range of elevation. Borsa et al[18] assessed elevation in the scapular and sagittal planes, Johnson[39] looked at elevation in the scapular plane, and Watson[41] examined elevation in the frontal plane. Ludewig et al[59] reported a mean of 36° of upward rotation and Lukasiewicz et al[22] reported a mean of 28.2° of upward rotation through 140° of humeral elevation, both in the scapular plane.

There are a number of likely explanations for the variability reported from these papers. It is likely that the plane in which the arm is being elevated affects the amount of scapular motion.[18] Additionally, Borsa and colleagues identified an initial period of scapular downward rotation (for a mean of 5 degrees) from rest to 30 degrees of elevation before scapular upward rotation began.[18] This pattern had not been previously reported and may at least partially explain their substantially lower mean for upward rotation motion. Instrumentation and experimental procedures varied among these studies, as did subject age and shoulder condition, which likely accounts for some of the variances between the reported results.[18] These collective findings, however, do reveal moderate to large ranges and standard deviations, again indicating a high degree of variability between individuals. This level of individual variability presents challenges with the interpretation of these measures in clinical practice.

While a clinical measure for scapular upward rotation was discussed in the literature as early as 2001,[39] there had been nothing available regarding a clinical measure of scapular posterior tilt. This gap in the literature was significant given that Ludewig & Cook[21] suggested in 2000 that movement into posterior tilt may be more critical than upward rotation for clearance of the rotator cuff tendons in the subacromial space. In 2014, Scibek & Carcia[40] reported on a measurement of anterior-posterior tilt of the scapula during arm elevation using a modified inclinometer. They compared the measurements obtained from the modified inclinometer to those obtained from an electromagnetic tracking device in 13 healthy individuals. The results demonstrated moderate validity for the use of the modified inclinometer. They reported a mean relative change of 20.06° of posterior tilt motion from anatomical neutral as measured by the inclinometer for humeral elevation to 120°.[40] It appears that motion above 120° of elevation was not assessed. The mean anatomical neutral position for scapular anterior-posterior tilt with the arm at rest was reported to be 68.68°,[40] which may be interpreted to mean 21.32° of anterior tilt. No further work to date has been identified that has assessed the use of this measure in individuals with shoulder pain. To our knowledge, there is also no literature currently available that has attempted to examine a clinical measure for scapular internal/external rotation, which is also considered to be an important, although highly variable, scapular motion for normal shoulder function.[17,22,51,58,59,85]

Scapular Dyskinesis

In an attempt to reduce some of the challenges or questions surrounding the measurement and subsequent clinical interpretation of specific scapular motions, a body of research shifted towards evaluating for the presence or absence of scapular dyskinesis. Dyskinesis has been defined as "a general term that is used to describe loss of control of normal scapular physiology, mechanics, and motion".[19(p366)] While variability is expected within the normal range of scapular kinematics, dyskinesis can most commonly be seen as prominence of the medial border or inferior-medial border, early or excessive scapular elevation during arm elevation, and/or rapid downward rotation during lowering of the arm.[86] Scapular dyskinesis has been identified in patients with shoulder impingement or SPS.[11,21,87] The prevalence of scapular dyskinesis has been reported to be between 68-100% in patients with shoulder pathologies such as glenohumeral instability, rotator cuff tears, and labral tears.[88-90] However, many people with scapular dyskinesis maintain healthy functional use of the extremity.[85]

In 2002, Kibler and colleagues[74] published a classification system for scapular dyskinesis based on a clinically practical visual assessment. This system consisted of four classifications, three which were considered abnormal patterns and one normal pattern of scapular motion. These were described as Type I, or inferior angle prominence; Type II, or medial border prominence; Type III, or superior scapular prominence ("shrug sign" commonly seen with excessive scapular elevation); and Type IV, or normal scapular motion. The original work by

Kibler et al[74] reported kappa values of 0.4 (intra-rater) and 0.5 (inter-rater). A reliability study by Ellenbecker et al[91] performed in a sample of uninjured professional baseball pitchers was unable to reproduce the earlier results of Kibler et al,[74] questioning not only the reliability but also validity of this test.

In 2009, McClure et al[38] conducted a reliability study on clinical judgment regarding the presence of dyskinesis using a different method, referred to as the Scapular Dyskinesis Test (SDT). Raters observed video recordings of overhead collegiate athletes performing bilateral, weighted shoulder flexion and frontal plane abduction. Scapular dyskinesis included the presence of winging and/or dysrhythmia and the examiners used three possible ratings: normal motion, subtle dyskinesis, or obvious dyskinesis. Their results demonstrated satisfactory reliability for clinical use (percent agreement between 75-82%, K_w=0.48-0.61). More recent work from Huang et al[92] reported moderate to substantial interrater reliability (percent agreement=83% and 68%; K=0.49-0.64) for a similar test of dyskinesis that involved a combined visual observation and palpation method.

Following the reliability study from McClure et al,[38] Tate et al[51] performed a validation study for the SDT by comparing the observed ratings of dyskinesis to 3D electromagnetic kinematic measures of scapular motion. The sample was again comprised of overhead collegiate athletes and the raters again used the normal, subtle dyskinesis, or obvious dyskinesis classifications. The results supported validity for the SDT, as differences were found between the normal and obvious dyskinesis groups. Subjects with obvious dyskinesis demonstrated less scapular upward rotation, less clavicular elevation, and greater clavicular protraction. The prevalence of dyskinesis was found to be greater during flexion, which coincided with the results from Uhl et al.[46] Although the raters were able to visually identify kinematic differences, the presence of scapular dyskinesis was not found to be related to shoulder symptoms,[51] indicating that dyskinesis was present in those with and without shoulder pain. The authors cautioned this finding, however, based on their use of a subclinical sample with minimal pain.[51] Work from Myers et al[50] has also reported a lack of an association between scapular dysfunction and future throwing-related injury in high school baseball players. These findings support that scapular dyskinesis is not always directly related to an injury nor does it always result in an injury.[19]

The current evidence suggests that there is a wide range of physiological normal in terms of scapular motion with a high degree of variability within and between individuals.[79] This makes comparing "normal" against "pathological" a considerable challenge.[79] Although the systematic review by Larsen et al[82] supports the use of the SDT in clinical practice based on acceptable clinometric properties, they also warn that the information gathered cannot provide sufficient information about the relationship between shoulder pain and scapular alterations. The presence of dyskinesis may simply represent normal kinematic variability[85] or may serve as an adaptive strategy.[79] Tate and colleagues[51] reported that individuals identified as having dyskinesis were no more likely to report shoulder symptoms. These concerns question the relevance of the findings[79] and indicate the need for either further investigation or consideration of another approach.

Summary

The current literature provides a great deal of information regarding scapular kinematics during arm elevation in individuals with and without shoulder pain or pathology. Although there are some inconsistencies in those findings, the consensus supports the combination of upward rotation,[58,59,66,67] posterior tilt (or reduction of anterior tilt),[58,59,66,67] and external rotation (or reduction of internal rotation)[58,59,66] of the scapula during elevation of the arm. Accordingly, a body of evidence has found a tendency towards decreased upward rotation,[21,58,87] increased anterior tilt (or insufficient posterior tilt)[21,22,58] and increased internal rotation (or insufficient external rotation)[21,58,87] in individuals with shoulder pathology, particularly SPS.[21] However, inconsistencies and variability with scapular motion in both normal and impaired shoulders must be acknowledged. Asymmetry between sides within subjects must also be recognized as common.[42-44,46,76,78,79]

The methods of clinical examination of the scapula that have been discussed, which include assessing position, assessing motion, and determining the presence of dyskinesis, have yielded a number of limitations and are not strongly supported by the literature primarily due to variable and asymmetrical findings within asymptomatic individuals. However, the digital inclinometer has been shown to be a valid instrument for measuring upward rotation and anterior-posterior tilt of the scapula.[93] Scapular dyskinesis is a common finding in asymptomatic individuals[54,94,95] and the scapular dyskinesis paradigm has been challenged due to concerns that tests lack construct validity, measurements are unreliable and are prone to error and bias, and a causal relationship is lacking between scapular dyskinesis and sypmtoms.[79] Additionally, these methods do not appear to yield sufficient information regarding the relationship between shoulder pain and scapular alterations, nor have they demonstrated the ability to detect scapular changes over time.[82] Consequently, there has been a more recent interest in the use of symptom modification tests to help identify scapulothoracic involvement in SPS, similar to what has been discussed and supported in the low back pain literature in response to similar limitations with clinical examination tests for the lumbar spine.[96,97] The Scapular Assistance Test (SAT) and

Scapula Reposition Test (SRT) have been described as symptom modification tests for individuals with shoulder dysfunction.

Research Specific to This Study

Scapular Assistance Test and Scapula Reposition Test

In 1998, Kibler[16] initially described a "muscle assistance" test which has been modified and termed the Scapular Assistance Test (SAT).[26] This test has demonstrated acceptable interrater reliability for clinical use (κ=0.53-0.62, percent agreement=77-91%)[26] when used as a diagnostic test with a reduction in pain of 2 or more points on the 11-point VNRS indicating a positive result.[26] The investigators found the SAT to be positive in individuals with various shoulder pathologies 49% of the time when testing motion in the scapular plane.[26] A more recent attempt to establish reliability for the SAT (or modified SAT) reported substantial agreement between examiners (κ=0.68) and concluded that the test was appropriate for inclusion in a clinical examination.[28]

The SAT has been shown to alter scapular kinematics in individuals with SPS and healthy controls[27] and in subjects with obvious dyskinesis as well as those with normal motion.[98] The observed changes in scapular kinematics included an increase in scapular upward rotation and posterior tilt during arm elevation in the scapular plane in all groups.[27,98] Based on the findings from the previously mentioned kinematic studies involving subjects with shoulder dysfunction, it is believed that increasing upward rotation and posterior tilt may help in reducing pain, possibly by influencing the subacromial space. An increase in acromiohumeral distance has been observed through use of the SAT in those with obvious scapular dyskinesis and those with normal motion.[98] The mean increase in acromiohumeral distance was 1.4mm.[98]

While the SAT is based on facilitating the desired motion from the scapula, previous studies have not thoroughly investigated scapular motion through the entire range of humeral elevation. Seitz et al[27,98] used 3D motion analysis to examine scapular upward rotation,[27,98] posterior tilt,[27,98] and external rotation[98] with the arm held statically at 0°, 45°, and 90° only. The relationship between the results of the SAT and the full range of scapular upward rotation and posterior tilt motion in a dynamic condition have not been reported. Individuals with restrictions in scapular upward rotation and/or posterior tilt might be more likely to have positive results on the SAT. The manual mobilization or facilitation of motion provided through the performance of the test may effectively address the presumed mobility deficit and result in a reduction in pain.

A second test, known as the Scapula Reposition Test (SRT), has been shown to have good reliability (ICC=0.964) when examining shoulder elevation strength during the repositioning in a mixed population of healthy and symptomatic overhead athletes.[25] The SRT resulted in a positive test in approximately 47% of subjects with a positive impingement test.[25] The performance of the test introduces retraction, posterior tilt, and external rotation to the involved scapula, attempting to create a more optimal scapular position with the goal of reducing pain and improving function. A positive test in this study[25] was defined as a 1-point reduction in pain on the VNRS, a value that is below the minimal detectable change (3)[99] or clinically important difference (2)[100] for that measure. The authors justified that decision based on the expectation of very low pain levels in their sample of collegiate athletes.[25]

Additional results from the study by Tate and colleagues[25] revealed improvements in isometric shoulder elevation (empty-can position) strength during application of the SRT in 26% of the athletes with SPS and 29% of the athletes without SPS. Significant increases in strength of the supraspinatus muscle (empty-can position) have also been reported in both individuals with shoulder dysfunction and healthy controls with the scapula held in a retracted position through manual contact in a manner very similar to the SRT.[101] The results from these two studies support the regional interdependence model and indicate that scapular position can affect the strength and function of the rotator cuff in those with and without shoulder pathology.

Despite good reliability findings for the SRT, a recent systematic review of physical examination tests for the scapula concludes, from very limited evidence, that the test has questionable validity as a diagnostic test to rule in SPS.[29] However, the SRT was not used as a diagnostic test in the primary study cited[25] but rather a movement test, meaning that the results of the test reveal information about a movement disorder. The test was not intended to provide the examiner with a diagnosis, but rather its purpose was to assist in directing treatment. This is typically the case with the growing body of symptom modification tests reported in the literature. Therefore, discussing the validity of the test in terms of being able to correctly rule in or rule out SPS is inappropriate based on this understanding.

Both the SAT and SRT utilize upward rotation, posterior tilt, and/or external rotation of the involved scapula, thereby addressing the most frequently discussed clinical concerns: insufficient upward rotation and excessive anterior tilt. The two tests differ in that the SRT[25,29] focuses on correcting scapular position with an emphasis on approximating the medial border to the thorax, while the SAT (or modified SAT)[19,26-28] focuses on correcting or facilitating scapular motion during dynamic arm elevation. Additionally, while both tests provide stability to the scapula they have significant differences in their primary intentions. The SRT intends to provide a corrected scapular position during the performance of a known provocative maneuver. The SAT intends to facilitate normal dynamic scapular motion (upward rotation and posterior tilt) during humeral elevation. In this manner, only the SAT may facilitate additional scapular range of motion in upward rotation and posterior tilt throughout the range of humeral elevation.

Difficulties in determining normal from pathologic in regards to scapular position and motion has led to persistent challenges and inadequacies in assessing the true impact of the scapula in the development or perpetuation of shoulder pain and dysfunction. The judgment of the SAT and SRT as either being able or unable to alter the patient's symptoms eliminates the need for making the challenging and controversial determination of normal versus abnormal scapular motion. Instead, the ability of the test to immediately alter the patient's symptoms is the indication of probable scapular involvement.

In a more general sense, symptom modification or alleviation tests for the shoulder have been described in the literature due to the concerns over the more commonly used symptom provocation tests.[6,79,102] Despite being their primary purpose, the provocation tests are unable to adequately isolate specific structures and are intended to correlate with the results obtained from diagnostic imaging studies which lack validity as not all structural pathology correlates with symptoms.[102] Due to these limitations, Lewis[102] has suggested that a new method of clinical examination is needed and described a Shoulder Symptom Modification Procedure (SSMP) with the intent of identifying one or more techniques that reduce a patient's symptoms by either decreasing pain or increasing motion. This approach supports the constructs behind the SAT and SRT and provides additional support for their continued investigation.

Measures of Scapular Upward Rotation and Posterior Tilt Range of Motion

This study further assessed scapular upward rotation and posterior tilt motion in patients with SPS in an attempt to improve the understanding of the SAT and SRT. Scapulohumeral rhythm has highlighted the significance of scapular upward rotation for normal, healthy upper extremity function. The literature to date has continued to emphasize the importance of upward rotation as the predominant scapulothoracic motion and has additionally placed importance on the motion of scapular posterior tilt.[17,21,22]

We currently have reliable and valid clinical measures for assessing upward rotation and posterior tilt active ROM. A measurement of upward rotation active ROM has been validated in at least two studies.[39,41] A recent study has successfully validated a measurement for posterior tilt active ROM in a sample of healthy subjects.[40] Both measurements involve the use of a modified inclinometer directly on the scapula. This study also investigated proposed measures for upward rotation and posterior tilt passive ROM which has not been previously discussed in the literature. Assessing both active and passive ROM enabled us to gain a better understanding whether the impairments in motion are more likely related to muscle stiffness or deficits in muscle strength or motor control.

Pectoralis Minor Muscle Length:

The pectoralis minor has the capability of limiting the amount of scapular posterior tilt and is commonly reported to influence scapular kinematics[103] and contribute to shoulder dysfunction. The assessment of pectoralis minor muscle length has produced some difficulty in attempting to create a clinical measure with good reliability and validity. While a common method of measuring the distance from the posterolateral aspect of the acromion to the table with the subject in supine demonstrated good to excellent reliability (ICCs > 0.88),[24,104] it was also shown to have poor diagnostic accuracy and its use was therefore cautioned.[104,105] Borstad[106] described a technique that measured the linear distance in cm between the anterior-inferior edge of the 4th rib one finger width lateral to the sternum and the medial-inferior aspect of the coracoid process of the scapula with the subject standing in their usual resting position. This method produced ICCs of 0.86 and 0.82 with the use of a tape measure. The technique was also shown to be valid by comparing the results obtained to in vitro measures of pectoralis minor length in cadavers.[106] Additional studies have also reported good reliability using this technique with small modifications. One of those studies reported ICCs ranging from 0.87-0.93 in subjects with shoulder pain when performing the measurement with the subject in supine with elbows extended.[107] Another study reported ICCs of 0.98 and 0.99 using a device called the Palpation Meter to obtain the measurement in lieu of a caliper or tape measure as originally described.[108] This study also found good validity for this measure when compared to values obtained from an electromagnetic motion analysis system.[108]

Scapulothoracic Muscle Force Generation

Information regarding scapulothoracic muscle force generation, specifically the middle trapezius, lower trapezius, and serratus anterior was also obtained during this study. The literature regarding the assessment of scapulothoracic muscles in patients with SPS has primarily involved EMG testing, providing information regarding the activation and timing of muscle activity, but not strength. Information regarding the activation and timing of the upper trapezius,[17,109,110] lower trapezius,[109] and serratus anterior[17,21,58] in individuals with SPS has been reported. Decreased EMG activity in the serratus anterior,[17,21,58] increased EMG activity in the upper trapezius,[17,109-111] and delayed activation of the lower trapezius[109] has been reported.

The importance of the serratus anterior muscle in individuals with shoulder pathology has been emphasized. Ludewig and Cook[21] reported decreased activity in the serratus anterior throughout the range of humeral elevation in patients with shoulder impingement. The serratus anterior is believed to have the best ability to produce posterior tilt of the scapula,[21,54] while also contributing to upward rotation[17] and external rotation of the scapula. Thus, the serratus anterior appears to play a role in producing all of the desired scapular motions and is therefore frequently cited as a key muscle to assess and treat.[17,21,23,58,59,112]

Changes in the activation and timing of the upper and lower trapezius may explain the common finding of excessive or premature scapular elevation during arm elevation, which is commonly observed in individuals with scapular dyskinesis.[38] More recent work by Michener et al[113] has revealed altered EMG relative muscle activity ratios between the upper trapezius and lower trapezius as well as between the serratus anterior and lower trapezius in individuals with SPS. The results indicated a higher UT/LT ratio and lower LT/SA ratio in participants with SPS when compared to age-matched controls, demonstrating that SPS is associated with alterations in neuromuscular control of these muscles.[113]

Additional evidence highlighting the clinical relevance of these particular muscles is provided through findings that isometric strength of the trapezius muscle affects upward rotation[114,115] and posterior tilt in asymptomatic shoulders.[115] Specifically, decreased lower trapezius and serratus anterior strength was related to a reduction in upward rotation[114] and greater upper trapezius and middle trapezius strength was associated with increased upward rotation during frontal plane elevation.[115] Greater lower trapezius strength was associated with increased posterior tilt during sagittal plane elevation.[115] Decreased lower trapezius force production has also been identified in athletes with dyskinesis when compared to athletes without dyskinesis.[114] This information supports the utility in assessing the strength and performance of these muscles in individuals with shoulder pain or dysfunction.

In contrast to the studies that utilized EMG data to assess muscle activation and timing, the present study assessed strength of the scapulothoracic muscles using handheld dynamometry

(HHD). The use of HHD for the assessment of scapulothoracic muscle strength has demonstrated good intrarater reliability in two separate studies with ICCs ranging from 0.75-0.99 (excluding the upper trapezius)[116] and 0.89-0.96.[117] Both studies included subjects with shoulder dysfunction. Michener et al[117] also examined the validity of HHD strength assessment by comparing the results from the muscle tests to information regarding muscle activation obtained through surface EMG. The results indicated the highest degree of muscle activation of the upper trapezius and lower trapezius muscles during their respective strength tests, representing good construct validity for those tests. However, muscle activity was not at its greatest during the middle trapezius and serratus anterior strength tests.

A systematic review on the reliability of HHD in the upper extremity was published by Schrama et al in 2014[118] which resulted in a general conclusion that there is an inability to rely on strength measures obtained through HHD in patients with upper extremity disorders. However, although 38 of the 54 included articles investigated the shoulder, only 6 of those articles included even a single scapulothoracic muscle test and just one of those articles[117] examined more than two scapulothoracic muscle tests. This should be considered an important limitation when interpreting their conclusion as it relates to the use of HHD for the scapular region. The authors also discussed that the more recently developed portable hand-held units, as were used in this study, have shown promising results.[118] Finally, it should be noted that the conclusion from this systematic review conflicts with previous results that reported both intraexaminer and interexaminer reliability were good to excellent for HHD.[119]

Thoracic Spine Manipulation for Shoulder Pain

Thoracic spine manipulation has been shown to be effective in the management of some patients with shoulder pain.[30-34,36,120] Decreased pain,[31-34,36,121] increased ROM,[34] and improvements in function[31,33,36] have been reported as immediate and short-term effects of thoracic spine manipulation in individuals with shoulder pathology. A systematic review examining the effect of thoracic manipulation on shoulder pain by Howard et al[120] in 2015 included 6 articles that all reported favorable outcomes and no adverse effects with thoracic manipulation. This led the authors to conclude that thoracic manipulation for the treatment of shoulder pain is a safe clinical decision and may offer benefits.[120] A strong recommendation for the use of thoracic manipulation could not be made at this time, however, due to a low to moderate level of evidence and absence of strong evidence.[120]

A definitive explanation as to why or how thoracic spine manipulation results in these improvements remains unclear. A 2012 systematic review by Coronado and colleagues[122] concluded that although the exact mechanisms behind spinal manipulation remain elusive, it is likely a non-specific effect which acts on the pain-modulating system. The effects are likely more neurophysiological in nature than biomechanical. Biomechanical,[31,34] neurophysiological,[33,34] and hypoalgesic[34] mechanisms have been suggested in an attempt to provide answers to these questions. The regional interdependence theory[55,70] has been offered as a possible explanation, suggesting that many musculoskeletal disorders may respond more favorably to a regional examination and treatment approach. This idea is often cited as a likely reason why manipulating the thorax might alleviate shoulder pain and dysfunction. Another theory offers neurophysiological effects as the means by which thoracic spine manipulation improves shoulder pain and function. This theory has received attention and is supported by the literature as neurophysiological effects have been demonstrated at the peripheral, spinal, and supraspinal levels with spinal thrust manipulation techniques.[122-124] Additionally, it has been demonstrated that spinal manipulation in general[123,125] and specifically thoracic manipulation[32,33,36,64,72] has resulted in no or insignificant biomechanical changes in symptomatic and asymptomatic individuals.

A change in scapular kinematics following thoracic spine manipulation has been suggested as an explanation for the observed improvements in pain and function.[31,34] However, Rosa et al[72] found no significant differences in scapular kinematics following a seated mid-thoracic spine manipulation in asymptomatic subjects. With this technique, the participant was seated with the arms crossed over the chest and hands over the shoulders. The therapist placed his chest at the level of the participant's middle thoracic spine and grasped the participant's elbows. After taking a deep breath, the participant was instructed to exhale and gentle flexion of the thoracic spine was introduced by the therapist to develop slight tension in the tissues at the contact point between the therapist's chest and participant's back. Then, a distraction thrust in a superior and posterior direction was delivered.[72] Using the same seated mid-thoracic technique, Haik et al[32] reported a small but not clinically important increase in upward rotation in subjects with and without SPS. A small increase in anterior tilt was also reported with elevation and lowering of the arm in asymptomatic subjects.[32] Kardouni et al[36] reported no significant differences in scapular kinematics following a single session of manual therapy that consisted of 3 different spinal manipulative techniques compared to sham techniques in subjects with subacromial impingement. Each technique was applied twice, for a total of 6 thoracic spine manipulations or sham manipulations. The manipulations performed included middle and lower thoracic spine techniques in prone and a cervicothoracic distraction technique in sitting with the participant's arms elevated and fingers laced behind the neck. Both groups demonstrated small but likely not clinically meaningful changes in scapular internal rotation.[36] From this evidence, it appears that a change in scapular kinematics may not be the explanation for the observed improvements in pain and function; however, this requires further investigation in symptomatic populations.

An increase in lower trapezius strength has been reported in healthy individuals following thoracic spine manipulation.[57] Significant differences in EMG activation of the middle trapezius has also been reported following thoracic spine manipulation in subjects with rotator cuff tendinopathy.[33] Earlier EMG studies have demonstrated greater activation of muscles adjacent to or opposite the site of manipulation.[126] It is possible that thoracic spine manipulation results in increased strength or neuromuscular activation of shoulder girdle muscles. Further research is needed to investigate this possible explanation, especially with the use of thoracic spine manipulation in subjects with shoulder pathology.

Many questions remain regarding how thoracic spine manipulation is effective for individuals with shoulder pain and whether or not there is a subgroup of shoulder pain patients that responds best to this treatment approach. In 2010, Mintken et al[35] attempted to identify individuals with shoulder pain who are likely to benefit from manipulation to the cervicothoracic junction and thoracic spine. They identified 5 variables that predicted a greater chance of short-term success: pain-free shoulder flexion < 127°, shoulder internal rotation < 53° at 90° abduction, negative Neer test, not taking medications for their shoulder pain, and symptoms < 90 days.[35] However, this research represented a derivation study and therefore did not include a control group. A follow-up study was published by Mintken et al[127] in 2016 that demonstrated the addition of 2 sessions of cervicothoracic manual therapy to an exercise program did not improve pain or disability in patients with shoulder pain but did improve patient-perceived success and acceptability of symptoms.

Table 2-1: Summary of Thoracic Spine Thrust Manipulation for Shoulder Pain Literature

Author and Study Design	Subjects	Technique(s) utilized	Follow-up Period and Results
Boyles et al, 2009[31] single group, pre-test/post-test design	56 pts with SIS 40 males, 16 females mean age 31.2 ± 8.9 years mean duration of symptoms not provided	multiple techniques: - seated mid-thoracic (arms across chest) - seated CT junction with axial distraction (hands behind neck) - supine rib opening (if rib angle pain present) - maximum of 2 attempts per technique	48 hour follow-up; statistically significant but not clinically significant decrease in pain and disability
Strunce et al, 2009[34] single group, pre-test/post-test design	21 subjects with shoulder pain 10 males, 11 females mean age 47 ± 12.6 years mean duration of symptoms 4.2 ± 4.8 months	multiple techniques: - seated CT junction with axial distraction (hands behind neck) - supine flexion/opening - supine rib - prone extension/closing - type and number of technique utilized was pt-specific	immediate follow-up; decrease in pain and increase in shoulder ROM - *no adverse effects*
Mintken et al, 2010[35] single group, pre-test/post-test design	80 subjects with shoulder pain mean age of success group 40.4 ± 13.5 years mean age of nonsuccess group 42.5 ± 12.8 years mean duration of symptoms 15.85 ± 53.7 months	multiple techniques: - supine CT junction (hands behind neck) - supine upper-thoracic (hands behind neck) - supine mid-thoracic (arms across chest) - prone mid-thoracic - seated mid-thoracic with axial distraction (arms across chest) - each technique was performed twice, for a total of 10 manipulations	49 (61%) subjects experienced a successful outcome (GROC score ≥ +4); successful outcome more likely with the presence of 5 factors: pain-free shoulder flexion < 127°, shoulder IR at 90° of abd < 53°, negative Neer test, not taking medication for shoulder pain, symptoms < 90 days - *no adverse effects*
Muth et al, 2012[33] single group, pre-test/post-test design	30 subjects with signs of RTC tendinopathy 16 males, 14 females mean age 30.6 ± 7.9 years mean duration of symptoms 4.2 months high level overhead athletes	multiple techniques: - seated mid-thoracic (arms across chest) - seated CT junction with axial distraction (hands behind neck) - all received mid-thoracic technique first, followed by CT junction technique - no more than 2 attempts for each technique	immediate follow-up; improvements in pain and function; no sig change in ROM or scapular kinematics (other than small decrease in UR); no change in muscle activation except for small (sig) diff in middle trap EMG

Rosa et al, 2013[72] 2 group (manip and sham), pre-test/post-test design	42 asymptomatic subjects - *Manip group*: 10 males, 11 females; mean age 23.81 ± 3.75 years - *Sham group*: 10 males, 11 females; mean age 23.95 ± 3.2 years	- seated mid-thoracic (arms across chest) - sham manipulation (used same position as manipulation technique, but high-velocity thrust was not performed) - maximum of 2 attempts	immediate follow-up; no differences in function between manip and sham; no sig differences in scapulohumeral rhythm or scapular kinematics during arm flexion *- no adverse effects*
Haik et al, 2014[32] RCT with 4 group, pre-test/post-test design	97 total subjects 50 subjects with SIS (mean age 31.8 ± 10.9 years) and 47 asymptomatic subjects (mean age 25.8 ± 5.0 years); mean duration of symptoms 49 ± 96 months SIS-manip (n=25) SIS-sham (n=25) asymp-manip (n=24) asymp-sham (n=23)	- seated mid-thoracic (arms across chest) - sham manipulation (used same position and same forces as manipulation technique, while holding position for a few seconds, without actually performing a thrust manipulation) - maximum of 3 attempts	immediate follow-up; statistically significant but not clinically significant reduction in pain for subjects with SIS in both manip and sham groups; small changes in scapular kinematics (increase in scapular UR of 2.2 degrees, increase in scapular IR) were not considered clinically important
Kardouni et al, 2015[36] RCT with 2 group, pre-test/post-test design	52 subjects with SIS - *Manip group*: 11 males, 15 females; mean age 30.8 ± 11.9 years - *Sham group:* 17 males, 9 females; mean age 33.2 ± 12.6 years	multiple techniques: - prone mid thoracic - prone lower thoracic - seated C-T junction with axial distraction (hands behind neck) - sham manipulation (identical body positioning with minimal pressure applied to maintain physical contact and skin lock; same range of motion but no thrust) - each technique done twice at each of the 3 regions for 6 manipulations in total	immediate follow-up; no sig change in thoracic motion or scap kinematics; improvements in pain and function, but no different than sham group; small increase in scapular IR in both groups
Kardouni et al, 2015[128] RCT with 2 group, pre-test/post-test design	45 subjects with SIS - *Manip group*: 10 males, 14 females; mean age 31.1 ± 12.3 years - *Sham group:* 12 males, 9 females; mean age 31.2 ± 12.1 years	multiple techniques: - prone mid thoracic - prone lower thoracic - seated C-T junction with axial distraction (hands behind neck) - sham manipulation (identical body positioning with minimal pressure applied to maintain physical contact and skin lock; same range of motion but no thrust) - each technique done twice at each of the 3 regions for 6 manipulations in total	immediate follow-up; no sig differences between groups for changes in PPT; no sig change in either group for PPT; pain and function improved in both groups but no differences between groups

Theoretical Model Supporting the Seated Manipulation over the Supine Manipulation

Previous studies examining thoracic spine manipulation for individuals with shoulder pain have either utilized multiple manipulative techniques[30,31,34,36,128] or only seated techniques.[32,33] A study comparing the effectiveness of a seated vs. supine technique in this patient population has not been conducted. The information that may be obtained from a comparative study like this would be important for a few reasons. First, information regarding the ability of different thoracic spine manipulation techniques to create an immediate effect on scapulothoracic motion or strength in individuals with SPS would be valuable. As it has been demonstrated in patients with neck pain,[129] one technique may result in greater improvements in shoulder pain and function than another due to possible factors including patient position, point of application of the force, or direction of the applied force. Clinicians would be able to incorporate this information into their day-to-day clinical reasoning when making treatment decisions for this patient population.

It is likely that the seated upper thoracic manipulation technique will provide greater improvements in scapulothoracic impairments based on the patient positioning and delivery of force utilized with that technique. During the delivery of the seated technique, the arms of the patient are elevated so that the hands can be placed behind the neck, positioning the glenohumeral joint in approximately 120° of elevation. That degree of humeral elevation causes the scapula to move into upward rotation and posterior tilt. Delivering a thrust manipulation to the upper thoracic spine while in this position may provide a quick stretch to the scapulothoracic muscles, and in theory the pectoralis minor in particular, through the initial positioning of the scapula in combination with the delivery of a distraction force in the cephalad direction. These factors may result in a greater effect on scapular motion and pectoralis minor length, possibly resulting in a facilitation of upward rotation and posterior tilt mobility of the scapula. The positioning that is involved in the supine technique will also move the humerus into a similar amount of elevation, thereby producing upward rotation and posterior tilt of the scapula, however will not create the same stretch to the scapulothoracic musculature through the posteriorly-directed force delivered. Additionally, it is likely that the supine positioning in itself may restrict mobility of the scapula. Examining for differences in pain, scapular motion, and scapulothoracic muscle strength between these two commonly used manipulation techniques may provide meaningful information. This knowledge may help us gain a better understanding of the effectiveness and best use of thoracic spine manipulation in this population.

Risks Associated with Thoracic Spine Thrust Manipulation

Adverse effects may be defined as sequelae that involve at least moderate level symptoms of medium- to long-term duration, and of a serious nature that is unacceptable to the patient and requires further treatment.[130] It must be recognized that adverse effects, as defined in this nature, are different than short-term side effects. Short-term side effects, possibly including pain, soreness, fatigue, or headache, are common following thoracic spine thrust manipulation.[130] A review of the current literature that has utilized thoracic spine thrust manipulation in individuals with shoulder pain reveals no reported adverse effects from the manipulative techniques utilized.[32,34,35,72,120] Additional studies that utilized thoracic spine thrust manipulation for individuals with neck pain also reported no adverse effects from this treatment.[131,132] A very recent systematic review on the safety of thoracic spine thrust manipulation[130] cautions that serious adverse effects can occur based on information obtained from 7 case reports. Only one of those case reports involved a PT who utilized both cervical and upper thoracic techniques in that case. The evidence at this time supports that following the completion of a thorough history and physical examination, with appropriate screening for red flags, the utilization of thoracic spine thrust manipulation is safe and carries minimal risk to patients.

Table 2-2: Summary of Adverse Effects Reported with Thoracic Spine Thrust Manipulation

Author	Population	Sample size	# of Adverse Effects
Strunce et al, 2009[34]	Individuals with shoulder pain; mean age 47 ± 12.6 years	21	0
Mintken et al, 2010[35]	Individuals with shoulder pain; mean ages 40.4 ± 13.5 years and 42.5 ± 12.8 years	80	0
Rosa et al, 2013[72]	Asymptomatic individuals; mean age 23.81 ± 3.75 years	42	0
Masaracchio et al, 2013[131]	Individuals with neck pain; 30.5 ± 9.5 years	64	0
Puentedura & O'Grady, 2015[130]	Review of 7 different case reports (1 case report included 4 subjects); treatment delivered by a PT in only 1 case report	10	10
Howard et al, 2015[120]	Review of 6 studies (1 RCT and 5 observational studies)	285	0

Summary

The SAT[26] and SRT[25] has demonstrated good reliability and appears to provide clinicians with the necessary information to determine the degree of contribution from the scapula in individuals presenting with shoulder pain. The SAT has been shown to alter scapular kinematics[27,98] and increase acromiohumeral distance.[98] While the SRT has been shown to increase humeral elevation strength,[25,101] relationships between impairments in scapulothoracic muscle strength or scapular motion have not been assessed in relation to either the SAT or SRT.

