EFFECTIVENESS OF CERVICOTHORACIC JUNCTION MANIPULATION VERSUS PLACEBO ON SHOULDER MUSCLE STRENGTH, ELECTROMYOGRAPHIC AMPLITUDE, AND PAIN IN PARTICIPANTS WITH SUBACROMIAL IMPINGEMENT SYNDROME

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DENTON, TEXAS

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DEDICATION

With all my love, I dedicate this work to my wife and daughters

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To my wife, Shannon, for all of your support for getting me here. Thank you for your patience and understanding for allowing me to achieve this milestone in my career.

To Kiera and Brigid, my beautiful daughters, for giving me the love and support that allowed me to do this. I love you more than you will ever know.

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ABSTRACT

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EFFECTIVENESS OF CERVICOTHORACIC JUNCTION MANIPULATION VERSUS PLACEBO ON SHOULDER MUSCLE STRENGTH, ELECTROMYOGRAPHIC AMPLITUDE, AND PAIN IN PARTICIPANTS WITH SUBACROMIAL IMPINGEMENT SYNDROME

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Considerable research has demonstrated the effectiveness of rotator cuff strengthening and scapular stabilization training at improving pain and disability in patients with subacromial impingement syndrome (SAIS). Cervicothoracic junction (CTJ) manipulation has been shown to be effective for reducing shoulder pain and improving shoulder motions in patients with SAIS. However, the effects of CTJ manipulation on shoulder muscle strength and muscle activity have not been studied on this patient population. The purpose of this study was to examine the effectiveness of CTJ manipulation as compared to placebo in patients with SAIS on shoulder external rotation (ER) muscle strength during a maximal voluntary isometric contraction (MVIC), muscle activity of the middle deltoid (MDELT), supraspinatus (SUPR), and infraspinatus (INFR) muscles during MVIC of shoulder ER, and pain level. Thirty-two participants with SAIS were randomly assigned into two treatment groups: manipulation group (n = 16) and placebo group (n = 16). Shoulder ER muscle strength was measured using hand-held dynamometry. Surface electromyographic (EMG) activity was recorded from the MDELT, SUPR, and INFR

muscles during shoulder ER MVIC strength test. The Numeric Pain Rating Scale (NPRS) was used to assess shoulder pain level. All outcome measures (muscle strength, EMG activity, and pain level) were assessed at baseline, and immediately, 15 minutes, 30 minutes, 45 minutes, 48-72 hours, and 6-7 days after intervention. The results of this study showed no significant difference between groups over time in the shoulder ER strength, the EMG amplitude of the SUPR and INFR muscles and the NPRS ($p > 0.05$). However, a significant difference was found in the MDELT muscle between groups between 45 min and 48-72 hours after intervention, with the manipulation group having significantly increased muscle activity, coinciding with the placebo group having significantly reduced muscle activity. The results also showed that all participants had significant pain reduction over one week. Although CTJ manipulation reduced shoulder significantly, the CTJ manipulation did not result in changes of shoulder ER muscle strength and shoulder muscle activity.

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CHAPTER I

INTRODUCTION

Shoulder pain prevalence is noted in the literature ranging from 7 to 46% in a general adult population (Meislin, Sperling, & Stitik, 2005; Michener, Walsworth, & Burnet, 2004; van der Windt, Koes, de Jong, & Bouter, 1995; van der Windt, Koes, Boeke, Deville, de Jong, & Bouter, 1996). In contemporary primary care practice, shoulder pain is the third most common musculoskeletal pain complaint behind neck and low back pain, with an incidence of 15 new cases per 1,000 patients seen in the primary care setting (Meislin et al., 2005; Michener et al., 2004; van der Windt et al., 1995; van der Windt et al., 1996). Further, an estimated seven billion dollars are expended annually directly attributable to shoulder pain, with approximately 10 to 20% of these expenses associated with shoulder impingement (Meislin et al., 2005).

Shoulder impingement (SI) is a syndrome classified by the impingement or pinching of soft tissue structures in the shoulder (Brossman et al., 1996; Diercks et al., 2014; Hawkins & Kennedy, 1980; Mitchell, Adebajo, Hay, & Carr, 2005). Subacromial impingement syndrome (SAIS), a type of shoulder impingement, is a clinical presentation characterized by the encroachment of soft tissue structures under the coracoacromial arch of the shoulder in the subacromial space (Burns & Whipple, 1993; Fu, Harner, & Klein, 1991). A diagnosis of SAIS is determined

following exclusion of other potential sources of shoulder pain, such as subacromial bursitis, acromioclavicular joint sprain, glenoid labral dysfunction, and osteoarthritis of the glenohumeral joint (Michener et al., 2004; Rossi, 1998). Pain typically is associated with actions that cause encroachment of the rotator cuff tendons, such as reaching overhead, behind back, or across the body. Symptom manifestations may include popping or snapping with active elevation, radiating lateral shoulder pain of a dull ache or sharp intensity, and pain-induced weakness related to the inflammatory process accompanying the active soft tissue encroachment (Brossman et al., 1996). The age of symptom manifestation reportedly varies in the literature, with most cases in the age range of 20-55 years old (Chard, Hazleman, Hazleman, King, & Reiss, 1991).

Evidence suggests that SAIS primarily manifests with shoulder pain (Michener, McClure, & Karduna, 2003; Michener et al., 2004). Common impairments for patients with SAIS include the presence of lateral shoulder pain, pain with active arm elevation, pain with resisted abduction and external rotation, and scapular dyskinesis (Michener et al., 2003; Michener et al., 2004). Postural faults (e.g. a forward-head posture) have been proposed as underlying mechanisms of progression of pathology in SAIS. (Michener et al., 2003). A forward-head posture could result in a decrease in the normal cervical lordotic spinal curve with concurrent pectoral muscle shortening and decreased motor recruitment of the scapular and rotator cuff musculature. This common posture dysfunction is

hypothesized to create anatomical and biomechanical faults that would diminish the subacromial space and thus increase the likelihood of encroachment of the rotator cuff tendons under the coracoacromial arch (Burns & Whipple, 1993).

In addition to postural faults, inappropriate firing of the rotator cuff and scapular stabilizing muscles during active arm elevation has been demonstrated to directly contribute to the development of SAIS (Teyhen, Miller, Middag, & Kane, 2008). The supraspinatus (SUPR) and infraspinatus (INFR) muscles play an integral role in the coordination of normal mobility and stability in the glenohumeral joint (Reddy, Mohr, Pink, & Jobe, 2000). Along with the subscapularis and teres minor muscles, the SUPR and INFR muscles form a force couple that aides in producing active shoulder elevation and also aides in shoulder stabilization (McClure, Michener, & Karduna, 2006; Reinhold et al., 2004). If the deltoid (DELT) muscle contracts unopposed in the absence of normal rotator cuff (SUPR, INFR, subscapularis, and teres minor muscles) function, there can be a superior migration of the humeral head during active elevation (Burns & Whipple, 1993). This superior humeral head migration would place the SUPR and INFR tendons at risk for encroachment under the coracoacromial arch, as there would be no concomitant force that would counteract the superior humeral head migration produced by the DELT muscle, thus leading to SAIS. Under normal conditions, the SUPR muscle plays an important role in producing the initial abduction at the shoulder, especially in the 20-30° range (McClure et al., 2006). With the other rotator cuff muscles functioning

in a syncytium, the humeral head is effectively compressed into the glenoid during humeral elevation through abduction, preventing the encroachment of the SUPR and INFR tendons under the coracoacromial arch.

There are two primary etiologies of SAIS cited in the literature, which are classified according to intrinsic (primary) or extrinsic (secondary) causes (Bigliani & Levine, 1997; Michener et al., 2003). Intrinsic causes include muscle weakness, muscle imbalance, overuse injury, and/or degenerative tendinopathy (Bigliani & Levine, 1997). Extrinsic causes consist of alterations in acromial morphology, glenohumeral instability, acromioclavicular joint degeneration, and/or coracoacromial ligament impingement (Bigliani & Levine, 1997). The optimal management of the impairments associated with SAIS is dependent on the particular etiology or etiologies as well as the severity of the presentation (Bigliani & Levine, 1997; Michener et al., 2003). Both the intrinsic and extrinsic factors contribute to the development and/or progression of shoulder impingement. Primary shoulder impingement refers the development of the disease process resulting directly from anatomical changes of the rotator cuff tendons or alterations in acromion morphology (Bigliani & Levine, 1997; Michener et al., 2003). Secondary shoulder impingement relates to an etiology resulting from another pathological process, such as glenohumeral instability (Bigliani & Levine, 1997; Michener et al., 2003).

Several investigations have focused on the contribution of the SUPR and INFR muscles to SAIS, and concluded that diminished neuromuscular activation of the rotator cuff musculature has a direct impact on development of subacromial pathology (Ardic et al., 2006; Bandholm, Rasmussen, Aagaard, Jensen, & Diederichsen, 2006; Bigliani & Levine, 1997; Escamilla, Hooks, & Wilk, 2014; McClure et al., 2006; Michener et al., 2003). As mentioned earlier, decreased activation of the rotator cuff creates an unopposed pull of the DELT during arm elevation, resulting in excessive superior migration of the humeral head (McClure et al., 2006). As excessive superior migration of the humeral head occurs, there is a higher probability of encroachment of the rotator cuff tendons under the acromion or coracoacromial arch (Bigliani & Levine, 1997). The impact of the rotator cuff tendons against the undersurface of the acromion due to rotator cuff weakness could result in secondary shoulder impingement (Bigliani & Levine, 1997). In addition to normal rotator cuff function, normal scapular muscle function is needed, as scapular muscles provide stability of the scapula so that normal movement of the upper limb can occur (Ardic et al., 2006; Bandholm et al., 2006; Michener et al., 2003).

Many conservative interventions have been postulated for use in the clinical management of SAIS (Ellenbecker & Cools, 2010; Fongemie, Buss, & Rolnick, 1998; Green, Buchbinder, & Hetrick, 2006). As with most conservative interventions, the main objective is to decrease pain and to improve muscle activation, thus enhancing

function in patients with SAIS (Chester et al., 2013; Escamilla et al., 2014). Escamilla et al. (2014) advocated that an ideal non-operative rehabilitative exercise program for a patient with SAIS should be used to address the etiological factors identified from the evaluation.

Exercise has been shown to alleviate dysfunction present in patients with SAIS (Michener et al., 2004; Park, Choi, Lee, & Kim, 2013). In a systematic review examining the effectiveness of rehabilitation regimens for patients with SAIS, Michener et al. (2003) determined that the most effective therapeutic exercise program consisted of a multi-modal approach using shoulder stretching, strengthening, and motor-learning activities to decrease morbidity associated with shoulder impingement. Park et al. (2013) explored the use of shoulder stabilization exercises as compared to modalities consisting of heat, ultrasound, laser, and interferential electrical stimulation at decreasing pain and improving function in patients with SAIS. The stabilization exercises were performed in supine and standing, focusing on rhythmic stabilization techniques administered by physical therapists in clinic for a total of 12 visits over 4 weeks (Park et al., 2013). The study revealed a statistically significant improvement in both active and passive shoulder flexion and abduction for the stabilization exercise treatment ($p = 0.045$) (Park et al., 2013). The study also revealed a difference between the two treatments with the stabilization exercise resulting a greater pain reduction ($p = 0.03$) and shoulder function improvement ($p = 0.04$) (Park et al., 2013).

McClure et al. (2006) examined the effect of a 6-week exercise program on improving function and 3-dimensional scapular kinematics in patients with SAIS. Thirty-nine participants completed the 6-week exercise program, consisting of shoulder stretching and resistance exercise, and had significant improvements in passive ROM and strength for shoulder external and internal rotation ($p < 0.001$) (McClure et al., 2006). Although a significant difference was found in ROM measurement, no difference was observed in scapular kinematics after the 6-week exercise program (McClure et al., 2006). However, improvement was observed for pain and shoulder function, using the University of Pennsylvania Shoulder Scale, at the conclusion of 6-week exercise program and maintained at a 6-month follow-up ($p < .001$) (McClure et al., 2006).

A systematic review conducted by Michener et al. in 2003 concluded that manual therapy techniques, such as glenohumeral joint mobilizations, spinal mobilization and manipulation to the cervical spine and thoracic spine, and soft tissue mobilization to the upper quadrant are effective in treatment of SAIS (Michener et al., 2003). In recent clinical trials, combinations of exercise and manual therapy, specifically thoracic spinal manual therapy, has been shown to be effective for treating the impairments associated with SAIS (Michener et al., 2004; Mintken et al., 2010). Bang and Deyle (2000) found a significant effect of rotator cuff and scapular stabilization strengthening, combined with manual therapy, on decreasing pain and improving morbidity in people with SAIS. Fifty-two patients

with SAIS were randomly assigned to an exercise group or a manual therapy with exercise group. Both groups received the assigned intervention six times over a 3-week period (Bang & Deyle, 2000). The exercises consisted of general shoulder stretching and shoulder strengthening using thera-tubing, and both groups performed the same exercise regimen (Bang & Deyle, 2000). The manual therapy with exercise group received manual therapy techniques in addition to the exercise program. The manual therapy techniques consisted of mobilizations to the glenohumeral joint, cervical spine, and thoracic spine (Bang & Deyle, 2000). The results showed a statistically significant difference in pain reduction, functional improvement, and shoulder strength improvement in the manual therapy plus exercise group as compared to exercise alone (p = .039) (Bang & Deyle, 2000).

In addition to Bang and Deyle's study, two other studies have shown favorable clinical outcomes of cervical and thoracic spinal manipulation on decreasing shoulder pain and improving upper quadrant function (Boyles et al., 2009; Mintken et al., 2010). Mintken et al. (2010) examined factors which are likely to predict a successful outcome in people with shoulder pain who received a cervicothoracic junction (CTJ) manipulation. Eighty participants with non-specific shoulder pain received a series of five different thrust manipulations to the thoracic spine and a non-thrust manipulation to the lower cervical spine (Mintken et al., 2010). At a follow-up two to four days after the initial assessment, a participant was deemed to have a successful outcome if they scored a +4 or better on the Global

Rating of Change (GROC) questionnaire. The results indicated a significant improvement in scores of the Shoulder Pain and Disability Index (SPADI) ($p = 0.001$) and pain-free shoulder flexion ($p = 0.017$) in the success group as compared to the nonsuccess group. Findings suggested a likely successful outcome when three of five factors were present, including pain free shoulder flexion less than 127°, shoulder internal rotation less than 53°, a negative Neer's test, not taking medication for shoulder pain, and symptoms less than 90 days (Mintken et al., 2010). In addition, Boyles et al. (2009) also found benefits of the use of thoracic spine manipulation to decrease pain and disability in 56 individuals with SAIS. The study demonstrated that thoracic spine manipulation resulted in a decrease of pain using the NPRS for the Hawkins and Neer's impingement signs, resisted external and internal rotation, resisted empty can, and active abduction at a 48-hour follow-up ($p = 0.01$) (Boyles et al., 2009). The results also revealed a statistically significant decrease in SPADI questionnaire scores, indicating an improvement at a 48-hour follow-up from baseline ($p = 0.001$) (Boyles et al., 2009).

Two models have been hypothesized to explain the underlying mechanism of spinal manipulation: a biomechanical effect and a neurophysiological effect that can be attributed to regional shoulder structure changes from a spinal manipulation (Evans, 2002; Pickar, 2002). The biomechanical effect of spinal manipulation is related to segmental changes that occur at the level of the vertebrae (Evans, 2002; Pickar, 2002). This effect refers to the true anatomical and biomechanical changes

that occur as a result of the manipulative procedure that has an effect on the facet joint capsule and other structures in the biomechanical upper quadrant chain (Evans, 2002; Pickar, 2002). These biomechanical effects include the release of synovial folds, relaxation of muscle hypertonicity, decrease in segmental stiffness, and the breakdown of articular adhesions (Evans, 2002). However, Cleland et al. (2007) found no significant relationship between the number of audible cavitations and improvements in cervical pain or range of motion in patients with mechanical neck pain (Cleland, Childs, Fritz, Whitman, & Eberhart, 2007). Cleland et al.'s study (2007) questioned the biomechanical treatment effect from spinal manipulation as well as the link between audible cavitations and treatment response (Cleland et al., 2007).

Several neurological effects of non-thrust spinal mobilization and thrust spinal manipulation have been observed, including hypoalgesia, sympathetic nervous system excitation, and alterations in muscle activation both locally as well as distally (Schmid, Brunner, Wright, & Bachmann, 2008; Vincenzino, Collins, Benson, & Wright, 1998, Wang & Meadows, 2010). A 94.2% increase of electromyographic (EMG) activity of the biceps brachii was found on the right (p = 0.0001) and an 80.1% decrease on the left (p = 0.0001) after a C5-6 cervical manipulation (Dunning & Rushton, 2009). The stimulation of low-threshold mechanoreceptors from a spinal manipulation is believed to override pain signals via high-threshold mechanoreceptors. Once pain intensity is reduced, activation of

the muscle groups innervated by the related segmental level subsequently increases (Dunning & Rushton, 2009; Pickar, 2002; Pickar & Bolton, 2012; Wang & Meadows, 2010). In addition to segmental effects, spinal manipulation could produce an inhibitory effect on central facilitation or sensitization. Central sensitization often occurs in patients with pathology and the typical clinical manifestation is increased excitability or responsiveness to a normal afferent input or a sub-threshold stimulus (Pickar, 2002).

The neurophysiological mechanisms underlying the effects of spinal manipulation are related to anatomical changes in the contiguous vertebra that lead to physiological alterations (Pickar, 2002; Pickar & Bolton, 2012). The physiological alterations that result from manipulation, such as enhanced muscle activation, result from nervous system adaptations that accompany the manipulative technique (Pickar, 2002; Pickar & Bolton, 2012). As spinal manipulation enhances joint mobility, an increase in muscle spindle activity and Golgi tendon activity enhances the ability of the lumbar spine to achieve an optimal lordosis (Pickar, 2002; Pickar & Bolton, 2012). In addition, spinal nerve roots could be stimulated mechanically with spinal manipulation, thus enhancing the activity of the dorsal nerve roots and dorsal root ganglia (Pickar, 2002; Pickar & Bolton, 2012). The increase in dorsal nerve root and dorsal root ganglia activity improves the transport rate of neuropeptides that facilitate a diminished pain response, thus leading to hypoalgesia attributable to spinal manipulation (Pickar, 2002; Pickar & Bolton, 2012). Although these

mechanisms are poorly comprehended, they currently represent the commonly accepted rationale for the observation of improvement in extremity pain, range of motion, muscle activation and patient-perceived disability immediately following a spinal manipulative procedure (Boyles et al., 2009; Mintken et al., 2010; Muth, Barbe, Lauer, & McClure, 2012; Strunce, Walker, Boyles, & Young, 2009).

Statement of the Problem

Considerable research has demonstrated the effectiveness of rotator cuff strengthening and scapular stabilization training at improving pain and disability in patients with SAIS (Mintken et al., 2010; Park et al., 2013). As discussed earlier, manual therapy, specifically CTJ manipulation, was shown to be effective for reducing shoulder pain and improving shoulder motions in patients with SAIS (Boyles et al., 2009; Mintken et al., 2010; Strunce et al., 2009). However, it is unclear how CTJ manipulation works, what type of effects CTJ manipulation produces, and how long CTJ manipulation effects last. Further, if we know how long CTJ manipulation effects last, we could coordinate CTJ manipulation with other interventions (e.g. exercises) better with a goal of shortening recovery time.

Spinal manual therapy is postulated to enhance muscle activity, thus improving the effectiveness of the muscles innervated in the manipulated spinal region. In particular, there have been no randomized controlled trials examining the effects of CTJ manipulation on the muscle activity of the shoulder. At this point, the direct effects that CTJ manipulation has on shoulder muscle activity in

individuals with SAIS are unclear. No studies to date have examined the effects of cervical or thoracic spinal manipulation on shoulder muscle activation in people with SAIS. In addition, there have not been any randomized controlled trials to date that have assessed the immediate and short-term carryover effects of CTJ manipulation on shoulder muscle activity in patients with shoulder pain associated with SAIS.

Purpose of the Study

The purpose of this study was to examine the effectiveness of CTJ manipulation as compared to placebo in patients with SAIS on: (a) shoulder external rotation (ER) muscle strength, (b) muscle activity of the middle DELT (MDELT), SUPR, and INFR during shoulder ER, and (c) pain level.

Research Questions

The following research questions were addressed in this study:

1. Would participants with SAIS who receive a CTJ manipulation have an increase in shoulder ER muscle strength more than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention?
2. Would all participants with SAIS have an increase in shoulder ER muscle strength immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days after receiving a CTJ manipulation or a placebo intervention?

3. Would participants with SAIS who receive a CTJ manipulation have an increase in EMG amplitude of the MDELT, SUPR, and INFR muscles more than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention?
4. Would all participants with SAIS have an increase in shoulder EMG amplitude of the MDELT, SUPR, and INFR muscles immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days after receiving a CTJ manipulation or a placebo intervention?
5. Would participants with SAIS who receive a CTJ manipulation have a decrease in the perception of shoulder pain, more than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention?
6. Would participants with SAIS have a decrease in the perception of shoulder pain immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days after receiving either a CTJ manipulation or a placebo intervention?

Research Hypotheses

The research hypotheses were generated for this study:

1. Participants with SAIS who receive a CTJ manipulation would have a greater increase in shoulder ER muscle strength than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.

2. All participants with SAIS would have an increase in shoulder ER muscle strength immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.
3. Participants with SAIS who receive a CTJ manipulation would have a greater increase in EMG amplitude of the MDELT, SUPR, and INFR muscles than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.
4. All participants with SAIS would have an increase in EMG amplitude of the MDELT, SUPR, and INFR muscles immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.
5. Participants with SAIS who receive a CTJ manipulation would have a greater pain reduction than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.
6. All participants with SAIS would have a decrease in the perception of shoulder pain immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.

Null Hypotheses

The null hypotheses were:

1. There would be no significant difference in shoulder ER muscle strength between participants with SAIS who receive a CTJ manipulation and those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.
2. There would be no difference in shoulder ER muscle strength immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days for all participants who either receiving a CTJ manipulation or a placebo intervention.
3. There would be no significant differences in EMG amplitude of the MDELT, SUPR, and INFR muscles between participants with SAIS who receive a CTJ manipulation and those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.
4. There would be no difference in EMG amplitude of the MDELT, SUPR, and INFR muscles immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days for all participants who either receiving a CTJ manipulation or a placebo intervention.
5. There would be no significant difference in the perception of shoulder pain between participants with SAIS who receive a CTJ manipulation and those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention.

6. There would be no difference in the perception of shoulder pain immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days for all participants who either receiving a CTJ manipulation or a placebo intervention.

Operational Definitions

1. SAIS pain: Pain in the lateral shoulder can occur when subacromial structures are impinged. The SAIS diagnosis is confirmed by positive results for at least three of five impingement tests, including the Neer's test, Hawkins-Kennedy test, painful arc test, empty can test, and ER weakness (see Appendix A for the description of each test).
2. Cervicothoracic junction (CTJ) manipulation: A technique involving the use of a high-velocity, low-amplitude force delivered to the junction of the cervical spine and thoracic spine beyond the available segmental movement. Spinal manipulation was performed only one time, regardless of whether or not a cavitation was heard or felt by the investigator or participant.
3. Placebo manipulation: A technique similar to a CTJ manipulation, but without delivery of the high-velocity, low-amplitude thrust.
4. Hand-held dynamometry: A gauge that is used to assess the force production of a muscle or a muscle group. The units of force include newtons (N), pounds (lbs), and kilograms-force (kgf).

5. EMG amplitude and root-mean-square (RMS): EMG amplitude represents the summation of action potentials produced by motor units in a specific muscle under load. The EMG amplitude is influenced by the extent of the muscle activation, which is dependent on the activation of motor units. (De Luca, 1997). RMS is a measure used to quantify EMG amplitude and was used for data analysis in this study. RMS was calculated by squaring each data point under the curve (i.e. EMG signal), summing the squares, dividing the sum by the number of observations, and taking the square root (De Luca, 1997).
6. Maximal voluntary isometric contraction (MVIC) testing: An assessment method for measurement of the peak force production of a muscle or muscle group using an isometric contraction.
7. Make test: A test for MVIC involving a gradual escalation to a maximum muscle contraction over a period of three to five seconds. Verbal cueing often is provided to a participant to encourage attainment of maximum force production.
8. Shoulder pain intensity: The subjective self-assessment of a participant's shoulder pain as assessed with the Numeric Pain Rating Scale (NPRS).
9. Perceived disability level: A subjective self-assessment of a participant's perceived level of disability in performing specific activities as determined by the Disability of the Arm, Shoulder, and Hand (DASH) questionnaire.

10. Fear avoidance behavior: A manifestation of behavior by a participant post injury involving the deliberate avoidance of specific functional activities due to the presence of pain present with movement.

Assumptions and Limitations

Assumptions

The assumptions for the study were as follows:

1. Participants provided an honest assessment of their shoulder pain intensity on the NPRS.
2. Participants provided an honest appraisal of perceived level of disability on the DASH.
3. Participants provided an honesty appraisal of the level of fear avoidance behavior on the FABQ.
4. The placements of the surface EMG electrodes were the ideal location for recording the EMG output of the muscles under study.
5. Participants provided their best effort during performance of the MVIC.

Limitations

The limitations associated with this study were as follows:

1. The sample of participants was one of convenience, which limited the generalizability of the results.
2. The clinical test for identification of SAIS could potentially produce false negatives.

3. A placebo effect in the placebo group could potentially lead to an increase in activation of the MDELT, SUPR, or INFR muscles.
4. Crosstalk could have occurred between the EMG electrodes due to the close proximity of electrode placement, thus having an effect on the EMG amplitude output.
5. There is a potential for inconsistency in electrode placement, which could have affected the results. To minimize any potential variation, the electrode placement procedure was standardized.
6. The physical effort put forth by a participant during an MVIC could have varied from participant to participant and from trial to trial. The inability to directly control this factor could potentially have affected the results of the study.
7. There are multiple techniques for performing CTJ manipulation. Participants may have had different reactions to CTJ manipulation, depending on the type of technique and force of application. In order to minimize variation, a standardized technique was used in this study, and a single investigator performed the spinal manipulative technique and the placebo intervention for all participants.

Significance of the Study

The literature supports the use of CTJ manipulation in patients with shoulder pain. In clinical studies, cervical and thoracic spinal manipulation has been

shown to decrease pain and improve function in patients with SAIS or patients with shoulder pain (Boyles et al., 2009; Mintken et al., 2010). However, the underlying mechanism of CTJ manipulation, such as its effects on shoulder muscle strength and muscle activation, has not been studied. To our knowledge, no study has explored how long CTJ manipulation effects would last. This study examined the immediate and carry-over effects of CTJ manipulation on shoulder ER strength and EMG amplitude of the MDELT, SUPR, and INFR muscles. The results of this study could shed light into lasting effects of CTJ manipulation, thus providing clinicians with additional information regarding timing of CTJ manipulation with exercise in the management of SAIS.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to examine the effectiveness of cervicothoracic junction (CTJ) manipulation as compared to placebo in patients with subacromial impingement syndrome (SAIS). More specifically, the purpose was to investigate the immediate and carry-over effects of CTJ manipulation versus placebo on shoulder external rotation (ER) strength, electromyographic (EMG) amplitude of the middle deltoid (MDELT), supraspinatus (SUPR), and infraspinatus (INFR) muscles, and pain intensity in patients with SAIS. This literature review explored the epidemiology, pathology and etiology, common impairments and functional limitations, outcome measures, and the common conservative interventions associated with patients with SAIS.

Epidemiology of SAIS

SAIS is considered to be the most common disorder of the shoulder, accounting for 44-65% of all patient reports of shoulder pain (Michener et al., 2003; van der Heijden, 1999; van der Windt et al., 1995; van der Windt et al., 1996). Shoulder pain point prevalence ranges from 7 to 41% in a general adult population, with some estimates ranging from 20% to 51% depending on the reference sample (Chard et al., 1991; van der Windt et al., 1996; Meislin et al., 2005; van der Heijden, 1999). The prevalence of shoulder pain in overhead athletes has been reported as

10-30% (Lo, Hsu, & Chan, 1990). Age is considered to be one of the best prognostic factors for the prevalence of SAIS (Michener et al., 2003; Michener et al., 2004). In a study examining the consultation prevalence of Swedish individuals with shoulder pain, Tekavec et al. (2012) noted a new consultation rate of 9 to 11 per 1,000 individuals. Shoulder pain is the third most common musculoskeletal pain complaint behind neck and low back pain, with an incidence of 15 new cases per 1,000 patients seen in primary care practice (Chen, Ginn, & Herbert, 2009; Meislin et al., 2005; van der Windt et al., 1996).