Additionally, contemporary literature has begun to describe an evolution towards the use of these symptom modification tests in clinical examination in hopes of providing relevant information that can be used to direct treatment decisions.[6,79,102]

Individuals with deficits in scapulothoracic muscle strength might be more likely to have positive results on the SAT or SRT for different reasons. The manual mobilization or facilitation of motion provided from the SAT may make up for the presumed mobility deficit associated with weakness or stiffness. On the other hand, the stabilization provided by the SRT might make up for a deficiency in scapular stability due to weakness or motor control deficits. Additional information regarding the SAT and SRT is needed to determine the utility of these tests to correctly identify impairments in scapular motion or muscle strength and to guide treatment.

Patients with SPS may present with limitations in scapular motion, especially upward rotation[21,58,87] and posterior tilt.[21,22,58] These motions should be examined in clinical practice to assess for impairments. Measures for scapular upward rotation[39,41] and posterior tilt[40] using an inclinometer have produced acceptable levels of reliability for clinical use. Both of these measures have also demonstrated good validity.[39,40] The anticipated restrictions in scapular motion may be due to pain, muscle weakness, muscle stiffness, impairments in muscle length, or something else. As a result, these motions should be assessed both actively and passively.

The literature has demonstrated that some individuals with shoulder pain, shoulder impingement, and/or Rotator Cuff tendinopathy benefit from thoracic spine manipulation.[30-34] Evidence has also shown that the risks associated with thrust manipulation to the thoracic spine in individuals with shoulder pain are very low, with multiple studies reporting no adverse effects from the treatment.[32,34,35,72] However, we do not know if a certain thoracic spine manipulation technique is more effective than another in this patient population, as has been reported in subjects with neck pain.[129] Previous studies have utilized either multiple manipulative techniques or a single technique. No studies to our knowledge have compared the effectiveness of different techniques.

Contribution of this Study to the Field of Physical Therapy

As McClure et al stated, "[a] method that can reliably identify people with scapular motion abnormalities and that is suitable for routine clinical use would be of great value...".[11(p1086)] While the clinical examination of scapular position and motion has appeared to offer minimal value due to naturally occurring variability, asymmetries, and small magnitudes of movement, the symptom modification tests appear promising in determining the role of the scapula in the presence of shoulder pain. The symptom altering nature of the SAT and SRT eliminates the commonly encountered difficulties and obstacles of other clinical tests for the scapula. Therefore, further investigation into the SAT and SRT in patients with SPS may provide significant information regarding the most effective management of these patients and may promote additional investigations of these tests.

This study investigated for relationships between positive results on the SAT and SRT and impairments in scapular upward rotation and/or posterior tilt motion. Impairments in scapulothoracic muscle strength, particularly the trapezius and serratus anterior muscles, were examined. Identifying whether or not impairments in scapular motion or strength are present in individuals with positive results on the SAT and SRT may help to provide validity that the tests may be useful in guiding treatment. The same can be said if those individuals who test positive on the SAT or SRT demonstrate greater deficits in scapulothoracic muscle strength than those who are negative on the tests. The utility of the test to identify a specific treatment approach targeting scapular motion, strength, or both may then be further supported.

Investigating potential differences in scapular motion or scapulothoracic muscle strength following the delivery of a seated or supine upper thoracic manipulation may also provide important information regarding the possible mechanism behind the effectiveness of thoracic spine manipulation for shoulder pain. This study compared the outcomes of both manipulations to a sham comparator. The two manipulations may work through different mechanisms due to the differences in their delivery. In theory, the seated technique may prove to be more effective through its incorporation of glenohumeral joint elevation with a cephalad-directed distraction force compared to the supine technique which utilizes a posteriorly-directed force with scapular motion somewhat restricted by the treatment table.

The effectiveness of thoracic spine thrust manipulation based on the results of the SAT, SRT, or SDT has not been previously reported and will represent new information. Thrust manipulation to the thoracic spine may facilitate improvements in muscle activation and/or strength of the scapulothoracic muscles, which can lead to improvements in scapular stability or mobility. If this were to occur, it would be reasonable to expect to see changes in scapular motion, scapulothoracic muscle strength, or any of the clinical tests (SAT, SRT, or SDT). Thoracic spine manipulation may also provide a quick stretch to stiff muscles or mobilize soft tissue in the thorax. Improvements in any baseline impairments following thoracic spine manipulation may help provide insight into how manipulation is effective for individuals with shoulder pain. If improvements in lower trapezius strength are observed in this patient population following thoracic spine manipulation, this would add to previous work by Cleland et al[57] that reported this finding in healthy subjects. The results obtained may again be helpful in directing treatment regarding the use of one manipulative technique over another, or perhaps in helping to identify individuals with shoulder pain who are likely to respond better to thoracic spine manipulation.

The possibility of a subgroup of patients within a larger category of SPS is an idea that warrants further investigation. It is an idea that has been mentioned in the literature discussing the symptom modification tests. Symptom altering tests may be effective in differentiating such a subgroup and in a manner similar to patients with low back pain, subgrouping patients with SPS may be a more effective approach to providing treatment. The results from this study may help guide future research examining the presence of subgroups within SPS that respond with greater effectiveness to different treatment approaches.

Most importantly, this study addresses current limitations in the literature within the area of clinical examination of the scapula in patients with SPS, particularly surrounding the use of the SAT and SRT. Additional information will be obtained regarding the clinical examination of scapular motion, both active and passive, with maximal humeral elevation and scapulothoracic muscle strength using HHD. This study also provides evidence on the comparative effectiveness of two different thoracic spine manipulation techniques, compared to a sham technique, for patients with SPS.

Chapter Summary

Although with some variability, a predictable combination of scapular motions associated with humeral elevation has been reported in the literature. Additionally, a sense of faulty or pathologic motions from the scapula that likely contribute to shoulder dysfunction has also been discussed. However, researchers and clinicians continue to encounter difficulties in assessing and interpreting the relevance of scapular position and movement due to the common presence of postural asymmetry and normal kinematic variability. With the lack of longitudinal data, it remains difficult to determine whether observed findings in patients with shoulder dysfunction are compensatory or contributory. Therefore, the relevance of these findings may often be questioned or altogether dismissed as being insignificant. The search continues for a reliable, feasible, and valid means of assessing the complexities associated with the scapula in hopes of more effectively identifying significant findings that are likely contributing to shoulder dysfunction.

The Scapular Assistance Test (SAT) and Scapula Reposition Test (SRT) attempt to move away from the possible challenges associated with quantifying scapular motions while still providing information that scapular dyskinesis is likely involved in the production or perpetuation of shoulder symptoms. Finding an examination method that can be used with confidence in routine clinical practice and that can help guide and improve the physical therapy management of these patients is important. This remains one of our greatest challenges when considering the complex and necessary contributions from the scapula to normal upper extremity function. The SAT and SRT have the potential to be valuable clinical tests and thus demand further investigation. Finally, the utilization of thrust manipulation to the thoracic spine has shown favorable results in individuals with shoulder dysfunction and warrants further investigation in hopes of determining additional insight into the proposed mechanisms and clinical effectiveness of different techniques.

CHAPTER 3: METHODOLOGY

Introduction

This chapter will discuss the research methodology that was used to achieve the research aims of this investigation. This research study examined the SAT and SRT, clinical measures of scapular upward rotation and posterior tilt active and passive motion, pectoralis minor muscle length, and scapulothoracic muscle strength in patients with SPS. This study also evaluated the immediate effects of two commonly used thoracic spine thrust manipulation techniques on pain, function, scapular upward rotation and posterior tilt motion, pectoralis minor muscle length, and scapulothoracic muscle strength in this population.

Research Methods

This study had two primary research aims. The first research aim involved a prospective, cross-sectional study to investigate the results of the SAT and SRT in individuals with SPS. The second research aim utilized a randomized controlled trial with pre- and post-intervention measures completed in a single session with a 48-hour follow-up to investigate the effects of two different manipulation techniques compared to a sham technique in individuals with SPS. Random assignment was used to determine whether subjects received the seated upper thoracic thrust manipulation, supine upper thoracic thrust manipulation, or sham technique as the intervention. Randomization was completed by a research assistant using a computer generated table of random numbers (www.randomizer.org) and following a block randomization scheme to permit equal allocation to each group. The table of random numbers was concealed in a separate folder and not viewed until the baseline measures had been completed for that participant. The study protocol was approved by the Institutional Review Boards at Sacred Heart University (Fairfield, CT) and Nova Southeastern University (Fort Lauderdale, FL).

Specific Procedures

An a priori power analysis was run to determine the necessary sample size to minimize the chance of a Type II error. A sample size of 54 total subjects (18 per group) was estimated using G*Power (http://www.gpower.hhu.de/en.html) to be necessary to provide 80% power, with alpha level set at 0.05, to detect an estimated 5 degree difference in scapular motion with one-way ANOVAs. To account for possible attrition, an additional 6 subjects were added for a total sample size estimate of 60 (20 per group).

A sample of convenience was gathered from patients currently experiencing shoulder pain associated with SPS who responded to recruitment flyers or emails distributed throughout a single university campus and agreed to participate in the study. Additional subjects were recruited by PTs in the local community that were informed about the study and agreed to participate in subject recruitment by referring patients to the principal investigator that met the inclusion/exclusion criteria and were interested in participating in the study. No financial compensation was provided to participants or to clinicians involved in subject recruitment for this study. All subjects were evaluated and treated during a single session by the principal investigator. For participants who were actively receiving PT care for their shoulder pain, the data collection session occurred within the first 7-14 days of initiating treatment in order to minimize the effects of that treatment. Patient-reported pain, satisfaction, and function using the Penn Shoulder Score was reassessed at 48 hours after the data collection session to allow for the analysis of carry-over effects of the treatment. Beyond the single study session required for data collection, PT treatment as determined by the subject’s primary PT was allowed to continue for those who were actively receiving PT care upon completion of the 48-hour follow-up. Participants were not required to pursue ongoing physical therapy care, however.

Inclusion Criteria:

Subjects were individuals between the ages of 18 and 65 years who were currently experiencing shoulder pain for less than 6 months. The diagnosis of SPS required at least 3 of the following 6 findings: 1) pain localized to the proximal anterolateral shoulder region, 2) positive Neer or Hawkins-Kennedy impingement test, 3) pain with active shoulder elevation (which may include a painful arc), 4) shoulder abduction AROM of at least 90°, 5) shoulder external rotation PROM of at least 45°, and 6) pain with isometric resisted abduction or external rotation.[11,14,15,21] Using a combination of tests increases the post-test probability of correctly arriving at a diagnosis of SPS.[15,133-135] According to van der Windt et al,[2] SPS accounts for 44-65% of all shoulder pain, which can be used as an estimate of the pre-test probability of having the condition. Using a test cluster previously described by Park et al[134] with a positive likelihood of 10.6 given positive results on all 3 tests results in an estimated post-test probability of 90-96% of having SPS.

Exclusion Criteria:

Subjects were excluded if they demonstrated signs of a complete rotator cuff tear, significant loss of glenohumeral motion (defined as $\geq$ 50% loss in 2 or more planes of motion, with the greatest loss of motion on external rotation),[14] or acute inflammation (as evidenced by severe resting pain or severe pain during impingement tests or isometric resisted abduction).[11,14] Signs of a complete rotator cuff tear include gross weakness on resisted abduction or external rotation, positive lag signs, or positive MRI findings.[11] Additional exclusion criteria included:

cervical spine-related symptoms including a primary complaint of neck pain, signs of central nervous system or cervical nerve root involvement, or reproduction of shoulder or arm pain with cervical rotation, axial compression, or Spurling test;[36] previous neck or shoulder surgery; positive apprehension test or relocation test; history of shoulder fracture or dislocation; history of nerve injury affecting UE function; or any contraindication for thrust manipulation to the thoracic spine including osteoporosis, fracture, malignancy, systemic arthritis, or infection.[32,36] Additionally, subjects who expressed a fear or unwillingness to undergo thoracic spine manipulation were excluded.[34]

All subjects who agreed to participate were examined by the principal investigator for the diagnosis of SPS as operationally defined above. The examining PT was not blinded to the results of the examination. The standardized examination procedures included the following:

1. assessment of motion, on the involved side
    a. glenohumeral joint AROM for scapular plane elevation AROM and PROM for scapular plane elevation, ER, and IR
    b. Scapular Dyskinesis Test (SDT)
    c. scapular upward rotation AROM and PROM
    d. scapular posterior tilt AROM and PROM
2. symptom modification tests, on the involved side
    a. Scapular Assistance Test (SAT)
    b. Scapula Reposition Test (SRT)
3. assessment of muscle length, on the involved side
    a. pectoralis minor
4. assessment of muscle force generation, bilaterally

a. middle trapezius

b. lower trapezius

c. serratus anterior

Strength measures were completed bilaterally to examine for any possible effects resulting from the manipulation technique that were experienced either bilaterally or unilaterally on the non-involved side.

Assessment of AROM and PROM of the shoulder was completed using a universal goniometer in the standard fashion.[136] The examiner assessed shoulder elevation AROM in the scapular plane with the subject standing. Goniometric measures of active elevation in the scapular plane have demonstrated intrarater ICCs of 0.87 and interrater ICCs of 0.92 with an MDC of 8 degrees.[137] Measurements of shoulder scapular plane elevation, internal rotation and external rotation PROM were obtained with the subject in supine. Measurements for internal rotation and external rotation PROM were completed with the shoulder abducted to 90° and elbow flexed 90°.[136] Goniometric measures of shoulder PROM have been shown to be highly reliable with intrarater ICCs ranging from 0.87-0.99 and interrater ICCs for flexion, abduction, and external rotation ranging from 0.84-0.90.[138] Similar reliability was reported in another study for measuring passive shoulder rotation, with intrarater ICCs of 0.88 and 0.93, interrater ICCs of 0.85 and 0.80, and interrater SEMs of 7.5 and 8.0 degrees.[139]

Scapular Dyskinesis Test:

The SDT was performed as described by McClure et al[38] Male subjects removed their shirts and female subjects were asked to wear halter tops to allow observation of the posterior thorax. The examiner observed the participants performing bilateral, weighted shoulder flexion and frontal plane abduction overhead as far as possible using the "thumbs-up" position. Subjects performed 5 repetitions of each motion, lifting to a 3-second count and then lowering to a 3-second count. The amount of weight used was standardized as 3 pounds for subjects weighing less than 150 pounds and 5 pounds for subjects weighing 150 pounds or more. Scapular dyskinesis may include the presence of winging (medial border and/or inferior angle prominence) and/or premature or excessive elevation or protraction, non-smooth or stuttering motion during arm elevation or lowering, or rapid downward rotation during arm lowering. The examiner qualified the motion observed using one of three possible ratings: normal motion, subtle dyskinesis, or obvious dyskinesis.[38] A reliability study examining the use of this test in overhead collegiate athletes resulted in satisfactory reliability for clinical use with examiners using the three rating options (percent agreement=75-82%, κ_w=0.48-0.61).[38] More recent work from Huang et al[92] reported moderate to substantial interrater reliability for a similar test of dyskinesis.

A validation study comparing the observed ratings of dyskinesis from the SDT to 3D electromagnetic kinematic measures of scapular motion has also been reported.[51] The sample was again comprised of overhead collegiate athletes and the raters again used the normal, subtle dyskinesis, or obvious dyskinesis classifications. The results supported validity for the SDT, as kinematic differences were found between the normal and obvious dyskinesis groups. Subjects with obvious dyskinesis demonstrated less scapular upward rotation, less clavicular elevation, and greater clavicular protraction. A very recent systematic review of the literature available regarding clinical examination of scapular position and function supports the use of the SDT with acceptable evidence for clinical use.[82]

Scapular Assistance Test:

The SAT was performed as described previously by Rabin et al.[26] The subject first elevated the involved arm in the scapular plane and rated the pain felt during movement on the 0-10 verbal numeric rating scale (VNRS). The examiner then manually assisted the scapula into upward rotation and posterior tilt by pushing superiorly and laterally on the inferior angle and pulling posteriorly on the superior aspect of the scapula as the patient elevates the arm. The test was documented as positive or negative, with a positive test resulting in a decrease in pain of 2 or more points on the VNRS during the SAT compared to active elevation of the arm without the application of the SAT.

Reliability of the SAT has been previously reported by Rabin et al,[26] with moderate interrater reliability in a sample of 46 subjects who presented to physical therapy for a variety of shoulder pathologies. The investigation utilized two examiners and compared the kappa values and percent agreement obtained from performance of the test in the scapular plane and sagittal plane. Slightly better reliability was found when the test was performed in the sagittal plane (κ=0.62, percent agreement=91% compared to κ=0.53, percent agreement=77%). This study did not examine the test validity and the authors recommended this as a step for future research.

Figure 3-1: Scapular Assistance Test

Scapula Reposition Test:

The SRT was performed as previously described by Tate et al.[25] The subject was asked to rate his/her pain with a provocative test (commonly arm elevation or resisted scaption) on the 0-10 verbal numeric rating scale (VNRS). This provocative test was then repeated with the scapula manually repositioned in the following manner: the examiner grasped the scapula with the fingers contacting the acromioclavicular joint anteriorly and thenar eminence contacting the scapular spine posteriorly, with the forearm placed obliquely across the posterior aspect of the scapula toward the inferior angle. A force was applied to the scapula to encourage posterior tilting and external rotation, and to approximate the scapula to the thorax. The subject then rated the pain felt while repeating the test with the manual repositioning using the 0-10 VNRS. The test was documented as positive or negative, with a positive test resulting in a decrease in pain of 2 or more points on the VNRS during the application of the SRT. Tate and colleagues[25] reported good reliability (ICC=0.964) with use of the SRT in a combination of symptomatic and healthy subjects. Again, validity of this test has not been addressed and remains a gap in the literature.

Figure 3-2: Scapula Reposition Test: A: for painful elevation, B: for painful resisted ER

Pilot testing was completed by the principal investigator prior to initiating data collection for this study. The data obtained during the pilot testing was used to examine the intrarater and interrater reliability of the methods utilized in the clinical examination. Reliability values were determined for the measures of scapular upward rotation and posterior tilt active and passive ROM, pectoralis minor length, and strength as measured using HHD in standard manual muscle test (MMT) positions for the middle trapezius, lower trapezius, and serratus anterior muscles.

Primary Dependent Variables:

For the variables described below, two trials were performed for each measurement during the baseline measures and one trial was performed for the post-treatment measures, with the exception of muscle strength which required two trials at both measurement periods. One trial was used for the post-treatment ROM measures in order to avoid introducing error by possibly stretching tissues or improving ROM through the performance of multiple trials. When more than one trial was completed, the mean of the trials was calculated and used for data analysis. The use of multiple trials allowed for the calculation of reliability, standard error of the measure (SEM), and minimal detectable change (MDC) for those measures.

Measurements of Scapular Range of Motion:

Measurements of scapular upward rotation and posterior tilt AROM and PROM were measured using a modified digital inclinometer (Pro 360, Baseline®, Fabrication Enterprises, White Plains, NY) during UE elevation in the scapular plane with the subject standing. The modification involved securing a platform to the bottom of the inclinometer which better accommodated the necessary scapular landmarks. The scapular plane was selected for this assessment as patients are typically more comfortable performing elevation in the scapular plane and previous literature reporting on these measures has tended to utilize this plane of motion.[18,39,40] Results from a systematic review indicated that elevation in the scapular plane is also most likely to demonstrate altered scapular kinematics.[87] The scapular plane was defined as 40 degrees anterior to the frontal plane[18,39] and was confirmed through a goniometric measure prior to asking the subject to elevate the arm.

Figure 3-3: Modified Baseline Digital Inclinometer

Scapular Upward Rotation AROM:

For the measurement of scapular upward rotation AROM, the subject started with the involved arm at the side of the body. The investigator confirmed the location of the scapular plane by placing the subject's arm at an angle 40 degrees anterior from the frontal plane as measured with a standard goniometer. The procedures used for measuring upward rotation of the scapula with a modified inclinometer during arm elevation have been described previously.[18,39,41] The digital inclinometer was zeroed on a horizontal surface and then placed along the scapular spine of the involved arm. The initial reading ("rest") from the inclinometer on the scapular spine with the arm at the side of the body was recorded. The subject was then instructed to elevate the arm in the scapular plane as high as he/she can go. The final reading ("end") from the inclinometer was then recorded at the end of the subject's maximal arm elevation. The total amount of scapular upward rotation ("total") was calculated as the change score by taking the difference between the final and initial readings. Downward rotation was recorded as negative values and upward rotation was recorded as positive values.

Scapular Posterior Tilt AROM:

For the measurement of scapular posterior tilt AROM, the subject again started with the involved arm at the side of the body. The investigator again confirmed the location of the scapular plane by placing the subject's arm at an angle 40 degrees anterior from the frontal plane as measured with a standard goniometer. The digital inclinometer was zeroed on a vertical surface and then placed vertically along the posterior surface of the medial border of the scapula, using the root of the scapular spine and the inferior angle of the scapula as landmarks as previously described.[40] The initial reading ("rest") from the inclinometer with the arm at the side of the body was recorded. The subject was then instructed to elevate the arm in the scapular plane as high as he/she can go. The final reading ("end") from the inclinometer was recorded at the end of the subject's maximal arm elevation. The total amount of scapular posterior tilt ("total") was calculated as the change score by taking the difference between the final and initial readings. Anterior tilt was recorded as negative values and posterior tilt was recorded as positive values.

Johnson et al[39] have previously reported good reliability (ICC=0.89-0.96) and validity (r=0.74-0.92) using an inclinometer placed over the scapular spine to measure upward rotation during elevation of the arm. The validity was established in that study by comparing the values obtained from the inclinometer to a magnetic tracking device. Additional work by Watson et al[41] also demonstrated good to excellent reliability (ICC=0.81-0.94) with this measure and an SEM of 5 degrees. Tucker and Ingram[140] also reported good to excellent intrarater reliability with ICC > 0.89 and SEM < 1.8 degrees. The systematic review from Larsen and colleagues[82] confirms the assessment of scapular upward rotation has acceptable evidence for clinical use.

Scibek & Carcia[40] recently reported on a technique to measure anterior-posterior tilt of the scapula. They compared measurements obtained from the inclinometer to those from an electromagnetic tracking system in 13 healthy college students. Their results supported moderate validity (r=0.63-0.86, p<0.01) for the use of the inclinometer. Additionally, they cited previous work by the primary investigator that revealed strong intrarater reliability (ICC=0.93-0.99) with this measurement technique.

Scapular Upward Rotation PROM:

Additional steps were made to examine PROM for scapular upward rotation and posterior tilt as well, which has not been reported previously to our knowledge. Measurements for scapular upward rotation PROM were made with the subject in standing. The subject started with the involved arm at the side of the body. The investigator confirmed the location of the scapular plane by placing the subject's arm at an angle 40 degrees anterior from the frontal plane as measured with a standard goniometer. The digital inclinometer was again zeroed on a horizontal surface and then placed along the scapular spine of the involved arm. The initial reading ("rest") from the inclinometer was recorded. The examiner then passively elevated the humerus in the scapular plane to end-range elevation, producing passive upward rotation of the scapula. The examiner moved the subject's arm through the full available elevation ROM passively for two consecutive trials. At the point of maximal passive arm elevation on the second repetition, the inclinometer was again placed along the scapular spine to obtain a measurement of upward rotation PROM ("end"). The total amount of scapular upward rotation ("total") PROM was calculated as the change score by taking the difference between the final and initial readings.

Scapular Posterior Tilt PROM:

Measurements for scapular posterior tilt PROM were also made with the subject standing. The investigator confirmed the location of the scapular plane by placing the subject's arm at an angle 40 degrees anterior from the frontal plane as measured with a standard goniometer. The digital inclinometer was now zeroed on a vertical surface and then placed vertically along the posterior surface of the medial border of the scapula, using the root of the scapular spine and the inferior angle of the scapula as landmarks as previously described.[40] The initial reading ("rest") from the inclinometer was recorded with the subject's arm at the side of the body. The examiner then passively elevated the humerus in the scapular plane to end-range elevation, producing passive posterior tilt of the scapula. The examiner moved the subject's arm through the full, available elevation ROM passively for two consecutive trials. At the point of maximal passive arm elevation on the second repetition, the inclinometer was again placed along the posterior surface of the medial border of the scapula to obtain a measurement of posterior tilt PROM ("end"). The total amount of scapular posterior tilt PROM ("total") was calculated as the change score by taking the difference between the final and initial readings.

Pectoralis Minor Muscle Length:

Assessment of pectoralis minor muscle length was performed as described previously by Borstad.[106] The pectoralis minor has the capability of limiting the amount of scapular posterior tilt and is commonly reported to influence scapular kinematics[103] and contribute to shoulder dysfunction. A tape measure was used to measure the linear distance in cm between the anterior-inferior edge of the 4th rib one finger width lateral to the sternum and the medial-inferior aspect of the coracoid process of the scapula. This measurement was completed while the subject was standing in their usual resting position.

The assessment of pectoralis minor muscle length has produced some difficulty in attempting to create a clinical measure with good reliability and validity. While a common method of measuring the distance from the posterolateral aspect of the acromion to the table with the subject in supine demonstrated good to excellent reliability (ICCs > 0.88),[24,104] it was also shown to have poor diagnostic accuracy and its use was therefore cautioned.[104,105] The technique described by Borstad[106] that was used in this study for the measurement of pectoralis minor muscle length produced ICCs of 0.86 and 0.82 with the use of a tape measure. The technique was also shown to be valid by comparing the results obtained to in vitro measures of pectoralis minor length in cadavers.[106] Additional studies have also reported good reliability using this technique with small modifications. One of those studies reported ICCs ranging from 0.87-0.93 in subjects with shoulder pain when performing the measurement with the subject in supine with elbows extended.[107] Another study reported ICCs of 0.98 and 0.99 using a device called the Palpation Meter to obtain the measurement in lieu of a caliper or tape measure as originally described.[108] This study also found good validity for this measure when compared to values obtained from an electromagnetic motion analysis system.[108]

Scapulothoracic Muscle Force:

Assessment of force generated in the MMT positions for the middle trapezius, lower trapezius, and serratus anterior was completed using a handheld dynamometer (HHD) (Hoggan microFET2, Salt Lake City, UT) with a “make test” as previously described.[114,116,117,141] The "make test" required the examiner to instruct the subject to slowly push into the HHD and increase their force production to a maximal level over a 5-second period of time.[141] The "make test" has generally demonstrated greater reliability over the "break test" for the performance of HHD.[119]

Figure 3-4: Hoggan microFET2 Handheld Dynamometer

Middle Trapezius Force:

The middle trapezius strength test was performed with the subject in prone and arm elevated to 90° of abduction with the elbow flexed 90° and fingers pointing down to the floor. The HHD was placed on the scapular spine, midway between the acromion and root of the spine and the resistance force was applied in a lateral direction.[117] For both the middle trapezius and lower trapezius strength assessments, the examiner stood on the side opposite the test limb.[141]

Figure 3-5: Middle Trapezius test position

Lower Trapezius Force:

The lower trapezius strength test was performed with the subject in prone and arm elevated to 140° of abduction.[116,117] The HHD was placed along the scapular spine, midway between the acromion and root of the spine. The resistance force through the HHD was applied in a superior and lateral direction.[117]

Figure 3-6: Lower Trapezius test position

Serratus Anterior Force:

The serratus anterior strength test was performed with the subject seated in a chair with feet flat on the floor, shoulder width apart. The shoulder was flexed to 120°, confirmed by a goniometer, with the thumb pointing upward.[114] The HHD was placed at the wrist, just proximal to the radial styloid process, and the subject was instructed to push up into the dynamometer so that arm elevation was resisted.[114] The examiner visually monitored for scapular winging during the test and stopped the test if winging is discovered. This method was selected over the supine test with force delivered through the long axis of the humerus to resist scapular protraction as construct validity has not been demonstrated for the test in supine.[117] An additional measurement was obtained for the subject's arm length to enable this force measure to be converted to a joint torque. The measure of subject arm length was made using a standard tape measure from the lateral tip of the acromion process to the ulnar styloid process with the elbow fully straightened and was recorded in cm.[25,27]

Figure 3-7: Serratus Anterior test position

Prior to maximal isometric testing of each muscle, a sub-maximal (50%) effort trial was performed to minimize learning effects.[27,114] Two maximal effort trials were performed for all tests with a 30-second rest between trials[27,114,116] and the average of the trials (recorded in kg) was used for data analysis.[117] Additionally, subject body weight in kg was recorded to allow for normalization of strength measures by dividing by subject body weight. Body weight has been identified as the most effective anthropometric measure for normalizing strength values.[142] Normalization of the strength measures allowed for comparison between individuals and groups. Pain was also recorded with all strength measures using the VNRS.

Measurement of scapulothoracic muscle strength, especially through the use of manual muscle tests (MMT), has typically created some difficulties in obtaining consistent results and has thus produced mixed levels of reliability and validity. Assessment through handheld dynamometry (HHD) seems to offer some improvements in reliability and validity over standard MMTs. The use of HHD for assessment of scapulothoracic muscle strength has demonstrated good intrarater reliability in two separate studies, with ICCs ranging from 0.75-0.99[116] and 0.89-0.96.[117] Both studies included subjects with shoulder dysfunction. A review of the literature by Kolber and Cleland in 2005[119] concluded that HHD was reliable and valid for the assessment of strength in healthy and impaired populations provided that a number of conditions are adhered to when testing. Michener et al[117] also examined the validity of HHD strength assessment by comparing the results from the muscle tests to information regarding muscle activation obtained through surface EMG. The results indicated high muscle activation for the upper trapezius and lower trapezius strength tests, but not the middle trapezius and serratus anterior strength tests.[117] A systematic review on this topic was published by Schrama et al in 2014[118] which concluded an inability to rely on strength measures obtained through HHD in patients with upper extremity disorders; however, their review of 54 publications included only 6 articles that examined any scapular muscle tests and just one of those articles[117] examined more than two scapular muscle tests. Therefore, that conclusion must be interpreted with caution. The authors also discussed that the more recently developed portable hand-held units, as will be used in this study, have shown promising results.[118] Finally, it should be noted that this conclusion conflicts with previous results that reported both intraexaminer and interexaminer reliability were good to excellent for HHD.[119]

Verbal Numeric Rating Scale (VNRS):

The verbal numeric rating scale (VNRS) was used for the participants to provide their self-reported pain during the physical examination. Participants were asked to rate their level of pain on a scale of 0 to 10, with 0 representing no pain and 10 representing the worst pain imaginable. When being used for upper extremity pain, the numeric rating scale has been reported to have an MDC of 3[99] and MCID of 2.17.[143] The test-retest reliability has demonstrated a range from 0.67-0.96.[99,144,145] The VNRS has been shown to have excellent reliability (ICC > 0.90) when used with an upper extremity orthopedic population.[146] This pain rating was particularly important to obtain during the SAT and SRT in order to determine whether the tests were positive or negative.

Penn Shoulder Score:

Self-reported pain, satisfaction, and function was assessed through use of the Penn Shoulder Score (PSS). The PSS is a 100-point shoulder-specific questionnaire consisting of 3 subscales of pain, satisfaction, and function (see Appendix F). The total maximum score of 100 points indicates high function, low pain, and high satisfaction with the shoulder.[147] The PSS has been shown to have excellent reliability with an ICC of 0.94, an SEM of 8.5 points, and MCID of 11.4 points.[147]

All examination findings were documented by the examiner, prohibiting the examiner from being blinded to the results of the examination. Participants were randomly allocated to one of three groups using a computer-generated number system. A randomized block design was used in order to equalize the number of participants in each group. The therapist and participants did not know the random allocation number (1=supine, 2=seated, 3=sham) as this was concealed in a folder until the baseline measures had been completed. Immediately following completion of the baseline measures, the examiner looked at the allocation number and each subject received the assigned intervention – either a seated cervicothoracic distraction thrust manipulation, a supine upper thoracic thrust manipulation, or a sham manipulation as previously described.[32-34,72] The manipulations were delivered to the upper-thoracic spine between the levels of C7-T4. The manipulations were performed two times, regardless of joint cavitation.