In a study examining the incidence of shoulder disorders in Dutch general practice, the cumulative incidence of shoulder complaints was reported as 11.2 cases per 100 patients seen in primary care practice (van der Windt et al., 1995). In addition, an estimated 7 billion dollars are expended annually directly attributable to shoulder pain, with approximately 10-20% of these expenses associated with SAIS (Meislin et al., 2005; van der Windt et al., 1996). In Europe, the cost attributed to shoulder pain is estimated to be 0.5% to 2% of the gross domestic product (Tekavec et al., 2012). Furthermore, less than 25% of patients with shoulder pain were reported to have a complete recovery at three months post onset (Rhon, Boyles, Cleland, & Brown, 2011). The recovery rate at 18 months post onset reportedly ranged from 49-59% (Rhon et al., 2011). A prospective study involving 349 patients with shoulder pain examined probable prognostic indicators of outcome and found that 41% of patients demonstrated persistent symptoms at a

12-month follow-up (van der Windt et al., 1996). The recovery rate is even less in elder people. In a study of 108 patients of age over 65 with shoulder pain, 80 patients were found to have persistent pain at a three-year follow-up after their initial diagnosis (Vecchio, Kavanagh, Hazleman, & King, 1995). The results revealed no effect of treatment on symptom resolution ($p = 0.008$), implying that age appears to have a potentially negative impact on recovery following diagnosis of shoulder pathology (Chard et al., 1991; Vecchio et al., 1995).

There are a multitude of studies illustrating the increase in prevalence of shoulder disorders in aging adults, accounting for 25% of musculoskeletal pain complaints in individuals 55 years and older (Chard et al., 1991; Chard & Hazleman, 1987). In a population of elderly individuals with shoulder pain, the prevalence of shoulder pathology in individuals over age 65 was reported to be 25% (Chard et al., 1991; Chard & Hazleman, 1987). The average age of individuals presenting with shoulder pain in a population of people with shoulder pain was 50-59 for females and 60-69 for males (Tekavec et al., 2012). Interestingly, the 45-64 year-old age category had the highest incidence of shoulder pathology in a general practitioner's practice (Greving et al., 2012).

SAIS also was found to be most prevalent in younger populations due to repetitive strain sports activities and in older adults due to repetitive strain or wdegenerative changes occurring in the shoulder region (Michener et al., 2004). Gender does not appear to be associated with the prevalence or incidence of SAIS

(van der Windt et al., 1995; van der Windt et al., 1996). Due to the impact that shoulder pain has on general musculoskeletal physical therapy practice, there is an emergent need to identify the likely source and subsequent comorbidities associated with the onset of pain to prevent the recurrence of the condition (Mintken et al, 2010; van der Heijden, 1999; van der Windt et al, 1996).

Subacromial Impingement Pathology and Etiology

Pathology of Subacromial Impingement

SAIS is defined as a condition where the structures are affected in the subacromial space, namely the rotator cuff tendons and subacromial bursa (Ardic et al., 2006; Michener et al., 2003). The disorder is characterized by pain and inflammatory responses that lead to a functional loss and disability of the involved upper extremity (Boyles et al., 2009). SAIS involves an encroachment of the rotator cuff tendons and subacromial space related to narrowing of the subacromial space (Michener et al., 2003). SAIS is also defined as compression of the rotator cuff between the undersurface of the acromion and the superior aspect of the coracoacromial arch (Chester, Smith, Hooper, & Dixon, 2010).

Neer (1983) postulated that degeneration of the acromioclavicular joint contributes to SAIS, with osteophyte formation on the undersurface of the acromion directly contributing to encroachment of subacromial tissues. Neer (1983) first defined SAIS as a mechanical compression injury of the tissues of the subacromial space. Consequently, Neer proposed three stages of the disease: stage I, stage II, and

stage III. Stage I was noted in patients less than 25 years of age with a history of repetitive overhead activity. Stage II was observed in patients 25-40 years of age with a progressive deterioration of the subacromial soft tissues. Stage III was observed in patients over the age of 40 whereby the deterioration progressed to a partial or full-thickness tendon tear. The main limitation to Neer's classification system is the lack of ability to specifically classify patients with SAIS based on the presenting impairments (Fu et al., 1991; Michener et al., 2003; Neer, 1983).

Clinical manifestations of SAIS could include shoulder pain, rotator cuff tendinopathy, and subacromial bursitis (Michener et al., 2003; Michener, Walsworth, Doukas, & Murphy, 2009). Although pain is the most common manifestation of the pathology, there also commonly exists concomitant loss of range of motion, rotator cuff muscle strength, and functional use of the extremity (Ardic et al., 2006; Hawkins & Kennedy, 1980; Michener et al., 2003;). In addition to a common clinical examination, imaging also is used to identify the degree of degeneration of the rotator cuff tendons or degree of bursal involvement, especially in cases of failure of conservative interventions (Boyles et al., 2009; Hamid et al., 2012; Michener et al., 2009).

Etiology of Subacromial Impingement

Little evidence has published on the etiology of SAIS. The main contributing factor to SAIS is the narrowing of the subacromial space, leading to pain and weakness with the involved structures (Tate, McClure, Young, Salvatori, & Michener,

2010). Subacromial impingement primarily occurs between the inferior aspect of the acromion process and the superior aspect of the humeral head (Michener et al., 2003; Michener et al., 2004). The encroachment of the subacromial structures is accomplished by two common factors that effectively diminish the subacromial space. The two common mechanisms related to the cause of SAIS are known as primary (intrinsic) and secondary (extrinsic) factors.

Primary Factors for Subacromial Impingement

Primary (intrinsic) factors include degenerative tendinopathy, muscle weakness, muscle imbalance, posture alteration, or posterior capsular tightness (Bigliani & Levine, 1997; Fu et al., 1991; Meislin et al., 2005; Michener et al., 2003). The SUPR tendon is the most frequently encroached tendon, especially with overhead repetitive activity (Bigliani & Levine, 1997; Michener et al., 2003). During shoulder elevation, the SUPR functions as both a primary mover and stabilizer of the upper extremity, active in one or both capacities during shoulder abduction, ER, and internal rotation (McClure et al., 2006). With the increase in activity of the SUPR muscle in people with SAIS, there is a possible increase in the occurrence of tendon overload (Michener et al., 2003).

In patients with SAIS, a postulated contributor to SUPR degeneration is the decrease in tendon vascularity due to encroachment under the coracoacromial arch (Adler et al., 2008; Bigliani & Levine, 1997; Fukuda, Hamada, & Yamanaka, 1990). The SUPR muscle possesses an area of decreased vascular supply near its insertion

onto the greater tuberosity of the humeral head, which is believed to be a contributing factor in the pathogenesis of degenerative SUPR tears associated with aging (Adler et al., 2008; Chansky & Iannotti, 1991; Fukuda et al., 1990; Lohr & Uhthoff, 1990; Rudzki et al., 2008). In addition, repetitive movements of the upper extremity above shoulder level could contribute to the hypovascularity of the SUPR muscle at the insertion site, furthering tendon degeneration (Bigliani & Levine, 1997; Fukuda et al., 1990; Rudzki et al., 2008).

In a repetitive strain scenario, as in repetitive overhead activity, there is a continual overload tension applied to the tissues under strain (Bigliani & Levine, 1997). Over time, the degenerative process in a muscle or tendon will progress, leading to thickening of the tendon under strain (Bigliani & Levine, 1997). With stresses resulting from degenerative changes, subacromial bursal thickening could develop and subsequently reduce subacromial space (Bigliani & Levine, 1997; Michener et al., 2003). When the subacromial space is compromised, a loss of soft tissue mobility for normal movement would occur, leading to a higher possibility for development of SAIS (Hamid et al., 2012; Michener et al., 2003).

Muscle weakness of the rotator cuff and scapular muscles could contribute to SAIS due to the repetitive strain or overloading of these muscles and tendons (Bigliani & Levine, 1997). As tension overload progresses in the muscle, degenerative changes may occur in the integrity of the tissue (Bigliani & Levine, 1997). Weakness or diminished motor control in the rotator cuff muscles can lead

to an increase in superior humeral head migration during active elevation of the upper extremity (Ardic et al., 2006; Bandholm et al., 2006; Brossman et al., 1996; McClure et al., 2006). The rotator cuff musculature acts in syncytium with each other, providing considerable mobility and stability for movement of the upper extremity through space (Brossman et al., 1996).

Muscle imbalance of glenohumeral and scapular musculature also could alter shoulder kinematics, leading to SAIS (Bandholm et al., 2006; McClure et al., 2006). In the presence of insufficient rotator cuff muscle strength, the rotator cuff muscle could be over-powered by the deltoid muscle, resulting in an excessive superior migration of the humerus during arm elevation (Bandholm et al., 2006). During scapular rotation, the serratus anterior muscle functions in a force couple relationship with the upper and lower trapezius (Larsen, Sogaard, Chreiteh, Holtermann, & Juul-Kristensen, 2013). When the upper trapezius muscle is more dominant than the serratus anterior muscle, there is an accompanying increase in scapular elevation and winging with glenohumeral elevation (McClure et al., 2006). A higher average activity in the upper trapezius muscle has been observed during reaching tasks in patients with SAIS (Chester et al., 2010; Cools, Witvrouw, Declercq, Danneels, & Cambier, 2003; Ludewig & Cook, 2000).

Postural alteration could contribute to SAIS due to changes in muscle length and strength, which further cause an increase in muscle and tendon overload, leading to development of tendon pathology (Lewis, Wright, & Green, 2005). Over

time, muscle imbalance from postural alteration could further lead to soft tissue changes such as posterior glenohumeral tightness, pectoral muscle shortening, and scapular muscle weakness (Michener et al., 2003). In the case of posterior capsule tightness, the limited mobility of the posterior capsule pushes the humeral head anteriorly (Chen et al., 2009). The altered resting position of the humeral head could change the normal motor firing pattern of the rotator cuff musculature, leading to the potential development of SAIS (Michener et al., 2003).

Secondary Factors for Subacromial Impingement

Secondary or extrinsic factors include alterations in acromial morphology, acromioclavicular joint degeneration, glenohumeral instability and forward-head posture (Bigliani & Levine, 1997; Kitay et al., 1995; Michener et al., 2003). The contribution of acromion morphology to the development and progression of SAIS was first noted by Neer (1983), and was found to be highly correlated to the development of SAIS (Bigliani, Ticker, Flatow, Soslowsky, & Mow, 1991). Acromion morphology is described by three different types of conditions (Bigliani & Levine, 1997; Hamid et al., 2012; Nicholson, Goodman, Flatow, & Bigliani, 1996; Zuckerman et al., 1992). A type I acromion possesses a flat appearance, which makes it less likely to result in impingement of the subacromial structures unless advanced degenerative joint disease is present (Bigliani, 1986; Bigliani et al., 1991; Nicholson et al., 1996). A type II acromion has a slightly curved shape, which slightly predisposes an individual to develop SAIS due to the lessening of the subacromial

space (Bigliani, 1986; Bigliani et al., 1991; Nicholson et al., 1996). The most common type of altered acromion morphology contributing to SAIS is a type III acromion, which appears to have a hook-like appearance that contributes to a partial tendon tearing over time (Bigliani & Levine, 1997; Neer, 1983; Nicholson et al., 1996). The variations of acromion morphology, particularly type III acromion, would contribute to the encroachment of the subacromial tissues due to reduced subacromial space, thus developing SAIS (Bigliani & Levine, 1997; Nicholson et al., 1996). Morrison (1987) examined the SUPR outlets using radiographs of 200 consecutive patients with shoulder pain and discovered that 80% of patients with a rotator cuff tear had a type-III acromion as noted during an arthrogram (Morrison, 1987). However, Nicholson et al. (1996) examined acromial morphology in 420 cadaveric specimens and found that acromial morphology does not change with age ($p = 0.05$).

In addition to the acromion shape, acromial osteophytes are believed to contribute to a rotator cuff tear. Hamid et al. (2012) examined the relationship between the presence of an acromial osteophyte and a full-thickness rotator cuff tear in 216 asymptomatic participants. The authors found the presence of an acromial osteophyte was highly associated with the presence of a full-thickness rotator cuff tear ($p = 0.003$) (Hamid et al., 2012). Neer (1983) also noted that osteophyte formation, on the undersurface of the acromion, would reduce subacromial space and cause an encroachment of soft tissues in this region (Bigliani

& Levine, 1997; Michener et al., 2003; Neer, 1983). In addition, degenerative changes in subacromial structures were observed concurrently with acromial osteophyte formation including thickening of the subacromial bursa, and calcification of the rotator cuff tendons (Bigliani & Levine, 1997; Michener et al., 2003; Neer, 1983). These degenerative changes in the rotator cuff tendons could further contribute to SAIS (Bigliani & Levine, 1997; Michener et al., 2003).

Glenohumeral instability is another potential contributor to SAIS, especially in overhead athletes (Bigliani & Levine, 1997; Michener et al., 2003). Slight glenohumeral subluxations, commonly anteriorly, could contribute to impingement especially during overhead activity (Bigliani & Levine, 1997; Michener et al., 2003). With shoulder laxity or instability, the humeral head has excessive movement in an anterior to posterior or multi-directional path (Chen et al., 2009; Lewis, Green, & Dekel, 2001). The excessive humeral head movement could alter the functional performance of the rotator cuff musculature, thus causing SAIS (Cook, Learman, Houghton, Showalter, & O'Halloran, 2014).

Patients with forward-head posture experience a fundamental alteration in the normal resting position of the glenohumeral and scapulothoracic joints (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005; McClure et al., 2006). The postural changes associated with this position alteration place the humerus in a position of medial rotation and the scapula in a position of protraction and depression (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005; McClure et

al., 2006;). This new position could alter the resting length of the rotator cuff musculature and scapular stabilizers (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005; McClure et al., 2006). In a forward head posture, the pectoral muscle shortening causing the aforementioned biomechanical alterations subsequently results in a weakening of the INFR muscles, a key mover and stabilizer (McClure et al., 2006; Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005). Postural faults have been linked to contributing to SAIS due to changes in shoulder joint kinematics and kinetics related to alterations in muscle length and strength, as well as changes in the orientation of the glenohumeral and scapulothoracic joints (Bandholm et al., 2006). In a position of medial rotation of the humerus and protraction of the scapula, the normal mobility and range of motion excursion of the humerus could be impaired, predisposing an individual to development of SAIS due to a concomitant loss of subacromial space in this abnormal postural position (McClure et al., 2006; Michener et al., 2003). The concurrent loss of humeral mobility due to alterations in muscle length and strength also could contribute to the loss of range of motion (McClure et al., 2006). Lastly, kinematic loss of clavicular rotation, humeral head migration, and scapular rotation due to faculty posture all would contribute to a loss of shoulder range of motion (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005; McClure et al., 2006).

Age and Gender with Subacromial Impingement

The etiology of SAIS is different between young and elder patients. Younger patients with SAIS typically present with etiologies related to acromion morphology, a traumatic mechanism of injury, or muscle imbalances (Bigliani & Levine, 1997; Michener et al., 2003). The most common traumatic mechanism of injury for younger patients with SAIS is related to repetitive stress with overhead activity or spontaneous muscle overload during an activity requiring extreme strength in an overhead position (Bigliani & Levine, 1997; Brossman et al., 1996; Joshi, Thigpen, Bunn, Karas, & Padua, 2011). In addition, a younger patient who presents with a type II or type III acromion is more likely to develop SAIS (Bigliani & Levine, 1997). As discussed earlier, the presence of a type III acromion is linked to rotator cuff pathology (Morrison, 1987). Lastly, younger patients with SAIS often present with muscle length and strength imbalances, due to a higher level of activity and type of sports (Lewis, Green, & Wright, 2005; Lewis et al., 2001).

In contrast to young patients, older patients with SAIS often present with degenerative tendon changes associated with prolonged overuse and repetitive strain (Bigliani & Levine, 1997; Lewis et al., 2001). The morphology of the acromion is not usually a consideration in the development of SAIS in an older adult, but rather the progression of degenerative changes in the shoulder region (Bigliani & Levine, 1997; Nicholson et al., 1996; Zuckerman et al., 1992). As discussed earlier, a degenerative process in the substance of the rotator cuff tendons results from long-

term overload or direct compression from osteophyte formation on the undersurface of the acromion (Bigliani & Levine, 1997; Morrison, 1987; Nicholson et al., 1996). Nevertheless, both young and older patients have similar likelihood for development of SAIS related to muscle imbalances and postural faults, but older patients have a higher likelihood of developing impingement symptoms due to the above-mentioned mechanisms (Bang & Deyle, 2000; Boyles et al., 2009; Michener et al., 2003).

Common Impairments and Functional Limitations in Subacromial Impingement

Common Impairments in Subacromial Impingement

Common impairments in people with SAIS include rotator cuff weakness, scapular muscle weakness, glenohumeral capsule tightness, and cervicothoracic joint dysfunction (Bigliani & Levine, 1997; Michener et al., 2003; Michener et al., 2004; Rhon et al., 2011). The rotator cuff musculature provides two distinct roles, shoulder mobility and stability. Several authors have noted a link between alterations in rotator cuff function and the development of SAIS (Bandholm et al., 2006; Michener et al., 2003; Michener et al., 2004). Although the SUPR tendon is the most common subacromial structure involved in SAIS, the contributions of the other three rotator cuff muscles are imperative to have normal shoulder mobility (Diederichsen et al., 2009). Diederichsen et al. (2009) examined EMG activity of 21 patients with SAIS and 20 asymptomatic individuals. Results revealed a significant

increase in activation of the SUPR muscle during active shoulder abduction (p = 0.003), but a significant decrease in activation of the INFR muscle during shoulder ER (p = 0.04) on the symptomatic side as compared to the asymptomatic side in patients with SAIS (Diederichsen et al., 2009). Contrary to Diederichsen et al.'s (2009) findings, Bandholm et al. (2006) found no difference in maximum voluntary abduction force between nine participants with SAIS and nine healthy matched controls (p = 0.001). However, a mild deficit in sensory-motor control, expressed as shoulder-abduction force steadiness and assessed using maximal voluntary isometric contraction (MVIC) of shoulder abduction, was found in the involved shoulder, but not to the point of limiting daily activity (Bandholm et al., 2006). Similar to Bandholm et al.'s (2006) study results, a study by Camargo, Haik, Raul Filho, Mattiello-Rosa, and Salvini (2008) revealed no statistically significant difference in any isokinetic test variables (acceleration time, time to peak torque, and peak torque) during shoulder concentric scaption between 17 factory workers with unilateral shoulder pain and 16 asymptomatic adults (p = 0.04) (Camargo et al., 2008).

Scapular muscle weakness or scapular dyskinesis also has been linked to the development of SAIS (Hebert, Moffet, McFadyen, & Dionne, 2002; Michener et al., 2003; Michener et al., 2004). The scapular musculature provides a stable foundation for normal movement of the upper extremity during normal functional activities (Cools et al., 2003; Hebert et al., 2002). Cools et al. (2003) examined the

timing of trapezius muscle activation in response to unanticipated movements of the upper extremity in patients with shoulder impingement and asymptomatic adults (Cools et al., 2003). Thirty-nine overhead athletes with shoulder impingement and 30 asymptomatic overhead athletes were examined for trapezius muscle latency during an unexpected lowering of the arm (Cools et al., 2003). The results of the study indicate that SAIS in the glenohumeral joint could result in abnormal scapular muscle (Cools et al., 2003).

A systematic review by Ratcliffe, Pickering, McLean, and Lewis (2013) examined the possible relationship between SAIS and scapular orientation in patients with SAIS and asymptomatic adults. A comprehensive search of the literature revealed 10 trials and concluded insufficient evidence to note the scapula adopts a specific position in patients with SAIS (Ratcliffe et al., 2013). However, a study, examining the activity of the scapular muscles during closed chain activities, revealed a significant difference in middle trapezius muscle activation ($p = 0.027$), as expressed as a percentage of MVIC, between symptomatic and asymptomatic individuals during a push-up on a stable and an unstable surface (Tucker, Armstrong, Gribble, Timmons, & Yeasting, 2010). There was a significant increase in activation of the middle trapezius in patients with shoulder impingement during push-ups on an unstable surface as compared to the asymptomatic participants.

Larsen, Sogaard, Chreiteh, Holtermann, and Juul-Kristensen (2013) examined the muscle activity of the serratus anterior and upper and lower trapezius muscles

to explore the potential for scapular imbalances in people with and without SAIS. The between-group difference was not statistically significant for the ratio of muscle activation or time to activity onset ($p < 0.001$), which suggested that the lack of between-group difference was likely caused by the variability of scapular muscle substitution in people with SAIS (Larsen et al., 2013).

Aside from the aforementioned impairments, posterior capsular tightness is commonly encountered in patients with SAIS (Ellenbecker & Cools; 2010; Larsen et al., 2013; Michener et al., 2003). A forward-head position is a common postural fault associated with SAIS, with the shoulder girdle assuming a position of protraction, depression and medial rotation (Ardic et al., 2006). Muraki et al. (2010) examined the effect of posteroinferior glenohumeral capsule tightness on the subacromial space in eight cadaveric shoulders during a simulated overhead pitching motion. The results noted a significant increase on contact pressure and area on the coracoacromial ligament during the follow-through phase ($p < 0.001$), indicating that posteroinferior capsule tightness can predispose a pitcher to SAIS (Muraki et al., 2010). The effects of posterior capsule tightness on the contact pressure of the coracoacromial arch also were examined in another cadaver study (Muraki et al., 2012), in which passive movement of internal rotation, ER, flexion, and abduction at 90° of abduction was studied in nine cadaveric shoulders. The largest peak contact pressure was found against the lesser tuberosity during passive flexion toward the end range of motion ($p < 0.001$) (Muraki et al., 2012). However,

Poitras et al. (2010) did not associate posterior capsule tightness with the development of SAIS. Poitras et al. (2010) examined the effect of posterior capsular tightening on subacromial pressure or superior humeral head translation during active abduction in the plane of the scapula. Ten cadaveric shoulders were subjected to three different treatment conditions, no tightening, 1-cm of tightening, and 2-cm of tightening (Poitras et al., 2010). The results indicated no effect on peak subacromial contact pressure or superior humeral translation with any of the tightening conditions ($p > 0.05$), suggesting that posterior capsule tightness may not have a direct contribution to increasing the likelihood of developing SAIS (Poitras et al., 2010).

Using the model of regional interdependence as suggested by Wainner, Whitman, Cleland, and Flynn (2007), the focus of identifying and examining impairments in the shoulder region should be more encompassing to include the cervical and thoracic spines. The concept of regional interdependence refers to the idea that impairments in a remote region may be related to an individual's primary pain location (Wainner et al., 2007). With this concept applied to patients with SAIS, a comprehensive examination should include an in-depth examination of the cervicothoracic regions to ensure that impairments in these areas are not actively contributing to the underlying pathological process in the shoulder (Boyles et al., 2009; Haik et al., 2014; Mintken et al., 2010; Muth et al., 2012; Strunce et al., 2009). However, Cook, Learman, Houghton, Showalter, and O'Halloran (2014)

demonstrated against the concept of regional interdependence between shoulder and cervical spine. Cook et al. (2014) examined addition of cervical mobilizations to a treatment program for 68 patients with shoulder impingement syndrome. All participants received a standard of care, i.e. a home exercise program, with the mobilization group receiving additional posterior-to-anterior mobilizations at C5-C6 or C6-C7 to the side of the shoulder with impingement. They found no between-group differences, indicating no substantial benefit of adding cervical mobilization in management of SAIS ($p > 0.05$) (Cook et al., 2014).

Common Functional Limitations in Subacromial Impingement

In addition to the common impairments associated with SAIS, there is a concomitant loss of upper quadrant function (Ludewig & Cook, 2000). The common functional limitations associated with SAIS include reaching in multiple planes of movement, performing basic activities of daily living (e.g. bathing and dressing, driving), performing repetitive upper extremity activities (e.g. lifting or carrying heavy objects), and performing upper extremity work, sport or recreational activities (Bigliani & Levine; 1997; Brossman et al., 1996; Burns & Whipple, 1993; Chard et al., 1991; Michener et al., 2003). Due to the relatively high point prevalence and incidence of SAIS, the morbidity associated with the condition can have a profound effect on an individual's function and quality of life (Chester et al., 2013; Meislin et al., 2005; van der Windt et al., 1996).

Several studies have examined the functional status and quality of life of people with SAIS using a functional outcome scale such as the Disability of the Arm, Shoulder, and Hand (DASH) (Angst, Schwyzer, Aeschlimann, Simmen, & Goldhahn, 2011; McClure & Michener, 2003). Camargo et al. (2009) found a significant improvement in DASH scores and isometric abduction in individuals with SAIS using a generalized shoulder strengthening and stretching program. DASH scores significantly improved following six weeks of training, indicating a significant improvement in upper extremity function (Camargo et al., 2009). Tate, McClure, Young, Salvatori, and Michener (2010) also found a significant improvement in DASH scores in 10 people with SAIS over a 12 week period using therapeutic exercise and manual therapy. At a 12-week follow-up, eight of 10 individuals experienced a 50% improvement in DASH scores. The 50% improvement in DASH scores represents a significant decrease in upper extremity disability (Tate et al., 2010). In a sample of 109 patients undergoing surgical intervention for subacromial impingement, the DASH was shown to be an effective instrument for demonstrating treatment effectiveness and improvement in upper extremity functional status (Gummesson, Atroshi, & Ekdahl, 2003). There have been no studies to date examining changes in DASH scores from baseline in people with SAIS as compared to asymptomatic individuals.

There are a few studies that have explored the use of the Shoulder Pain and Disability Index (SPADI) to examine alterations in function and quality of life in

people with shoulder impingement (Angst et al., 2011; McClure et al., 2003). The SPADI is a 13-item shoulder specific measure of shoulder disability, with higher scores indicating higher levels of disability and a score of 100 indicating maximal pain or disability (Lentz, Barabas, Day, Bishop, & George, 2009). Worsley et al. (2013) found a significant improvement in SPADI scores in people with shoulder impingement (20 ± 9.2 points) over asymptomatic individuals (0 ± 0) points using a scapular motor control retraining program. The lack of change from baseline in asymptomatic individuals was expected but the significant improvement in SPADI scores from baseline indicated a significant reduction in shoulder pain and disability (Worsley et al., 2013). In addition, Boyles et al. (2009) found a statistically significant decrease in self-reported shoulder disability using in SPADI in people with SAIS following thoracic manipulation. Although the decrease in the SPADI score was 6.8 points, the result did not reach the level of clinically meaningful significance, as the minimal clinical important difference of the SPADI is 10 points (Boyles et al., 2009).

Outcome Measures

A multitude of outcome measures are used to quantify shoulder function, in both symptomatic and asymptomatic individuals. Each outcome measure is used to quantify different elements of shoulder function, including pain, disability, and muscle activity. The effectiveness of an outcome measure is assessed, in part, by its

ability to discern change from baseline by chance as compared to the effect of a specific intervention.

Shoulder Muscle Strength

Shoulder muscle strength is commonly assessed using manual muscle testing and held-held dynamometry (HHD). The reliability of HHD for assessing shoulder muscle strength has been well established. Andersen, Christensen, Samani, and Madeline (2014) examined the between-day reliability of using HHD to assess shoulder strength during flexion, abduction, internal rotation, and ER in asymptomatic individuals. The results indicated intraclass correlation coefficients (ICCs) of 0.91 for shoulder flexion, 0.94 for shoulder abduction, 0.98 for shoulder internal rotation, and 0.89 for shoulder ER (Andersen et al., 2014). Cools et al. (2014) assessed the reliability of HHD using a MicroFET 2 hand-held dynamometer for shoulder internal rotation and ER strength and found ICCs of 0.85-0.99 for intra-examiner reliability and ICCs of 0.94-0.99 for inter-examiner reliability. Kolber, Beekhuizen, Cheng, and Fiebert (2007) examined the reliability of assessment of shoulder internal rotation and ER muscle strength using a hand-held dynamometer with a portable stabilization device and found intra-examiner ICCs = 0.97 for the test-retest of two trials of internal rotation and ER. In addition, the reliability of HHD for assessing shoulder muscle strength of overhead-throwing athletes was also established given that these athletes may have greater shoulder muscle strength (Donatelli et al., 2000). Donatelli et al. (2000) use HHD to measure the strength of

the shoulder internal rotator, external rotator, and SUPR muscles in asymptomatic professional baseball pitchers and found high intra-examiner reliability for the muscle tests for SUPR (ICC = 0.96), internal rotators (ICC = 0.93), and external rotators (ICC = 0.82).