Thoracic Spine Thrust Manipulation:

The seated manipulation targeted the cervicothoracic junction with the patient sitting with fingers laced behind the neck. The examiner stood behind the patient and threaded his arms through the patient's arms and clasped his hands near the C7-T1 level. The examiner made contact with his chest against the patient's upper thoracic region to serve as a fulcrum. The patient was then instructed to take a deep breath, and upon exhalation the examiner applied a high-velocity, low-amplitude distraction thrust in a cephalad direction.[33,36]

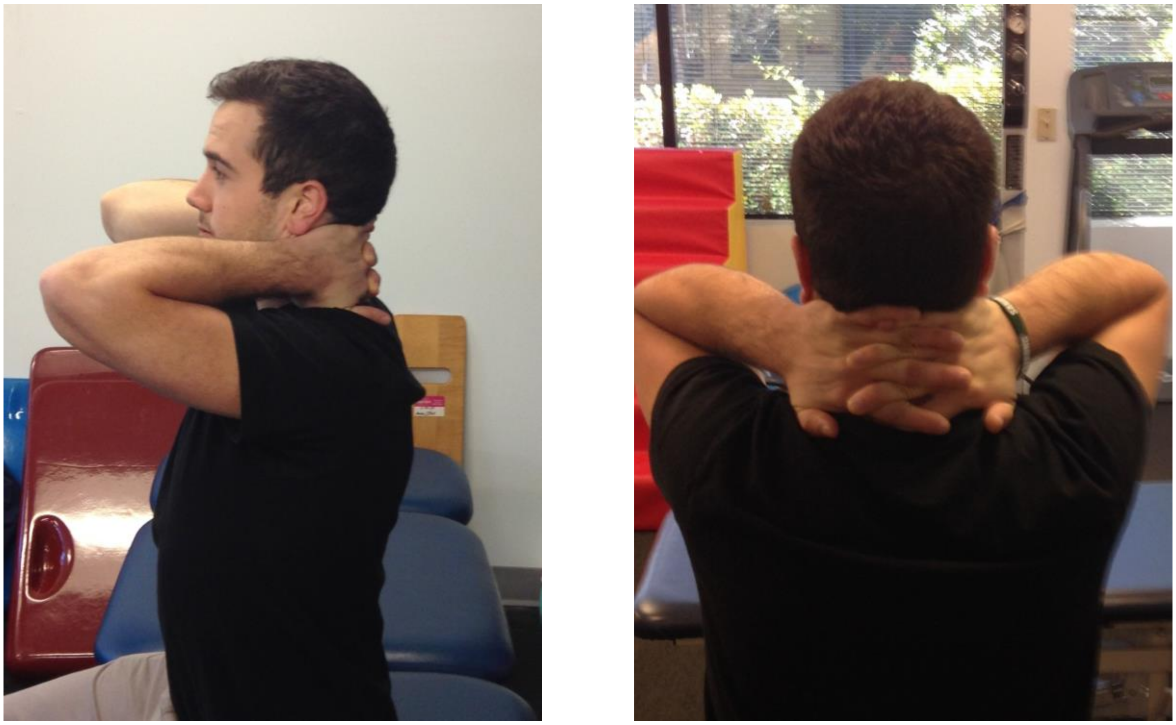


Figure 3-8: Patient set-up for Seated Cervicothoracic Distraction Manipulation

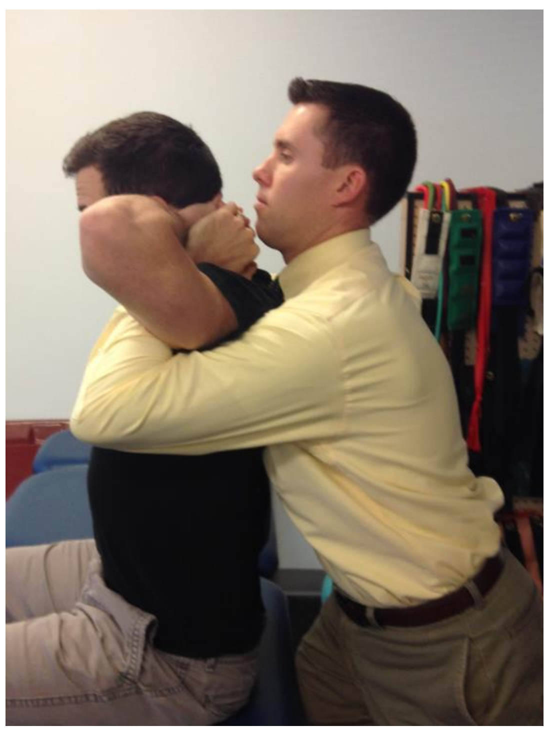


Figure 3-9: Seated Cervicothoracic Distraction Manipulation

The supine manipulation targeted the upper thoracic spine and was performed as previously described by Mintken et al.[35] The participant was asked to lace his or her fingers behind the neck and bring his or her elbows close together in front of the chest. If the participant could not do this, he or she was instructed to attempt to get the hands as close to the superior shoulders or lateral neck and elbows as close together in front of the chest as possible. The examiner placed one hand just below the targeted upper thoracic region (at either the T3 or T4 level) using a pistol grip or loose fist to make contact with both transverse processes of the T3 or T4 vertebrae. The examiner then used his body to push down through the patient's upper arms to provide a high-velocity, low-amplitude thrust in the anterior-to-posterior direction.[35]

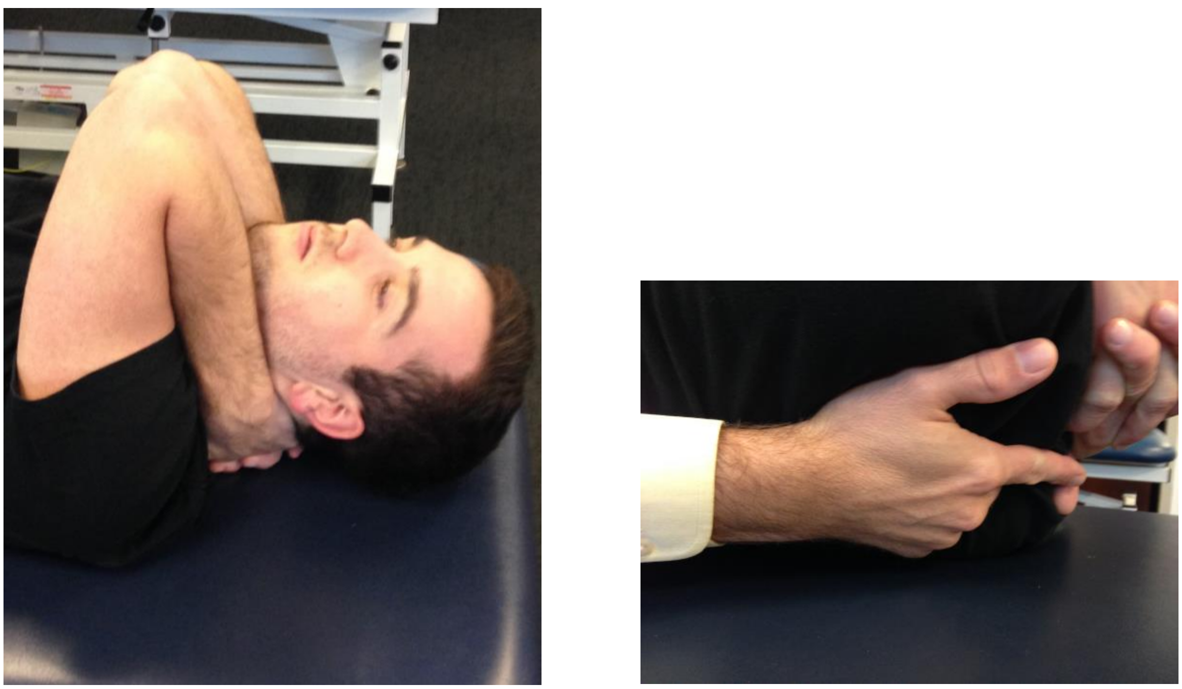


Figure 3-10: Patient set-up for Supine Upper Thoracic Manipulation

Figure 3-11: Supine Upper Thoracic Manipulation

The sham manipulation was performed with the patient and the examiner positioned in the same manner as for the seated manipulation, however the examiner applied only minimal pressure to maintain physical contact and “skin lock” with the patient.[36,148] The examiner then moved the patient through the same range of motion but delivered no manipulative thrust.[36] This sham was previously validated as a plausible active treatment.[148]

Following the delivery of the randomly assigned thoracic spine thrust manipulation technique or sham technique, all of the variables measured at baseline were immediately reassessed by the same examiner. The SDT, SAT, and SRT, as well as measurements of scapular upward rotation and posterior tilt active and passive ROM, scapulothoracic muscle strength, pectoralis minor muscle length, and pain were reassessed and recorded by the examiner.

Data Analysis

SPSS Version 23.0 (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY) was used for data analysis. Testing for the underlying assumptions necessary to utilize parametric tests was completed using the Kolmogorov-Smirnov test to test for a normal distribution of the data and Levene's test to test for homogeneity of variance.

There were several dependent variables collected in this study. The primary dependent variables of interest, representing continuous level data, included: scapular upward rotation AROM and PROM, scapular posterior tilt AROM and PROM, pectoralis minor muscle length, middle trapezius strength, lower trapezius strength, and serratus anterior strength collected through handheld dynamometry using standard MMT positions. Patient-reported pain using the verbal numeric rating scale (VNRS) and self-reported pain, satisfaction, and function using the Penn Shoulder Score (PSS), representing ordinal level data, were also collected.

There were two different sets of independent variables for the different research questions. For the first research aim, the independent variables were the results of the SAT (positive vs. negative) and the SRT (positive vs. negative). For the second research aim, the treatment delivered (supine manipulation, seated manipulation, or sham manipulation) represented the independent variable.

Pilot testing was completed by the principal investigator prior to commencing data collection for this study. The data obtained from the pilot testing was used to examine the intrarater and interrater reliability of the methods utilized in the clinical examination. Intrarater reliability for the principal investigator and interrater reliability for a group of four separate examiners was determined from the data collected during two separate pilot testing periods. Intrarater reliability for the principal investigator was also determined for all measurements collected from the current study through the completion of two trials for each measure. We were unable to assess the reliability of the SDT, SAT, and SRT in this study design as only one examiner was used for the data collection and that examiner could not easily be blinded when completing those tests due to the nature of the tests. Reliability was evaluated for measures of the dependent variables, including scapular upward rotation and posterior tilt active and passive ROM, pectoralis minor length, and strength as measured through HHD of the middle trapezius, lower trapezius, and serratus anterior muscles. Since all of these variables represent continuous level data, ICC (model 3,2) was used.

Descriptive statistics were determined for demographical information for all subjects. This data included age, gender, height, weight, BMI, duration of symptoms, hand dominance, involved shoulder (dominant or non-dominant), self-reported pain through the VNRS, and self-reported pain, satisfaction, and function through the PSS. Appropriate measures of central tendency and variability were calculated for the demographic characteristics of the subjects. The count and percentage of the total sample was determined for nominal data, including gender, hand dominance, and involved shoulder. Median and interquartile range was reported for ordinal data, including BMI, pain, and self-reported pain, satisfaction, and function. Mean and standard deviation will be reported for continuous level data, including age, height, weight, and duration of symptoms. Both mean and standard deviation as well as median and interquartile range (IQR) were reported for all values of scapular upward rotation AROM and PROM, scapular posterior tilt AROM and PROM, pectoralis minor muscle length, middle trapezius strength, lower trapezius strength, and serratus anterior strength at both measurement periods.

Both parametric and non-parametric analyses were run and the results were compared. The results of the non-parametric analyses have been reported due to the lack of a normal distribution on some measures and the ordinal nature of some measures.

The parametric analysis included one-way ANOVAs to assess for differences in the dependent variables prior to the delivery of the treatment between those with positive and negative results on the SAT and SRT. This analysis addressed the first research aim. Paired t-tests were used to assess each group for within-group differences in the dependent variables from baseline to post-treatment to determine if the provided treatment resulted in any significant changes from baseline. Mixed-model ANOVAs were used for the second research aim to assess for differences in the dependent variables between groups to determine if one intervention was more effective than the other. This involved a 3x2 mixed model ANOVA with group (supine manipulation, seated manipulation, or sham manipulation) and time (pre- and immediately post-treatment) as the factors. Comparisons of interest included main effects of each treatment on the dependent variables as well as interaction effects. Also, change scores for self-reported pain via the VNRS were assessed using the Mann-Whitney U test.

The non-parametric analyses for the first research aim utilized the Mann-Whitney U test to assess for any significant differences in the demographic variables between groups based on the results of the SAT (positive or negative) and SRT (positive or negative). Mann-Whitney U tests were also used to assess for differences in the dependent variables prior to the delivery of the treatment between those with positive and negative results on the SAT. The same analysis was run to examine for differences in the dependent variables between those with positive and negative results on the SRT. The Kruskal-Wallis test was used to assess for any significant differences in the demographic variables between groups based on the results of the SDT (normal, subtle, or obvious). Chi square test was used for nominal level demographic variables.

For the second research aim, the Kruskal-Wallis test was performed to assess for significant differences in the demographic variables between the three treatment groups (supine manipulation, seated manipulation, or sham manipulation). Chi square test was used for nominal level demographic variables. The Wilcoxon test was used to assess for significant within group differences in the dependent variables from baseline to post-intervention in each of the groups. The dependent variables of scapular kinematics and scapular plane humeral elevation AROM, scapulothoracic muscle strength, and pectoralis minor muscle length were then compared using the Kruskal-Wallis test to assess for differences between the three groups based on the treatment provided. Pairwise comparisons were examined for any significant findings that resulted from the Kruskal-Wallis. Pain, function, and satisfaction measures obtained from the Penn Shoulder Score were also compared using the Kruskal-Wallis test to assess for differences between the three treatment groups.

Specific Analysis for Research Aim 1

Mann-Whitney U tests were run to answer multiple questions surrounding Research Aim #1. Questions 1-3 involved running these tests while using the result on the SAT (positive or negative) as the factor.

For Question 1, the following baseline dependent variables were entered into the Mann-Whitney U test: mean UR AROM at rest, mean UR AROM at end-range elevation, mean UR AROM total motion, mean UR PROM at rest, mean UR PROM at end-range elevation, mean UR PROM total motion, mean PT AROM at rest, mean PTAROM at end-range elevation, mean PT AROM total motion, mean PT PROM at rest, mean PT PROM at end-range elevation, mean PT PROM total motion, and scapular plane elevation AROM.

For Question 2, the following baseline dependent variables were entered into the Mann-Whitney U test: mean normalized involved MT strength, mean normalized non-involved MT strength, mean normalized involved LT strength, mean normalized non-involved LT strength, mean normalized involved SA strength, mean normalized involved SA torque, mean normalized non-involved SA strength, and mean normalized non-involved SA torque.

For Question 3, mean pectoralis minor length and pectoralis minor index (PMI) were entered into the analysis.

Questions 4-6 involved running the same analyses as Questions 1-3, but now with the result of the SRT (positive or negative) as the factor.

For Question 4, the following baseline dependent variables were entered into the Mann-Whitney U test: mean UR AROM at rest, mean UR AROM at end-range elevation, mean UR AROM total motion, mean UR PROM at rest, mean UR PROM at end-range elevation, mean UR PROM total motion, mean PT AROM at rest, mean PTAROM at end-range elevation, mean PT AROM total motion, mean PT PROM at rest, mean PT PROM at end-range elevation, mean PT PROM total motion, and scapular plane elevation AROM.

For Question 5, the following baseline dependent variables were entered into the Mann-Whitney U test: mean normalized involved MT strength, mean normalized non-involved MT strength, mean normalized involved LT strength, mean normalized non-involved LT strength, mean normalized involved SA strength, mean normalized involved SA torque, mean normalized non-involved SA strength, and mean normalized non-involved SA torque.

For Question 6, mean pectoralis minor length and pectoralis minor index (PMI) were entered into the analysis.

Specific Analysis for Research Aim 2

For the second research aim, the Kruskal-Wallis test was performed to assess for significant differences in the baseline demographic variables between the three treatment groups (supine manipulation, seated manipulation, or sham manipulation). Wilcoxon tests were then run to examine for within-group differences from baseline to post-treatment in all 3 groups for the dependent variables of scapular motion, scapulothoracic muscle strength, and pectoralis minor length to determine if the intervention resulted in any significant changes from the baseline measures. Wilcoxon tests were also used to assess for within-group differences in pain, satisfaction, function, and total scores on the PSS from baseline to 48-hour follow-up in all 3 groups. Kruskal-Wallis tests were then run to assess for between-group differences in the dependent variables from baseline to the immediate post-treatment follow-up. For the variables of pain, satisfaction, function, and total scores obtained through the PSS, the Kruskal-Wallis test was used to assess the between-group differences from baseline to 48-hour follow-up.

For Question 1, a Kruskal-Wallis test was completed to examine for differences in scapular motion between the three groups from baseline to post-treatment. The results of the pairwise comparisons were examined for any significant results obtained from the Kruskal-Wallis.

For Question 2, a Kruskal-Wallis test was completed to examine for differences in scapulothoracic muscle strength between the three groups from baseline to post-treatment. The results of the pairwise comparisons were examined for any significant results obtained from the Kruskal-Wallis.

For Question 3, a Kruskal-Wallis test was completed to examine for differences in pectoralis minor length between the three groups from baseline to post-treatment. The results of the pairwise comparisons were examined for any significant results obtained from the Kruskal-Wallis.

For Question 4, measures of pain from the VNRS and Penn Shoulder Score (PSS), as well as measures of function, satisfaction, and total score obtained from the PSS were compared using a Kruskal-Wallis test to assess for differences between the three treatment groups from baseline to the 48-hour follow-up.

CHAPTER 4: RESULTS

Introduction

There were two primary research aims in this study, both of which were completed during a single session. The first was to assess for differences in baseline measures of scapular motion, scapulothoracic muscle force, and pectoralis minor length between those who tested positive vs. negative on two independent symptom modification tests for the scapula previously described in the literature – the Scapular Assistance Test (SAT) and Scapula Reposition Test (SRT). The second research aim involved determining whether those baseline variables changed immediately following the delivery of a randomized manipulation technique targeting the upper thoracic spine. To achieve both research aims, baseline measures were obtained, the assigned intervention was performed, and follow-up measures were completed immediately after the intervention. Additional outcomes surrounding self-reported pain, satisfaction, and function were obtained through completion of the Penn Shoulder Score 48 hours after the study session.

Data Analysis

All statistical analyses were performed using SPSS Version 23.0 (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.) with the significance level set at $\alpha = 0.05$. The Kolmogorov-Smirnov test was used to assess for a normal distribution of the data in order to determine if parametric analyses could be utilized. The results of the Kolmogorov-Smirnov test showed that all of the kinematic variables had a normal distribution with $p > .05$ with the exception of the measures for baseline and post-intervention scapular plane elevation AROM. The baseline measures of mean normalized involved middle trapezius strength, mean normalized non-involved middle trapezius strength, and mean normalized non-involved serratus anterior torque were not normally distributed. All of the post-intervention mean normalized strength variables were found to have a normal distribution, with the exception of the non-involved serratus anterior torque. The post-intervention measures of pectoralis minor muscle length and change in pectoralis minor muscle length were also not normally distributed. The function subscale of the PSS at baseline and the pain and satisfaction subscales of the PSS post-intervention were also not normally distributed. As a result of this information, and with the additional consideration of the sample size (n=20) in each group, a decision was made to use all non-parametric analyses.

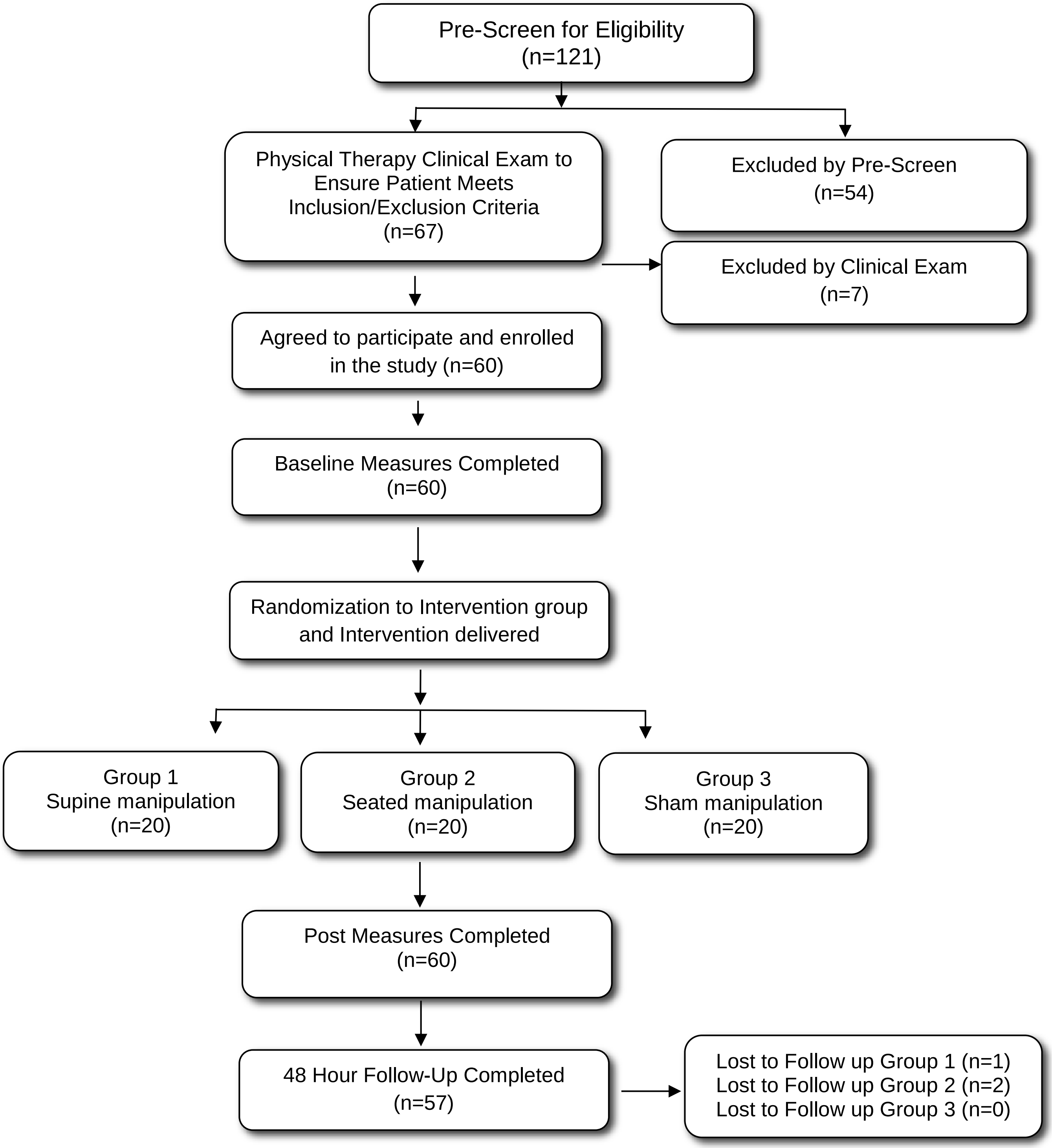
For the first research aim, the Mann-Whitney U test was performed to assess for any significant differences in the demographic variables between groups based on the results of the SAT (positive or negative) and SRT (positive or negative). The Chi-square test was used for nominal level demographic variables. The Kruskal-Wallis test was used to assess for any significant differences in the demographic variables between groups based on the results of the SDT (normal, subtle, or obvious); the Mann-Whitney U test was used when the SDT was dichotomized into normal vs. obvious. Mann-Whitney U tests were then used to assess for differences in the dependent variables at baseline between those with positive and negative results on the SAT. The same analysis was run to examine for differences in the dependent variables at baseline between those with positive and negative results on the SRT.

For the second research aim, the Kruskal-Wallis test was performed to assess for significant differences in the demographic variables between the three treatment groups (supine manipulation, seated manipulation, or sham manipulation). The Chi-square test was used for nominal level demographic variables. The Wilcoxon test was then used to assess for significant within group differences in the dependent variables from baseline to post-intervention in each of the groups. The dependent variables of scapular kinematics and scapular plane humeral elevation AROM, scapulothoracic muscle force, pectoralis minor muscle length, and pain on the VNRS were then compared using the Kruskal-Wallis test to assess for differences between the three groups based on the treatment provided. Pairwise comparisons were examined for any significant findings that resulted from the Kruskal-Wallis. Pain, function, satisfaction, and total scores obtained from the Penn Shoulder Score at the 48-hour follow-up were also compared using the Kruskal-Wallis test to assess for differences between the three treatment groups.

Subjects

One hundred twenty-one individuals were screened for eligibility. Fifty-four individuals were excluded by the pre-screen for reasons of pain > 6 months (n=25), concurrent neck pain (n=8), age > 65 (n=6), history of instability (n=5), history of shoulder surgery (n=4), history of rotator cuff tear (n=1), history of labral tear (n=1), history of shoulder fracture (n=1), history of neck surgery (n=1), history of cancer (n=1), and history of systemic arthritis (n=1). An additional 7 individuals were excluded based on the clinical exam due to not meeting the requirement for 3 of the 6 criteria used to make the diagnosis of SPS (n=4), having referred pain from the neck (n=1), signs of a rotator cuff tear (n=1), and signs of instability (n=1). Sixty participants met the necessary inclusion and exclusion criteria, provided informed consent and were enrolled in the study from February 2016 – October 2016. The subject flow diagram can be seen in **Figure 4-1**.

Figure 4-1: Flow of the Study



Three participants (2 in the seated manipulation group and 1 in the supine manipulation group) did not return the 48-hour follow-up information which resulted in a decision to run that analysis two different ways – one analysis carried those individuals' baseline measures forward to the 48-hour follow-up measures and the other analysis excluded those 3 participants.

Study participants had a mean age of 36.6±14.9 years with shoulder pain for a mean duration of 9.7±6.4 weeks. Thirty-seven participants (61.7%) were male and 53 (88.3%) were right-hand dominant. The involved shoulder was the dominant shoulder in 33 (55.0%) subjects. The pain values obtained on the NPRS resulted in median scores of 3/10 at the present time, 7/10 at worst, and 0/10 at best. The median score for baseline level of function as scored on the PSS was 48.0 out of a maximum score of 60. Descriptive statistics were computed for the demographic variables of the sample and are shown in **Table 4-1** below.

Table 4-1.
Demographic Characteristics of the Participants

Variable	Participants
Age (yrs)	36.6 (14.9)
Height (m)	1.73 (0.10)
Weight (kg)	81.4 (18.0)
BMI (kg/m^2)	27.2 (5.2)
Duration (weeks)	9.7 (6.4)
Sex (male)	37 (61.7)
Hand dominance (R)	53 (88.3)
Dominant shoulder involved	33 (55.0)
NPRS	
Current	3.0 (1.0, 4.0)
Worst	7.0 (6.0, 8.0)
Best	0.0 (0.0, 2.0)
PSS (at baseline)	
Pain score	20.0 (17.0, 23.0)
Satisfaction score	4.5 (2.0, 6.8)
Function score	48.0 (41.2, 51.2)
Total score	71.6 (62.2, 77.2)

Nominal values are expressed as number (%); ordinal values are expressed as median (IQR); continuous variables are expressed as mean (SD)
BMI = body mass index, NPRS = numeric pain rating scale, PSS = Penn Shoulder Score

Research Aim 1 Questions

1. Are there differences in scapular upward rotation (UR) and/or posterior tilt (PT) motion during maximal arm elevation in patients with SPS who test positive vs. negative on the SAT?

2. Are there differences in force generated with manual muscle test positions for the middle trapezius (MT), lower trapezius (LT), and/or serratus anterior (SA) muscles in patients with SPS who test positive vs. negative on the SAT?

3. Are there differences in length of the pectoralis minor muscle in patients with SPS who test positive vs. negative on the SAT?

4. Are there differences in scapular upward rotation (UR) and/or posterior tilt (PT) motion during maximal arm elevation in patients with SPS who test positive vs. negative on the SRT?

5. Are there differences in force generated with manual muscle test positions for the middle trapezius (MT), lower trapezius (LT), and/or serratus anterior (SA) muscles in patients with SPS who test positive vs. negative on the SRT?

6. Are there differences in length of the pectoralis minor muscle in patients with SPS who test positive vs. negative on the SRT?

Results for Research Aim 1

During baseline testing, 25 participants (41.7%) had a positive result on the SAT and 17 participants (28.3%) had a positive result on the SRT. Additionally, the results of the SDT at baseline revealed 6 (10.0%) with normal motion, 28 (46.7%) with subtle dyskinesis, and 26 (43.3%) with obvious dyskinesis on the involved side.

There were no significant differences in baseline demographic variables between the groups formed by the result of the SAT (positive or negative) (**Table 4-2**). There was a significant difference in age ($p = .025$) between those who tested positive vs. negative on the SRT, with those who tested positive tending to be younger (29.9±12.7) than those who were negative (39.2±15.0) (**Table 4-3**).

Additionally, the baseline variables were analyzed based on the results of the SDT. There were significant differences in body weight and self-reported pain level at worst (NPRS) between the 3 groups based on the results of the SDT. Specifically, significant differences in body weight were found between those with normal motion and subtle dyskinesis ($p = .026$) and between those with subtle and obvious dyskinesis ($p = .049$), with those in the normal group and obvious dyskinesis group weighing more. Significant differences existed in self-reported level of pain at worst between those with normal motion and obvious dyskinesis ($p = .020$) and between those with subtle and obvious dyskinesis ($p = .035$), with the obvious dyskinesis group reporting greater pain. When the SDT result was dichotomized, significant differences existed in age ($p = .028$) and pain level at worst ($p = .003$) between the normal and obvious dyskinesis groups.

Table 4-2.
Participant Characteristics by Group Based on Result of Scapular Assistance Test

Variable	**(+) SAT (n=25)**	**(-) SAT (n=35)**
Age (yrs)	34.0 (15.3)	38.4 (14.6)
Height (m)	1.71 (0.10)	1.74 (0.10)
Weight (kg)	77.2 (18.7)	84.4 (17.1)
BMI (kg/m^2)	26.2 (5.5)	27.9 (4.8)
Duration (weeks)	9.7 (7.1)	9.7 (5.9)
Sex (male)	12 (48)	25 (71.4)
Hand dominance (R)	22 (88)	31 (88.6)
Dominant shoulder involved	14 (56)	18 (51.4)
SRT result	Positive = 10 (40) Negative = 15 (60)	Positive = 7 (20) Negative = 28 (80)
SDT result	Normal = 1 (4) Subtle = 14 (56) Obvious = 10 (40)	Normal = 5 (14.3) Subtle = 14 (40) Obvious = 16 (45.7)
NPRS at baseline		
Current	3.0 (1.5, 4.0)	2.0 (0.0, 4.0)
Worst	7.0 (6.0, 8.0)	6.0 (5.0, 8.0)
Best	1.0 (0.0, 3.0)	0.0 (0.0, 1.0)
PSS at baseline		
Pain score	19.0 (17.0, 21.0)	20.0 (17.0, 24.0)
Satisfaction score	5.0 (3.0, 6.5)	4.0 (2.0, 7.0)
Function score	46.0 (39.5, 51.0)	49.0 (43.0, 52.0)
Total score	69.0 (62.4, 76.4)	73.0 (62.0, 80.0)

Nominal values are expressed as number (%); ordinal values are expressed as median (IQR); continuous variables are expressed as mean (SD)
BMI = body mass index, SRT = scapula reposition test, SDT = scapular dyskinesis test, NPRS = numeric pain rating scale, PSS = Penn Shoulder Score

Table 4-3.
Participant Characteristics by Group Based on Result of Scapula Reposition Test

Variable	**(+) SRT (n=17)**	**(-) SRT (n=43)**
Age (yrs)	29.9 (12.7)*	39.2 (15.0)*
Height (m)	1.75 (0.09)	1.72 (0.10)
Weight (kg)	79.6 (16.2)	82.1 (18.8)
BMI (kg/m^2)	25.9 (4.5)	27.7 (5.3)
Duration (weeks)	10.0 (6.8)	9.6 (6.3)
Sex (male)	12 (70.6)	25 (58.1)
Hand dominance (R)	14 (82.4)	39 (90.7)
Dominant shoulder involved	10 (58.8)	22 (51.2)
SAT result	Positive = 10 (58.8) Negative = 7 (41.2)	Positive = 15 (34.9) Negative = 28 (65.1)
SDT result	Normal = 2 (11.8) Subtle = 6 (35.3) Obvious = 9 (52.9)	Normal = 4 (9.3) Subtle = 22 (51.2) Obvious = 17 (39.5)
NPRS at baseline		
Current	3.0 (2.0, 4.5)	2.0 (1.0, 4.0)
Worst	7.0 (6.0, 8.0)	7.0 (5.0, 8.0)
Best	1.0 (0.0, 2.5)	0.0 (0.0, 2.0)
PSS at baseline		
Pain score	18.0 (15.0, 20.5)	20.0 (18.0, 24.0)
Satisfaction score	3.0 (2.0, 7.5)	5.0 (2.0, 6.0)
Function score	46.0 (38.4, 49.0)	49.0 (42.0, 51.6)
Total score	66.0 (58.5, 74.0)	73.0 (63.0, 78.5)

Nominal values are expressed as number (%); ordinal values are expressed as median (IQR); continuous variables are expressed as mean (SD)
BMI = body mass index, SAT = scapular assistance test, SDT = scapular dyskinesis test, NPRS = numeric pain rating scale, PSS = Penn Shoulder Score
*p = .025

Multiple measures for the dependent variables were completed by a single examiner at baseline to enable determination of the intrarater reliability, standard error of the measure (SEM), and minimal detectable change (MDC) of the measures. Multiple measurements were also obtained for the scapulothoracic muscle force, normalized to body weight, generated with manual muscle tests post-intervention. Intraclass correlation coefficients (ICC), SEM_{90} ($SEM_{90}=SD\sqrt{(1-ICC)}*1.64$), and MDC_{90} ($MDC_{90}=SEM_{90}*1.41$) for the measures performed in this study are summarized in **Table 4-4**.

Table 4-4.
Reliability, SEM, and MDC of Measures

Measure	**ICC (95% CI)**	**SEM_{90}**	**MDC_{90}**
Motion (degrees):			
UR AROM rest	0.97 (0.94-0.98)	1.61°	2.28°
UR AROM end	0.96 (0.93-0.97)	3.75°	5.29°
UR AROM total	0.94 (0.88-0.96)	4.30°	6.06°
UR PROM rest	0.97 (0.95-0.98)	1.66°	2.34°
UR PROM end	0.95 (0.91-0.97)	2.50°	3.53°
UR PROM total	0.92 (0.86-0.95)	3.23°	4.55°
PT AROM rest	0.95 (0.92-0.97)	2.22°	3.14°
PT AROM end	0.95 (0.92-0.97)	3.23°	4.55°
PT AROM total	0.92 (0.86-0.95)	3.92°	5.52°
PT PROM rest	0.96 (0.93-0.98)	1.95°	2.74°
PT PROM end	0.95 (0.91-0.97)	2.70°	3.81°
PT PROM total	0.90 (0.82-0.94)	3.38°	4.77°
Baseline Force (% body weight or Nm/kg):			
Normalized Involved MT strength	0.94 (0.84-0.97)	1.36%	1.92%
Normalized Non-involved MT strength	0.94 (0.87-0.96)	1.46%	2.06%
Normalized Involved LT strength	0.95 (0.90-0.97)	1.03%	1.45%
Normalized Non-involved LT strength	0.92 (0.82-0.96)	1.12%	1.58%
Normalized Involved SA strength	0.96 (0.90-0.98)	0.98%	1.39%
Normalized Non-involved SA strength	0.97 (0.95-0.98)	0.79%	1.11%
Normalized Involved SA torque	0.96 (0.91-0.98)	0.054 Nm/kg	0.076 Nm/kg
Normalized Non-involved SA torque	0.97 (0.95-0.98)	0.043 Nm/kg	0.061 Nm/kg
Post-Intervention Force (% body weight or Nm/kg):			
Normalized Involved MT strength	0.97 (0.88-0.99)	1.02%	1.43%
Normalized Non-involved MT strength	0.97 (0.94-0.98)	1.11%	1.57%
Normalized Involved LT strength	0.97 (0.95-0.98)	0.84%	1.18%
Normalized Non-involved LT strength	0.95 (0.91-0.97)	1.19%	1.68%
Normalized Involved SA strength	0.96 (0.94-0.98)	0.92%	1.30%
Normalized Non-involved SA strength	0.96 (0.94-0.98)	0.90%	1.26%
Normalized Involved SA torque	0.96 (0.94-0.98)	0.049 Nm/kg	0.069 Nm/kg
Normalized Non-involved SA torque	0.96 (0.94-0.98)	0.049 Nm/kg	0.070 Nm/kg
Muscle length (cm):			
Pectoralis minor muscle length	0.99 (0.99-1.00)	0.27 cm	0.38 cm

UR = upward rotation, PT = posterior tilt, AROM = active range of motion, PROM = passive range of motion, MT = middle trapezius, LT = lower trapezius, SA = serratus anterior

Question 1:

No significant differences were found in active or passive scapular motions of UR and PT between those who tested positive and those who tested negative on the SAT. Of the motions assessed, total scapular UR PROM was the closest to approaching significance with p = .066. Both the mean (SD) and median (IQR) values for both groups for the measures examined are presented in **Table 4-5** and boxplots can be seen in **Figure 4-2**.

Question 2:

Although there were significant differences between the involved and non-involved sides in baseline mean normalized force for the MT, LT, and SA muscles in both groups (all p values ≤ .001), there were no significant differences in any of those strength measures between those who tested positive compared to those who tested negative on the SAT. Of the muscles assessed, the mean normalized torque for the non-involved serratus anterior was the closest to approaching significance with p = .060. Rather than seeing a difference in strength that was associated with the result of the SAT, both groups demonstrated a decreased ability to produce force from the involved shoulder. Median pain levels reported on the VNRS during the muscle tests were as follows: 3.0 for MT, 4.0 for LT, and 2.0 for SA on the involved side (0.0 on the non-involved side) for those with positive SAT and 2.0 for MT, 3.0 for LT, and 2.0 for SA on the involved side (0.0 on the non-involved side) for those with negative SAT. Both the mean (SD) and median (IQR) values for both groups for the measures examined can be seen in **Table 4-5** and boxplots can be seen in **Figure 4-3**.