Different methods used to assess shoulder muscle strength have been examined. Hayes, Walton, Szomor, and Murrell (2002) compared HHD, spring-scale dynamometry, and manual muscle testing for isometric assessment of the shoulder musculature for five movements in asymptomatic subjects. The study revealed that HHD was the most reliable assessment of shoulder strength, with ICCs of 0.79-0.96 for intra-examiner and 0.79-0.92 for inter-examiner reliability (Hayes et al., 2002). Leggin, Neuman, Iannotti, Williams, and Thompson (1996) examined the reliability of three distinct dynamometers (hand-held, stationary, and isokinetic) for assessing strength of shoulder internal rotation, ER, and abduction. The intra-examiner reliability for all three devices was found to be high, with ICCs ranging from 0.84 to 0.99. However, the inter-examiner reliability was fair-to-good with ICCs ranging from 0.79 to 0.97. Although HHD was the least time-consuming, the lowest ICC value of 0.79 was found for HHD in assessing shoulder abduction (Leggin et al., 1996).

Shoulder muscle strength collected using HHD has been compared to other functional outcome measure scores. MacDermid, Ramos, Drosdowech, Faber, and Patterson (2004) found isometric ER strength was the most predictive of disability

using the SPADI with a Pearson correlation coefficient (r = 0.56) (MacDermid et al., 2004). Roy et al. (2009) examined the concurrent validity of HHD by comparing it to a stationary dynamometer for isometric strength testing of shoulder flexion, abduction, and ER. The results revealed good concurrent validity and strong Pearson correlation coefficients (r = 0.81-0.87) (Roy et al., 2009).

In summary, manual muscle testing is an efficient mechanism to assess muscle strength but there is a certain degree of subjectivity in the assessment. Hand-held dynamometry provides an objective means to quantify strength testing in the clinical or laboratory setting. As noted in the literature, HHD is a valid and reliable measure to quantify strength testing.

Shoulder Electromyography

Electromyography (EMG) is commonly used to assess the activity of a specific muscle at rest and with activity (Alpert, Pink, Jobe, McMahon, & Mathiyakom, 2000). The reliability of EMG for assessing shoulder muscle activity has been well established. Joshi, Thigpen, Bunn, Karas, and Padua (2011) examined INFR EMG activity prior to and following a scapular rotation fatigue protocol and found moderate intra-examiner reliability for the INFR assessment with ICC = 0.88. Reinold et al. (2004) examined the electromyographic activity, expressed as a percentage of MVIC, of the INFR and SUPR during seven shoulder exercises and found moderate to high reliability for the INFR (ICCs = 0.73 to 0.97) and SUPR (ICCs = 0.71 to 0.97) muscles.

Different methods used to assess shoulder muscle EMG have been examined. Alpert et al. (2000) performed an EMG analysis of deltoid and rotator cuff function under varying loads and speeds during a isotonic scaption motion, and found peak activity for the MDELT occurred between 0° to 30° in the scapular plane ($p < 0.05$). The SUPR and INFR muscles also were found to reach peak activity between 0° to 30° and 30° to 60° in the scapular plane ($p < 0.05$) (Alpert et al., 2000). Bandholm et al. (2006) examined the EMG amplitude of the shoulder abduction, internal rotation, and ER musculature during MVIC in people with unilateral SAIS and found no significant between-group differences in any of the strength variables or maximal muscle activity (Bandholm et al., 2006). In contrast, Diederichsen et al. (2009) examined the EMG amplitude of eight shoulder muscles in people with and without subacromial impingement and found significantly increased EMG amplitude in the SUPR ($p = 0.03$) and decreased in the MDELT ($p = 0.05$) in the symptomatic side as compared to the asymptomatic side during shoulder abduction. During shoulder ER, the EMG amplitude of the INFR was significantly decreased ($p = 0.04$). These findings indicate that an increase in SUPR muscle activity during abduction and a decrease in INFR muscle activity during ER could be compensations for diminished activity of the MDELT muscle in people with SAIS (Diederichsen et al., 2009). Therefore, EMG could be a useful assessment for distinguishing patients with SAIS from asymptomatic individuals.

Shoulder Pain

There are a multitude of methods to assess for pain intensity or severity. Although quantifying pain using a scale is a subjective assessment of a patient's pain intensity, many pain scales have been shown to be a valid and reliable way to objectively assess an individual's pain level. The reliability for assessing pain intensity using the Numeric Pain Rating Scale (NPRS) has been well established. The Numeric Pain Rating Scale (NPRS) is a verbal scale used to objectify a patient's pain intensity (Farrar, Young, LaMoreaux, Werth, & Poole, 2001). The NPRS is an 11-point Likert scale ranging from 0 (no pain present) to 10 (worst pain one could imagine) (Farrar et al., 2001). Mintken, Glynn, and Cleland (2009) examined the test-retest reliability of the NPRS in a study of individuals with shoulder pain receiving spinal manipulation and found ICC = 0.74. Price, Bush, Long, and Harkins (1994) reported the NPRS to be a reliable assessment of clinical and experimental pain intensity. In a study assessing the test-retest stability of pain intensity over time, Jensen and McFarland (1993) found a stability coefficient over seven days of ratings of 0.92 for one pain rating per day and a coefficient of 0.95 with four pain ratings per day. The stability coefficient refers to the consistency of pain ratings over a set time period (Jensen & McFarland, 1993). In an article evaluating the reliability of six different pain intensity scales, the reliability of all of the pain intensity scales was moderate to strong with ICCs ranging from 0.65 to 0.88 (Jensen, Karoly, & Braver, 1986). A study by Jensen, Turner, Romano, and Fisher (1999)

examined the reliability of the NPRS in patients with chronic pain and found a moderate test-retest reliability with ICCs ranging from 0.55 to 0.65 when administered between a 1-month and 2-month follow-up. In examining the composite pain intensity scores, the study noted a moderate to high test-retest reliability with ICC being 0.71 when the mean score was determined from the average, current, and worst intensity (Jensen, Turner, Turner, & Romano, 1996; Jensen et al., 1999). The NPRS also has been demonstrated to have fair-to-moderate test-retest reliability in a study of patients with mechanical neck pain (Cleland, Childs, & Whitman, 2008).

Different psychometric properties of the NPRS have been examined. In a study examining the construct validity of the NPRS, Young, Cleland, Michener, and Brown (2010) found the NPRS to be a valid assessment of pain in patients with cervical radiculopathy. In addition, Jensen et al. (1996) examined the correlation between composite intensity scores for least and worst pain and average pain intensity and found a strong correlation (r = 0.87), indicating that the mean of least and worst pain is a good predictor of average pain intensity. In a review article of pain intensity rating scales, Williamson and Hoggart (2005) concluded that the NPRS has good sensitivity to detect change in pain levels over time (Williamson & Hoggart, 2005).

The responsiveness of the NPRS also has been well established. Childs, Piva, and Fritz (2005) examined the responsiveness of the NPRS in patients with low back

pain and found a minimal detectable change of two points. In a study of patient with shoulder pain, Mintken et al. (2009) found the NPRS to have a minimal clinically important difference of 1.1. Lastly, Young et al. (2010) reported a minimal detectable change of 2.2 in patients with cervical radiculopathy. In summary, the NPRS has been shown to be a valid and reliable assessment to quantify pain intensity in patients with musculoskeletal pain.

In addition to the NPRS, the Visual Analog Scale (VAS) also has been found to be a reliable assessment of pain intensity. The Visual analog scale (VAS) consists of a 10-cm line used to quantify pain intensity on a scale of 0 (no pain at all) to 10 (worst pain ever). Pain intensity is assessed by having an individual place a mark on the line corresponding to their current pain level, with the pain rating determined by measuring the distance from 0 to the line indicating the person's pain severity. The test-retest reliability of the VAS has been reported to be strong (ICC = 0.967) in patients with low back pain (Kim et al., 2014), but the reliability has not been reported in patients with shoulder pain.

In summary, both the NPRS and the VAS are noted in the literature to be reliable assessments to quantify pain intensity in people with musculoskeletal pain. There is no evidence to date examining a comparison of the NPRS and VAS in people with shoulder dysfunction.

Shoulder Function and Disability

There are a multitude of functional outcome questionnaires to quantify functional status and disability in the upper quadrant, with some specific to the shoulder region. In an article examining upper quadrant measures of adult function, Angst et al. (2011) reported the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire to be the most widely studied and used instrument for assessment of shoulder function. The DASH questionnaire is comprised of 30 items and each item is scored on a scale from 1 to 5, with 1 indicating no disability and 5 indicating maximum disability (Beaton et al., 2001; Hudak et al., 1996; McClure & Michener, 2003). The DASH questionnaire was chosen over other shoulder outcome measures due to the comprehensive nature of this questionnaire and the fact that it inquires about functional deficits of the upper quarter.

The reliability of the DASH for assessing shoulder function has been well established. The test-retest reliability of the DASH questionnaire was reported as good in the literature, with ICCs ranging from 0.90 to 0.96 (Beaton et al., 2001; Roy, MacDermid, & Woodhouse, 2009; Roy et al., 2009; McClure & Michener, 2003). In addition, the validity of the DASH to assess for changes in shoulder function has been established. The internal consistency of the DASH was determined by no change of two DASH scores administered three to five days apart prior to commencement of intervention with the concomitant report of no change by the patients (McClure & Michener, 2003). Lastly, the DASH has been shown to have

good discriminant validity, as noted by the instrument's ability to discriminate between pathologies noted to vary in severity and intensity (Atroshi, Gummesson, Andersson, Dahlgren, & Johansson, 2000).

Furthermore, the DASH has been found to correlate with other shoulder disability assessments such as the SPADI with $r > 0.69$ (Beaton et al., 2001). In addition, the minimal detectable change of the DASH was found to be 10.5 and a minimal clinically important difference to be 10.2 (Roy et al., 2009; Roy, MacDermid, & Woodhouse, 2009). Michener, Valier, and McClure (2013) used the DASH and the Global Rating of Change (GROC) questionnaires to examine clinical benefits of an impairment-based therapeutic exercise program and reported a receiver operating characteristic analysis of a cut-point of 11 points for the DASH (AUC = 0.76, $p < 0.05$) (Michener, Valier, & McClure, 2013). However, the results found that a change of 11 points for the DASH did not appear to be sufficient to assess for improvement due to poor discriminatory ability (Michener et al., 2013). In summary, the DASH has been shown to be a valid, reliable, and responsive outcome measure to assess for shoulder function in patients with shoulder pathology.

In addition to the DASH, the SPADI is another shoulder outcome measure used to measure pain and disability associated with shoulder pathology (McClure & Michener, 2003). The SPADI consists of 2 subscales: pain (5 items) and function (8 items). The reliability of the SPADI has been well established. The test-retest reliability of the SPADI has been reported as moderate to strong (ICC = 0.66 to 0.91)

(McClure & Michener, 2003). In addition, the validity of the SPADI has also been established (McClure & Michener, 2003). In addition, the minimally clinical important difference of the SPADI was found to be 10 points (McClure & Michener, 2003).

In summary, both the DASH and SPADI are outcome measures commonly used to quantify patient functional status or patient perceived disability in people with shoulder dysfunction (McClure & Michener, 2003; Bot et al., 2004). Although the SPADI has been well studies in people with shoulder dysfunction, the DASH is more extensively utilized in the literature to document functional status of people with shoulder dysfunction (McClure & Michener, 2003; Bot et al., 2004). In a review article examining the clinimetric properties of the SPADI and DASH, the authors found the DASH to have better clinimetric properties as compared to the SPADI for responsiveness and test-retest reliability. Nevertheless, the authors conclude that the DASH and SPADI are appropriate for evaluating function in a clinical setting (Bot et al., 2004).

There is a growing body of literature regarding the development of fear avoidance behavior in patients with musculoskeletal pain. Fear avoidance behavior is noted as the development of aberrant or alternative movement strategies as a compensatory mechanism to avoid performing a painful activity (Waddell, Newton, Henderson, Somerville, & Main, 1993). The Fear Avoidance Belief Questionnaire (FABQ) was developed by Waddell et al. (1993) to investigate the presence of fear-

avoidance behavior in patients with musculoskeletal pain. The FABQ consists of two subscales, one assessing physical activity (FABQ-PA) and the other assessing work activity (FABQ-W). Mintken et al. (2010) explored the reliability and validity of the FABQ to assess for pain related fear in patients with shoulder pain and found a strong test-retest reliability with ICC = 0.88 for the FABQ-PA and ICC = 0.94 for the FABQ-W.

A correlation for pain-related fear measures and shoulder pain and disability produced a slight correlation with a Pearson value of (r = 0.323) for the SPADI and FABQ-PA (George & Stryker, 2011). A study by George, Fritz, and Erhard (2001) examining the fear-avoidance beliefs in patients with lumbar and cervical spine pain reported a slight correlation (r = 0.48) of the FABQ-PA and disability as noted by the Modified Oswestry Low Back Questionnaire. In a separate trial by George, Fritz, Bialosky, and Donald (2003) examining the effect of fear-avoidance-based intervention for patients with acute low back pain, the results revealed an effect in the standard of care treatment group receiving a patient education handout with fear-avoidance beliefs remaining a predictor of 4-week disability ($p < 0.031$) and 6-month disability ($p < 0.016$). In a secondary analysis study examining the influence of fear-avoidance beliefs on disability in patients with SAIS, Kromer, Sieben, de Bie, and Bastiaenen (2014) concluded a significant contribution of fear-avoidance beliefs to disability at baseline ($p < 0.05$), but not to disability at 3 months.

Conservative Interventions for SAIS

Considerable research has examined the effectiveness of conservative interventions for patients with SAIS (Escamilla, Hooks, & Wilk, 2014; Faber, Kuiper, Burdorf, Miedema, & Verhaar, 2006; Fongemie, Buss, & Rolnick, 1998; Green, Buchbinder, & Hetrick, 2006; Kamkar, Irrgang, & Whitney; 1993). Substantial evidence exists for the use of therapeutic exercise as an efficacious intervention for the treatment of impairment attributable to SAIS (Ballantyne et al., 1993; Bang & Deyle; 2000; Bergman et al., 2004; Chen, Ginn, & Herbert; 2009; Chester et al., 2013; Cook et al., 2014; Desmeules, Cote, Fremont, 2003). Moderate evidence at present also supports the use of manual therapy combined with therapeutic exercise to facilitate a resolution of the condition (Bang & Deyle, 2000; Escamilla et al., 2014; Green et al., 2006). In the past decade, spinal manipulation has been used regularly by physical therapists to address impairments in pain and loss of mobility due to musculoskeletal pathology (Bialosky, Simon, Bishop, & George, 2012). However, one recent systematic review by Chester et al. (2013) concluded no significant association between prognostic factors and outcome from physiotherapy treatment in patients with shoulder pain. The authors attributed this lack of association to the inconsistencies noted between prognostic factors and observed outcomes in the varied studies (Chester et al., 2013).