Question 3:

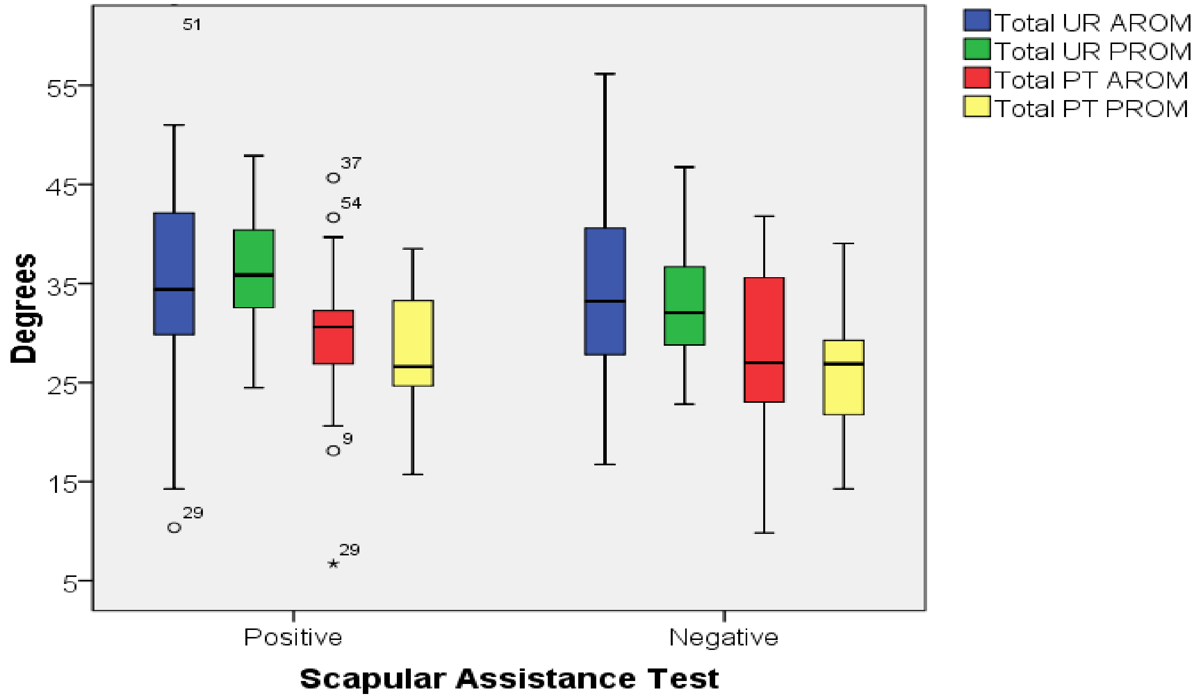
Significant differences were found in the length of the pectoralis minor muscle (p = .023) and pectoralis minor index (PMI) (p = .023), with those who tested positive on the SAT having decreased muscle length and lower PMI scores than those who tested negative. Both the mean (SD) and median (IQR) values for both groups can be seen in **Table 4-5** and boxplots can be seen in **Figure 4-4**.

Table 4-5.
Baseline Measures for Positive and Negative Results on Scapular Assistance Test

	(+) SAT (n=25)		(-) SAT (n=35)	
Variable	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
UR AROM rest	-1.12 (5.03)	-0.35 (-4.12, 2.12)	-0.57 (1.00)	-1.65 (-4.80, 4.85)
UR AROM end	33.67 (13.38)	35.55 (26.65, 42.22)	33.41 (9.01)	33.50 (26.25, 37.00)
UR AROM total	34.79 (11.78)	34.40 (28.78, 42.58)	33.98 (8.82)	33.20 (27.15, 40.80)
UR PROM rest	-1.26 (4.82)	-0.85 (-3.85, 1.75)	-0.75 (6.57)	-1.75 (-7.10, 5.20)
UR PROM end	34.81 (6.91)	35.10 (30.28, 39.20)	32.17 (6.26)	32.25 (28.00, 36.25)
UR PROM total	36.07 (6.55)	35.85 (32.20, 40.50)	32.92 (6.35)	32.05 (28.55, 36.75)
PT AROM rest	-15.27 (5.46)	-15.60 (-19.4, -12.68)	-15.23 (6.51)	-14.35 (-20.75, -10.70)
PT AROM end	14.04 (9.13)	13.10 (8.78, 19.85)	12.54 (8.99)	12.35 (6.50, 17.25)
PT AROM total	29.31 (7.94)	30.60 (25.02, 32.60)	27.77 (7.97)	27.00 (23.00, 35.75)
PT PROM rest	-14.58 (5.33)	-16.10 (-17.75, -11.25)	-14.90 (6.35)	-15.25 (-19.80, -9.65)
PT PROM end	13.06 (6.59)	13.75 (9.08, 17.02)	11.03 (7.12)	10.75 (5.35, 15.80)
PT PROM total	27.63 (6.01)	26.60 (23.72, 33.28)	25.93 (6.30)	26.90 (21.15, 29.30)
Scapular plane elevation AROM	152.20 (18.38)	155.00 (145.00, 165.00)	156.57 (12.82)	155.00 (150.00, 165.00)
Involved MT*	5.67 (2.34)	5.10 (3.88, 7.25)	7.19 (2.92)	6.45 (5.25, 9.10)
Normalized	7.6% (3.0%)	7.2% (5.3%, 10.4%)	8.7% (3.4%)	7.7% (6.3%, 10.5%)
Non-involved MT	7.37 (2.83)	7.10 (5.08, 9.02)	8.60 (2.97)	8.15 (6.95, 10.40)
Normalized	9.8% (3.7%)	9.3% (7.5%, 11.4%)	10.3% (3.2%)	9.9% (7.9%, 11.7%)
Involved LT	4.86 (2.24)	4.85 (2.90, 6.70)	5.18 (2.02)	4.15 (3.75, 6.45)
Normalized	6.6% (3.1%)	6.5% (3.4%, 9.1%)	6.2% (2.4%)	5.9% (4.4%, 7.3%)
Non-involved LT*	5.89 (1.58)	6.10 (4.58, 7.12)	7.05 (2.19)	7.25 (5.65, 8.35)
Normalized	7.9% (2.4%)	8.2% (6.3%, 10.1%)	8.4% (2.4%)	7.8% (7.0%, 10.2%)
Involved SA	4.93 (2.16)	4.55 (3.10, 6.60)	6.06 (2.46)	5.45 (4.40, 7.30)
Normalized	6.5% (2.8%)	6.1% (4.5%, 8.8%)	7.3% (2.8%)	7.0% (5.2 %, 9.3%)
Involved SA torque	26.93 (12.95)	22.76 (15.73, 36.10)	33.49 (13.95)	31.02 (23.78, 41.32)
Normalized (Nm/kg)	0.35 (0.16)	0.34 (0.23, 0.43)	0.40 (0.15)	0.39 (0.28, 0.48)
Non-involved SA*	5.85 (2.20)	5.20 (4.22, 7.68)	7.59 (2.73)	6.90 (5.35, 9.10)
Normalized	7.7% (2.7%)	7.9% (5.4%, 9.5%)	9.1% (2.9%)	8.8% (6.8, 11.3%)
Non-involved SA torque*	31.93 (13.71)	27.55 (21.71, 40.28)	41.82 (15.78)	37.57 (28.54, 54.74)
Normalized (Nm/kg)	0.42 (0.16)	0.40 (0.28, 0.50)	0.50 (0.16)	0.47 (0.36, 0.61)
Pectoralis minor length*	15.20 (1.98)	14.50 (13.80, 16.60)	16.38 (2.09)	16.00 (14.85, 17.70)
PMI*	8.86 (0.87)	8.75 (8.32, 9.28)	9.43 (1.00)	9.46 (8.78, 10.14)

Values expressed are mean (SD) and median (IQR)
ROM values expressed in degrees; strength values expressed in kg; normalized strength values expressed as % body weight; torque values expressed in N*m; length measures expressed in cm
UR = upward rotation, PT = posterior tilt, AROM = active range of motion, PROM = passive range of motion, MT = middle trapezius, LT = lower trapezius, SA = serratus anterior, PMI = pectoralis minor index
*p value < .05

Figure 4-2.
Scapular Kinematic Values with Maximal Arm Elevation by SAT Result



UR=upward rotation, PT=posterior tilt, AROM=active range of motion, PROM=passive range of motion

Figure 4-3.
Normalized Strength Values by SAT Result

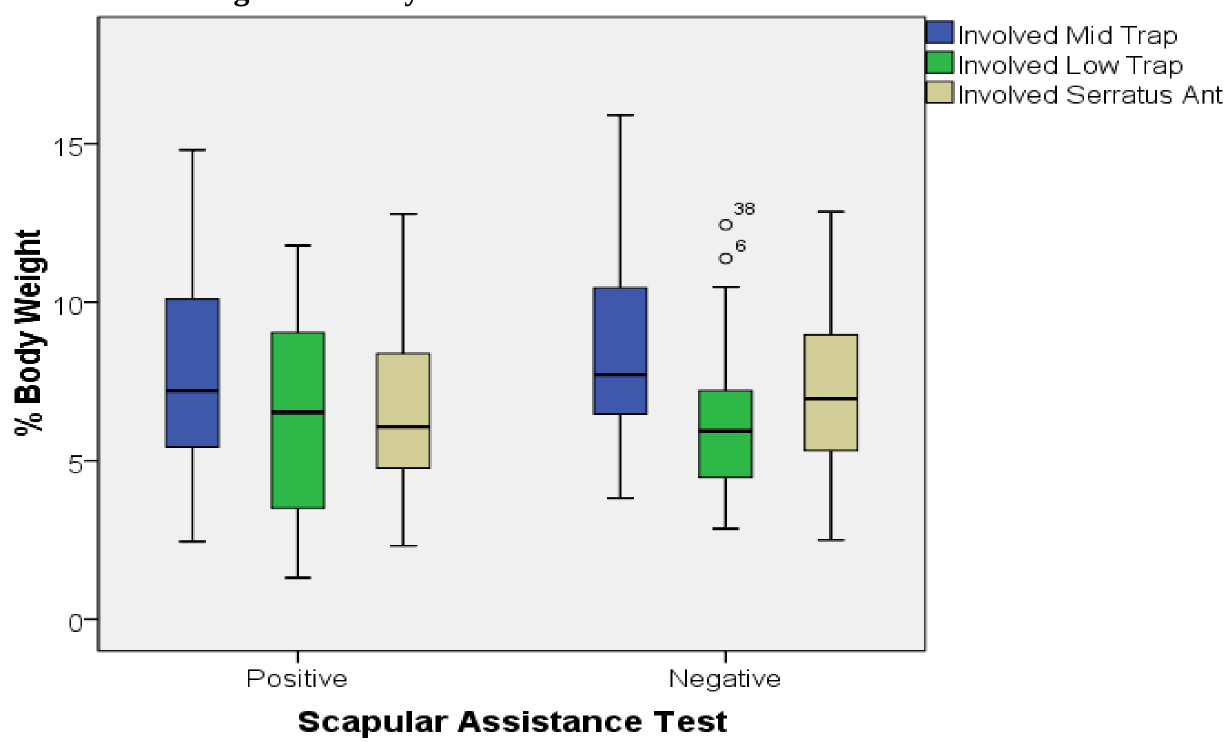
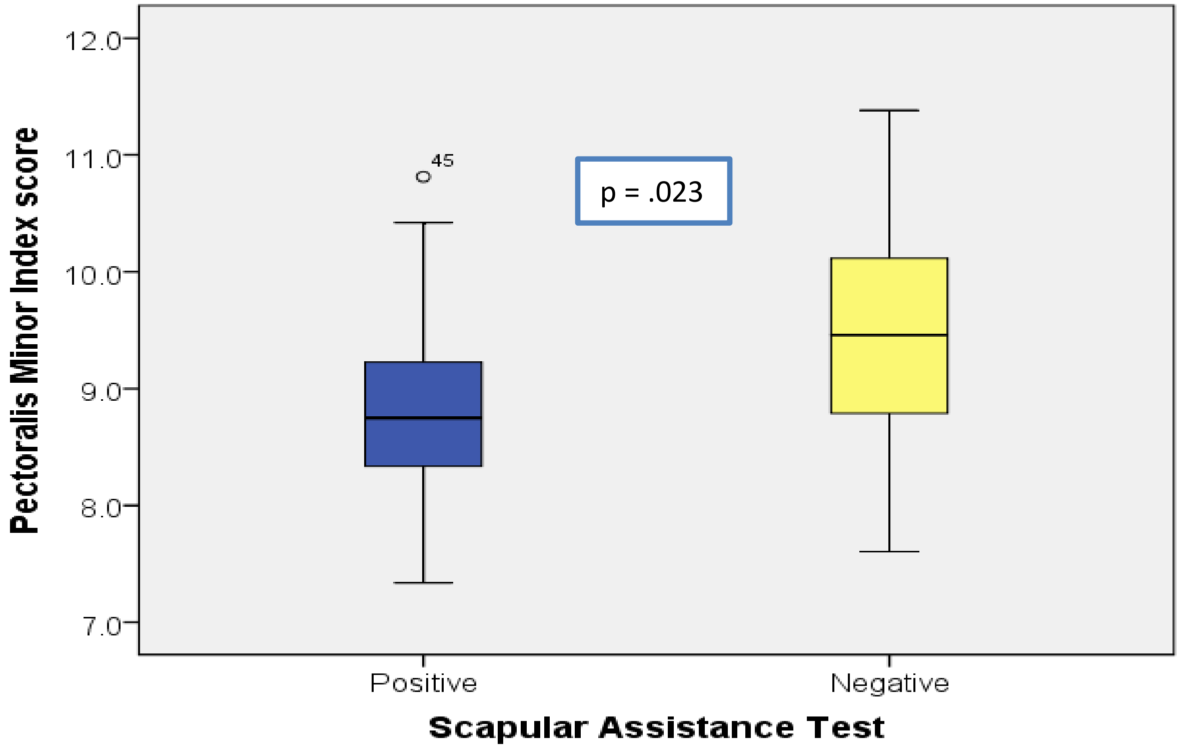


Figure 4-4.
Pectoralis Minor Index Score by SAT Result



Question 4:

No significant differences were found in scapular motion between those who tested positive and those who tested negative on the SRT. Of the motions examined, end-range scapular UR PROM and total scapular UR PROM were closest to approaching significance with P-values of .063 and .069, respectively. The median differences between those with positive and negative results on the SRT were 3.5° for end-range UR PROM and 5.3° for total UR PROM, both favoring those with negative results and both of which meet or exceed the MDC for those measures. The mean (SD) and median (IQR) values for both groups for the measures examined can be seen in **Table 4-6** and boxplots can be seen in **Figure 4-5**.

Question 5:

Although there were significant differences between the involved and non-involved sides in baseline mean normalized force for the MT, LT, and SA muscles in both groups (all P values $\leq .013$), there were no significant differences in any of those strength measures between those who tested positive compared to those who tested negative on the SRT. Rather than seeing a difference in strength that was associated with the result of the SRT, both groups demonstrated a decreased ability to produce force from the involved shoulder. Median pain levels reported on the VNRS during the muscle tests were as follows: 3.0 for MT, 4.0 for LT, and 2.0 for SA on the involved side (0.0 on the non-involved side) for those with positive SAT and 2.0 for MT, 3.0 for LT, and 2.0 for SA on the involved side (0.0 on the non-involved side) for those with negative SAT. Both the mean (SD) and median (IQR) values for both groups for the measures examined can be seen in **Table 4-6** and boxplots can be seen in **Figure 4-6**.

Question 6:

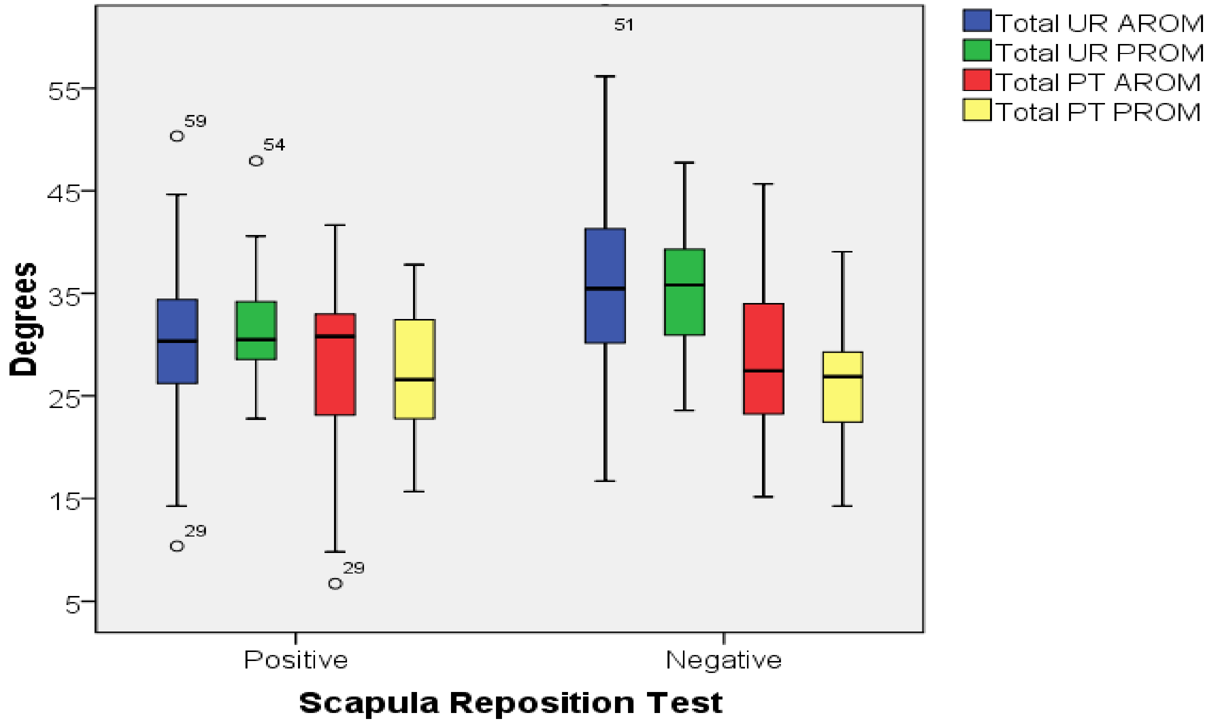
No significant differences were found in pectoralis minor muscle length or pectoralis minor index (PMI) between those who tested positive and those who tested negative on the SRT. The mean (SD) and median (IQR) values for both groups can be seen in **Table 4-6** and boxplots can be seen in **Figure 4-7**.

Table 4-6.
Baseline Measures for Positive and Negative Results on Scapula Reposition Test

	(+) SRT (n=17)		(-) SRT (n=43)	
Variable	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
UR AROM rest	-1.07 (4.45)	-0.30 (-3.98, 2.90)	-0.69 (5.93)	-1.40 (-4.75, 4.85)
UR AROM end	29.74 (12.05)	28.50 (26.28, 35.58)	35.02 (10.23)	35.55 (28.75, 41.65)
UR AROM total	30.81 (10.31)	30.35 (25.10, 37.60)	35.71 (9.74)	35.45 (29.85, 41.30)
UR PROM rest	-1.48 (5.13)	-2.00 (-4.60, 2.25)	-0.76 (6.18)	-1.00 (-4.55, 3.10)
UR PROM end	30.46 (6.57)	30.10 (25.42, 35.38)	34.38 (6.36)	33.60 (31.00, 38.75)
UR PROM total	31.93 (6.73)	30.50 (27.85, 36.20)	35.14 (6.35)	35.80 (30.70, 39.40)
PT AROM rest	-16.46 (6.06)	-17.55 (-20.70, -13.20)	-14.76 (6.04)	-13.80 (-19.65, -10.70)
PT AROM end	11.04 (10.01)	10.05 (7.92, 18.20)	14.00 (8.55)	13.45 (7.00, 18.20)
PT AROM total	27.51 (9.47)	30.80 (22.55, 33.88)	28.76 (7.32)	27.45 (23.10, 35.75)
PT PROM rest	-15.46 (5.74)	-17.60 (-18.90, -11.88)	-14.49 (6.01)	-14.50 (-19.10, -9.65)
PT PROM end	11.80 (7.16)	11.15 (7.38, 14.12)	11.90 (6.91)	11.75 (6.55, 16.50)
PT PROM total	27.26 (6.53)	26.60 (22.55, 32.85)	26.40 (6.11)	26.90 (22.35, 29.30)
Scapular plane elevation AROM	150.29 (21.17)	155.00 (140.00, 165.00)	156.51 (12.27)	155.00 (150.00, 165.00)
Involved MT	6.26 (3.19)	5.55 (4.32, 7.25)	6.67 (2.63)	5.85 (4.55, 8.65)
Normalized	7.8% (3.4%)	6.9% (5.3%, 9.4%)	8.4% (3.3%)	7.8% (6.0%, 10.7%)
Non-involved MT	7.89 (3.32)	7.00 (5.50, 9.78)	8.16 (2.83)	8.15 (6.20, 9.55)
Normalized	10.0% (4.1%)	8.7% (7.4%, 11.7%)	10.1% (3.2%)	9.9% (7.9%, 11.5%)
Involved LT	4.40 (2.23)	3.95 (2.98, 5.90)	5.30 (2.02)	4.90 (3.75, 6.60)
Normalized	5.7% (2.9%)	4.6% (3.8%, 8.6%)	6.7% (2.6%)	6.2% (4.9%, 8.6%)
Non-involved LT	5.97 (1.82)	6.20 (4.20, 7.15)	6.80 (2.08)	7.10 (5.05, 8.10)
Normalized	7.6% (2.1%)	7.7% (6.3%, 9.0%)	8.4% (2.4%)	8.2% (6.9%, 10.2%)
Involved SA	5.43 (2.51)	4.65 (3.55, 6.85)	5.65 (2.37)	5.05 (3.80, 7.30)
Normalized	6.8% (2.8%)	6.2% (5.0%, 8.7%)	7.0% (2.8%)	7.0% (4.5%, 9.1%)
Involved SA torque	30.26 (14.35)	25.68 (20.00, 38.21)	30.95 (13.78)	28.57 (21.70, 40.68)
Normalized (Nm/kg)	0.38 (0.16)	0.34 (0.28, 0.47)	0.38 (0.15)	0.38 (0.25, 0.47)
Non-involved SA	6.61 (2.82)	6.15 (4.60, 7.82)	6.96 (2.61)	6.40 (4.70, 8.85)
Normalized	8.3% (2.9%)	7.9% (6.2%, 10.4%)	8.6% (2.8%)	8.8% (5.9%, 10.6%)
Non-involved SA torque	36.74 (16.35)	35.90 (25.66, 43.70)	38.08 (15.51)	34.53 (26.19, 49.47)
Normalized (Nm/kg)	0.46 (0.17)	0.43 (0.34, 0.58)	0.47 (0.16)	0.47 (0.34, 0.59)
Pectoralis minor length	15.81 (1.93)	15.50 (14.12, 17.10)	15.91 (2.20)	15.50 (14.00, 17.55)
PMI	9.03 (0.93)	8.90 (8.41, 9.75)	9.26 (1.00)	9.23 (8.61, 9.99)

Values expressed are mean (SD) and median (IQR)
ROM values expressed in degrees; strength values expressed in kg; normalized strength values expressed as % body weight; torque values expressed in N*m; length measures expressed in cm
UR = upward rotation, PT = posterior tilt, AROM = active range of motion, PROM = passive range of motion, MT = middle trapezius, LT = lower trapezius, SA = serratus anterior, PMI = pectoralis minor index

Figure 4-5.
Scapular Kinematic Values with Maximal Arm Elevation by SRT Result



UR=upward rotation, PT=posterior tilt, AROM=active range of motion, PROM=passive range of motion

Figure 4-6.
Normalized Strength Values by SRT Result

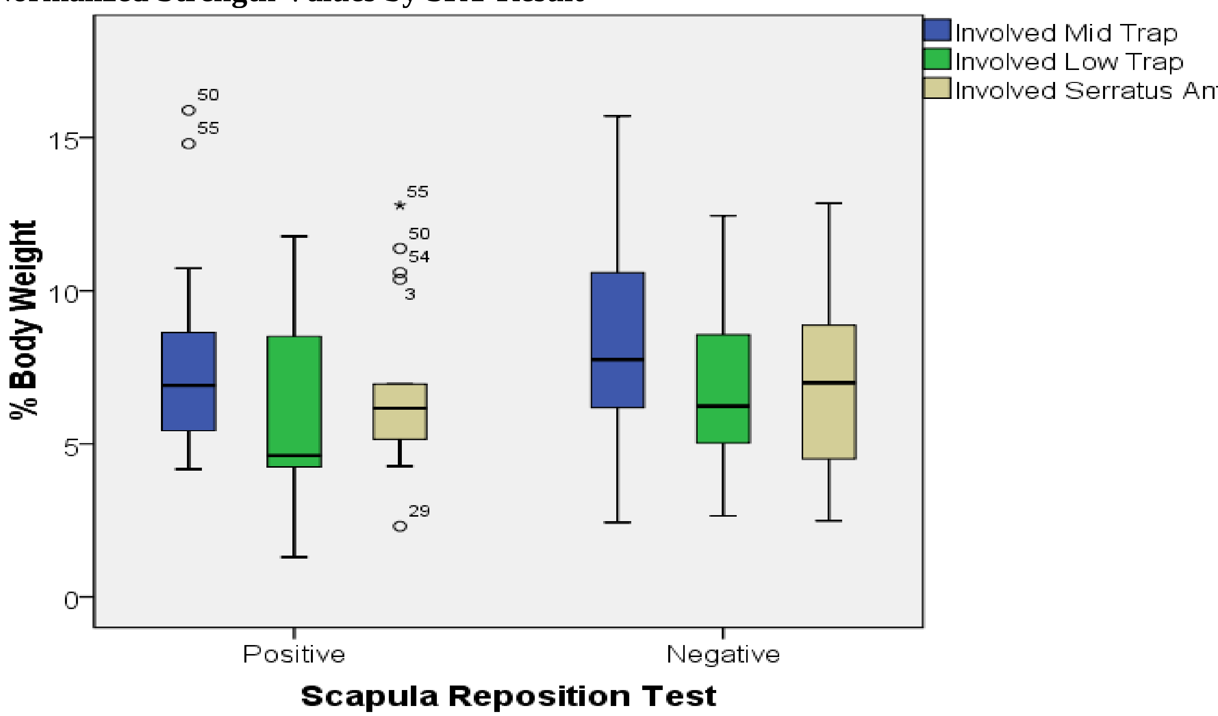
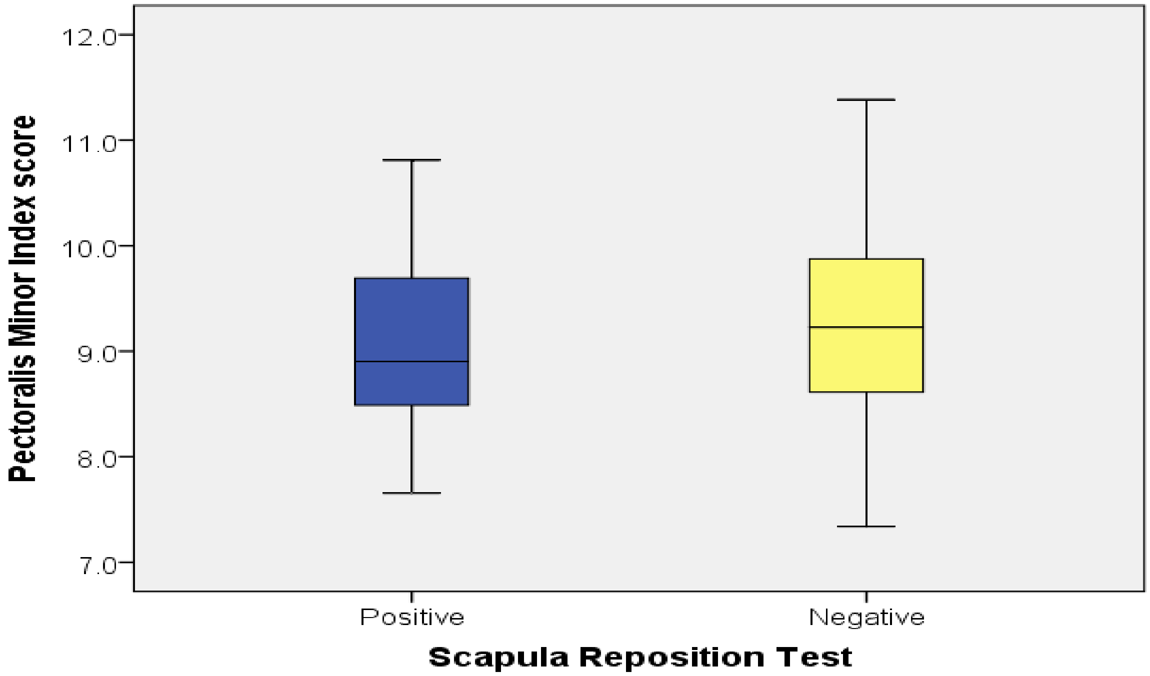


Figure 4-7.
Pectoralis Minor Index Score by SRT Result



Research Aim 2 Questions

1. Do individuals with subacromial pain syndrome (SPS) experience greater improvements in scapular motion with a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?

2. Do individuals with subacromial pain syndrome (SPS) experience greater improvements in scapulothoracic muscle force generation with a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?

3. Does length of the pectoralis minor muscle, as indicated by a measure of muscle length, change following a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?

4. Do individuals with SPS experience greater improvements in pain and function with a seated vs. supine thrust manipulation to the upper thoracic spine when compared to a sham manipulation?

Results for Research Aim 2

The same sample of 60 participants with shoulder pain was assigned via block randomization using a random number generator to one of three intervention groups: supine upper thoracic manipulation, seated upper thoracic manipulation, or sham manipulation. Subjects were blinded to group allocation to the extent possible with the use of manual therapy interventions. There were no significant differences in baseline demographic variables between the three treatment groups except for the results of the SDT ($p = .030$) (**Table 4-7**).

After completion of the baseline measures, the investigator looked up the previously determined allocation number and delivered the assigned intervention. Follow-up measures were then obtained. The immediate effect of the intervention on pain was assessed through the use of the VNRS and rated during active elevation of the involved arm in the scapular plane at baseline testing and immediately after delivery of the intervention. Measures of self-reported pain, satisfaction, and function were also collected at 48 hours by asking the participant to complete the PSS independently and return the completed form to the investigator via email or fax.

Table 4-7.
Participant Characteristics by Intervention Group

Variable	Supine Upper Thoracic Manip (n=20)	Seated Upper Thoracic Manip (n=20)	Seated Sham Manip (n=20)
Age (yrs)	37.6 (15.3)	35.6 (14.7)	36.5 (15.5)
Height (m)	1.70 (0.09)	1.73 (0.10)	1.74 (0.09)
Weight (kg)	77.6 (14.8)	78.7 (20.7)	88.0 (17.1)
BMI (kg/m^2)	26.7 (4.0)	25.9 (5.7)	29.0 (5.3)
Duration (weeks)	10.4 (7.7)	10.0 (6.4)	8.6 (4.8)
Sex (male)	10 (50)	12 (60)	15 (75)
Hand dominance (R)	17 (85)	17 (85)	19 (95)
Dominant shoulder involved	9 (45)	12 (60)	12 (60)
SDT result	Normal = 0 (0) Subtle = 8 (40) Obvious = 12 (60)	Normal = 1 (5) Subtle = 12 (60) Obvious = 7 (35)	Normal = 5 (25) Subtle = 8 (40) Obvious = 7 (35)
SAT result	Positive = 7 (35) Negative = 13 (65)	Positive = 11 (55) Negative = 9 (45)	Positive = 7 (35) Negative = 13 (65)
SRT result	Positive = 4 (20) Negative = 16 (80)	Positive = 5 (25) Negative = 15 (75)	Positive = 8 (40) Negative = 12 (60)
NPRS at baseline			
Current	3.0 (1.0, 4.8)	2.0 (0.2, 3.8)	3.0 (1.2, 3.8)
Worst	7.0 (6.0, 8.0)	7.0 (6.0, 8.0)	6.0 (5.0, 8.0)
Best	0.0 (0.0, 2.8)	0.5 (0.0, 2.8)	0.5 (0.0, 1.8)
PSS at baseline			
Pain score	19.0 (17.0, 21.0)	20.0 (17.0, 23.8)	20.0 (16.5, 24.0)
Satisfaction score	4.5 (1.0, 6.0)	4.0 (3.0, 6.8)	5.0 (2.0, 7.0)
Function score	45.0 (36.8, 50.4)	45.5 (38.9, 50.8)	51.0 (47.0, 52.0)
Total score	69.5 (54.8, 72.9)	68.5 (62.0, 77.0)	76.2 (67.3, 81.5)

Nominal values are expressed as number (%); ordinal values are expressed as median (IQR); continuous variables are expressed as mean (SD)
BMI = body mass index, SDT = scapular dyskinesis test, SAT = scapular assistance test, SRT = scapula reposition test, NPRS = numeric pain rating scale, PSS = Penn Shoulder Score

Wilcoxon tests were used to assess each group for significant within-group differences from baseline to post-intervention to determine if the treatment delivered resulted in any significant changes in scapular motion, scapulothoracic muscle force, pectoralis minor muscle length, or self-reported pain or function. The results indicated significant changes within all 3 groups. The supine manipulation group experienced a statistically significant ($p = .002$) improvement in total upward rotation AROM and active shoulder elevation in the scapular plane ($p = .003$). The seated manipulation group experienced a statistically significant ($p < .001$) gain in shoulder active elevation in the scapular plane despite not having a significant improvement in total scapular UR or PT motion. The sham manipulation group experienced a statistically significant ($p = .033$) improvement in total posterior tilt AROM and shoulder active elevation in the scapular plane ($p < .001$). Additional significant findings were found with the resting position for UR AROM in the seated manipulation group ($p = .015$), end-range motion for UR AROM in the supine manipulation ($p = .002$), seated manipulation ($p = .014$), and sham manipulation ($p = .012$) groups, resting position for UR PROM in the seated ($p = .015$) and sham ($p = .024$) groups, and end-range PT AROM in the seated ($p = .022$) and sham ($p = .013$) groups. This information can be seen in **Table 4-8a-b** and **Figures 4-8, 4-9, and 4-10**.