Therapeutic Exercises for SAIS

Michener, Walsworth, and Burnet (2004) performed a systematic review of the literature examining the effectiveness of interventions used in the rehabilitation of patients with SAIS. The review included 12 studies for analysis, with the authors concluding that therapeutic exercise and joint mobilizations are efficacious for patients with SAIS (Michener, Walsworth, & Burnet, 2004). Two systematic reviews have been conducted to examine therapeutic exercise effects specifically on SAIS (Kromer, Tautenhahn, de Bie, Staal, & Bastiaenen, 2009; Kuhn, 2009). These systematic reviews made similar recommendations in support of the use of therapeutic exercise for treatment of SAIS. Kromer et al. (2009) compared the efficacy of physiotherapy and surgical intervention in patients with SAIS. The review included 16 studies and the authors concluded that physiotherapist-led exercises and surgical intervention were equally effective for managing SAIS (Kromer et al., 2009). In addition, this systematic review also identified that the most effective exercise programs often include capsular stretching, functional strengthening, movement pattern normalization, rotator cuff strengthening, scapular muscle strengthening, and motor control of the rotator cuff and scapular musculature (Kromer et al., 2009). Another systematic review examined the effectiveness of exercise in addressing dysfunction associated with SAIS (Kuhn, 2009). This systematic review included 11 articles that met the inclusion criteria. The author made the same conclusion as the systematic review conducted by

Kromer el al. (2009), that exercise include the above-mentioned components is an effective approach at reducing pain and improving function in patients with SAIS (Kuhn, 2009). Other studies have also examined the effectiveness of specific exercise programs in the management of SAIS with moderate evidence supporting a comprehensive impairment-based approach (Escamilla et al., 2009; Escamilla et al., 2014; Michener et al., 2004). However, a systematic review examining the clinical outcomes of exercise type in the management of SAIS found only four studies of good quality, but overall limited evidence for an ideal specific type of exercise for patients with SAIS (Kelly, Wrightson, & Meads, 2010). The authors concluded that a specific exercise type could not be established due to variability in exercise prescription and the lack of specificity in frequency and duration of the exercise programs (Kelly et al., 2010).

Ludewig and Borstad (2003) investigated the effect of a 10-week home exercise program in construction workers with daily repetitive overhead activity, along with shoulder pain and impingement. The home exercise program consisted of posterior shoulder stretch, pectoralis corner stretch, scaption exercise, serratus anterior strengthening exercise, and an ER resistance band exercise at 0° and 90° of shoulder abduction (Ludewig & Borstad, 2003). The symptomatic participants were randomized into a treatment group and control group, with a group of asymptomatic workers serving as an additional control group (Ludewig & Borstad, 2003). The results illustrated a significantly greater reduction in shoulder pain and

disability in the treatment group than in the control groups ($p < 0.001$) (Ludewig & Borstad, 2003). McClure, Michener, and Karduna (2006) examined the potential effects an exercise program may have on scapular kinematics, physical impairments and functional limitations in patients with SAIS. Thirty-nine patients completed a six-week rehabilitation program consisting of a standardized exercise program developed based in physical impairments associated with SAIS (McClure et al., 2006). The standardized exercises consisted of shoulder external and internal rotation with elastic resistance, internal rotation towel stretch, cross-body stretch, upper thoracic extension stretch, pectoral muscle stretch, shoulder flexion stretch using a T-bar, and shoulder ER using a T-bar (McClure et al., 2006). At the conclusion of the program and at a six-month follow-up, improvements were noted in passive movement and force production for internal rotation and ER ($p < 0.001$) (McClure et al., 2006). There was also a significant improvement in pain levels and shoulder function ($p < 0.001$) (McClure et al., 2006). Park, Choi, Lee, and Kim (2013) examined the effect of scapular stabilization exercises on pain and upper extremity function in patients post operatively with SAIS. Thirty participants were randomly assigned to stabilization group or traditional exercise group (Park et al., 2013). The stabilization group performed in a side-lying position on the uninvolved side, with the therapist applying manual resistance against scapular elevation, depression, retraction, and protraction with participants performing 3 sets of 10 repetitions for 10 seconds each (Park et al., 2013). The traditional shoulder exercise

consisted of closed-chain standing rhythmic stabilization exercise with the therapist-applied force with participants performing 3 sets of 10 repetitions for 10 seconds each (Park et al., 2013). Results favored the stabilization group over the traditional exercise group for active and passive abduction ($p < 0.05$) (Park et al., 2013).

Litchfield (2013) conducted a randomized controlled trial comparing the effectiveness of specific exercises versus non-specific exercise in 97 participants with SAIS. The specific exercise group received two eccentric internal rotation and ER exercises, scapular elevation, depression, and protraction, and a posterior capsule stretch (Litchfield, 2013). The non-specific exercise group received basic active range of motion exercises for the neck and shoulder without resistance (Litchfield, 2013). The results revealed a statistically significant improvement in the specific exercise group over the non-specific group for pain levels and DASH scores, with the intervention group experiencing a lower number of participants opting for surgical intervention ($p < 0.05$) (Lewis, 2012; Litchfield, 2013). Worsley et al. (2013) compared the effectiveness of a scapular motor control retraining for individuals with SAIS. The scapular motor control retraining program consisted of active elevations in the frontal, sagittal, and scaption planes to 90°, as well as rhythmic stabilization activities to promote motor control (Worsley et al., 2013). The results showed that 16 symptomatic individuals with SAIS and 16

asymptomatic individuals made a significant improvement in EMG activity in the serratus anterior and lower trapezius muscles ($p < 0.05$) (Worsley et al., 2013).

Manual Therapy for SAIS

Recent investigations have examined the use of cervical and thoracic manual therapy to decrease pain and improve patient self-report function in subjects with shoulder pain (Brantingham et al., 2011; Ho, Sole, & Munn, 2009; Isabel de-laLlave-Rincon, Puentedura, & Fernandez-de-las-Penas, 2011; Sueki & Chaconas, 2011; Walser, Meserve, & Boucher, 2009). In a recent clinical trial examining the effects of thoracic spine manipulation in patients with rotator cuff tendinopathy, the authors observed an improvement in pain levels with shoulder flexion and improved shoulder force production (Muth et al., 2012). However, in a separate study examining the effect of seated thoracic manipulation on changes in scapular kinematics in asymptomatic participants, the authors noted no significant change in 3D scapular kinematics during arm flexion (Rosa, Alburquerque-Sendin, Salvini, & Camargo, 2013). In a study of healthy subjects, Wassinger et al. (2016) examined 20 healthy subjects exploring the effects of cervical and CTJ manipulations using experimentally induced shoulder pain with eccentric shoulder exercises on pain pressure threshold of the INFR muscle. The results indicated a significant reduction in pain reports ($p = 0.001$) and increase in pain pressure threshold ($p < 0.001$) in participants who received a cervical or cervicothoracic manipulation. These findings suggest that manipulation of the cervical and thoracic regions can

effectively decrease pain and improve pressure pain tolerance in individuals with shoulder pain (Wassinger et al., 2016).

The evidence for cervical and thoracic mobilization and manipulation to date has focused on the benefits of improving pain and patient perceived disability in patients with SAIS (Boyles et al., 2009; Kardouni et al., 2015; Mintken et al., 2010; Mintken et al., 2016; Strunce et al., 2009; Sueki et al., 2011). Michener, Kardouni, Albers, and Ely (2013) and Michener, Kardouni, Sousa, and Ely (2014) compared the effectiveness of a thoracic manipulative technique to a sham intervention on shoulder active range of motion and perceived effect of treatment in patients with SAIS. The thoracic manipulative technique consisted of one CTJ seated distraction technique and two prone middle and lower thoracic techniques (Michener et al., 2013; Michener et al., 2014). The sham techniques were similar to the thoracic manipulative techniques, but no thrust was delivered (Michener et al., 2013; Michener et al., 2014). No significant difference was found between groups with regard to perceived effects of treatment ($p = 0.69$) (Michener et al., 2013; Michener et al., 2014). However, the sham thoracic manipulation technique and the thoracic manipulative technique were found to have no effect on shoulder active range of motion (Michener et al., 2013; Michener et al., 2014).

Kromer, de Bie, and Bastiaenen (2013) examined the effectiveness of manual physiotherapy and exercise as compared to exercise alone in patients with shoulder impingement syndrome. In a trial of 90 participants, there was no significant

difference between the groups for pain and disability (Kromer, de Bie, & Bastiaenen, 2013). In a different studies examining the effectiveness of the prior trial at a one year follow-up, the authors found no difference between the two groups at a one year follow-up, but concluded that individualized exercise programs resulted in reduced costs when including manual therapy as part of the intervention plan (Kromer, de Bie, & Bastiaenen, 2010; Kromer, de Bie, & Bastiaenen, 2014).

There is a plethora of evidence in the literature for the use of manual therapy, combined with therapeutic exercise, to address the impairments and functional limitations present with SAIS (Michener et al., 2004). Desmeules, Cote, and Fremont (2003) performed a systematic review to assess the effectiveness of therapeutic exercise and manual therapy in the treatment of patients with SAIS. There review concluded that there was limited evidence to support the efficacy of manual therapy combined with therapeutic exercise in the management of patients with SAIS (Desmeules et al., 2003). Bang and Deyle (2000) examined the effectiveness of the addition of manual therapy to a standard-of-care exercise program in patients with SAIS. The manual therapy combined with therapeutic exercise group experienced significantly larger improvements in pain levels, strength, and pain free function as compared to control (Bang & Deyle, 2000). These results illustrate the benefit of including manual therapy as part of a comprehensive intervention plan at enhancing the therapeutic outcome of patients with SAIS. In a case series experiment, Tate et al. (2010) described a standard intervention regimen

for patients with SAIS. Ten patients with SAIS were treated over a 6- to 8-week program, including strengthening, manual stretching, spinal mobilization and manipulation, patient education, and a home exercises (Tate et al., 2010). At a 12-week follow-up, 80% of participants experienced a significant improvement in DASH scores from baseline (Tate et al., 2010). In addition, Senbursa, Baltaci, and Atay (2007) compared the effectiveness of soft tissue and joint mobilization to a self-training program in patients with SAIS. The self-training program included active range of motion, stretching, and strengthening of the rotator cuff muscles, rhomboids, levator scapulae, and serratus anterior with patients performing every day for 4 weeks (Senbursa et al., 2007). There were statistically significant improvements in shoulder range of motion and function in the manual therapy group as compared to the self-training group ($p > 0.05$) (Senbursa et al., 2007).

Walser, Meserve, and Boucher (2009) conducted a systematic review and meta-analysis examining the effectiveness of thoracic spinal manipulation for the clinical management of several musculoskeletal conditions. The conclusion noted limited evidence for the use of thoracic spine manipulation for shoulder conditions, but reported enough evidence existed to facilitate a more rapid recovery in the short term (Walser et al., 2009). In an online questionnaire attempting to evaluate the evidence based treatment of patients with shoulder impingement syndrome by Dutch-speaking physiotherapists, Struyf, De Hertogh, Gulinck, and Nijs (2012) discovered that manual therapy and exercise were used by most of the 119 survey

respondents (Struyf et al., 2012). Strunce et al. (2009) examined the immediate effects of thoracic spine manipulation on reducing pain and improving range of motion in subjects with shoulder pain. Twenty-one patients with shoulder pain were treated with a thoracic manipulation with the outcome showing a 51% reduction in shoulder pain and an increase in shoulder range of motion by 30-38° (Strunce et al., 2009).

Sueki and Chaconas (2011) performed a literature review examining the effects of thoracic manipulation on shoulder pain and found a consensus in the literature that spinal manipulation is effective at reducing pain and improving range of motion in patients with shoulder pain. In a mixed-model design, 104 participants with SAIS received either a single triamcinolone acetonide corticosteroid injection or 6 visits of manual therapy to the shoulder and spine (Rhon et al., 2011; Rhon et al., 2014). At a one-year follow-up, there were no significant between-group differences for pain level of functional scores, but the injection group did require more healthcare utilization for SAIS over the manual therapy group (Rhon et al., 2011; Rhon et al., 2014). The effect of seated thoracic manipulation on alterations in scapular kinematics and scapulohumeral rhythm was examined in 42 asymptomatic participants receiving either manipulation or placebo (Rosa et al., 2013). There was no significant difference in DASH scores, scapular kinematics, or scapulohumeral rhythm between the manipulation and placebo groups (Rosa et al., 2013). Muth et al. (2012) examined the effects of thoracic spine manipulation on scapulohumeral

rhythm and electromyography amplitude of INFR, upper trapezius, middle trapezius, lower trapezius, and serratus anterior muscles. Thirty subjects with signs of rotator cuff tendinopathy were assessed pre-manipulation and post-manipulation with the results finding no change in scapular kinematics or range of motion with thoracic manipulation (Muth et al., 2012). There was a small but significant enhancement in muscle activation of the middle trapezius resulting from the thoracic spinal manipulation but not with any of the other muscles (Muth et al., 2012).

From an examination in patients with shoulder pain, Mintken et al. (2010) attempted to identify prognostic variables that were likely to result in a higher likelihood of success with spinal manipulation as an adjunctive intervention. The five prognostic factors noted in the regression model were pain-free shoulder flexion less than 127°, shoulder internal rotation less than 53°, a negative Neer's test, not taking any medications for shoulder pain and duration of symptoms less than 90 days (Mintken et al., 2010). The results of the trial demonstrated success in 49 of 80 subjects and found the change of attaining a successful outcome to be 89% when three of five prognostic variables were present (Mintken et al., 2010). A systematic review of the literature examined the possible effect of manual and manipulative therapy for shoulder pain, concluding fair evidence for the use of manipulative therapy to the shoulder, cervical and thoracic spines in patients with shoulder pain (Brantingham et al., 2011). Gebremariam et al. (2014) also conducted

a systematic review examining the effectiveness of physiotherapy and manual therapy in managing patients with shoulder impingement syndrome. Once again, the results indicated moderate evidence for the use of exercise and mild evidence for using manual therapy as an adjunctive intervention for patients with shoulder impingement, but noted limited evidence existed for any other interventions (Gebremariam et al., 2014).