Table 4-8a. Median Within-Group Differences in Motion

Motion	Supine (n=20)	Seated (n=20)	Sham (n=20)
UR AROM resting			
Pre	-1.48 (-6.30, 4.52)	-1.10 (-4.46, 3.05)	-0.22 (-4.39, 4.45)
Post	0.30 (-3.30, 4.15)	2.25 (-5.55, 4.55)	0.85 (-1.42, 4.25)
Change	1.45 (-2.39, 3.15)	**1.85 (-0.26, 3.58)***	0.95 (-0.69, 3.74)
UR AROM end			
Pre	34.08 (28.56, 38.29)	36.28 (28.96, 46.24)	29.28 (24.65, 36.25)
Post	39.20 (33.32, 45.12)	36.95 (31.10, 51.45)	32.15 (28.30, 41.65)
Change	**4.55 (1.28, 13.56)***	**2.62 (0.30, 6.15)***	**3.18 (0.06, 7.62)***
UR AROM total			
Pre	33.78 (29.22, 40.70)	36.75 (32.49, 43.65)	29.95 (22.79, 40.89)
Post	37.75 (33.60, 50.30)	38.00 (30.98, 47.45)	33.05 (27.60, 40.32)
Change	**5.85 (0.79, 11.71)***	1.22 (-3.35, 6.21)	2.50 (-0.61, 5.90)
UR PROM resting			
Pre	-1.88 (-7.21, 2.68)	-0.62 (-4.90, 2.40)	-2.08 (-3.45, 4.30)
Post	-1.45 (-4.75, 3.95)	1.20 (-4.90, 4.92)	0.95 (-1.62, 4.32)
Change	0.68 (-0.52, 1.99)	**1.48 (0.40, 2.82)***	**0.95 (-0.11, 2.11)***
UR PROM end			
Pre	32.02 (27.28, 38.78)	35.45 (31.02, 38.94)	32.42 (28.39, 35.69)
Post	34.50 (30.42, 38.18)	36.30 (32.40, 41.32)	32.95 (31.25, 36.50)
Change	2.00 (-2.55, 4.29)	0.65 (-1.55, 4.55)	1.25 (-0.42, 4.00)
UR PROM total			
Pre	34.00 (29.72, 39.11)	35.75 (31.70, 40.79)	31.20 (27.50, 36.49)
Post	34.20 (32.00, 38.05)	37.80 (32.65, 40.95)	32.85 (27.78, 36.52)
Change	0.30 (-3.16, 4.62)	-0.18 (-3.51, 3.94)	0.92 (-1.30, 2.72)
PT AROM resting			
Pre	-13.72 (-19.61, -9.45)	-16.45 (-19.82, -11.28)	-15.12 (-21.85, -12.84)
Post	-13.75 (-18.58, -7.52)	-15.25 (-19.92, -10.35)	-15.35 (-21.18, -10.90)
Change	1.08 (-1.59, 4.01)	-0.42 (-2.34, 4.08)	-0.02 (-1.45, 2.24)
PT AROM end			
Pre	14.10 (8.78, 22.58)	12.52 (7.74, 19.09)	8.70 (6.02, 14.44)
Post	14.70 (6.65, 26.15)	16.45 (8.38, 22.35)	14.25 (5.88, 19.48)
Change	0.15 (-4.95, 2.90)	**3.15 (-0.81, 6.15)***	**3.02 (-0.69, 6.85)***
PT AROM total			
Pre	30.25 (26.04, 35.81)	27.52 (23.45, 36.00)	25.60 (22.12, 31.21)
Post	27.65 (23.72, 34.40)	32.20 (25.40, 39.18)	29.20 (22.35, 34.80)
Change	-0.88 (-3.59, 1.88)	3.75 (-2.08, 6.09)	**3.92 (-1.55, 6.25)***
PT PROM resting			
Pre	-14.38 (-19.01, -7.76)	-16.20 (-18.31, -11.19)	-15.82 (-20.70, -11.81)
Post	-14.30 (-17.92, -7.55)	-15.80 (-18.70, -9.98)	-14.80 (-17.48, -11.88)
Change	0.18 (-1.18, 2.75)	1.25 (-2.18, 3.49)	0.05 (-1.44, 2.70)
PT PROM end			
Pre	11.50 (6.14, 18.32)	11.58 (9.06, 15.68)	11.50 (4.46, 14.34)
Post	11.85 (4.78, 19.28)	14.00 (9.50, 17.00)	11.20 (4.35, 17.28)
Change	-1.12 (-2.71, 3.38)	1.88 (-0.70, 4.78)	0.95 (-1.55, 4.02)
PT PROM total			
Pre	25.78 (22.41, 32.24)	27.45 (22.42, 31.70)	26.45 (21.01, 29.94)
Post	26.55 (22.42, 29.48)	27.90 (24.00, 34.42)	26.90 (19.55, 31.65)
Change	-0.68 (-2.89, 3.80)	0.30 (-2.71, 6.40)	0.58 (-1.81, 3.71)
Scapular plane elevation			
Pre	155.00 (145.00, 165.00)	157.50 (150.00, 170.00)	155.00 (142.50, 165.00)
Post	165.00 (160.00, 173.75)	165.00 (160.00, 175.00)	165.00 (156.25, 170.00)
Change	**10.00 (5.00, 15.00)***	**10.00 (5.00, 15.00)***	**10.00 (5.00, 15.00)***

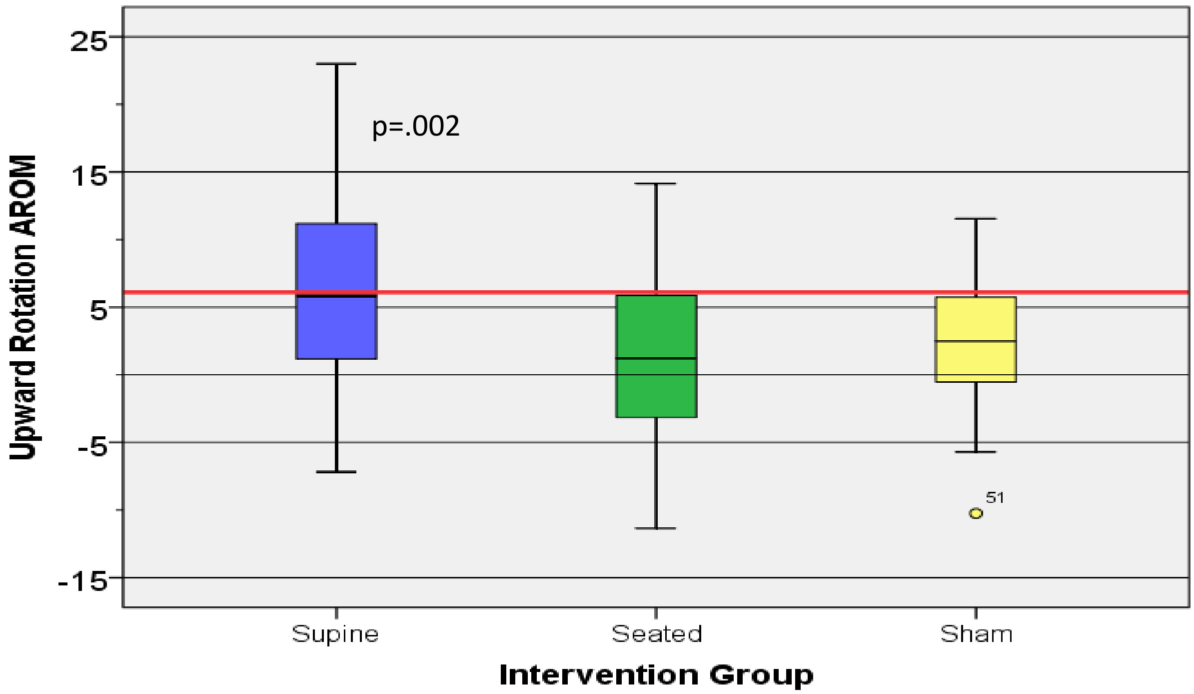
Values are in degrees and are expressed as median (IQR)
UR = upward rotation, PT = posterior tilt, AROM = active range of motion, PROM = passive range of motion; * = p value < .05

Table 4-8b.
Mean Within-Group Differences in Motion

	Supine (n=20)			Seated (n=20)			Sham (n=20)		
Motion	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**
UR AROM resting	-1.08 (5.63)	-0.34 (6.31)	0.74 (3.33)	-0.85 (6.29)	0.88 (6.98)	**1.74* (2.70)**	-0.47 (4.79)	0.78 (3.94)	1.25 (2.70)
UR AROM end	33.28 (6.75)	40.80 (8.62)	**7.52* (8.78)**	36.22 (13.86)	39.62 (15.94)	**3.40* (5.56)**	31.06 (10.94)	34.62 (8.31)	**3.56* (5.32)**
UR AROM total	34.36 (6.57)	41.14 (10.43)	**6.78* (8.12)**	37.07 (10.57)	38.73 (13.13)	1.66 (6.49)	31.53 (11.99)	33.84 (8.78)	2.30 (5.79)
UR PROM resting	-1.66 (6.02)	-1.06 (5.74)	0.60 (2.76)	-0.86 (6.90)	0.36 (7.27)	**1.22* (2.19)**	-0.36 (4.71)	0.72 (4.12)	**1.08* (1.94)**
UR PROM end	32.68 (7.77)	34.90 (8.05)	2.23 (6.30)	35.08 (6.18)	36.68 (6.01)	1.60 (4.16)	32.05 (5.63)	33.54 (4.88)	1.49 (3.69)
UR PROM total	34.34 (6.28)	35.97 (7.38)	1.63 (7.00)	35.94 (6.66)	36.32 (5.99)	0.39 (4.38)	32.41 (6.60)	32.82 (6.08)	0.41 (4.21)
PT AROM resting	-14.12 (6.30)	-13.34 (6.30)	0.78 (3.55)	-15.28 (6.01)	-15.05 (7.80)	0.23 (4.05)	-16.33 (5.92)	-15.82 (6.03)	0.51 (2.65)
PT AROM end	16.50 (9.75)	16.14 (10.58)	-0.35 (5.00)	13.12 (9.86)	15.70 (12.37)	**2.57* (4.26)**	9.87 (6.01)	13.30 (6.88)	**3.43* (5.17)**
PT AROM total	30.62 (7.21)	29.49 (7.28)	-1.13 (4.69)	28.40 (8.75)	30.74 (10.26)	2.34 (6.14)	26.20 (7.50)	29.12 (8.21)	**2.92* (5.61)**
PT PROM resting	-13.57 (6.35)	-13.54 (6.40)	0.03 (2.87)	-14.88 (5.54)	-14.42 (7.30)	0.47 (3.57)	-15.85 (5.86)	-15.22 (5.74)	0.62 (2.33)
PT PROM end	13.10 (8.76)	12.98 (8.99)	-0.12 (4.16)	12.24 (6.03)	14.13 (7.79)	1.89 (4.40)	10.27 (5.57)	11.10 (6.64)	0.83 (4.22)
PT PROM total	26.68 (6.66)	26.52 (5.72)	-0.16 (4.41)	27.12 (6.67)	28.54 (6.62)	1.42 (5.37)	26.12 (5.43)	26.33 (6.37)	0.21 (4.13)
Scapular plane elevation	155.75 (11.27)	165.00 (11.58)	**9.25* (10.04)**	155.50 (19.26)	165.50 (15.97)	**10.00* (6.88)**	153.00 (15.25)	163.00 (12.50)	**10.00* (8.27)**

Values are in degrees and are expressed as mean (SD)
UR = upward rotation, PT = posterior tilt, AROM = active range of motion, PROM = passive range of motion
* = p value < .05

Figure 4-8.
Change in Upward Rotation Motion (degrees) (red line indicates MDC)



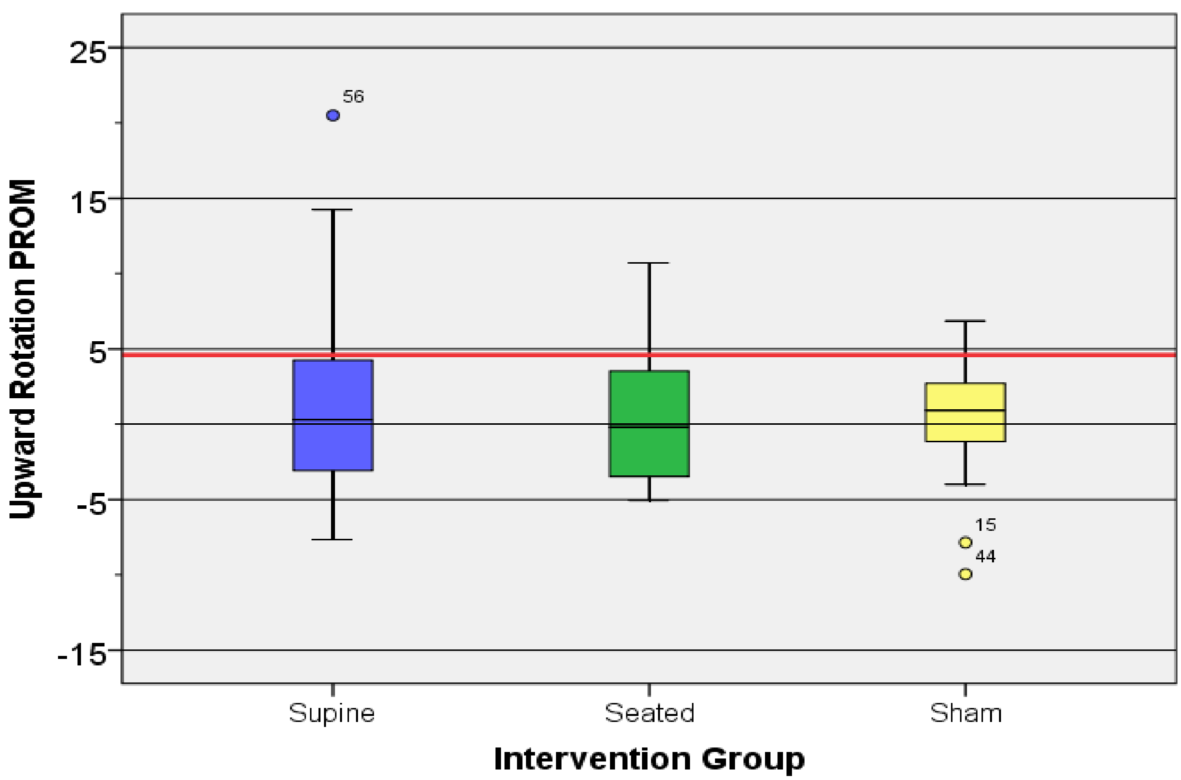
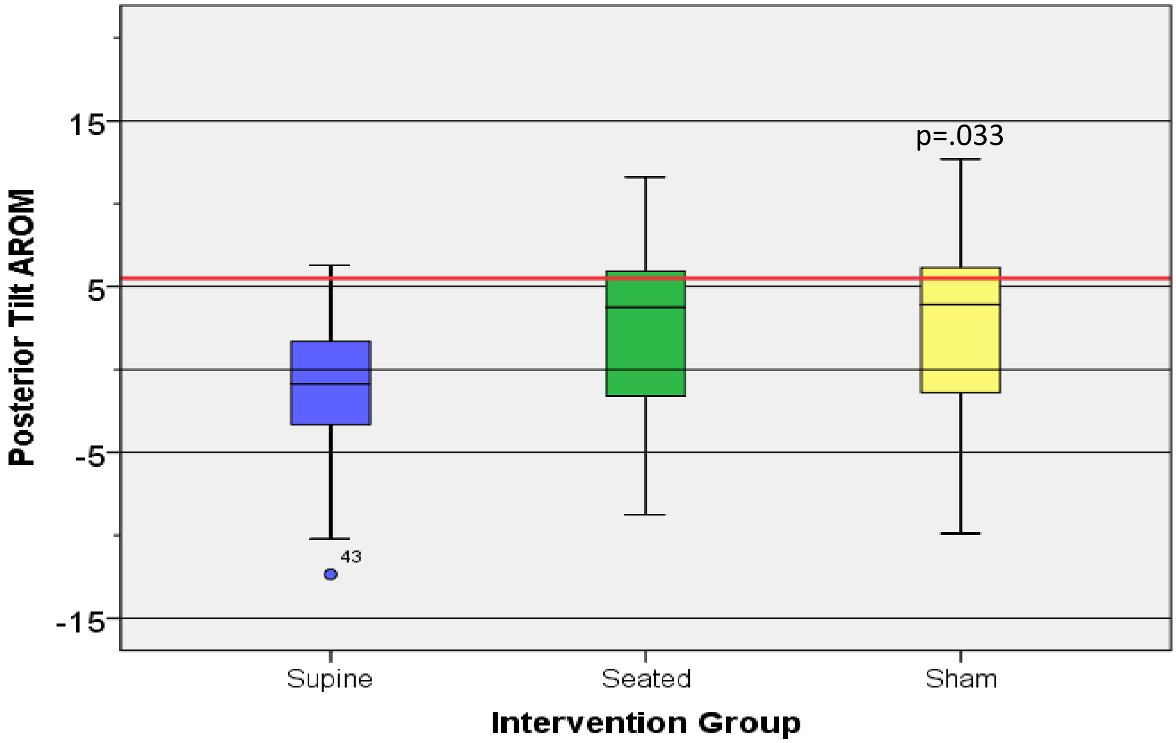


Figure 4-9.
Change in Posterior Tilt Motion (degrees) (red line indicates MDC)



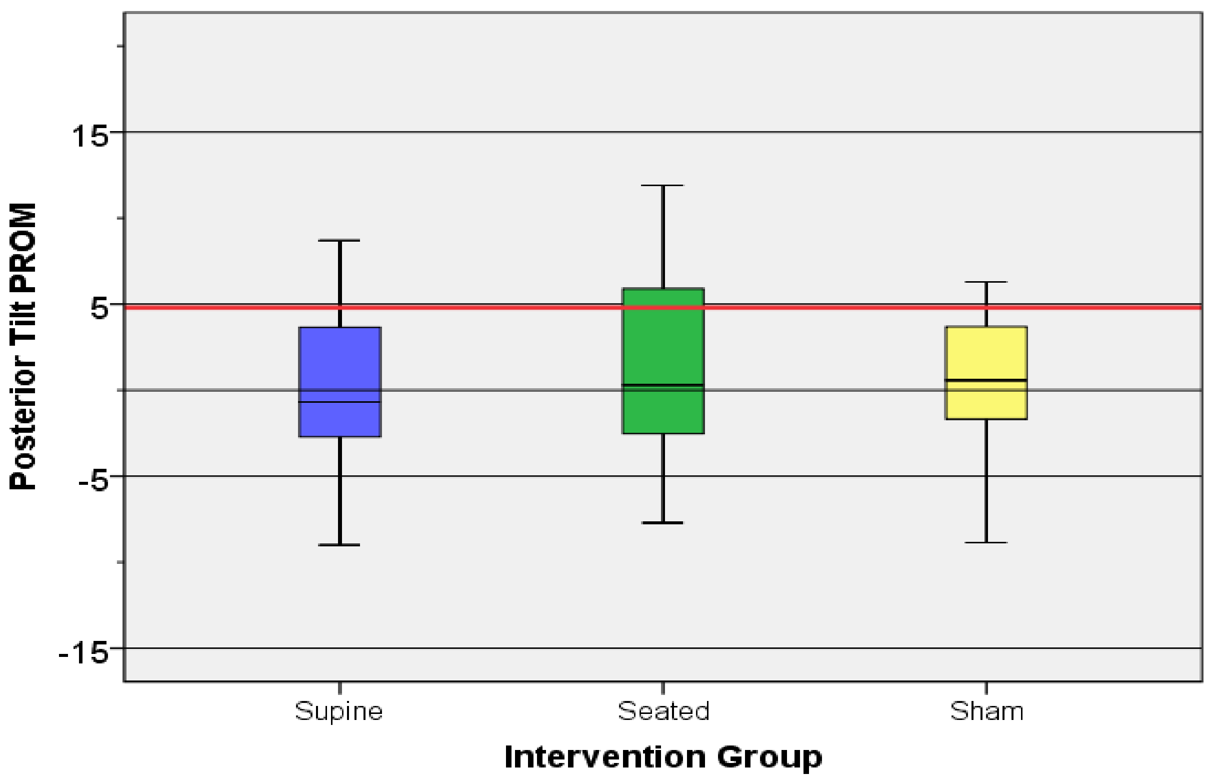
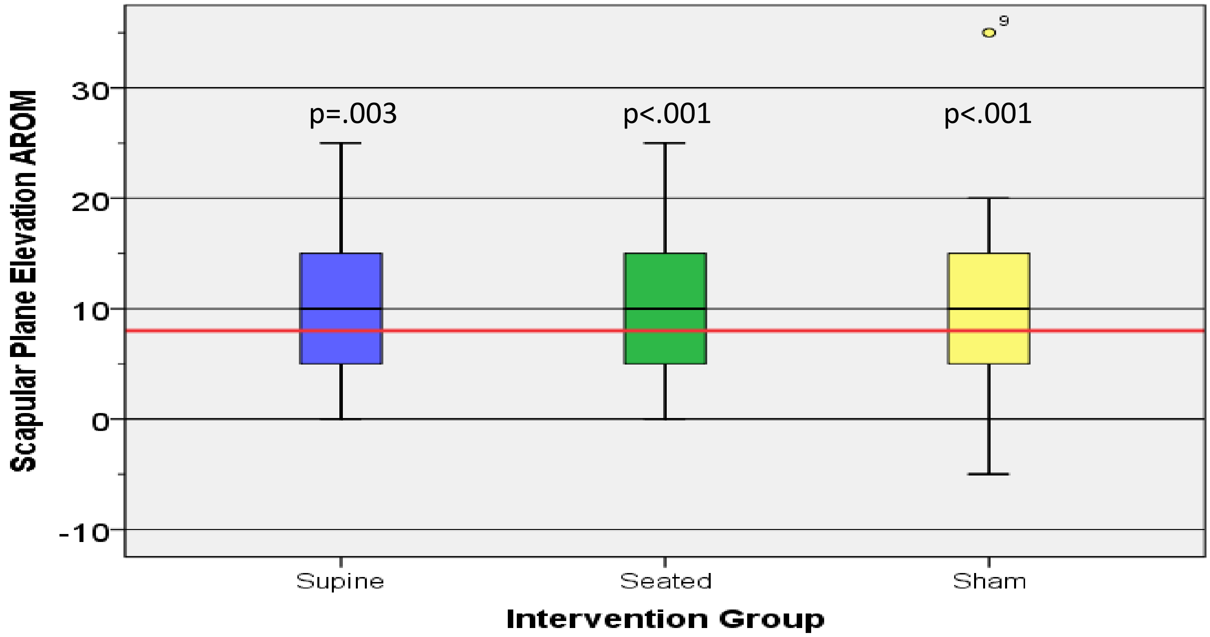


Figure 4-10.
Change in Scapular Plane Elevation (degrees) (red line indicates MDC)



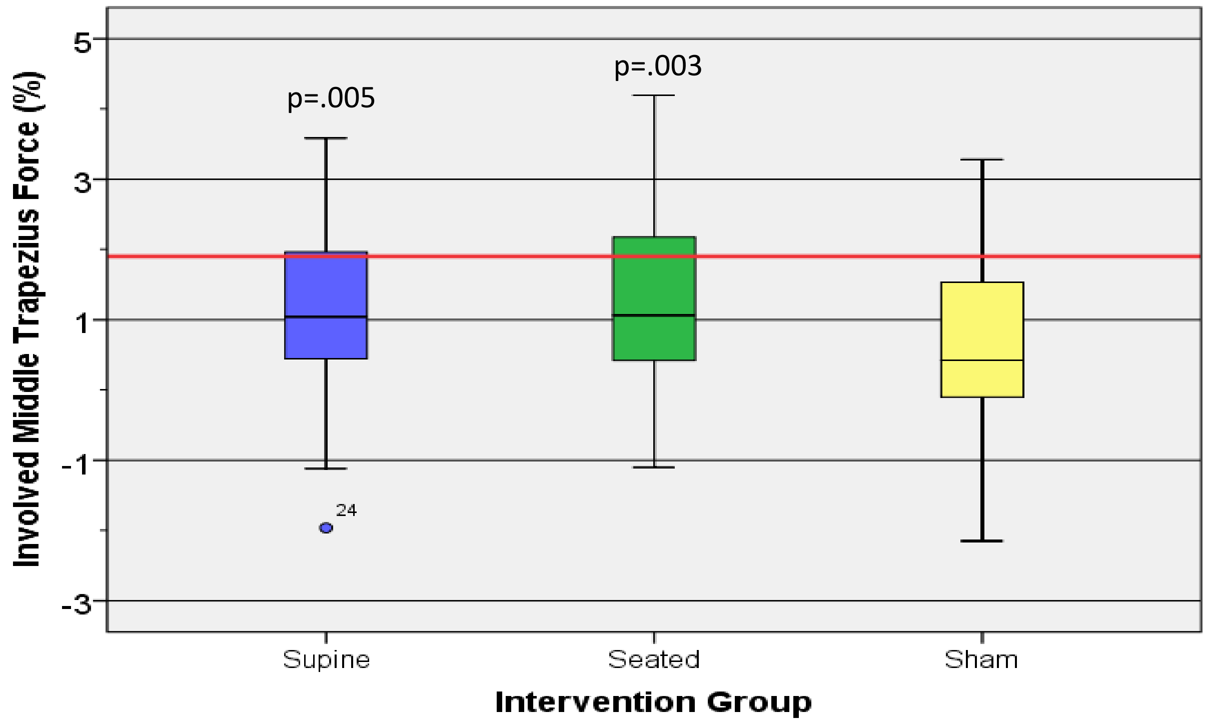
Significant findings were discovered in mean normalized force changes within all 3 groups as well. The supine manipulation group experienced statistically significant gains in the involved middle trapezius ($p = .005$) (1.04%; MDC_{90}=1.92%) and lower trapezius ($p = .001$) (1.27%; MDC_{90}=1.45%), as well as the non-involved lower trapezius ($p = .001$) (1.16%; MDC_{90}=1.58%). The seated manipulation group experienced statistically significant gains in the involved middle trapezius ($p = .003$) (1.06%; MDC_{90}=1.92%), lower trapezius ($p < .001$) (1.23%; MDC_{90}=1.45%), and serratus anterior ($p = .005$) (0.028Nm/kg; MDC_{90}=0.076Nm/kg), as well as the non-involved middle trapezius ($p = .004$) (1.19%; MDC_{90}=2.06%) and lower trapezius ($p < .001$) (1.18%; MDC_{90}=1.58%). The sham manipulation group experienced a statistically significant gain in the involved lower trapezius ($p = .010$) (1.08%; MDC_{90}=1.45%), while both the involved and non-involved serratus anterior approached significance ($p = .052$ for both). This information can be seen in **Table 4-9** and **Figures 4-11, 4-12, and 4-13.**

Table 4-9.
Median Within-Group Differences in Normalized Strength

Muscle	Supine (n=20)	Seated (n=20)	Sham (n=20)
Involved MT			
Pre	8.13 (4.97, 11.79)	7.11 (5.29, 10.12)	7.58 (6.55, 14.00)
Post	9.15 (6.35, 12.34)	7.84 (6.27, 11.77)	8.94 (6.44, 10.93)
Change	**1.04 (0.39, 1.98)***	**1.06 (0.35, 2.19)***	0.42 (-0.18, 1.71)
Non-involved MT			
Pre	11.03 (8.88, 12.12)	8.28 (6.68, 10.99)	8.96 (7.72, 10.98)
Post	11.52 (9.50, 12.94)	9.93 (6.78, 14.14)	8.82 (7.59, 11.90)
Change	0.36 (-0.43, 1.49)	**1.19 (0.36, 2.32)***	-0.01 (-0.60, 0.67)
Involved LT			
Pre	6.17 (4.97, 8.70)	5.68 (3.61, 8.34)	6.25 (4.33, 8.47)
Post	8.18 (6.05, 9.82)	7.27 (4.79, 9.39)	7.97 (6.02, 9.44)
Change	**1.27 (0.56, 2.23)***	**1.23 (0.45, 1.67)***	**1.08 (0.09, 2.34)***
Non-involved LT			
Pre	7.79 (6.59, 10.23)	7.57 (5.31, 9.94)	8.20 (7.74, 9.84)
Post	9.42 (7.56, 10.88)	8.54 (5.97, 11.61)	8.19 (7.04, 9.77)
Change	**1.16 (0.22, 1.99)***	**1.18 (0.48, 2.53)***	-0.20 (-0.91, 1.06)
Involved SA torque			
Pre	0.359 (0.227, 0.538)	0.368 (0.260, 0.461)	0.372 (0.287, 0.476)
Post	0.394 (0.246, 0.531)	0.407 (0.303, 0.487)	0.427 (0.286, 0.544)
Change	0.011 (-0.029, 0.060)	**0.028 (0.015, 0.054)***	0.024 (-0.018, 0.086)
Non-involved SA torque			
Pre	0.448 (0.330, 0.582)	0.381 (0.301, 0.546)	0.461 (0.393, 0.602)
Post	0.420 (0.344, 0.622)	0.422 (0.333, 0.564)	0.434 (0.336, 0.595)
Change	0.009 (-0.031, 0.038)	0.030 (-0.013, 0.057)	-0.016 (-0.055, 0.001)

Values shown are median (IQR)
Strength expressed as % body weight; torque expressed as Nm/kg
MT = middle trapezius, LT = lower trapezius, SA = serratus anterior
* = p value < .05

Figure 4-11.
Change in Normalized Middle Trapezius Force (% body weight) (red line indicates MDC)



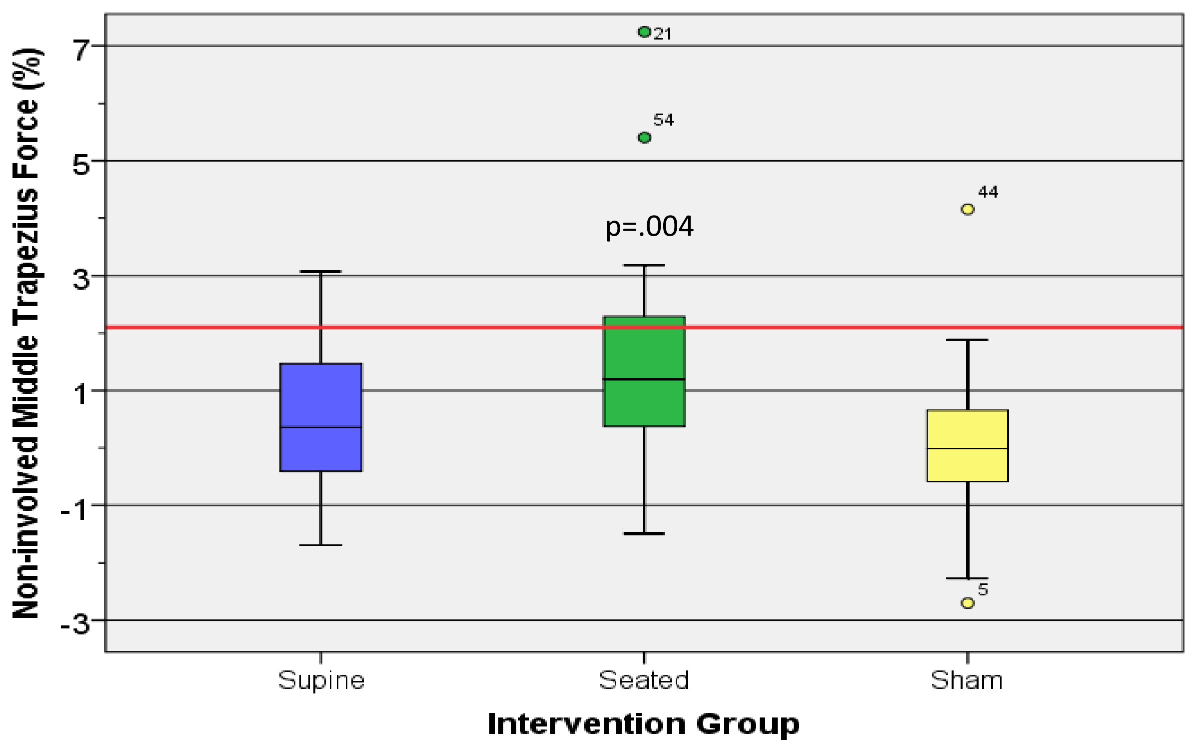
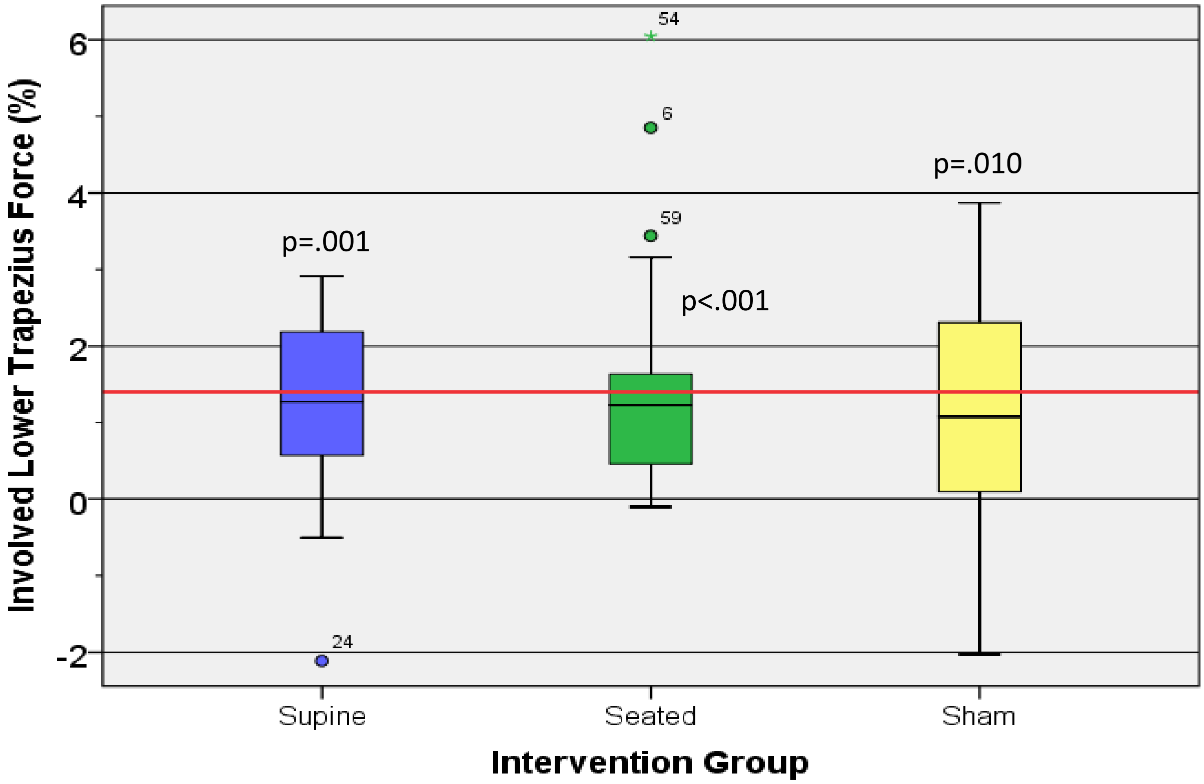


Figure 4-12.
Change in Normalized Lower Trapezius Force (% body weight) (red line indicates MDC)