Boyles et al. (2009) examined the short-term effects of thoracic spine manipulation in 56 patients with SAIS. The authors noted a statistically significant reduction in patient self-reported pain using the Numeric Pain Rating Scale, self-reported disability using the SPADI, and a significant difference in GROC scores at the 48-hour follow-up, indicating that an overall real change was observed from a patient perspective as a result of the intervention as compared to baseline (Boyles et al., 2009). In a study by McClatchie et al. (2009), the authors examined the effect of mobilizations of the asymptomatic cervical spine in 21 patients with non-specific shoulder pain. Cervical mobilization was demonstrated to significantly decrease shoulder pain intensity and to improve shoulder abduction painful arc, suggesting that this may be an effective adjunctive intervention to expedite recovery in patients with shoulder pain (McClatchie et al., 2009).

On the contrary, in some studies, adding manual therapy to exercises was not found to be more beneficial in treatment of SAIS (Cook et al., 2014; Haik et al., 2014; Ho et al., 2009). Cook et al. (2014) examined the addition of cervical unilateral

posterior-anterior mobilizations as a treatment for patients with SAIS. The authors found no difference between groups with regard to the neck intervention, but both groups did experience improvements within the groups, indicating that the addition of cervical mobilization to a standard of care program for the shoulder does not have any significant impact in patients with SAIS (Cook et al., 2014). Ho, Sole, and Munn (2009) performed a systematic review of the literature examining the effectiveness of manual therapy techniques for the management of musculoskeletal pathologies of the shoulder region. The analysis of manual therapy for SAIS showed that there was not enough conclusive evidence to note enhanced benefit using manual therapy over other interventions (Ho et al., 2009). Haik et al. (2014) examined the effects of thoracic spine manipulation in symptomatic and asymptomatic people on scapular kinematics and pain during arm elevation and lowering. Although a decrease in pain occurred after spinal manipulation in the SAIS group ($p < 0.04$), no changes in scapular kinematics were noted to be clinically important post manipulation (Haik et al., 2014).

A case report examined the management of a patient with generalized shoulder pain that was treated with cervical mobilization and upper limb neurodynamic techniques, resulting in complete resolution of shoulder pain and disability at a six-month follow-up (Haddick, 2007). Conroy and Hayes (1998) examined the effectiveness of glenohumeral joint mobilization in the management of patients with SAIS. Fourteen subjects participated in an experimental group

receiving standard intervention combined with joint mobilization, while the control group received standard intervention alone (Conroy & Hayes, 1998). Results indicated the experimental group had less 24-hour pain as compared to the control group, indicating that shoulder joint mobilization may be an effective adjunctive intervention in people with impingement syndrome (Conroy & Hayes, 1998).

Bracing and Taping for SAIS

Walther, Werner, Stahlschmidt, Woefel, and Gohlke (2004) conducted a prospective clinical trial examining the effectiveness of self-training, conventional physiotherapy and bracing in patients with SAIS. The self-training program consisted of shoulder and scapular strengthening exercises using elastic resistance, pendulum exercises, and shoulder inferior distraction stretching. The conventional physiotherapy group received 10 visits of physical therapy consisting of the same program as the self-training group, but under direct therapist supervision (Walther, Werner, Stahlschmidt, Woefel, & Gohlke, 2004). Participants in the bracing group received a functional shoulder brace and were instructed to use the brace as much as possible during the day and evening (Walther et al., 2004). After a 12-week trial, there was no statistically significant difference between the groups in age, pain level, and duration of dysfunction (Walther et al., 2004). Santamato et al. (2009) examined the potential effect of high-intensity laser therapy versus ultrasound therapy in participants with SAIS. Seventy participants received 10 treatments over a two-week period concluding a greater reduction in pain and improvement in

articular movement in the high-intensity laser therapy group (Santamato et al., 2009).

Several studies have found some benefits of taping in the treatment of SAIS (Hsu, Chen, Lin, Wang, & Shih, 2009; Kaya, Zinnuroglu, & Tugcu; 2011; Kaya, Baltaci, Toprak, & Atay, 2014; Selkowitz, Chaney, Stuckey, & Vlad, 2007). Selkowitz, Chaney, Stuckey, and Vlad (2007) examined the effects of scapular taping on the surface electromyography amplitude of the upper and lower trapezius in patients with SAIS. Scapular taping resulted in a significant reduction in upper trapezius muscle activity during extremity elevation above 90 degrees ($p < 0.002$) (Selkowitz et al., 2007). A significant interaction was noted during shoulder abduction using scapular tape with a resultant reduction in the EMG signal amplitude ($p < 0.047$) as compared to no tape (Selkowitz et al., 2007). Kaya, Baltaci, Toprak, and Atay (2014) examined the effects of manual therapy with exercise versus kinesiotaping with exercise in reducing pain and disability, as well as altering SUPR tendon thickening using diagnostic ultrasound, in patients with SAIS. Fifty-four patients with SAIS received 6 weeks of guided intervention that resulting in no significant differences between the two groups (Kaya et al., 2014). Another clinical trial examined the efficacy of kinesiotaping with a home exercise program versus physical therapy modalities (ultrasound, hot pack, and electrical stimulation) with a home exercise program in patients with SAIS (Kaya et al., 2011). There were statistically lower pain scores for the kinesiotaping group at the first week as compared to the modalities group, but

there was no significant difference between the groups at the second week follow-up (Kaya et al., 2011). Hsu, Chen, Lin, Wang, and Shih (2009) examined the effects of taping on scapular kinematics and scapular muscle activity in a sample of amateur baseball players with SAIS. The electromyographic activity of the upper trapezius, middle trapezius, and serratus anterior muscles was analyzed during shoulder elevation in the scapular plane (Hsu et al., 2009). All participants received both elastic taping and placebo taping with the results revealing enhancements in lower trapezius muscle activity in the 60-30° arm-lowering condition ($p < 0.05$) as compared to placebo taping (Hsu et al., 2009).

Summary

There are a multitude of postulations on the etiology of SAIS. A literature review of the common possible contributing factors to SAIS included acromial morphology changes, muscle imbalances, postural faults, and repetitive strain activities. The common impairments related to SAIS are multifactorial in nature and vary depending on the age of the individual. The common functional limitations present with SAIS contribute to significant loss of function and morbidity with loss of upper extremity ability as the condition progresses.

This literature review presented some common interventions used in the clinical management of SAIS. There is moderate evidence for the use of therapeutic exercise and manual therapy for managing SAIS. The most effective therapeutic exercise regimens cited in the literature include a multi-modal approach consisting

of stretching, strengthening and motor control activities, addressing both the shoulder and scapular musculature. The commonly cited manual therapy techniques in the literature include shoulder joint mobilizations, scapulothoracic mobilizations, and manipulations to the cervical and thoracic spine. There also exists moderate evidence for the use of manual therapy to decrease pain and improve function in patients with SAIS. Despite all of the evidence presented in this literature review, the evidence regarding the alteration of shoulder muscle activity following spinal manipulative therapy is lacking. This study will attempt to examine the immediate and carry-over effects of CTJ manipulation on shoulder strength, muscle activation, and pain in individuals with SAIS. To date, no study has explored the effectiveness of CTJ manipulation on shoulder muscle strength, muscle activation, and pain in people with SAIS.

CHAPTER III

METHODS

Subacromial impingement syndrome (SAIS) is a common clinical presentation associated with altered muscular activity of the shoulder and scapular musculature (Michener et al., 2003). This altered muscle activity leads to disruptions in force couple activity of the shoulder and scapular musculature, causing pain and disability with daily activities. The conservative management of SAIS involves reducing pain and improving muscle activity of the rotator cuff and scapular stabilizers. The current standard of care for the conservative management of SAIS includes the use of exercise and manual therapy to facilitate a resolution of the morbidity of SAIS (Michener et al., 2004). The current evidence for using exercise to address impairments of SAIS has focused on increasing strength of the impaired muscles (Michener et al., 2004; Park et al., 2013). Research concerning the use of manual therapy to address impairments associated with SAIS has focused primarily at improving joint restrictions in the shoulder, cervical and thoracic spine to enhance recovery from SAIS (Bang & Deyle, 2000; Boyles et al., 2009; Mintken et al., 2010). The purpose of this study was to examine the effectiveness of cervicothoracic junction (CTJ) manipulation as compared to placebo in patients with SAIS on: (a) shoulder muscle strength of external rotation (ER) using hand-held dynamometry (HHD), (b) electromyography (EMG) amplitude of the middle deltoid

(MDELT), supraspinatus (SUPR), and infraspinatus (INFR) muscles, and (c) pain level. This chapter describes the research design, participants, instrumentation, data collection, and data analyses used for the study.

Research Design

This study was a randomized clinical trial using a two-way (2x7) mixed-design to examine the immediate and carry-over effects of a CTJ manipulation on shoulder muscle strength, electromyographic (EMG) activity, and pain level. The between-subject factor was treatment with two levels: manipulation and placebo, and the within-subject factor was time with seven different time points: baseline, and immediately, 15 minutes, 30 minutes, 45 minutes, 48-72 hours, and 6-7 days post intervention. The dependent variables were: 1) shoulder ER strength (in newton-meter or N·m), 2) EMG amplitude of the MDELT, SUPR, and INFR muscles during shoulder ER strength testing, and 3) pain intensity.

Participants

Participants with SAIS were recruited for this study from the Fort Worth area using flyers and word-of-mouth outreach. Prior to initiating participant recruitment, an a priori power analysis using G*Power version 3.1.3 (Faul, Erdfelder, Lang, & Buchner, 2007) was conducted to estimate the appropriate sample size. The analysis was performed with a small-medium effect size of 0.20, alpha level at 0.05, correlation among repeated measures at 0.50, and power at 0.80 for a 2 x 5 repeated measure (RM) ANOVA. A 2 (group) x 5 (time) RM ANOVA,

rather than a 2 (group) x 7 (time) RM ANOVA was used for the a priori power analysis to avoid under-estimating the sampling size because the data was collected five times on the same day and once on each of two separate days for the other two data collections. As a result of the power analysis, it was determined that a minimum of 32 participants would be required to ensure adequate power for an ANOVA with repeated measures analysis. With the potential for a 10% attrition rate, four additional participants were recruited for a total of 36 participants (18 in CTJ manipulation group, 18 in placebo group).

Individuals who were 18-70 years old, had shoulder pain for less than 12 weeks and had a shoulder pain rating of at least 3/10 using the numerical pain rating scale (NPRS), were recruited in the study (Appendix B). Participants were excluded if they were over the age of 70 due to the possible presence of other conditions, such as osteoarthritis or adhesive capsulitis that could affect the results of the study. All participants were informed of the risks, benefits and procedures of the study. Once participants agreed to participate in the study, they were asked to sign a written informed consent form. Prior to the commencement of the study, approvals were obtained from the Institutional Review Boards (IRB) of the University of North Texas Health Science Center (UNTHSC) and Texas Woman's University (TWU). An IRB approval was required from both institutions, as data collection occurred at UNTHSC and as a dissertation requirement at TWU.

After a written consent was obtained from the participant, the principal investigator (PI) asked the participant about his/her medical and surgical history. A demographic intake form was used to obtain the participant's medical and surgical history (Appendix C). The participant was excluded if he or she had: (1) osteoporosis, (2) a history of full thickness rotator cuff tear, (3) a history of cervical spine or shoulder surgery, (4) an upper quarter peripheral nerve injury, (5) cervical radiculopathy, (6) serious spinal conditions, such as tumor or fracture, (7) adhesive capsulitis, (8) cervical myelopathy, (9) a history of systemic disease (e.g. systemic lupus erythematosus, rheumatoid arthritis, and bleeding disorders), and (10) no prior treatment for this episode of shoulder or neck pathology by a physical therapist, chiropractor, or physician over the last past three months.

Cervical radiculopathy was identified using the cluster of diagnostic tests recommended by Wainner et al. (2003). To confirm the presence of cervical radiculopathy, there needs to be abnormal findings for at least three of five clinical tests. These clinical tests include the upper limb tension test for the median nerve, Spurling's test, dermatomal tests, myotomal tests, and a compression or distraction test (Wainner et al., 2003). Adhesive capsulitis was identified using a range of motion assessment where a multidirectional limitation in movement was noted. The confirmation of adhesive capsulitis was also discerned with the presence of a capsular pattern limitation in the shoulder with a loss of abduction greater than a loss of internal rotation (Malhi & Khan, 2005). The presence of a full-thickness

rotator cuff tear was confirmed with the positive findings of two of three clinical tests as noted by Park, Yokota, Gill, El Rassi, and MacFarland (2005). The clinical tests included the painful arc test, drop arm test, and INFR test (Park et al., 2005). The presence of cervical myelopathy was discerned using a cluster of positive tests used to confirm upper motor neuron dysfunction. The clinical tests included Hoffman's reflex, Babinski's reflex, and an ankle clonus assessment (Cook, Roman, Stewart, Liethe, & Isaacs, 2009; & Cook et al., 2010).

Next, the investigator performed five shoulder tests to determine the eligibility of the participant, including: the Neer's test, Hawkins-Kennedy test, painful arc test, empty-can test, and ER strength test (Appendix A) (Calis et al., 2000; Michener et al., 2009; Park et al., 2005). Participants were eligible for the study if they had positive results for at least three of these five clinical tests. The descriptions of these tests are included in Appendix A.

Instrumentation

Hand-held Dynamometer

A MicroFET hand-held dynamometer (Hoggan Scientific, West Jordan, UT) was used to determine maximal voluntary isometric contraction (MVIC) of shoulder muscle strength in the study (Appendix D). The device has the ability to register muscle strength in newtons (N), which was used as the primary unit of measurement. HHD has been demonstrated to be a valid and reliable method to objectively measure the force production capability of a muscle or muscle group

(Andersen et al., 2014; Celik, Dirican, & Baltaci; 2012; Cools et al., 2014; Downar & Mattacola, 2003; Hayes et al., 2002; Kelln, McKeon, Gontkof, & Hertel, 2008; Kolber et al., 2007; Krasnow et al., 2011; Leggin et al., 1996; Ludwig, Gardenhour, Riemann, & Davies, 2009; MacDermid et al., 2004; Martelli, Ciccarone, Grazzini, Signorini, & Urgelli, 2013; Riemann, Davies, Ludwig, & Gardenhour, 2010). We conducted a pilot study of 24 asymptomatic participants to establish the within-day and between-day intra-tester reliability of the shoulder strength testing protocol used in this dissertation study. In order to compare shoulder ER strength between participants, torque was calculated for each participant by multiplying the force output (newton) by the distance (meter) where the hand-held dynamometer was placed perpendicular to the midpoint of the forearm (N·m). Forearm length was determined by measuring the distance from the lateral epicondyle to the radial styloid using a tape measure. The MVIC of shoulder ER strength was collected for the reliability analysis. The results of this pilot study revealed excellent within-day test-retest reliability of the HHD testing protocol used in this dissertation study, with ICCs being 0.97 to 0.99, and excellent between-day test-retest reliability with ICCs being 0.96 to 0.99.