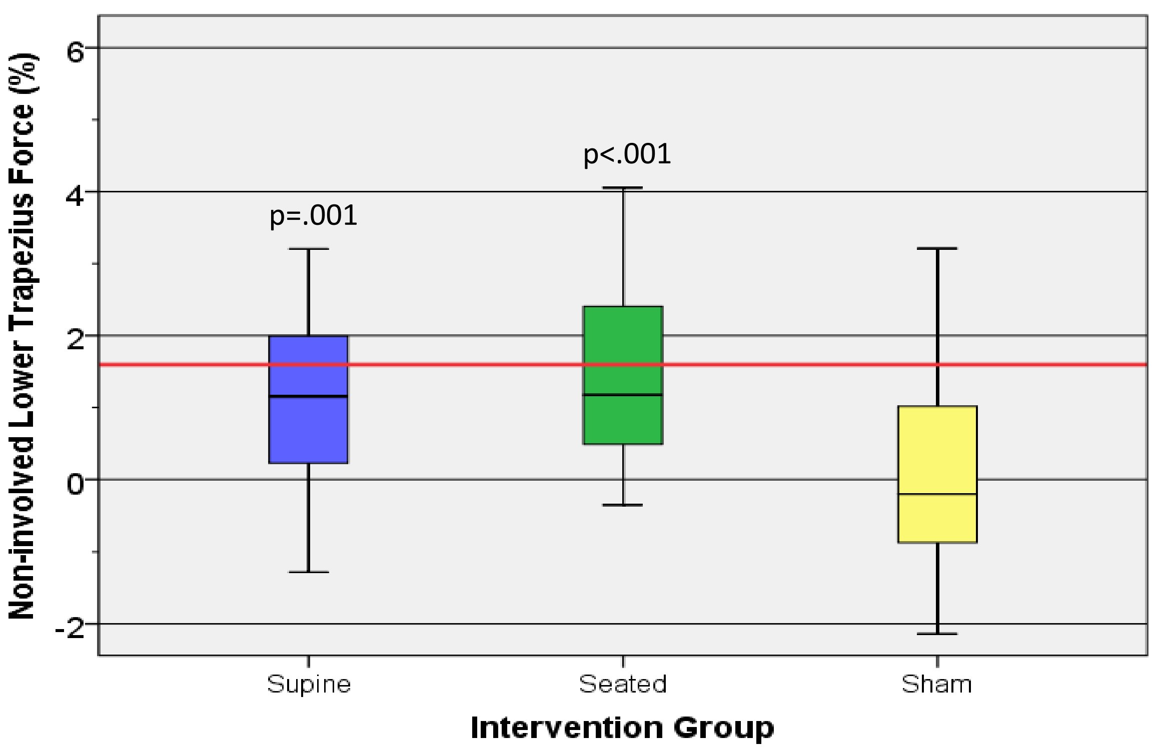
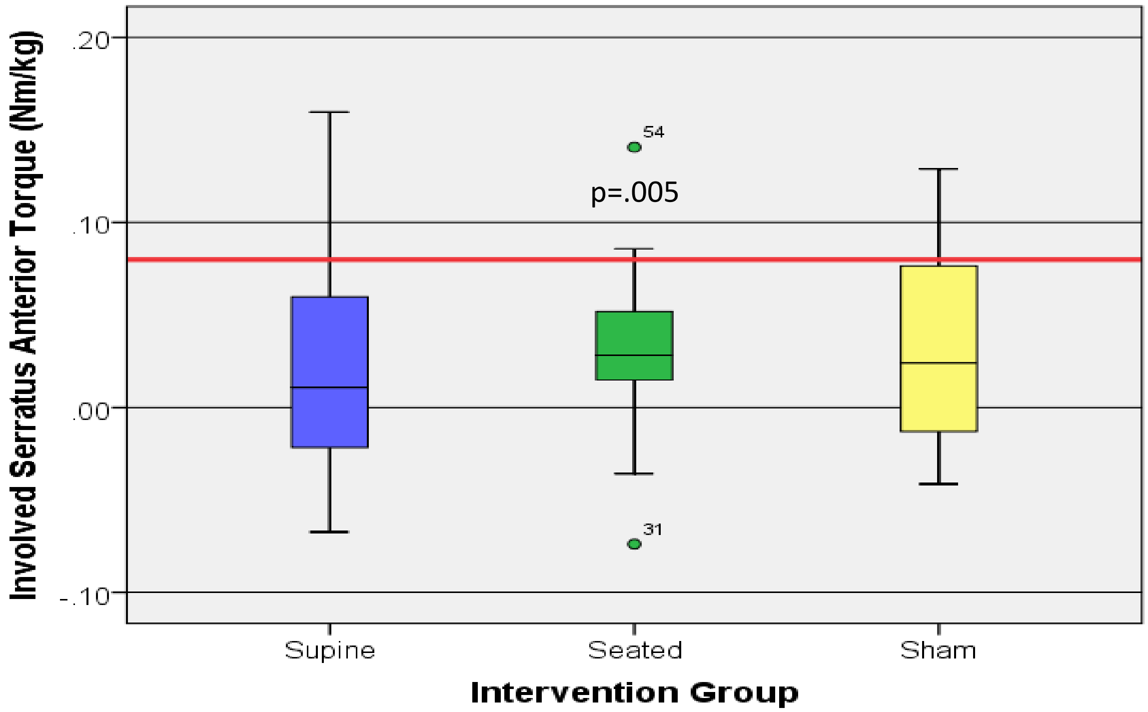
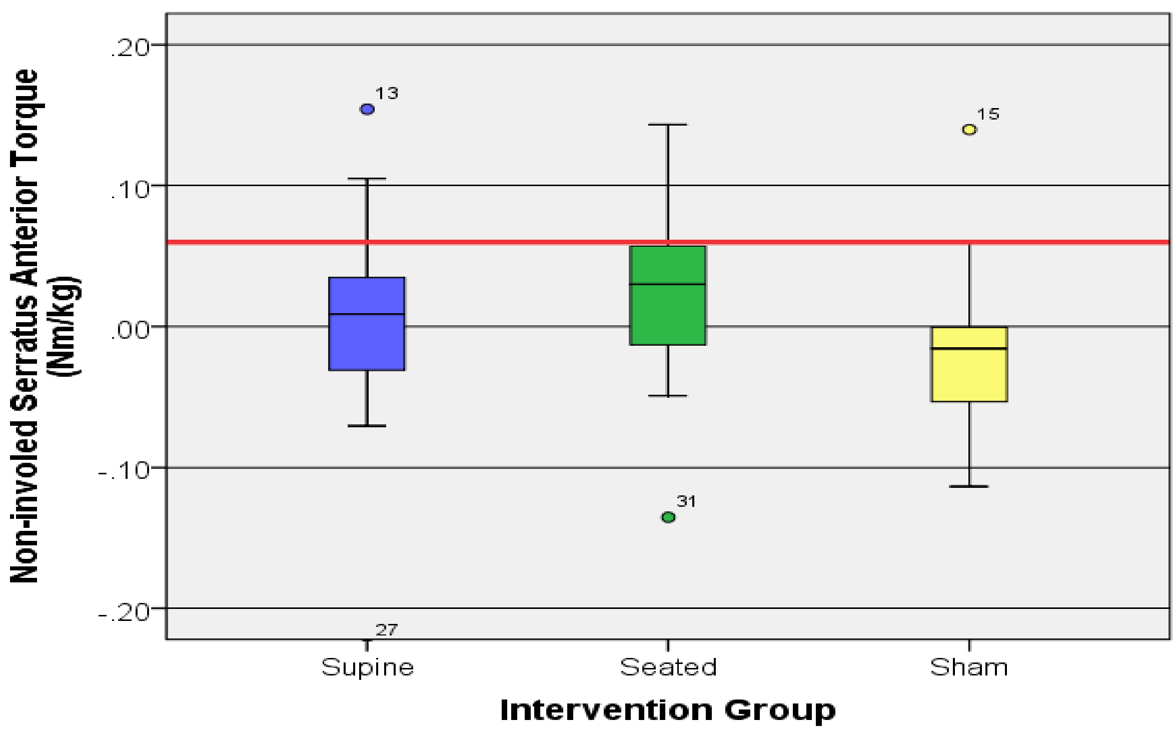


Figure 4-13.
Change in Normalized Serratus Anterior Torque (Nm/kg) (red line indicates MDC)





In terms of pectoralis minor muscle length, the seated manipulation group and sham manipulation group experienced statistically significant improvements in length (p = .001 and p = .031, respectively). While the median values for pre-treatment and post-treatment measures in the sham group give the appearance of a reduction in muscle length, the median change score indicates a gain in length. The improvement in muscle length in the sham group is more apparent when the data is reported as mean and standard deviation, which is shown in **Table 4-10b** for that purpose**.** The median change values for both groups were small in magnitude and did not exceed the MDC of 0.38 cm. While the median value for the change score in the sham group is a positive number which indicates an increase in muscle length, it is important to note that the IQR includes negative values which represent a reduction in length. When the pectoralis minor muscle length information is normalized to subject height, resulting in the PMI, the only significant difference existed within the seated manipulation group (p = .033). This information can be seen in **Tables 4-10a-b and 4-11a-b** and **Figure 4-14.**

Table 4-10a.
Median Within-Group Differences in Pectoralis Minor Muscle Length

	Supine (n=20)	Seated (n=20)	Sham (n=20)
Pre	15.25 (14.00, 16.75)	15.52 (13.95, 17.48)	15.80 (14.14, 17.56)
Post	15.25 (14.12, 17.25)	16.10 (14.20, 17.58)	15.65 (14.42, 18.32)
Change	0.00 (-0.14, 0.50)	**0.30 (0.01, 0.64)***	**0.20 (-0.11, 0.50)****

Values are in cm and are expressed as median (IQR)
*p value = .001, **p value = .031

Table 4-10b.
Mean Within-Group Differences in Pectoralis Minor Muscle Length

	Supine (n=20)	Seated (n=20)	Sham (n=20)
Pre	15.68 (2.01)	15.88 (2.32)	16.09 (2.08)
Post	15.86 (2.10)	16.24 (2.44)	16.32 (2.19)
Change	0.18 (0.40)	0.35 (0.36)	0.23 (0.41)

Values are in cm and are expressed as mean (SD)

Table 4-11a.
Median Within-Group Differences in Pectoralis Minor Index (PMI)

	Supine (n=20)	Seated (n=20)	Sham (n=20)
Pre	9.11 (8.61, 9.66)	8.95 (8.37, 9.88)	9.13 (8.35, 10.05)
Post	9.17 (8.66, 9.86)	9.54 (8.81, 10.87)	8.86 (8.29, 9.40)
Change	0.11 (-0.08, 0.30)	**0.09 (-0.07, 0.32)***	0.17 (0.00, 0.31)

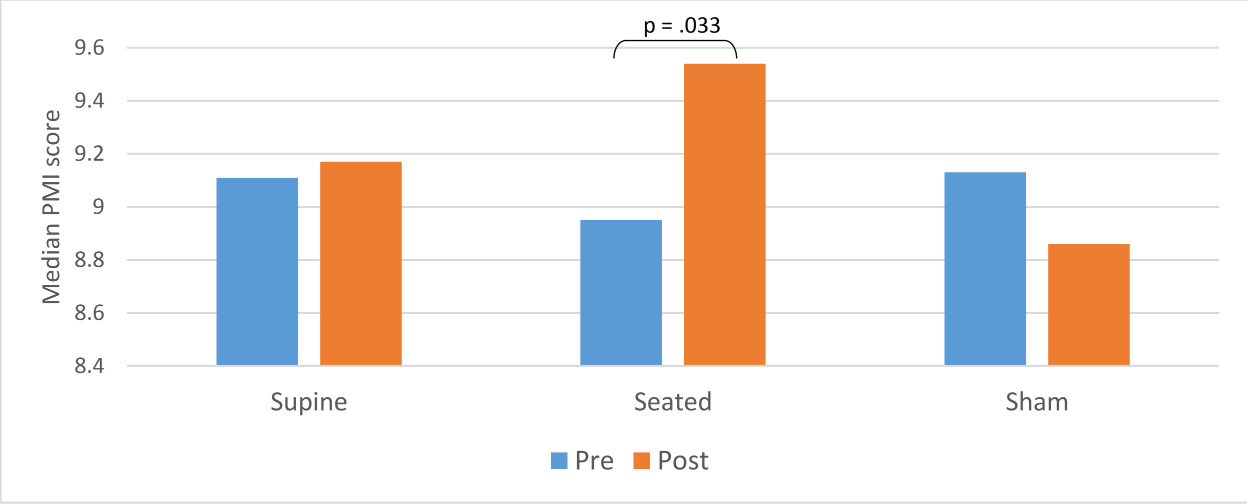
Values are expressed as median (IQR)
*p value = .033

Table 4-11b.
Mean Within-Group Differences in Pectoralis Minor Index (PMI)

	Supine (n=20)	Seated (n=20)	Sham (n=20)
Pre	9.20 (0.78)	9.14 (1.07)	9.24 (1.11)
Post	9.23 (0.79)	9.71 (1.16)	9.07 (1.07)
Change	0.12 (0.23)	0.13 (0.25)	0.18 (0.19)

Values are expressed as mean (SD)

Figure 4-14.
Median Pectoralis Minor Index Scores



To assess for immediate change in pain following the intervention, subjects were asked to rate their pain using the VNRS during active elevation of the involved arm in the scapular plane at baseline and immediately after delivery of the intervention. The seated manipulation group ($p = .009$) and sham manipulation group ($p = .001$) experienced a statistically significant improvement in pain, while the supine group did not ($p = .073$). The median (IQR) change in pain for both groups was 1.0 (0.0-2.0). No significant between-group differences existed.

Measures of pain, function, and satisfaction were assessed with the PSS at baseline and 48-hour follow-up. Due to losing 3 participants to follow-up, this analysis was run two ways – one analysis carried those individuals' baseline measures forward to the 48-hour follow-up measures and the other analysis excluded those 3 participants. Although the P values changed slightly between the two analyses, the significant findings remained the same regardless of the analysis that was performed. The results of the PSS indicated that all 3 groups experienced statistically significant improvements in pain scores between baseline and 48-hour follow-up (supine: $p < .001$, seated: $p = .001$, sham: $p < .001$). Additionally, all 3 groups experienced statistically significant improvements in function (supine: $p = .010$, seated: $p = .018$, sham: $p = .004$). Only the sham group experienced a statistically significant increase in satisfaction with the affected shoulder ($p = .003$). Statistically significant improvements in PSS total scores were seen in all 3 groups (supine: $p < .001$, seated: $p = .004$, sham: $p < .001$). Pairwise comparisons revealed significant differences in post-treatment scores between the supine and sham groups for satisfaction ($p = .022$ or $p = .031$ with the 3 subjects removed), function ($p = .021$ or $p = .030$ with the 3 subjects removed), and total score ($p = .016$ or $p = .029$ with the 3 subjects removed), with greater results in all three outcomes for the sham group. This data is summarized in **Table 4-12a-b** and boxplots for the sample of 57 can be seen in **Figures 4-15, 4-16, and 4-17**.

Table 4-12a.
Median Within-Group Differences in Pain, Function, Satisfaction, and Total PSS Scores (n=60)

PSS Category	Supine (n=20)	Seated (n=20)	Sham (n=20)
Pain			
Pre	19.0 (17.0, 21.0)	20.0 (17.0, 23.8)	20.0 (16.5, 24.0)
48 hour	24.0 (19.0, 27.0)	25.0 (22.2, 28.0)	26.5 (24.2, 28.8)
Change	**5.0 (1.2, 6.8)***	**4.5 (0.0, 7.8)***	**5.0 (2.0, 9.8)***
Function			
Pre	45.0 (36.8, 50.4)	45.5 (38.9, 50.8)	51.0 (47.0, 52.0)
48 hour	47.5 (40.0, 52.4)	51.5 (40.5, 57.8)	53.5 (49.0, 58.5)
Change	**2.0 (0.2, 4.8)***	**2.0 (0.0, 6.0)***	**3.8 (0.0, 8.7)***
Satisfaction			
Pre	4.5 (1.0, 6.0)	4.0 (3.0, 6.8)	5.0 (2.0, 7.0)
48 hour	5.0 (2.0, 7.0)	7.0 (2.5, 8.0)	8.0 (4.2, 9.0)
Change	1.0 (0.0, 1.8)	0.5 (-0.8, 3.8)	**1.5 (0.0, 3.8)***
Total			
Pre	69.5 (54.8, 72.9)	68.5 (62.0, 77.0)	76.2 (67.3, 81.5)
48 hour	74.5 (66.2, 84.1)	84.5 (68.0, 92.5)	89.4 (76.0, 95.2)
Change	**6.0 (2.2, 14.0)***	**7.6 (0.0, 13.8)***	**11.0 (5.0, 19.8)***

Values are expressed as median (IQR)
PSS = Penn Shoulder Score *p value < .05

Table 4-12b.
Median Within-Group Differences in Pain, Function, Satisfaction, and Total PSS Scores (n=57)

PSS Category	Supine (n=19)	Seated (n=18)	Sham (n=20)
Pain			
Pre	19.0 (17.0, 21.0)	20.0 (17.0, 23.2)	20.0 (16.5, 24.0)
48 hour	24.0 (22.0, 27.0)	25.0 (22.8, 28.2)	26.5 (24.2, 28.8)
Change	**5.0 (2.0, 7.0)***	**5.0 (1.5, 8.2)***	**5.0 (2.0, 9.8)***
Function			
Pre	46.0 (35.0, 50.5)	45.5 (39.0, 50.6)	51.0 (47.0, 52.0)
48 hour	48.0 (39.0, 53.0)	51.5 (41.5, 58.2)	53.5 (49.0, 58.5)
Change	**2.0 (1.0, 5.0)***	**2.6 (0.8, 6.3)***	**3.8 (0.0, 8.7)***
Satisfaction			
Pre	5.0 (1.0, 6.0)	4.0 (3.0, 5.2)	5.0 (2.0, 7.0)
48 hour	5.0 (2.0, 7.0)	7.0 (1.8, 8.2)	8.0 (4.2, 9.0)
Change	1.0 (0.0, 2.0)	1.5 (-1.2, 4.0)	**1.5 (0.0, 3.8)***
Total			
Pre	71.0 (52.7, 73.0)	68.5 (62.0, 77.0)	76.2 (67.3, 81.5)
48 hour	76.0 (67.0, 84.5)	85.4 (68.0, 93.5)	89.4 (76.0, 95.2)
Change	**7.0 (3.0, 14.0)***	**9.0 (4.5, 14.5)***	**11.0 (5.0, 19.8)***

Values are expressed as median (IQR)
PSS = Penn Shoulder Score *p value < .05

Figure 4-15.
Change in Penn Shoulder Score Pain Subscale (red line indicates MDC)

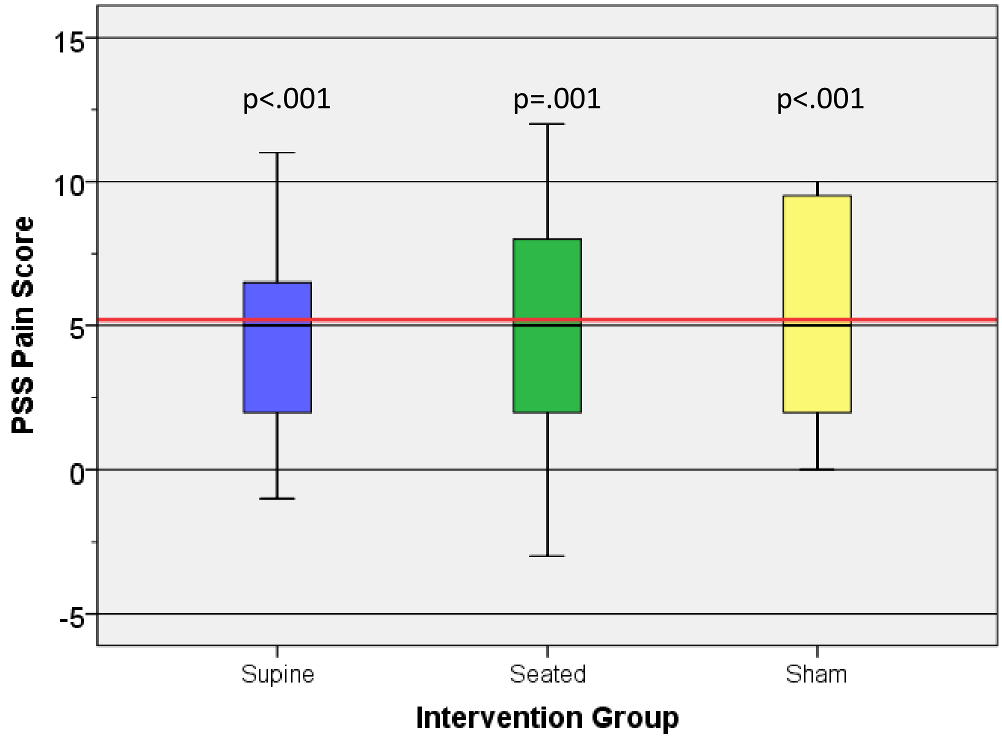


Figure 4-16.
Change in Penn Shoulder Score Function Subscale (red line indicates MDC)

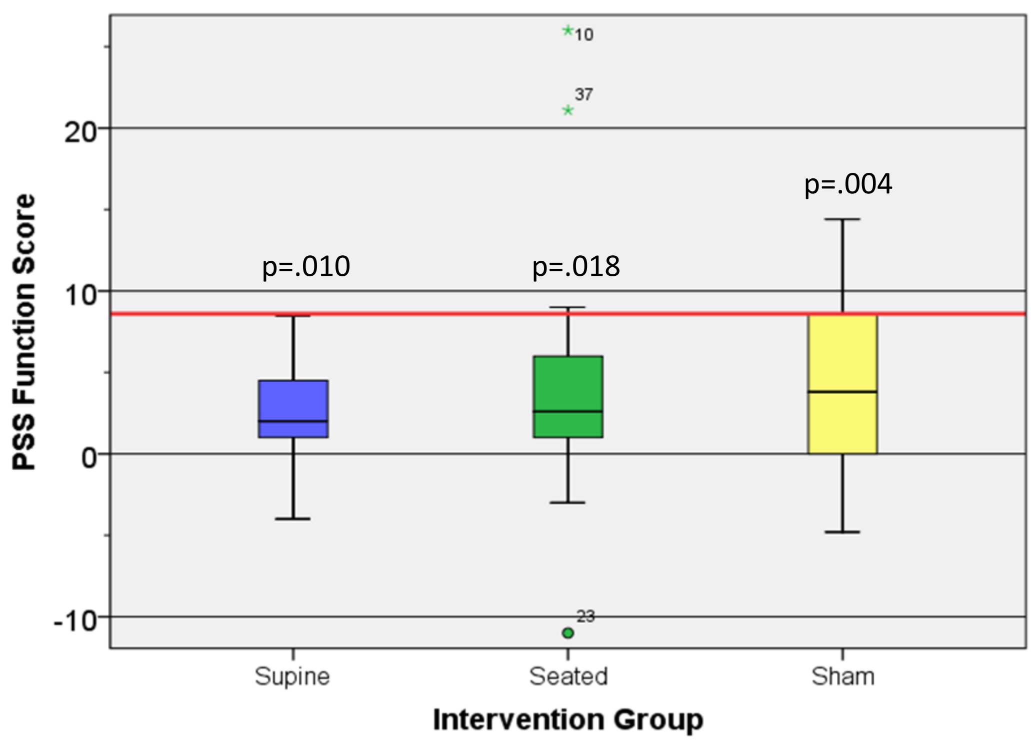


Figure 4-17.
Change in Penn Shoulder Score Total Score (red line indicates MDC)

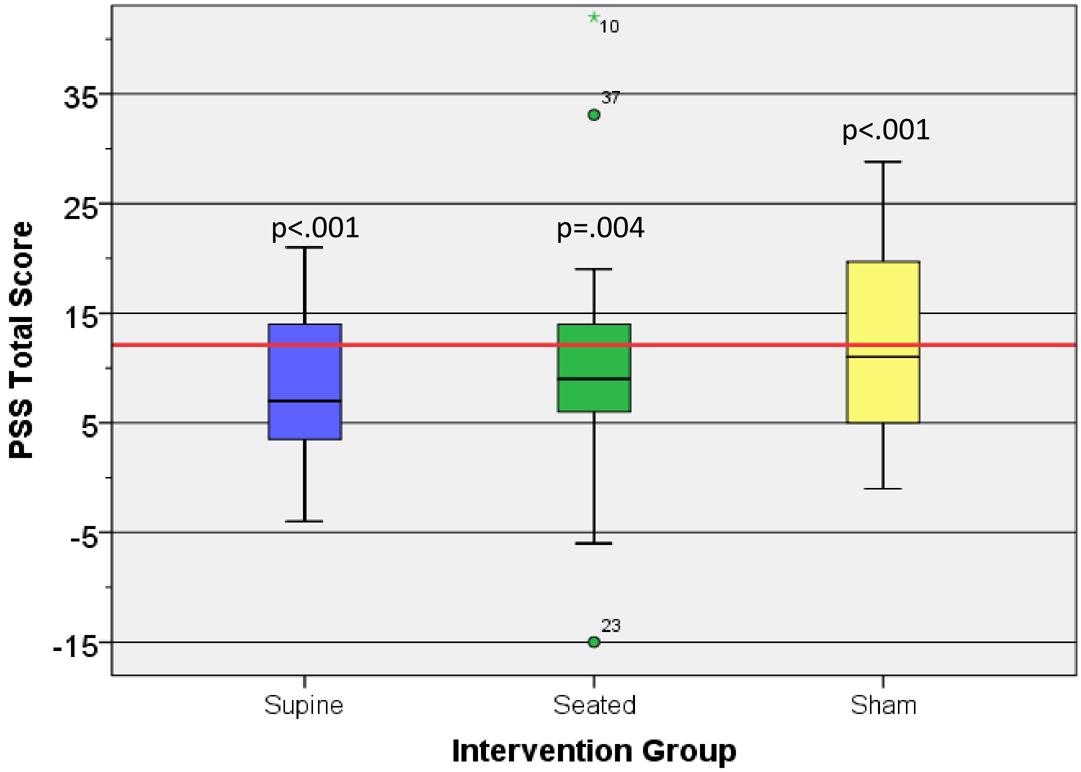


Table 4-13. Summary of Significant Within-Group Changes

Group	Variable	Change	P-value
Supine	Total UR AROM	5.85 (0.79, 11.71)	**.002**
	Scapular plane elev AROM	10.00 (5.00, 15.00)	**.003**
	End-range UR AROM	4.55 (1.28, 13.56)	**.002**
Seated	Scapular plane elev AROM	10.00 (5.00, 15.00)	**<.001**
	Resting UR AROM	1.85 (-0.26, 3.58)	**.015**
	End-range UR AROM	2.62 (0.30, 6.15)	**.014**
	Resting UR PROM	1.48 (0.40, 2.82)	**.015**
	End-range PT AROM	3.15 (-0.81, 6.15)	**.022**
Sham	Total PT AROM	3.92 (-1.55, 6.25)	**.033**
	Scapular plane elev AROM	10.00 (5.00, 15.00)	**<.001**
	End-range UR AROM	3.18 (0.06, 7.62)	**.012**
	Resting UR PROM	0.95 (-0.11, 2.11)	**.024**
	End-range PT AROM	3.02 (-0.69, 6.85)	**.013**
Supine	Involved MT strength	1.04 (0.39, 1.98)	**.005**
	Involved LT strength	1.27 (0.56, 2.23)	**.001**
	Non-involved LT strength	1.16 (0.22, 1.99)	**.001**
Seated	Involved MT strength	1.06 (0.35, 2.19)	**.003**
	Involved LT strength	1.23 (0.45, 1.67)	**<.001**
	Involved SA torque	0.028 (0.015, 0.054)	**.005**
	Non-involved MT strength	1.19 (0.36, 2.32)	**.004**
	Non-involved LT strength	1.18 (0.48, 2.53)	**<.001**
Sham	Involved LT strength	1.08 (0.09, 2.34)	**.010**
Seated	Pectoralis minor length	0.30 (0.01, 0.64)	**.001**
	Pectoralis minor index	0.09 (-0.07, 0.32)	**.033**
Sham	Pectoralis minor length	0.20 (-0.11, 0.50)	**.031**
Seated	Pain (VNRS)	1.0 (0.0-2.0)	**.009**
Sham	Pain (VNRS)	1.0 (0.0-2.0)	**.001**
Supine	PSS Pain score	5.0 (1.2, 6.8)	**<.001**
	PSS Function score	2.0 (0.2, 4.8)	**.010**
	PSS Total score	6.0 (2.2, 14.0)	**<.001**
Seated	PSS Pain score	4.5 (0.0, 7.8)	**.001**
	PSS Function score	2.0 (0.0, 6.0)	**.018**
	PSS Total score	7.6 (0.0, 13.8)	**.004**
Sham	PSS Pain score	5.0 (2.0, 9.8)	**<.001**
	PSS Function score	3.8 (0.0, 8.7)	**.004**
	PSS Satisfaction score	1.5 (0.0, 3.8)	**.003**
	PSS Total score	11.0 (5.0, 19.8)	**<.001**

Values expressed are median (IQR)
Motion expressed in degrees; strength expressed as % body weight; torque expressed as Nm/kg; pectoralis minor muscle length expressed in cm
UR = upward rotation, PT = posterior tilt, AROM = active range of motion, PROM = passive range of motion, MT = middle trapezius, LT = lower trapezius, SA = serratus anterior

Research Aim 2

Question 1:

There were no significant between-group differences for the baseline measures of scapular motion or UE scapular plane elevation. There were also no significant differences for the post-intervention measures. The results of the Kruskal-Wallis test revealed significant findings for the change in end-range posterior tilt AROM ($p = .043$) and change in total posterior tilt AROM ($p = .039$). However, the pairwise comparisons were not significant between any of the groups. The total amount of UR AROM following intervention approached significance with $p = .059$ and favored the supine manipulation group. There were no other significant between-group differences in scapular motion based on the intervention received.

Question 2:

There were no significant between-group differences for the baseline or post-intervention measures of mean normalized force for the MT or LT, or mean normalized torque for the SA. Significant differences were found in the amount of change from pre- to post-intervention in the non-involved MT, LT, and SA. Pairwise comparisons were examined and indicated significant differences with greater gains in the non-involved MT force ($p = .028$), non-involved LT force ($p = .009$), and non-involved SA torque ($p = .027$) with the seated manipulation compared to the sham.

Question 3:

There were no significant between-group differences in baseline muscle length or PMI, post-intervention muscle length or PMI, or change in muscle length or PMI for the pectoralis minor based on the intervention received.

Question 4:

There were no significant differences between the groups at baseline for pain, function, satisfaction, and total scores as measured through the PSS. Significant differences did exist in post-treatment level of satisfaction (n=60, p = .026; n=57, p = .037), level of function (n=60, p = .026; n=57, p = .036), and total score (n=60, p = .021; n=57, p = .034). Pairwise comparisons for these measures revealed significant differences in post-treatment scores between the supine and sham groups for satisfaction (n=60, p = .022; n=57, p = .031), function (n=60, p = .021; n=57, p = .030), and total score (n=60, p = .016; n=57, p = .029), with greater results in all three outcomes for the sham group (see **Figure 4-11**). There were no significant differences in the amount of change in pain, function, satisfaction, or PSS total score based on the treatment delivered.

Summary

For the first research aim, the results of this study indicated no significant differences in scapular upward rotation or posterior tilt active or passive motion for individuals with SPS who tested positive on the SAT or SRT compared to those who tested negative. There were also no significant differences in mean normalized force between those who tested positive and negative on the SAT or the SRT. Significant differences did exist in force generated with manual muscle test positions of the middle trapezius, lower trapezius, and serratus anterior on the involved side compared to the non-involved side regardless of outcome on the SAT or SRT, likely due to pain-related muscle inhibition during the test. There were significant differences in pectoralis minor muscle length and PMI based on the results of the SAT but not for the SRT. Individuals who tested positive on the SAT demonstrated decreased pectoralis minor muscle length. Additionally, the methods utilized in this study for measuring scapular upward rotation and posterior tilt active and passive ROM, scapulothoracic muscle force using handheld dynamometry, and pectoralis minor muscle length demonstrated excellent intrarater reliability with ICCs ranging from 0.90-0.99. SEM and MDC values were calculated and reported for these measures based on the data from this study.

For the second research aim, small but statistically significant improvements in various measures of active scapular motion and upper extremity elevation, scapulothoracic muscle force, and pectoralis minor muscle length were seen within all 3 groups. The supine group experienced a significant improvement in total UR AROM and the sham group experienced a small increase in total PT AROM. However, the lack of significant between-group differences in these variables indicates that thrust manipulation delivered to the upper thoracic spine in either a seated or supine position did not result in significant changes in scapular kinematics. Arm elevation in the scapular plane increased significantly and by the same amount in all groups, indicating that the improvement was not a direct result of the manipulation. The manipulation techniques utilized in this study did not lead to meaningful immediate changes in force produced by the MT, LT, or SA, other than an incidental finding of improvements in the non-involved muscles following the seated manipulation. Significant improvements were seen in immediate change in pain in the seated and sham groups, as well as pain, function, and total PSS scores obtained 48 hours after treatment in all 3 groups. Significant between-group differences existed in the post-treatment scores for function, satisfaction with the involved shoulder, and total PSS score, all favoring the sham manipulation. No significant differences existed between groups in the change in those scores from baseline to post-treatment. Small but significant improvements in pectoralis minor length existed in the seated and sham groups; however, there was no between-group difference. These results indicate that the change cannot be attributed solely to the manipulative thrust.

Because of the positive effects observed in the sham group, other factors that could contribute to the positive effects of manual therapy including patient expectation, therapist-client interaction, placebo effect, passage of time, positive effects that can be associated with manual contact, and psychosocial factors need to be considered.[32,36] The benefits from spinal manipulative therapy may be derived from aspects of the treatment other than the manipulative thrust. It appears, as other studies have reported, that immediate changes in symptoms are likely not due to biomechanical changes at the scapulothoracic articulation.[32,33,36]

Chapter 5: Discussion

Introduction

The Scapular Assistance Test (SAT)[19,26-28] and the Scapula Reposition Test (SRT)[25,29] have been previously described as symptom modification tests that may be helpful in identifying scapular contributions to the pain and dysfunction often experienced by patients with Subacromial Pain Syndrome (SPS). However, little has been reported on the clinical utilization of the SAT and SRT in examining patients with SPS and it is currently unknown whether or not the results of these tests are an indication of the presence of impairments previously found to be related to abnormal scapular motion. Specifically, we were interested in discerning whether differences exist in scapular mobility (passive and active), scapulothoracic muscle force generation, or pectoralis minor muscle length between individuals who test positive and those who test negative. This knowledge may help in determining the ability of these tests to detect clinically relevant impairments at the scapulothoracic articulation in people with shoulder pain and dysfunction.

Additionally, while it has been shown that individuals with SPS benefit from thoracic spine thrust manipulation, the explanatory mechanisms have yet to be elucidated. Prior research has reported improvements in shoulder range of motion (ROM)[34] as well as self-reported pain[33,34,36] and function.[33,36] The effects of thoracic spine thrust manipulation on clinical measures of scapular motion, muscle force generated by the middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA), and length of the pectoralis minor have yet to be determined. Previous studies have either performed multiple manipulative techniques on each subject without a sham or control group or compared a single technique to a sham treatment. Furthermore, whether patients respond differently to the technique that is utilized has yet to be determined. Therefore, the second research aim of this study was to investigate the immediate and short-term effects of two different thoracic spine thrust manipulation techniques commonly used for the treatment of shoulder pain, compared to a sham technique, in individuals with SPS to investigate the effects of those techniques on impairments associated with abnormal scapular motion.

Discussion: Research Aim 1

For the first research aim, the results of this study indicated no significant differences in scapular upward rotation (UR) or posterior tilt (PT) active or passive motion for individuals with SPS who tested positive on the SAT or SRT compared to those who tested negative. There were also no significant differences in mean normalized force generated in the MMT positions for the MT, LT, or SA between those who tested positive and negative on the SAT or the SRT. Although not related to our research questions, significant differences were found to exist in force generated for the MT, LT, and SA muscle tests on the involved side compared to the non-involved side regardless of outcome on the SAT or SRT, likely due to pain-related muscle inhibition during the test. Significant differences existed in pectoralis minor muscle length and pectoralis minor index (PMI) based on the results of the SAT but not for the SRT. Individuals who tested positive on the SAT demonstrated a significant decrease in pectoralis minor muscle length compared to those who tested negative. Additionally, the methods utilized for measuring scapular UR and PT active and passive ROM, scapulothoracic muscle force generated in the MMT positions for MT, LT, and SA, and pectoralis minor muscle length demonstrated excellent intrarater reliability with all ICCs ≥ 0.90. SEM and MDC values were calculated and reported for these measures and can be seen in **Table 4-4**.

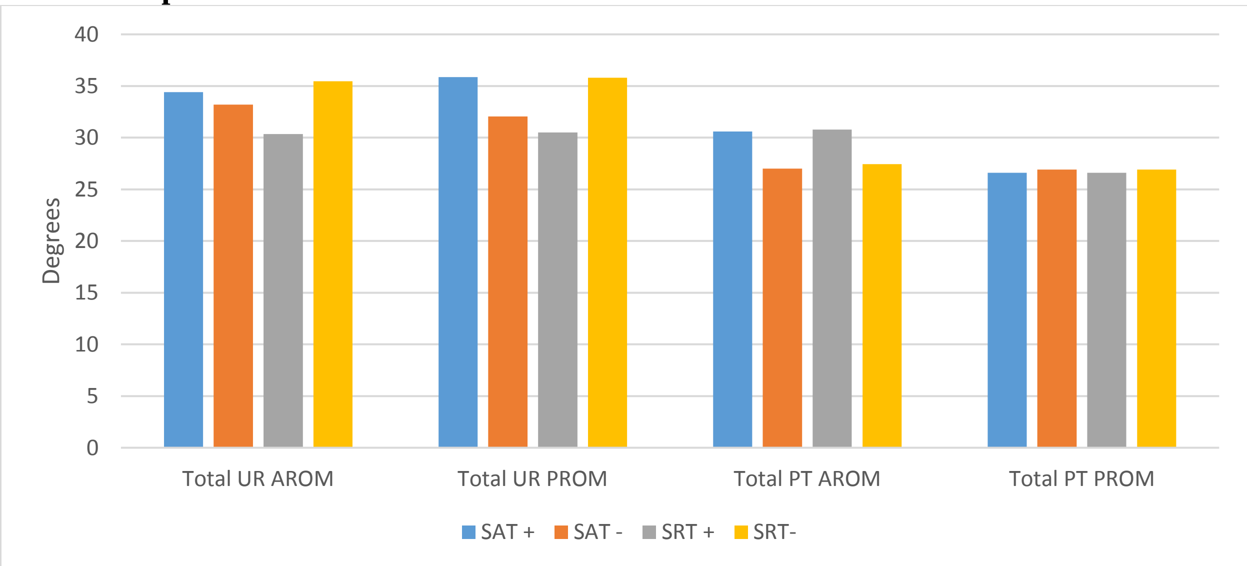
Scapular Motion

No significant differences existed in scapular UR or PT active or passive motion between individuals who tested positive and those who tested negative on either the SAT or SRT when those tests were examined independently of one another. For the SAT, median differences of 1.2° for active total UR, 3.8° for passive total UR, 3.6° for active total PT, and 0.3° for passive total PT existed between the positive and negative groups. For the SRT, median differences of 5.1° for active total UR, 5.3° for passive total UR, 3.4° for active total PT, and 0.3° for passive total PT existed between the positive and negative groups. The amount of error associated with each of these measures ranged from 3.2° to 4.3°, indicating that the median differences between SAT groups and SRT groups were small in magnitude and true differences may not exist.

Although we hypothesized that individuals with SPS who test positive on the SAT or SRT would be more likely to demonstrate impairments in scapular motion, the median values for those motions provided evidence to the contrary. We specifically hypothesized that those who tested positive on the SAT would demonstrate deficits with UR. Although the difference was not significant, the amount of active total UR and passive total UR was actually slightly greater (median difference of 1.2° and 3.8°, respectively) in those individuals. In contrast to the results of the SAT, the findings from the SRT revealed slightly less total UR motion in those who tested positive compared to those who tested negative, both actively (median difference of 5.1°) and passively (median difference of 5.3°). However, we did not specifically hypothesize on the relationship between the results of the SRT and the amount of UR motion because the procedure behind the SRT does not have an intentional component involving UR motion. We also hypothesized that those who tested positive on the SRT or SAT would present with greater impairments in PT motion but no significant differences existed. (**Figure 5-1)**

It appears that the SAT and SRT may not help us in identifying meaningful impairments in scapular UR and PT motion in individuals with SPS. Although we did not find significant differences in scapular motion, we are confident in the measures that were utilized as our results are comparable to previously reported findings. Our median values for total UR are similar to values previously reported with the use of 3D motion analysis[22,59] and a modified digital inclinometer[39] in both symptomatic and asymptomatic populations. Similarly, our median values for total PT are comparable to values previously reported using both 3D motion analysis and a modified digital inclinometer.[40] Furthermore, our results indicated excellent reliability for these measures with ICCs ranging from 0.90-0.97. We acknowledge that there is a large degree of variance in these measures of scapular motion and it is likely that we did not see a difference because of the variability in the data. It is also possible that our measurements are not precise enough based on the calculated standard errors to detect a difference if one truly exists.

Figure 5-1.
Median Scapular Kinematic Values with Maximal Arm Elevation



UR = upward rotation, PT = posterior tilt, AROM = active range of motion, PROM = passive range of motion, SAT = scapular assistance test, SRT = scapula reposition test

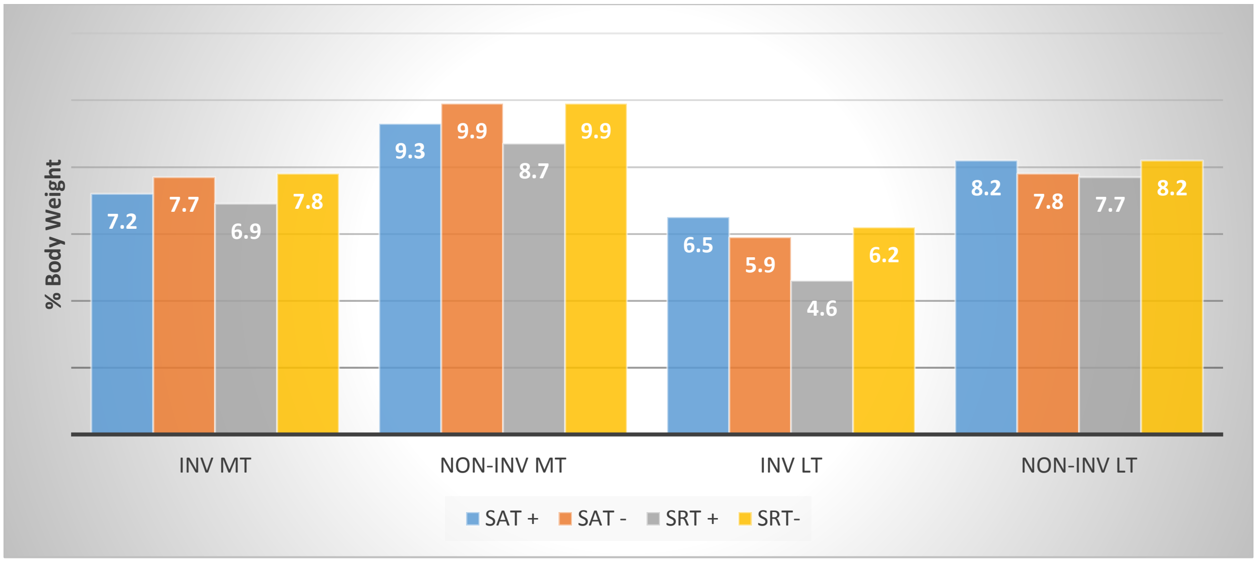
It was an interesting finding that PROM values for scapular PT were less than AROM. Kai et al[149] reported finding a significant reduction in UR with passive elevation of the arm compared to active elevation but did not find a significant difference with PT. We believe that this difference was most likely due to the methods used in assessing this motion passively. The procedure required the examiner to passively elevate the arm, through contact at the distal humerus, in the scapular plane to the end-range of elevation for two repetitions. The measurement of scapular motion was obtained with the digital inclinometer at the point of maximal passive arm elevation on the second repetition. It is our opinion that the inability to provide manual contact directly at the scapula, as well as the lack of coordinated muscle activity around the scapula to produce that motion, resulted in lesser motion passively. Additionally, we obtained these measurements with the subject in standing, a position that likely allowed some movement from the trunk and which could have been greater during active elevation of the arm.

Scapulothoracic Muscle Force

There were no significant differences in the normalized force generated in the MMT positions for the MT, LT, or SA between those who tested positive vs. negative on the SAT or SRT. These findings did not support our hypothesis that those who tested positive would demonstrate impairments in strength of those muscles. There did appear to be a trend towards decreased ability to produce force across all muscles examined in those who tested positive on the SAT and SRT. That trend was also present on the non-involved side and may indicate a more general or regional impairment of force generation in these individuals. (**Figure 5-2)** Although we did not detect significant differences, our measurements had excellent levels of reliability with ICCs ranging from 0.92-0.97 and small degrees of error (0.79%-1.46% of body weight).

It appears that the SAT and SRT may not be effective in detecting impairments in force generation in the MT, LT, or SA in individuals with SPS. Rather than seeing a difference in force generation that was associated with the result of the SAT or SRT, both groups (positive or negative) demonstrated a decreased ability to produce force from the involved shoulder. This finding was most likely due to the presence of pain during testing of the involved shoulder potentially resulting in muscle inhibition. Median pain levels reported on the VNRS during the muscle tests were significantly different on the involved side for the three tests performed (MT=2.0/10, LT=3.0/10, SA=2.0/10) compared to the non-involved side (0.0/10 for MT, LT, and SA) for all participants. The significant differences between the involved and non-involved side pain did not differ based on SAT or SRT groups. Therefore, it appears that the presence of pain was a factor related to the force generation deficits on the involved side in this study.

Figure 5-2.
Median Normalized Muscle Force Values



INV = involved, NON-INV = non-involved, MT = middle trapezius, LT = lower trapezius, SAT = scapular assistance test, SRT = scapula reposition test

Pectoralis Minor Muscle Length

The current study found that those who tested positive on the SAT had lower pectoralis minor muscle length (p = .023) and PMI scores (p = .023) than those who tested negative (**Table 4-6**). For those who tested positive on the SAT, the median length was 14.5 cm (IQR: 13.8-16.6 cm) and median PMI was 8.75 (IQR: 8.32-9.28) compared to 16.0 cm (IQR: 14.8-17.7 cm) and 9.46 (IQR: 8.78-10.14) for those who tested negative. There was not a statistically significant difference in pectoralis minor length associated with the results of the SRT (PMI: p = .389). The measurement used in the current study for pectoralis minor muscle length yielded a high intrarater reliability (ICC=0.99) with an MDC of 0.38cm.

We suspected that the length of the pectoralis minor may contribute to our hypothesized deficit in PT motion. The pectoralis minor has the capability of limiting the amount of PT and has been reported to influence scapular kinematics as demonstrated by Borstad and Ludewig[103] and may therefore contribute to shoulder dysfunction. It was therefore surprising to find a significant difference in pectoralis minor length when there was not a significant difference in total or end-range PT motion actively or passively between the positive and negative SAT groups. This finding may warrant further investigation.

Taking into consideration the lower prevalence of positive results on the SRT, we suggest combining the results of the SAT and SRT for clinical decision making. In this manner, patients can either be positive on the combined test by having a positive result on either test, or negative by having negative results on both. This combined test would produce 32 (53.3%) participants with positive results and 28 (46.7%) with negative results. (**Table 5-1)** A significant difference in baseline PMI values existed between the two groups, with those who tested positive having shorter muscle length values (p = .037, median: 8.89 cm compared to 9.47 cm). Additional significant findings were discovered between these two groups for baseline level of pain on the VNRS with those who tested positive having greater pain compared to those who tested negative (3.5/10 and 1.0/10, respectively; P < .001). There were still no significant between-group differences in scapular motion or scapulothoracic muscle force generation.

Table 5-1
Results of combined SAT/SRT and dichotomized SDT at Baseline

	SDT Results	
SAT & SRT	**Normal**	**Obvious**
Positive on at least one (N=32; 53.3)*	18 (56.2)	14 (43.8)
Negative on both (N=28; 46.7)	16 (57.1)	12 (42.9)

*10 (16.7%) positive on both
Values are expressed as number (%)
SAT = scapular assistance test, SRT = scapula reposition test, SDT = scapular dyskinesis test

Discussion: Research Aim 2

The goal of the second research aim was to determine whether a specific thoracic manipulation technique had a greater immediate effect on pain, function, and possible explanatory factors including changes in scapulothoracic muscle force generation, scapular UR and PT motion with maximal arm elevation, or pectoralis minor muscle length in patients with SPS. There were no significant between-group differences for immediate change in pain or 48-hour improvement in pain, function, satisfaction with the involved shoulder, and total PSS score. No other differences existed between treatment groups. Small but significant improvements in various measures of active scapular motion and upper extremity elevation and scapulothoracic muscle force generation were seen within all 3 groups. Small but significant improvements in pectoralis minor length existed in the seated and sham groups. Significant improvements were seen in immediate change in pain in the seated and sham groups, as well as pain, function, and total PSS scores obtained 48 hours after treatment in all 3 groups.

Scapular Motion

There were no significant between-group differences in scapular motion based on the intervention received. Participants in all 3 groups experienced significant improvements in end-range scapular UR AROM (supine: $p = .002$, seated: $p = .014$, sham: $p = .012$) and humeral elevation in the scapular plane (supine: $p = .003$, seated: $P < .001$, sham: $P < .001$). The median increase in scapular plane active elevation for all 3 groups exceeded the MDC_{95} of 8 degrees that has been previously reported by Kolber et al.[137] The majority of participants (36 in total, consisting of 12 participants from each group) had a change in scapular plane elevation that exceeded the MDC. Change that exceeds the MDC is commonly defined as meaningful because it is likely to represent true change.[27] A significant immediate increase in shoulder elevation and rotation ROM following thoracic manipulation in subjects with shoulder pain has been previously reported by Strunce et al.[34] However, because arm elevation in the scapular plane increased significantly and by the same amount in all groups in the present study, the improvement cannot be attributed to the thrust manipulation.

The significant improvements in scapular motion that were observed did not exceed the MDC and are therefore less likely to represent change beyond error. Results indicated significant improvements in total UR AROM in the supine manipulation group ($p = .002$) (5.85°; MDC_{90}=6.06°) and total PT AROM in the sham manipulation group ($p = .033$) (3.92°; MDC_{90}=5.52°). However, the lack of between-group differences in these variables indicates that thrust manipulation delivered to the upper thoracic spine in either a seated or supine position did not result in significant changes in scapular kinematics. The improvement in scapular plane elevation experienced in the seated manipulation group occurred without a significant improvement in total scapular UR or PT motion. Additional significant findings existed with the resting position for UR AROM in the seated manipulation group ($p = .015$), end-range motion for UR AROM in the supine manipulation ($p = .002$), seated manipulation ($p = .014$), and sham manipulation ($p = .012$) groups, resting position for UR PROM in the seated ($p = .015$) and sham ($p = .024$) groups, and end-range PT AROM in the seated ($p = .022$) and sham ($p = .013$) groups. However, due to multiple comparisons being performed without adjusting the p-value, we acknowledge that some of these findings may be arbitrary.

Similar to our results, previous studies examining the effects of thoracic spine thrust manipulation on scapular motion reported differences that were either not significant or not clinically important. Muth et al[33] found no significant change in humeral elevation ROM or scapular kinematics as measured with 3D motion analysis other than a small decrease in UR. Rosa et al[72] also found no significant differences in scapular kinematics using 3D motion analysis following a seated mid-thoracic manipulation in asymptomatic subjects. Delivering the same seated mid-thoracic technique, Haik et al[32] reported a small but not clinically important increase in UR of 2.2°, again using 3D motion analysis, in subjects with and without SPS. The 2.2° increase in UR motion is very similar to what we found with both a comparable seated manipulation technique and our sham technique which was also in sitting. The supine technique in the current study, however, resulted in a 5.8° increase in UR and may warrant further investigation. Kardouni et al[36] reported no significant differences in scapular kinematics with 3D motion analysis following a single session of manual therapy that consisted of 3 different spinal manipulative techniques compared to sham techniques in subjects with subacromial impingement. They concluded, as other authors have, that a change in scapular kinematics does not appear to provide the explanation for improvements in pain and function that may be experienced.[36] The results from this study support this notion.

Scapulothoracic Muscle Force

There were no significant between-group differences for the post-intervention measures of normalized force generation for the MT or LT, or normalized torque for the SA. Therefore, the results did not support our hypothesis that the seated manipulation technique would result in greater improvements. Significant within-group changes did exist in normalized force in all 3 groups. Despite reaching statistical significance, the median values did not exceed the MDCs for any of the measures and therefore do not exceed the error of the measure, challenging the clinical relevance of these findings.

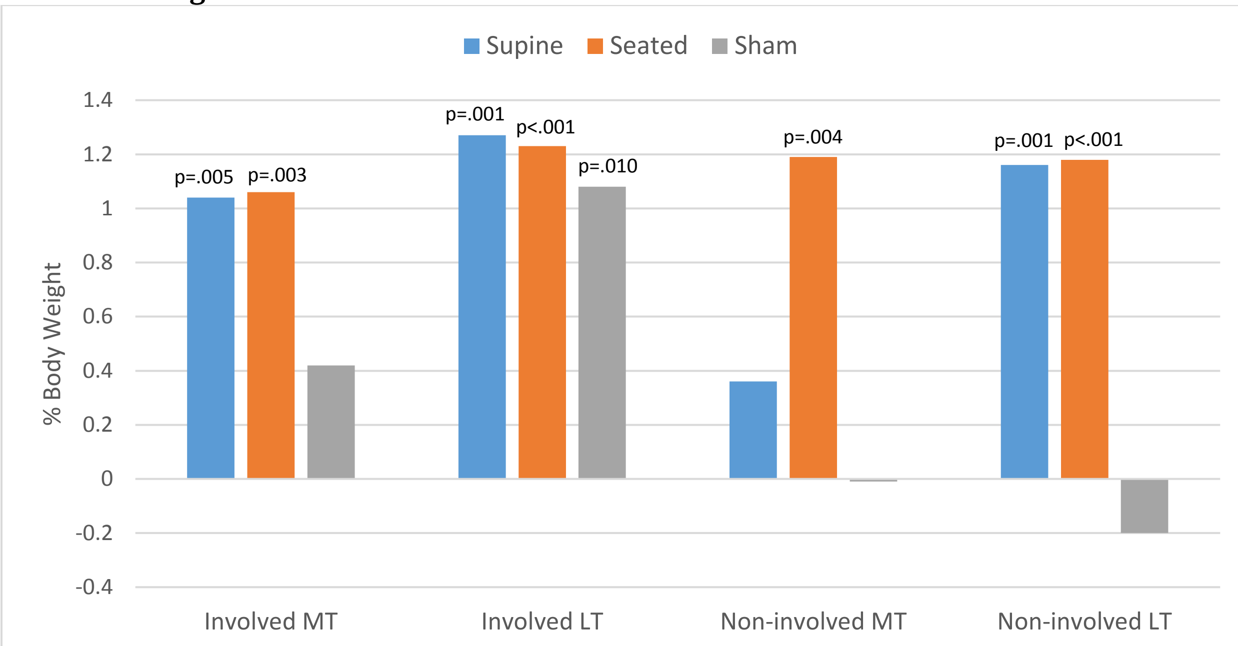
While this was not one of our proposed questions or research hypotheses, we did look at whether there were differences in force generation on the non-involved side. Significant differences were found within the active treatment groups (supine and seated manipulations) from pre- to post-intervention in the non-involved MT and LT. The seated manipulation group had a greater gain in the non-involved MT ($p = .028$), non-involved LT ($p = .009$), and non-involved SA ($p = .027$) compared to the other two groups.

Specifically, 19 (31.7%) subjects across all 3 groups (6 in the supine manipulation group, 6 in the seated manipulation group, and 3 in the sham manipulation group) exceeded the MDC for normalized involved MT force. The greatest percentage of subjects improving beyond the MDC was seen in the involved LT, with 25 (41.7%) subjects (9 in the supine manipulation group, 8 in the seated manipulation group, and 8 in the sham manipulation group) exceeding the MDC. Twelve (20.0%) subjects exceeded the MDC for normalized involved SA torque (4 in the supine manipulation group, 3 in the seated manipulation group, and 5 in the sham manipulation group).

By group allocation, the supine manipulation group experienced significant gains in the involved MT ($p = .005$) and LT ($p = .001$), as well as the non-involved LT ($p = .001$). The seated manipulation group experienced significant gains in the involved MT ($p = .003$), LT ($p < .001$), and SA ($p = .005$), as well as the non-involved MT ($p = .004$) and LT ($p < .001$). The sham manipulation group experienced a significant gain in the involved LT ($p = .010$) only.

The observed improvements in force production might have been the result of motor learning associated with multiple repetitions of the same test. The increase in force might also be explained by a reduction in pain. However, improvements in strength also existed on the non-involved side, where participants reported pain to be 0/10 on the VNRS in 85.6% of the strength tests performed. The absence of pain in the majority of these tests indicates that the gains were not because of pain reduction. Further, the significant within-group changes in force on the non-involved side existed in the active treatment groups and were not present following the sham technique. In effect, force production actually remained the same or worsened slightly following the sham as shown in **Figure 5-3**. It appears that the manipulations were able to produce improvements in strength in the absence of pain which did not occur with the sham technique. Improvements in force production in healthy (asymptomatic) individuals have been previously reported following thoracic spine manipulation[57] and mobilization.[56]

Figure 5-3.
Median Change in Normalized Muscle Force Values



MT = middle trapezius, LT = lower trapezius

The current collection of literature specifically examining the effects of thoracic spine thrust manipulation in subjects with shoulder pain[32,33,36] has not included an assessment of scapulothoracic muscle force. Muth et al[33] included handheld dynamometry to assess shoulder elevation strength only, and EMG to assess muscle activity of the upper, middle, and lower trapezius, infraspinatus, and serratus anterior. Following a combination of two different seated thoracic manipulation techniques, they discovered a significant increase in shoulder elevation force production of 2.5 kg ($p < .001$), but no significant differences in scapulothoracic muscle activity other than a small increase in the MT.[33] Our findings indicated significant, but small, increases in force production in the MMT positions used for the MT and LT following the supine manipulation and in the MT, LT, and SA following the seated manipulation. Comparatively, the sham treatment only resulted in a significant increase in LT strength. These results provide an indication that thoracic spine thrust manipulation may have the potential to produce an increase in scapulothoracic muscle force generation in individuals with SPS; however, the effects of thoracic spine thrust manipulation were not found to be significantly different from the sham treatment in this study.

Pectoralis Minor Muscle Length

No significant between-group differences existed in post-intervention muscle length or change in muscle length for the pectoralis minor or the PMI based on the intervention received and, therefore, our hypothesis was not supported. There were significant improvements in pectoralis minor muscle length in the seated manipulation group and sham manipulation group ($p = .001$ and $p = .031$, respectively) and PMI ($p = .033$) in the seated manipulation group. These findings may provide some support behind our proposed theory that the seated technique might have the ability to exert a greater influence on the pectoralis minor tissue through the positioning of the subject's arms and the cephalad direction of the force. Because a significant improvement in length was also observed in the sham treatment group, it appears that the positioning and application of the force were possibly more important in producing the effect than the manipulative thrust.

A total of 22 (36.7%) subjects exceeded the MDC for pectoralis minor muscle length of 0.38cm, with 9 of those subjects coming from the seated manipulation group (7 in the supine manipulation group and 6 in the sham manipulation group). A previous study[150] reported mean values for PMI which were lower for those who tested positive on the SDT compared to those who tested negative; however, our results did not support that finding. That study also stated that increasing PMI was associated with a reduction in the likelihood of exhibiting dyskinesis,[150] yet our findings did not support this either.

Pain

The immediate effect of the intervention on pain was assessed through the use of the VNRS and rated during active elevation of the involved arm at baseline testing and immediately after delivery of the intervention. There were no between-group differences. The seated manipulation group (p = .009) and sham manipulation group (p = .001) experienced significant improvements in pain, while the supine group did not (p = .073). The median (IQR) for change in pain for both groups was 1.0 (0.0-2.0), representing change that did not exceed the MDC of 3.0[99] or MCID of 2.17[143] and therefore the clinical meaning of these changes is questionable. The magnitude of this immediate change in pain was similar to that previously reported.[31-33,36] In addition, the results of this study indicated that the sham treatment resulted in an equal or greater reduction in pain than either active treatment. These findings suggest that the manipulative thrust may not be the component of spinal manipulation treatment that reduces pain. Other interactions and potential variables not collected in this study, such as psychosocial factors including patient expectation, may be involved.

Penn Shoulder Score

The PSS is a composite that captures self-reported pain, function, and satisfaction with excellent reliability (ICC=0.94) and measurement properties (SEM=8.5 points, MDC=12.1 points, MCID=11.4 points).[147] Significant between-group differences existed in post-treatment level of satisfaction, self-reported function, and total Penn Shoulder score. Due to losing 3 participants to follow-up, this analysis was completed with baseline measures carried forward to the 48-hour follow-up measures and completed with excluding those 3 participants for comparison. Results were consistent regardless of the methods used for the analysis. Pairwise comparisons revealed significant differences between the supine and sham groups in post-treatment scores for satisfaction ($p = .022$ or $p = .031$ with the 3 subjects removed), function ($p = .021$ or $p = .030$ with the 3 subjects removed), and total score ($p = .016$ or $p = .029$ with the 3 subjects removed), with greater results in all three outcomes for the sham group. There were no significant differences in the amount of change in pain, function, satisfaction, or PSS total score based on the treatment delivered. Kardouni and colleagues[36] have previously reported no significant differences in the improvements in patient-reported outcomes between active and sham treatments in this population. Our results provide the same conclusion.

Significant improvements in PSS total scores were seen in all 3 groups between baseline and 48-hour follow-up (supine: $p < .001$, seated: $p = .004$, sham: $p < .001$). The median change in PSS values were 7.0 for the supine manipulation group, 9.0 for the seated manipulation group, and 11.0 for the sham manipulation group. A total of 22 (36.7%) participants had an improvement in PSS total score that exceeded the MDC of 12.1 points (6 in the supine manipulation group, 6 in the seated manipulation group, and 10 in the sham manipulation group) and 23 (38.3%) participants had scores that exceeded the MCID of 11.4 points. In addition, all 3 groups experienced significant improvements in pain (supine: $p < .001$, seated: $p = .001$, sham: $p < .001$) and function (supine: $p = .010$, seated: $p = .018$, sham: $p = .004$) between baseline and 48-hour follow-up that were slightly below the MDC of 5.2 for the pain subscale.[147] There was an improvement in pain at 48 hours regardless of intervention received, indicating that the manipulative thrust may not be the element of the treatment that resulted in the reduction in pain. This has been discussed previously by other authors.[32,36] Only the sham group experienced a significant increase in level of satisfaction with the affected shoulder ($p = .003$). In fact, if we look at the mean change values instead of the median, the sham group numbers exceeded the

MDCs for the pain and function subscales, as well as the total score, while no other change score from either active treatment group did the same.

Lopes et al[110] has reported that individuals with dyskinesis scored lower in total PSS score and in the function subscale. Our results support this finding. Participants that were rated as having obvious dyskinesis had statistically significant lower scores compared to participants with normal/subtle dyskinesis for pain (median: 23.0 compared to 27.0; $p = .001$), satisfaction (median: 5.0 compared to 8.0; $p = .024$), function (median: 47.0 compared to 52.5; $p = .028$), and total score (median: 72.0 compared to 85.8; $p = .003$). Additionally, the change in function score ($p = .040$) and change in total score ($p = .011$) were significantly different between these groups. This indicates a possible association between the presence of dyskinesis and higher levels of self-reported pain and dysfunction and may be something to consider with these patients.

Additionally, the SAT, SRT, and SDT were reassessed immediately after the delivery of the intervention to identify any changes from baseline. Fourteen fewer participants tested positive on the SAT (4 from the supine group, 7 from the seated group, and 3 from the sham group) and 8 fewer tested positive on the SRT (2 from the supine group, 2 from the seated group, and 4 from the sham group). This was due in large part to a reduction in pain with arm elevation, such that arm elevation was either no longer painful or the pain level on the VNRS was at a value that was too low for the SAT or SRT to provide at least a 2 point reduction. The improvement in shoulder pain with elevation was seen in all 3 groups and therefore cannot be said to have resulted from the manipulation itself. The results of the SDT were largely unaffected by the intervention delivered with only a single participant in the supine manipulation group changing from subtle to normal, indicating that manipulation was not effective in reducing scapular dyskinesis. In fact, with the results of the SDT dichotomized into normal or obvious, there was no difference in dyskinesis from baseline to post-intervention in any of the groups. It is important to note that while the examiner was blinded to group assignment during collection of the baseline measures, he was not blinded to the intervention or to the pre-treatment test outcomes while collecting the post-treatment measures. The lack of a change in dyskinesis despite improvements in pain and function has been reported by other authors.[151,152] These results are summarized in **Table 5-2 and 5-3**.

Table 5-2.
Results of SAT, SRT, and SDT for all Participants at Baseline and Post-Intervention

	Baseline	**Post-Intervention**
SAT	Positive = 25 (41.7)	Positive = 11 (18.3)
	Negative = 35 (58.3)	Negative = 49 (81.7)
SRT	Positive = 17 (28.3)	Positive = 9 (15.0)
	Negative = 43 (71.7)	Negative = 51 (85.0)
SDT	Normal = 6 (10.0)	Normal = 7 (11.7)
	Subtle = 28 (46.7)	Subtle = 27 (45.0)
	Obvious = 26 (43.3)	Obvious = 26 (43.3)
SDT dichotomized	Normal = 34 (56.7)	Normal = 34 (56.7)
	Obvious = 26 (43.3)	Obvious = 26 (43.3)

Values are expressed as number (%)
SAT = scapular assistance test, SRT = scapula reposition test, SDT = scapular dyskinesis test

Table 5-3.
Results of SAT, SRT, and SDT by Group at Baseline and Post-Intervention

	Supine Upper Thoracic Manip (n=20)	Seated Upper Thoracic Manip (n=20)	Seated Sham Manip (n=20)
SDT - Baseline	Normal = 0 (0) Subtle = 8 (40) Obvious = 12 (60)	Normal = 1 (5) Subtle = 12 (60) Obvious = 7 (35)	Normal = 5 (25) Subtle = 8 (40) Obvious = 7 (35)
SDT – Post-intervention	Normal = 1 (5) Subtle = 7 (35) Obvious = 12 (60)	Normal = 1 (5) Subtle = 12 (60) Obvious = 7 (35)	Normal = 5 (25) Subtle = 8 (40) Obvious = 7 (35)
SAT - Baseline	Positive = 7 (35) Negative = 13 (65)	Positive = 11 (55) Negative = 9 (45)	Positive = 7 (35) Negative = 13 (65)
SAT - Post-intervention	Positive = 3 (15) Negative = 17 (85)	Positive = 4 (20) Negative = 16 (80)	Positive = 4 (20) Negative = 16 (80)
SRT - Baseline	Positive = 4 (20) Negative = 16 (80)	Positive = 5 (25) Negative = 15 (75)	Positive = 8 (40) Negative = 12 (60)
SRT - Post-intervention	Positive = 2 (10) Negative = 18 (90)	Positive = 3 (15) Negative = 17 (85)	Positive = 4 (20) Negative = 16 (80)

Values are expressed as number (%)
SAT = scapular assistance test, SRT = scapula reposition test, SDT = scapular dyskinesis test

If we combine the results of the SAT and SRT for clinical decision making, the post-intervention results of the combined test and SDT can be seen in **Table 5-4.** Based on the baseline results of the combined test, a significant difference existed between the two groups (positive and negative) in the improvement in active arm elevation in the scapular plane ($p = .047$) (mean (95% CI): 12.0° (9.1°-15.0°) vs. 7.1° (4.0°-10.2°)) and immediate change in pain on the VNRS ($p < .001$) (median 2.0/10 vs. 0.0/10) with those who tested positive having greater improvements. There were still no significant between-group differences in scapular motion, scapulothoracic muscle force generation, or pectoralis minor length. The results of the proposed combined SAT/SRT test may help in identifying patients with SPS that are likely to experience a greater reduction in pain or greater improvement in scapular plane elevation AROM following treatment.

Table 5-4.
Results of combined SAT/SRT and dichotomized SDT

SAT & SRT Results	Baseline	Post-Intervention
Positive on at least one	32 (53.3)*	13 (21.7)*
Negative on both	28 (46.7)	47 (78.3)
Positive on at least one	N=32 **SDT Result:** Normal = 18 (56.2) Obvious = 14 (43.8)	N=13 **SDT Result:** Normal = 6 (46.2) Obvious = 7 (53.8)
Negative on both	N=28 **SDT Result:** Normal = 16 (57.1) Obvious = 12 (42.9)	N=47 **SDT Result:** Normal = 28 (59.6) Obvious = 19 (40.4)

*10 (16.7%) positive on both at baseline and 7 (11.7%) positive on both at post-intervention
Values are expressed as number (%)
SAT = scapular assistance test, SRT = scapula reposition test, SDT = scapular dyskinesis test

Does the manipulation technique matter?

Based on the results of this study, it appears that the selection of a seated versus a supine thoracic spine thrust manipulation for individuals with SPS does not matter. In fact, neither technique appears to have a significant effect on scapular motion during arm elevation in the scapular plane when compared to a sham treatment. Thoracic spine thrust manipulation may have the potential to produce force generation gains in positions used to assess scapulothoracic muscle strength; however, these results demonstrate that the gains are no better than those achieved with a sham treatment and the mechanisms behind that improvement remain largely unknown. The only significant between-group difference that resulted in terms of muscle force was with the scapulothoracic muscles on the non-involved side, where the seated manipulation produced greater improvements. Strength gains were not observed on the non-involved side following the sham manipulation, which may provide support to the proposed neurophysiological effects of spinal thrust manipulation. Small but statistically significant differences were detected in pectoralis minor muscle length favoring the seated and sham manipulation groups; however, no significant between-group differences existed. Because the sham manipulation incorporated the same positioning and direction of force as the seated manipulation, just without the manipulative thrust, this finding would seem to indicate that the positioning and not the thrust was the more important element of that technique. No significant differences existed for the 48-hour change in pain, satisfaction, function, and total scores from the PSS. Likewise, immediate improvements in pain with thoracic manipulation were no better than the sham treatment. In summary, the only significant result from this study that provided support for the use of thoracic spine thrust manipulation over a sham treatment was the small improvement in strength on the non-involved side, suggesting a more central mechanism may be present but without immediate benefit to the involved shoulder. Otherwise, the sham treatment performed equally well to both a supine and seated thrust manipulation technique for the thoracic spine in individuals with SPS.

Because of the positive effects observed in the sham group, other factors that could contribute to the positive effects of manual therapy including patient expectation, therapist-client interaction, placebo effect, passage of time, positive effects that can be associated with manual contact, and psychosocial factors need to be considered.[32,36] Additionally, as the present study had the same clinician perform both the treatment and the assessment, the possible effects of the examiner not being blinded to the intervention group or measurements must be considered. The benefits from spinal manipulative therapy may be derived from aspects of the treatment other than the manipulative thrust. It appears, as other studies have reported, that immediate changes in symptoms are likely not due to biomechanical changes at the scapulothoracic articulation.[32,33,36]

Implications

This study offers additional knowledge surrounding the clinical examination and treatment of individuals with SPS, a classification which represents as much as 65% of all shoulder pain[2] and therefore has increased relevance to clinical practice. In addition, the measurements performed in this study for the dependent variables are feasible for the clinical practice setting and have shown levels of reliability that are appropriate for continued clinical use. The results that have been obtained may help to inform clinicians about the utility and current limitations of the SAT and SRT in the clinical examination of patients with SPS and about the effectiveness of thoracic spine thrust manipulation for this population.

First, impairment-level information believed to be associated with abnormal scapular motion and frequently a focus of treatment in rehabilitation for SPS was compared in patients with positive versus negative results on the SAT and SRT, two previously described tests for shoulder pain built on the symptom alleviation approach. Unfortunately, the failure to find statistically significant and clinically meaningful differences in these impairment measures between individuals who tested positive and negative leads to more questions than answers at this time. There are a number of possibilities as to why differences did not exist, and some of these may lead us to reconsider our views on the potential clinical utility or value of the SAT and SRT. It is possible that these groups are not homogenous or the test outcomes are not solely based on influence or alterations at the scapula. Perhaps the scapular contributions to shoulder dysfunction involve something other than alterations in position, motion, or strength which we did not assess. Maybe shoulder dysfunction is not related to scapular motion or muscle force impairments to the extent that we thought it might be and perhaps other factors such as motor control are more significant. Perhaps this sample, consisting mostly of individuals that were not actively seeking treatment for their shoulder pain, was not impaired enough for differences to be detected with these measures and subjects with greater dysfunction are needed to identify a difference. Nonetheless, the results provide information that helps to fill in a gap in the literature and contributes to the growing body of knowledge. The hope for rehabilitation professionals is that this symptom alleviation approach will better serve to inform treatment decisions and may help in identifying sub-categories to improve the efficiency and effectiveness of care, but more research is necessary to determine the factors that are associated with positive clinical findings of the SRT and SAT that can be used to direct treatment.

The second research aim of this study contributes to the current knowledge by providing a direct comparison of two different thoracic spine thrust manipulation techniques to a sham treatment. Previous studies examining the effectiveness of thoracic spine manipulation for shoulder pain have either combined multiple manipulative techniques or compared a single technique to a sham treatment. This study adds new information about the effects of a supine upper thoracic manipulation as recent studies that incorporated motion analysis equipment were unable to utilize supine techniques. Furthermore, to our knowledge, no previous study has compared the effects of a supine thoracic spine thrust manipulation to a sham treatment, allowing for the determination of whether or not the observed effects were truly due to the application of the manipulative thrust.

The results from this study suggest that thoracic spine thrust manipulation may be helpful in reducing pain and improving function in individuals with subacromial pain syndrome; however, the manipulation techniques used in this study did not produce greater differences than a sham treatment and thoracic spine thrust manipulation is not without risk. Improvements in pain and function that occur following thoracic manipulation appear not to be due to biomechanical changes in scapular kinematics, muscle force generation, or pectoralis minor muscle length and may result instead from aspects of the treatment other than the manipulative thrust. There is currently limited evidence to support or refute thoracic spine manipulation as a stand-alone treatment for SPS. Therefore, the need for thoracic spine manipulation in this population must be questioned and further investigations are necessary to more confidently determine its effectiveness.

Limitations and Delimitations

This study had a number of limitations. First, the variability in the data was greater than expected and we were unsuccessful in obtaining a normal distribution for some of the variables with the estimated sample size of 20 in each group. This resulted in the decision to use non-parametric statistical analyses. As a result, we recognize that our results may be impacted by Type II error. The examiner was not blinded and was also the individual who performed the intervention. While we were intentional in including a 48-hour follow-up, there was no additional follow-up beyond that timeframe so our results cannot be generalized to long-term effects. This study involved a single-session design and utilized standardized manual therapy techniques for each participant that were not specific to the impairments or needs of that individual. While the single-session design helped in minimizing subject attrition, it is not common to clinical practice. In addition, the single session of manual therapy might not have been the appropriate dosage to elicit meaningful improvements. Although the sham treatment technique had been previously validated and determined to be believable,[148] the believability of the sham technique was not assessed in this study. The sample obtained for this study had a mean baseline pain of 2.7/10 on the VNRS, which might have led to a floor effect and difficulty achieving a clinically meaningful improvement in pain. A low percentage (approximately 20%) of subjects were actively seeking treatment for their shoulder pain at the time of their participation in the study. Measurements of scapular motion were limited to humeral elevation in the scapular plane and similar results cannot be assumed with elevation in other planes. Furthermore, the measurements of scapular motion were obtained with the participants in standing and might have allowed for compensatory movements from the trunk or legs. Finally, the use of a single site and sample of convenience limits the generalizability of these findings to a larger population.

Limitations for this study included the frequency or number of referrals for patients with SPS to the participating outpatient physical therapy clinic, other clinics that were assisting in participant recruitment, or the principal investigator. The prevalence of positive findings on the SDT, SAT, and/or SRT in this population were additional limitations. Our results for the prevalence of the outcomes of these tests were similar to previous findings and resulted in a good balance of participants that tested positive and negative on the SAT, but produced unbalanced groups in terms of the results on the SRT and SDT.

Recommendations for Future Research

Future studies can look to improve upon the aforementioned limitations within this study or build off of these results. We would propose a few changes in research methods from the present study. First, we would suggest incorporating an additional investigator to improve internal validity by allowing the investigator serving as the examiner to remain blinded to the intervention and the investigator delivering the intervention to remain blinded to the examination data. We would also recommend including a minimum pain rating of at least 3/10 on the VNRS as part of the inclusion criteria in hopes of improving the ability to demonstrate a clinically meaningful improvement in pain if one exists. We would also seek to obtain a larger percentage or complete sample of subjects who are actively seeking treatment for their shoulder pain. Finally, we would obtain the measures of scapular motion with the participants in a seated position as a means of minimizing compensatory movements from the trunk and legs.

Future research can consider investigating the effects of manipulating other regions of the thoracic spine in individuals with shoulder pain. We chose to compare the effects of two different manipulations delivered to the upper thoracic spine; however, the results may differ for techniques aimed at the mid-thoracic or lower-thoracic region. The effects of manual therapy delivered to the thoracic spine versus the scapula can be compared. This approach may also serve to investigate the effects of manipulation versus mobilization for these respective regions. Additionally, the effects of the presence or absence of cavitation during manipulation can be explored further. Future research should seek to utilize a greater dose of manual therapy and include a multimodal approach to treatment. Specifically, therapeutic exercise should be included with manual therapy and compared to exercise alone and/or manual therapy alone. A more pragmatic approach to treatment can be utilized by completing a manual therapy examination first and then providing individually-designed treatment to each participant based on the exam findings. Additionally, a long-term follow-up is needed to determine if the observed changes persist beyond 48 hours.

Another line of future research can look to expand the current knowledge of the clinical utility of the symptom alleviation approach to examination and treatment of the shoulder, with continued investigation into the SAT, SRT, and other tests as described by Lewis and colleagues.[6,102] Although the results of this study did not identify significant or clinically meaningful differences in scapular motion, scapulothoracic muscle force generation, or pectoralis minor muscle length, these tests may still have clinical utility if they can demonstrate the ability to assist in directing treatment in a linear and prospective examination approach.

Summary

The Scapular Assistance Test (SAT) and Scapula Reposition Test (SRT) are clinical tests used to assist in determining whether treatment to address scapular impairments (strength, motion, muscle length, posture, etc.) should be included in the rehabilitation of a patient with shoulder pain. It is currently unknown whether impairments associated with abnormal scapular motion, position, or function, like scapulothoracic muscle strength or pectoralis minor muscle length, differ in individuals with subacromial pain syndrome (SPS) who have positive results on the SAT or SRT. Additionally, while it has been shown that individuals with SPS benefit with regard to improvements in pain and function from thoracic spine thrust manipulation, the mechanisms for these have yet to be elucidated. Whether there are immediate effects on impairments in scapular motion (upward rotation or posterior tilt), pectoralis minor muscle length, or scapulothoracic muscle force following a seated thoracic manipulation or a supine thoracic manipulation compared to a sham manipulation remains undetermined. Furthermore, no prior studies have compared the change in pain and function across thoracic manipulation techniques including a sham control group. Therefore, this study was designed with two research aims. The first aim was to investigate for differences in scapular upward rotation (UR) and posterior tilt (PT) motion, force generation in the MMT positions for the middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA), and length of the pectoralis minor in individuals with SPS who test positive or negative on the SAT or SRT. The second research aim was to determine if there were differences in the immediate effects on self-reported pain and function, force generation for the MT, LT, and SA muscles, scapular UR and PT motion, or pectoralis minor muscle length following a supine thoracic spine manipulation or seated thoracic spine manipulation when compared to sham technique in patients with SPS.

Researchers and clinicians continue to encounter difficulties in assessing and interpreting the relevance of scapular position and movement due to the common presence of postural asymmetry and normal kinematic variability. Further, the lack of longitudinal data makes it difficult to determine whether observed scapular findings in patients with shoulder dysfunction are compensatory or contributory. Therefore, the relevance of these findings may often be questioned or altogether dismissed as being insignificant. Although variability in scapular motion is understood, normal 3D scapular motions associated with humeral elevation have been established. Additionally, scapular motions that are likely to contribute to shoulder dysfunction have also been discussed. It has been reported that patients with SPS may have alterations in active scapular motion, especially upward rotation[21,58,87] and posterior tilt.[21,22,58] These alterations may be due to pain, muscle weakness, loss of passive motion due to muscle stiffness or muscle length, or other factors. These motions should therefore be examined in clinical practice. Measures for scapular upward rotation[39,41] and posterior tilt[40] using an inclinometer have produced acceptable levels of reliability for clinical use. Both of these measures have also demonstrated good validity.[39,40]

The SAT and SRT attempt to move away from the possible challenges associated with quantifying scapular motions while still providing information that scapular motion or position is likely involved in the production or perpetuation of shoulder symptoms. The SAT[26] and SRT[25] have demonstrated good reliability and appear to provide clinicians with useful information that can be used to determine the level of influence of the scapula in individuals presenting with shoulder pain. The SAT has been shown to alter scapular kinematics[27,98] and increase acromiohumeral distance,[98] while the SRT has been shown to increase humeral elevation strength.[25,101] However, relationships between impairments in scapulothoracic muscle force generation or scapular motion have not been assessed in relation to either the SAT or SRT.

Given an understanding of the challenges often confronted by clinicians in examining the scapula for contributions to shoulder dysfunction, there are a number of reasons this research was pursued. First of all, gaining an understanding of the presence or absence of strength and motion impairments at the scapula for individuals testing positive or negative on the SRT and SAT may provide evidence to support the utility of these tests. If significant differences were found to exist, this information may be helpful in guiding treatment decisions for patients with SPS. This knowledge may also contribute towards defining a subgroup or classification within SPS. Additionally, contemporary literature has begun to describe an evolution towards the use of symptom modification tests, like the SAT and SRT, in clinical examination in hopes of providing relevant information that can be used to direct treatment decisions.[6,79,102] Finding an examination method that can be used with confidence in routine clinical practice and that can help guide and improve the physical therapy management of these patients is important. This remains one of our greatest challenges when considering the complex and necessary contributions from the scapula to normal upper extremity function. The SAT and SRT have the potential to be valuable clinical tests and thus demand further investigation.

We hypothesized that individuals with deficits in scapular motion or scapulothoracic muscle force generation would be more likely to have positive results on the SAT or SRT. Our results did not support those hypotheses. The hope for rehabilitation professionals is that this symptom alleviation approach will better serve to inform treatment decisions and may help in identifying sub-categories to improve the efficiency and effectiveness of care. The failure to find statistically significant and clinically meaningful differences in these measures between individuals who tested positive and negative indicates that these tests may not render that information. More research is necessary to determine the factors that may be associated with positive clinical findings on the SRT and SAT and if that information can be used to effectively direct treatment.

Our second research aim focused on investigating the effectiveness of two different thoracic spine thrust manipulation techniques compared to a sham technique in individuals with SPS. The literature has demonstrated that some individuals with shoulder pain benefit from thoracic spine manipulation.[30-34] Evidence has also shown that the risks associated with thrust manipulation to the thoracic spine in individuals with shoulder pain are very low, with multiple studies reporting no adverse effects from the treatment.[32,34,35,72] However, it is unknown if a certain thoracic spine thrust manipulation technique is more effective than another in this patient population, as has been reported in subjects with neck pain.[129] Previous studies have either utilized multiple manipulative techniques[30,31,34] or seated techniques only,[32,33] yet we are unaware of anything that has previously compared the immediate effects of a seated technique or supine technique against a sham treatment for patients with SPS. The utilization of thrust manipulation to the thoracic spine has shown favorable results in individuals with shoulder dysfunction and warrants further investigation in hopes of determining additional insight into the proposed mechanisms and clinical effectiveness of different techniques.

For the first research aim, the results of this study indicated no significant differences in scapular UR or PT active or passive motion for individuals with SPS who tested positive on the SAT or SRT compared to those who tested negative. There were also no significant differences in mean normalized force generated with manual muscle test positions of the MT, LT, and SA between those who tested positive and negative on the SAT or the SRT. Significant differences did exist in force generated on the involved side compared to the non-involved side regardless of outcome on the SAT or SRT, likely due to pain-related muscle inhibition during the test. Significant differences also existed in pectoralis minor muscle length and PMI based on the results of the SAT but not for the SRT. Individuals who tested positive on the SAT demonstrated decreased pectoralis minor muscle length compared to those who tested negative. Additionally, the methods utilized in this study for measuring scapular UR and PT active and passive ROM, scapulothoracic muscle force generated in the MMT positions for the MT, LT, and SA, and pectoralis minor muscle length demonstrated excellent intrarater reliability with ICCs ranging from 0.90-0.99. SEM and MDC values were calculated and reported for these measures based on the data from this study.

For the second research aim, small but statistically significant improvements in various measures of active scapular motion and upper extremity elevation, scapulothoracic muscle force generation, and pectoralis minor muscle length were seen within all 3 groups. However, our results indicated that thrust manipulation delivered to the upper thoracic spine in either a seated or supine position did not result in changes in scapular kinematics, force generation, or pectoralis minor length that were any greater than the sham treatment. Arm elevation in the scapular plane increased significantly and by the same amount in all groups, indicating that the improvement was not a direct result of the manipulation but may be related to improvements with repeated measures. The manipulation techniques utilized in this study did not lead to significant immediate changes in force generated in the MMT positions for the MT, LT, or SA, other than incidental improvements in the non-involved muscles following the seated manipulation. These strength gains were not observed on the non-involved side following the sham manipulation. This may serve as an indication of the previously described neurophysiological effects believed to result from spinal thrust manipulation techniques. Small but significant improvements in pectoralis minor length existed in the seated and sham groups, which again indicate that the change cannot be attributed to the manipulative thrust. Significant improvements were seen in immediate change in pain in the seated and sham groups, as well as pain, function, and total PSS scores obtained 48 hours after treatment in all 3 groups. No significant between-group differences existed in the 48-hour change in pain, function, satisfaction with the involved shoulder, and total PSS scores.

Because of the positive effects observed in the sham group, other factors that could contribute to the positive effects of manual therapy including patient expectation, therapist-client interaction, placebo effect, passage of time, positive effects that can be associated with manual contact, and psychosocial factors need to be considered.[32,36] The benefits from spinal manipulative therapy may be derived from aspects of the treatment other than the manipulative thrust. As other studies have reported, it appears that immediate changes in symptoms are likely not due to biomechanical changes at the scapulothoracic articulation.[32,33,36]

Appendix A

Proposed Testing Sequence:

- Testing for Inclusion Criteria
    - Neer's or Hawkins-Kennedy test
    - Pain with active elevation (may be painful arc)
    - Abduction AROM > 90°
    - ER PROM > 45°
    - Pain with isometric resistance on abduction or ER
- Testing for Exclusion Criteria
    - complete cuff tear (lag signs, (+) MRI)
    - significant loss of glenohumeral motion (defined as ≥ 50% loss in 2 or more planes of motion, greatest motion loss with external rotation)
    - acute inflammation (as evidenced by severe resting pain or severe pain during impingement tests or isometric resisted abduction)
    - cervical spine-related symptoms (pain with cervical rotation, axial compression, or Spurling test)
    - positive apprehension test or relocation test

- Measures/Dependent Variables:
    - Glenohumeral joint AROM for scapular plane elevation and pain rating
    - Scapular Assistance Test (SAT)
    - Scapula Reposition Test (SRT)
    - Scapular Dyskinesis Test (SDT)
    - Scapular upward rotation AROM
    - Scapular upward rotation PROM
    - Scapular posterior tilt AROM
    - Scapular posterior tilt PROM
    - Pectoralis minor muscle length
    - Force generation in MMT position for middle trapezius
    - Force generation in MMT position for lower trapezius
    - Force generation in MMT position for serratus anterior

- Manipulate
    - Supine thrust manipulation
    - Seated distraction thrust manipulation
    - Sham manipulation

- Reassess
  - Glenohumeral joint AROM for scapular plane elevation and pain rating
  - Scapular Assistance Test (SAT)
  - Scapula Reposition Test (SRT)
  - Scapular Dyskinesis Test (SDT)
  - Scapular upward rotation AROM
  - Scapular upward rotation PROM
  - Scapular posterior tilt AROM
  - Scapular posterior tilt PROM
  - Pectoralis minor muscle length
  - Force generation in MMT position for middle trapezius
  - Force generation in MMT position for lower trapezius
  - Force generation in MMT position for serratus anterior
  - PROM for scapular plane elevation, IR, and ER

Appendix B

The Immediate Effects of a Seated versus Supine Upper Thoracic Spine Thrust Manipulation Compared to Sham Manipulation in Individuals with Subacromial Pain Syndrome

Principal Investigator: Jason Grimes, PT, MPT, OCS, ATC
Co-Investigators: M. Samuel Cheng, PT, MS, ScD; Amee Seitz, PT, PhD;
Emilio Puentedura, PT, DPT, PhD, OCS, FAAOMPT

IRB # 151119A

INFORMED CONSENT FORM

Invitation and basis for subject selection: You are being invited to participate in a research study conducted by the researchers listed above. You are being asked to volunteer since you meet the requirements for enrollment into this study. Your participation is voluntary which means you can choose whether or not you want to participate. You may withdraw at any time without penalty. If you choose not to participate, there will be no loss of benefits to which you are entitled. Before you can make your decision, you will need to know what the study is about, the possible risks and benefits of being in this study, and what you will have to do in this study. The research team is going to talk to you about the study, and they will give you this consent form to read. If you have any questions whatsoever, or find some of the language difficult to understand, please ask the researcher and/or the research team about this form. If you decide to participate, you will be asked to sign this form. If you decide not to participate and then change your mind at a later time and decide to consent to this study, or if you want to contact the principal investigator for answers to more questions, you may contact the principal investigator at grimesj@sacredheart.edu or 203-396-8018 (office/day time).

Overall Purpose: The study for which you are being asked to participate is designed to see if there are any differences in shoulder motion, shoulder strength, shoulder muscle flexibility, or pain immediately after receiving one of three different manual therapy techniques to the upper back. These techniques are routinely performed by physical therapists for a variety of common conditions, including neck pain and/or stiffness, shoulder pain, shoulder dysfunction, and lower back pain. Results from this study will provide physical therapists with information about whether any of these treatments create immediate changes in shoulder motion, shoulder strength, shoulder muscle flexibility, or pain. Additionally, results may indicate whether one technique is more effective at creating these desired changes than another.

Explanation of Procedures: To be a voluntary participant in this study, you will be asked to fill out a consent form and answer a short questionnaire about your shoulder pain and current health history. The researcher will then screen you for any findings that would exclude you from the study. If you meet all of the criteria, the researcher will then begin collecting multiple measures of your current level of pain, range of motion, strength, and flexibility of your painful shoulder. The researcher will then provide the manual therapy technique that you have been randomly assigned to receive. The technique you will receive will be one of the following: a quick stretch technique to your upper back while lying on your back, a quick stretch technique to your upper back in a seated position, or a slow stretch technique to your upper back in a seated position.

Immediately after delivery of the treatment, the researcher will repeat the same measures that were completed before the treatment.

Your total participation in the study will take 1 session. Each session will last approximately 60 minutes. You will not receive financial compensation for participation in the study. One of the investigators will make a follow-up visit, phone call and/or e-mail to you within 1 week from the date of your participation in the study. Your response to this portion of the study will involve reporting on any change in your pain or functional abilities and will take no more than 10 minutes.

Description of Risks & Discomforts: It is expected that participation in this study will provide you with no more than minimal risk or discomfort. However, there is always the chance that there are some unexpected risks. The procedures used in this study are often used by physical therapy clinicians and researchers for patients with shoulder pain. Short-term effects including minor and temporary soreness or fatigue may result from the data collection process and/or treatment. Short-term effects may be defined as effects that are mild in nature, non-serious, short-lasting and reversible. You may experience an increase in your pain intensity after the stretch technique is performed. This soreness typically resolves within 1-48 hours. We have minimized these risks by ensuring that the physical therapists participating in this study already routinely use these techniques in the management of patients with shoulder pain and have been specifically trained in the techniques that will be used in this study. As a potential subject, you will be appropriately screened and notified of any findings that may place you at increased risk for a serious complication. <u>If you feel uncomfortable or distressed, please tell the researcher and he/she will ask you if you want to continue.</u> Because this is research and does not have anything to do with the current services you are receiving for your shoulder pain, you can withdraw from the study at any time without penalty.

Description of Benefits: The foreseeable benefit is that your shoulder pain gets better to a varying degree following this single session. Your participation in this study will help improve the knowledge surrounding the examination and treatment of shoulder pain. This information may benefit other people with shoulder pain as well as other conditions that have been shown to respond favorably to these treatment techniques, including neck pain and lower back pain. Of the three techniques included in this study, you might receive one that may result in no foreseen benefit.

Assurance of Confidentiality: The investigators and staff involved with this study will keep your personal information collected for the study strictly confidential. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Your identity will be kept strictly confidential by the use of a subject identification number in place of your name. All records pertaining to your involvement in this research study will initially be stored in a locked file cabinet at the site in which the data collection occurred and will be transported to a locked file cabinet in the Physical Therapy Department at Sacred Heart University at least every 6-8 weeks. Only individuals directly involved in the study will have access to this information.

Financial Obligations: There is no monetary obligation for this study.

Financial Compensation: There is no monetary compensation for this study.

Voluntary Participation, Subject Withdrawal: Participation is voluntary. Your decision whether or not to participate will not affect your present or future clinical care with Sacred Heart University and/or the local facility you are presently attending. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time.

If you have questions regarding your participation in this research study or have any questions about your rights as a research subject, please contact the Principal Investigator using the information at the bottom of this form. Concerning your rights or treatment as a research subject, you may contact the Institutional Review Board at Sacred Heart University through Dr. James Carl at 203-396-8454.

Conclusion: You are making a decision whether or not to participate. Your signature indicates that you have decided to participate, having read the information provided above. You will be given a copy of this consent form to keep.

I acknowledge that I am between the ages of 18 and 65 and that I am not currently under the influence of any substance that would impair my ability to understand and accept the risks explained above.

Print Participant Name and Sign	Date
Print Witness Name and Sign	Date
Signature of Investigator	Date

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Appendix C

Shoulder Pain Study
Subject Inclusion Criteria Screening Sheet

Subject #: ________   Involved shoulder: R   L

Inclusion Criteria:	YES	NO
18-65 years of age		
Shoulder pain < 6 months		
AT LEAST 3 of the following:		
Proximal anterolateral shoulder pain		
+ Neer or Hawkins-Kennedy		
Pain with active elevation		
Abduction AROM > 90	AROM =	
ER PROM > 45	PROM=	
Pain with isometric abduction or ER		
Exclusion Criteria:		
Signs of complete RTC tear		
≥ 50% loss of motion in ≥ 2 planes		
Acute inflammation		
Cervical spine related symptoms:		
primary neck pain		
signs of CNS involvement		
signs of nerve root involvement		
shoulder/arm pain with cervical rotation		
shoulder/arm pain with axial compression		
shoulder/arm pain with Spurling test		
(+) apprehension/relocation test		
Previous neck/shoulder surgery		
Hx of shoulder fracture or dislocation		
Hx of nerve injury affecting UE function		
Contraindication to thrust manipulation:		
Osteoporosis		
Spinal fracture		
Malignancy		
Systemic arthritis		
Infection		
Pt fear or unwillingness		

Appendix D

Shoulder Pain Study
Subject Information Sheet

Subject #: __________ Age: ________ Male Female

Height: __________ Weight: _____________ BMI (calculated by researcher): __________

Hand dominance (if ambidextrous, circle both)	Right handed	Left handed
Painful shoulder (circle one) (if both, circle the worst)	Right	Left

Duration of shoulder pain (in weeks): _________________________

Have you had surgery for your shoulder?	Yes	No
Have you had an MRI of your shoulder?	Yes	No
Do you presently have any neck pain?	Yes	No
Have you ever had surgery on your neck or shoulder?	Yes	No
Have you ever broken your shoulder?	Yes	No
Have you ever dislocated your shoulder?	Yes	No

Do you have any of the following?

- Osteoporosis	Yes	No
- Spinal fracture	Yes	No
- History of cancer	Yes	No
- History of systemic arthritis	Yes	No
- Current infection	Yes	No

Please rate the pain you are experiencing in your shoulder using the following scale:

0 1 2 3 4 5 6 7 8 9 10
No pain at all Worst pain imaginable

What is your current level of pain? ______/10____

What is your pain level at its worst? ______/10____

What is your pain level at its best? ______/10____

Appendix E: Shoulder Pain Study - Subject Data Collection Sheet, PAGE 1

Randomization Code: ______

Subject #: ______ Involved shoulder: R L Dominant shoulder: R L

Height: ____________ Weight: ___________

Shoulder AROM: scaption _______ **PROM**: scaption ________ ER ______ IR _______

Test	Pre-treatment	Post-treatment
Scapular Dyskinesis Test (SDT) Male subjects will need to remove their shirts and female subjects will need to wear halter tops to allow observation of the posterior thorax. Observe the subject performing **bilateral, weighted shoulder flexion and frontal plane abduction overhead as far as possible** using the **"thumbs-up" position**. The subject will perform **5 repetitions** of each motion, lifting to a 3-second count and then lowering to a 3-second count. The amount of weight used will be **3 pounds for subjects weighing less than 150 pounds and 5 pounds for subjects weighing 150 pounds or more**. Scapular dyskinesis may include the presence of winging (medial border and/or inferior angle prominence) and/or premature or excessive elevation or protraction, non-smooth or stuttering motion during arm elevation or lowering, or rapid downward rotation during arm lowering. Examiners will qualify the motion observed using **one of three possible ratings: normal motion, subtle dyskinesis, or obvious dyskinesis.**	Normal Subtle Obvious	Normal Subtle Obvious
Scapular Assistance Test (SAT) The subject will first elevate the involved arm in the **scapular plane** and rate the pain felt during movement on the 0-10 verbal numeric rating scale (VNRS). The examiner will stand behind the subject and manually assist the scapula into **upward rotation and posterior tilt** by pushing superiorly and laterally on the inferior angle and pulling posteriorly on the superior aspect of the scapula as the subject elevates the arm again in the scapular plane. The subject will rate the pain felt while performing the movement with the assistance of the examiner on the 0-10 VNRS. The test will be documented as positive or negative, with a **positive test resulting in a decrease in pain of 2 or more points on the VNRS** during the SAT compared to active elevation of the arm without the application of the SAT.	Initial Pain = ___/10 Pain with SAT ___/10 Positive Negative	Initial Pain = ___/10 Pain with SAT ___/10 Positive Negative
Scapula Reposition Test (SRT) The subject will be asked to rate his/her pain with a **provocative test** (commonly arm elevation or resisted scaption) on the 0-10 verbal numeric rating scale (VNRS). This provocative test will then be repeated with the scapula manually repositioned in the following manner: the examiner will grasp the scapula with the fingers contacting the acromioclavicular joint anteriorly and thenar eminence contacting the scapular spine posteriorly, with the forearm placed obliquely across the posterior aspect of the scapula toward the inferior angle. A force can then be applied to the scapula to encourage posterior tilting and external rotation, and to approximate the scapula to the thorax. The subject will then rate the pain felt while performing the test with the manual repositioning using the 0-10 VNRS. The test will be documented as positive or negative, with a **positive test resulting in a decrease in pain of 2 or more points on the VNRS** during the application of the SRT.	Initial Pain = ___/10 Pain with SRT ___/10 Positive Negative	Initial Pain = ___/10 Pain with SRT ___/10 Positive Negative

Shoulder Pain Study - Subject Data Collection Sheet, PAGE 2

Randomization Code: ______

Subject #: ______ Involved shoulder: R L Dominant shoulder: R L

Variable	**Pre-treatment**						**Post-treatment**		
	Trial 1			**Trial 2**			**Trial 1**		
	Rest	**End**	**Pain**	**Rest**	**End**	**Pain**	**Rest**	**End**	**Pain**
	Inclinometer zeroed horizontally and placed along scapular spine *Document downward rotation as (-) and upward rotation as (+)* **for **R shoulder**, reverse sign that is shown on inclinometer; for **L shoulder**, use sign as shown*								
Scapular UR **AROM** (0.1°)	+ -	+ -	/10	+ -	+ -	/10	+ -	+ -	/10
Scapular UR **PROM** (0.1°)	+ -	+ -	/10	+ -	+ -	/10	+ -	+ -	/10
	Inclinometer zeroed vertically and placed along scapular medial border *Document anterior tilt as (-) and posterior tilt as (+)* **for **both R and L shoulder**, reverse sign that is shown on inclinometer*								
Scapular PT **AROM** (0.1°)	+ -	+ -	/10	+ -	+ -	/10	+ -	+ -	/10
Scapular PT **PROM** (0.1°)	+ -	+ -	/10	+ -	+ -	/10	+ -	+ -	/10
	Measure from med-inf aspect of coracoid process to ant-inf aspect of 4th rib one finger width lateral to sternum with subject in standing								
Pectoralis minor length (0.1cm)	cm			cm			cm		

Cavitation: YES NO

	Pre-treatment						**Post-treatment**					
	Involved shoulder			**Non-involved shoulder**			**Involved shoulder**			**Non-involved shoulder**		
	Trial 1	**Trial 2**	**Pain**	**Trial 1**	**Trial 2**	**Pain**	**Trial 1**	**Trial 2**	**Pain**	**Trial 1**	**Trial 2**	**Pain**
	Use a make test, instructing subject to slowly push into the dynamometer and increase force over 5 sec period; have subject perform one sub-max isometric effort for each muscle prior to maximal effort test for that muscle; provide 30 sec rest between trials, which is when you can test the contralateral side											
Middle trap strength (0.1kg)			/10			/10			/10			/10
Lower trap strength (0.1kg)			/10			/10			/10			/10
Serratus ant strength (0.1kg)			/10			/10			/10			/10
	Involved shoulder			**Non-involved shoulder**								
	Measure from lateral acromion to radial styloid											
Arm length (0.1cm)	cm			cm								

Shoulder AROM: scaption ________ **PROM**: scaption _________ ER _______ IR_______

Appendix F

Penn Shoulder Score

The Penn Shoulder Score, Part 1: Pain and Satisfaction Subscales

Please circle the number closest to your level of pain or satisfaction	Office Use Only
Pain at rest with your arm by your side: 0 1 2 3 4 5 6 7 8 9 10 No pain ... Worst pain possible	______ (10 – # circled)
Pain with normal activities (eating, dressing, bathing): 0 1 2 3 4 5 6 7 8 9 10 No pain ... Worst pain possible	______ (10 – # circled) (Score 0 if not applicable)
Pain with strenuous activities (reaching, lifting, pushing, pulling, throwing): 0 1 2 3 4 5 6 7 8 9 10 No pain ... Worst pain possible	______ (10 – # circled) (Score 0 if not applicable)
Pain score:	=____/30
How satisfied are you with the current level of function of your shoulder? 0 1 2 3 4 5 6 7 8 9 10 Not satisfied ... Very satisfied	____/10 (# circled)

From: Leggin BG, Michener LA, Shaffer MA, Brenneman SK, Iannotti JP, Williams GR, Jr. The Penn shoulder score: reliability and validity. *J Orthop Sports Phys Ther.* 2006;36(3):138-151.

The Penn Shoulder Score: Function Subscale

Please circle the number that best describes the level of difficulty you might have performing each activity	No difficulty	Some difficulty	Much difficulty	Can't do at all	Did not do <u>before</u> injury
1. Reach the small of your back to tuck in your shirt with your hand	3	2	1	0	X
2. Wash the middle of your back/hook bra	3	2	1	0	X
3. Perform necessary toileting activities	3	2	1	0	X
4. Wash the back of opposite shoulder	3	2	1	0	X
5. Comb hair	3	2	1	0	X
6. Place hand behind head with elbow held straight out to the side	3	2	1	0	X
7. Dress self (including put on coat and pull shirt off overhead	3	2	1	0	X
8. Sleep on affected side	3	2	1	0	X
9. Open a door with affected arm	3	2	1	0	X
10. Carry a bag of groceries with affected arm	3	2	1	0	X
11. Carry a briefcase/small suitcase with affected arm	3	2	1	0	X
12. Place a soup can (1-2 lb) on a shelf at shoulder level without bending elbow	3	2	1	0	X
13. Place a one gallon container (8-10 lb) on a shelf at shoulder level without bending elbow	3	2	1	0	X
14. Reach a shelf above your head without bending your elbow	3	2	1	0	X
15. Place a soup can (1-2 lb) on a shelf overhead without bending your elbow	3	2	1	0	X
16. Place a one gallon container (8-10 lb) on a shelf overhead without bending your elbow	3	2	1	0	X
17. Perform usual sport/hobby	3	2	1	0	X
18. Perform household chores (cleaning, laundry, cooking)	3	2	1	0	X
19. Throw overhand/swim/overhead racquet sports (circle all that apply to you)	3	2	1	0	X
20. Work full-time at your regular job	3	2	1	0	X

SCORING
Total of columns = ____ (a)
Number of Xs × 3 =____(b), 60 – ____(b) = ____ (c) (if no Xs are circled, function score = total of columns)
Function Score = ____(a) ÷ ____(c) = ____ × 60 ____/60

From: Leggin BG, Michener LA, Shaffer MA, Brenneman SK, Iannotti JP, Williams GR, Jr. The Penn shoulder score: reliability and validity. *J Orthop Sports Phys Ther.* 2006;36(3):138-151.

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