Surface Electromyography (EMG)

A 16-channel Delsys Myomonitor IV EMG system with three tethered surface electrodes and one reference electrode (Delsys Inc., Natick, MA) was used to record the EMG activity of MDELT, SUPR, and INFR muscles (Appendix E) (Alpert et al.,

2000). The three surface electrodes were placed on the participant following the recommendations of the Surface Electromyography for the Non-invasive Assessment of Muscles (SENIAM) project's international standards and based on the work by Criswell (2010). The preamplifier gain was 1,000 and the frequency bandwidth was 20 to 450 Hz. Surface EMG has been demonstrated to be a valid and reliable measure for assessment of shoulder muscle activity in both asymptomatic and symptomatic participants (Alpert et al., 2000; Andersen et al., 2014; Ballantyne et al., 1993; Bandholm et al., 2006; Diederichsen et al., 2009; Joshi et al., 2011; Marta et al., 2013; Reddy et al., 2000; Reinold et al., 2004). In our pilot study of 24 asymptomatic adults, EMG activity of the MDELT, SUPR, and INFR was collected simultaneously during shoulder ER strength tests. The EMG results revealed excellent intra-tester within-day test-retest reliability for all three muscles, with ICCs being 0.97 for the MDELT muscle, 0.98 for the SUPR muscle, and 0.96 for the INFR muscle. The EMG results revealed excellent intra-tester between-day test-retest reliability for all three muscles, with ICCs being 0.94 for the MDELT muscle, 0.96 for the SUPR muscle, and 0.95 for the INFR muscle.

Numeric Pain Rating Scale (NPRS)

The NPRS (Appendix B) was used to obtain baseline and subsequent changes in a participant's self-reported pain intensity (Childs et al., 2005). The NPRS is an 11-point Likert scale ranging from 0 (no pain present) to 10 (worst pain one could imagine). A participant was asked to use the NPRS scale to rate their pain intensity

at present (current), and then at best and at worst in the past 24 hours, respectively. The average of the three pain scores was used to determine participant eligibility (i.e. NPRS ≥ 2/10), but current NPRS score was used for data analysis later. The NPRS has been demonstrated to be a valid and reliable measure of pain intensity (Farrar et al., 2001; Jensen et al., 1986). The test-retest reliability for the NPRS was found to be 0.74 and the minimal clinically important difference (MCID) of 1.1 in a study involving patients with shoulder pain (Mintken et al., 2009; Kahl & Cleland, 2005).

Disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire

The DASH questionnaire (Appendix F) was used to determine the participant's self-reported level of disability directly attributable to upper extremity pathology (Angst et al, 2011; Atroshi et al., 2000; Franchignoni et al., 2014; Gummesson et al., 2003; Hudak et al., 1996; Sorensen, Howard, Tan, Ketchersid, & Calfee, 2013). The DASH questionnaire is comprised of 30 items and each item is scored on a scale from 1 to 5, with 1 indicating no disability and 5 indicating maximum disability (Beaton et al., 2001; McClure & Michener, 2003). A formula is used to calculate a DASH disability/symptom score = [(sum of n responses/n) – 1] x 25 with a final score between 0 to 100 in percentage (Beaton et al., 2001; McClure & Michener, 2003). Higher scores are indicative of higher levels of perceived disability. The MCID of the DASH questionnaire was found to be 10 points (or 10%) in postoperative patients who underwent an arthroscopic acromioplasty for SAIS

(Gummesson et al., 2003). The DASH questionnaire includes 21 questions asking a participant about the degree of difficulty in performing different daily activities because of arm, shoulder or hand dysfunction (Beaton et al., 2001; McClure & Michener, 2003), and five questions about the intensity of symptoms, such as pain, activity-related pain, tingling, weakness and stiffness as well as the impact on social activities, work, sleep, and self-image (Gummesson et al., 2003). There are two additional modules assessing for the impact of upper extremity disability on work (4 items) and sports/performing arts (4 items) (McClure & Michener, 2003). These additional items are scored separately.

Fear Avoidance Belief Questionnaire (FABQ)

The FABQ (Appendix G) was developed to investigate the presence of fear-avoidance behavior in patients with musculoskeletal pain (George & Stryker, 2011; Hart et al., 2009). The questionnaire score can be used as a predictor to identify individuals likely to develop fear avoidance behavior from specific day-to-day activities (Karels et al., 2007; Kromer, Sieben, de Bie, & Bastiaenen, 2014; Lentz, Barabas, Day, Bishop, & George, 2009; Sindhu et al., 2012; Vlaeyen & Linton; 2000; Waddell et al., 1993). The FABQ consists of two subscales, a physical activity subscale (FABQ-PA) and a work subscale (FABQ-W). It contains a total of 16 items with each item scored from 0 - 6 (4 items for FABQ-PA and 7 items for FABQ-W). However, the FABQ is scored only by using four items in the FABQ-PA subscale (items 2, 3, 4, and 5) and seven items in the FABQ-W subscale (items 6, 7, 9, 10, 11,

12, and 15). Higher FABQ scores correlate to higher levels of fear-avoidance behavior. The range of possible scores is 0 - 24 for the FABQ-PA and 0 - 42 for the FABQ-W. The FABQ has been validated in a population of chronic low back pain (Mintken et al., 2010; Waddell et al., 1993), and in patients with low back pain (Al-Obaidi, Beattie, Al-Zoabi, Al-Wekeel, 2005). Studies have examined the test-retest reliability for using the FABQ in the shoulder region with the results indicating an ICC being 0.88 for FABQ-PA and ICC being 0.98 for FABQ-W (Inrig, Amey, Borthwick, & Beaton, 2012; Mintken et al., 2010).

Investigators

Two investigators who are physical therapists at the UNTHSC were responsible for the participant recruitment, for obtaining consent from each participant, and for data collection. Investigator #1, the PI of this study, had 14 years of experience as a physical therapist and was a board certified orthopedic physical therapy specialist at the time of the study. The PI was responsible for all aspects of study design, study implementation, data collection, and data analysis. Investigator #2, who administered the intervention, either a CTJ manipulation or a placebo treatment, had 25 years of experience as a physical therapist and was a board certified orthopedic physical therapy specialist at the time of the study. Prior to the commencement of the study, the two investigators met and standardized the study procedure as well as both CTJ manipulation and placebo treatment techniques.

Procedures

Following an initial screening for inclusion by phone, potential participants were scheduled for an initial session (Appendix H). A standardized script was used for the initial screen. The script inquired about the potential participant's age, duration of shoulder pain, intensity of shoulder pain, and the current, best, and worst NPRS score (Appendix B). On the initial session, all participants were informed of the risks, benefits, and the procedure of the study. After participants agreed to participate in the study, they each were asked to sign a written informed consent form and then to complete a brief demographic form, asking about their age, gender, and overall health status. The demographic form was used to gather demographic data and health history (Appendix C). A clinical screening examination was then performed to determine eligibility of each participant for the study. The shoulder examination, in part, was based on a prior validated cluster of tests developed by Michener et al. (2009) and was used to confirm the presence of SAIS with at least 3 of 5 positive tests. The five tests (Appendix A) for SAIS consisted of the empty-can test, the Hawkins-Kennedy test, the painful arc test, the Neer's test, and ER weakness (Calis et al., 2000; Michener et al., 2009; Park et al., 2005). Once eligibility for participation in the study was determined, each participant was asked to complete a baseline NPRS, DASH questionnaire, and FABQ.

To determine the within-day test re-test reliability, two baseline sessions of shoulder strength and EMG testing were performed on the first 10 participants during their first visit, and two trials were collected during each session. To determine between-day test-retest reliability, these first 10 participants were asked to return 24 hours following the initial assessment to repeat one shoulder strength and EMG testing. For these first 10 participants, the randomization process was performed on the second visit of testing following the baseline testing. All other participants were randomized following assessment of baseline testing on the first visit.

Participants were asked to select one of 32 sealed envelopes in total, 16 envelopes for each treatment group. Participants who selected "Manipulation" were assigned to the manipulation group, and participants who selected "Placebo" were assigned to the placebo group. In the event a participant dropped out of the study, the participant's selection was returned to the sealed envelope for possible selection by future participants. The random assignment was performed by Investigator #2, the treatment provider, after the baseline testing, so that the PI who collected the outcome measures was blinded to the group assignment.

Next, the participant assumed a sitting position in a chair or at the edge of a treatment table for EMG electrode placements (Andersen et al., 2014). The skin area for electrode placement was prepared with alcohol swipes to decrease skin impedance. If the skin area for electrode placement contained excessive hair, the

area was shaved using a disposable razor. Disposable adhesive tape was used to affix the electrodes to the skin over the muscle bellies of the MDELT, SUPR, and INFR muscles.

Three EMG electrodes (Appendix I) were placed on the skin of the MDELT, SUPR, and INFR muscles following the recommendations by the SENIAM Project Standards (SENIAM Project Standards) and Criswell (2010). A reference electrode was affixed on the participant's sternum to ensure an adequate grounding for signal acquisition. The MDELT electrode was placed one finger width distal and lateral to the acromion. The SUPR electrode was placed above the spine of the scapula in the suprascapular fossa over the muscle belly of SUPR. The INFR electrode was placed 4 cm below the spine of the scapula over the infrascapular fossa. Once the electrodes were affixed to the skin, the electrode placements were confirmed by performing manual muscle testing (Appendix J) of shoulder abduction for the MDELT and SUPR EMG activity, and ER for the INFR EMG activity with the participant in a sitting position (Kelly, Kadrmas, & Speer, 1996; Riemann et al., 2010).

Next, the PI began shoulder ER strength testing. For purposes of normalization of EMG signals, two 5-second samples of EMG activity at rest were recorded. Normalization of the EMG activity was established to ensure consistency of assessment across all data points. EMG of the MDELT, SUPR, and INFR muscles were collected simultaneously during shoulder ER strength testing. The participant assumed a supine position with the arm positioned at 20-30° of shoulder abduction

and 90° of elbow flexion (Appendix J). The angle of 20-30° of shoulder abduction was found to correlate to the activity of the SUPR muscle without being overpowered by the MDELT muscle (Donatelli et al., 2000). The position of the shoulder and elbow were confirmed using goniometric assessment.

During shoulder ER strength testing, the MVIC was obtained. The MVIC testing was assessed using the 'make test' procedure (Bohannon, 1988). The 'make test' procedure involves having a participant build up to a maximum effort against applied resistance for a sustained time period (Bohannon, 1988). During MVIC testing, the participant was provided with verbal cueing, asking the participant to push as hard as possible (Bohannon, 1988). MVIC sustained for a total of five seconds was recommended in the previous study (Bohannon, 1988).

Muscle strength of shoulder ER was recorded using a hand-held dynamometer (Cools et al., 2014). During the shoulder strength testing, the dynamometer was placed perpendicular to the midpoint of the forearm with the elbow in 90° flexion. The distance between the lateral epicondyle and the radial styloid was measured to determine the midpoint of the forearm and was used for torque calculation (Netwon * meter) (McDaid, Kozin, Thoder, & Porter, 2002). To minimize the potential for fatigue, only two MVICs of shoulder ER were obtained during each strength assessment with a minimum of one-minute rest between the two MVICs. The average of the peak of two trials was used for data analysis (Boettcher, Ginn, & Cathers, 2008).

Once the baseline assessment was completed, the PI left the room to be fully blinded to the participant's group assignment, i.e. manipulation (Appendix L) versus placebo (Appendix M). This specific CTJ technique used in this study was adapted from prior work by Mintken et al. (2010) and Boyles et al. (2009). The technique was performed by localizing the direction of force in a posterior direction at the CTJ. The participants in the manipulation group received a CTJ manipulation and were informed of the procedure and possible risk prior to administration of the manipulation. Next, the participant lied in a supine position, and the treating investigator (Investigator #2) placed one hand in a pistol grip position at the level of the participant's CTJ. Next, the participant was asked to assume a bear-hug position with the arms crossed in front of the chest. The force of the technique was directed through the folded arms toward the pistol-grip hand. Prior to administering the manipulation, the treating investigator placed the participant at the end of the manipulation position and asked the participant if he or she tolerated the position. The treating investigator applied an inferior traction force of the first thoracic vertebra relative to the seventh cervical vertebra, prior to application of the thrust technique. Once verbal permission was obtained from the participant, the treating investigator applied a high-velocity, low-amplitude (HVLA) thrust. Following the application of the CTJ manipulation technique, the participant was questioned for the presence of any symptomology resulting from the manipulation technique. The

presence or absence of a cavitation, or "pop", following the manipulation in the treatment group was recorded by investigator #2.

Participants in the placebo group received a slight variation of the CTJ manipulation technique without the thrust component. The treating investigator performed the same setup procedure leading up to the application of the manipulation technique. Once the pre-application position was achieved, the position was maintained for five seconds and no manipulation was administered. Rather than utilizing a pistol grip technique, the placebo technique involved the treating investigator using a flat hand at the level of the first thoracic vertebra.

Immediately following the intervention, the PI returned to the room to collect the current NPRS scores and performed two trials of the shoulder ER strength testing as described earlier, separated by one minute. The current NPRS score and two trials of shoulder ER strength testing were collected again from all participants at 15, 30, and 45 minutes post intervention on the same day.

In addition to the manipulation or placebo intervention, all participants were instructed in an active-assistive range of motion (AAROM) exercise (Appendix N) program. The AAROM exercise program was given because it is a part of standard care to maintain available shoulder motions for patients with shoulder pain. In addition, this mode of exercise is not intended to increase muscle activity, but rather to maintain joint mobility. All participants were provided with a detailed description of each exercise, in addition to a pictorial description of the activity. The

AAROM exercise program consisted of three exercises using a wand or T-bar to assist with the movements of shoulder flexion, abduction, and ER. Each participant was instructed to perform three sets of 10 repetitions for each exercise at a frequency of one time per day. In order to track compliance and adherence, each participant was issued an exercise tracking form (Appendix O). All participants were instructed to return tracking forms on the last day of testing to ensure compliance with the exercise protocol. No other interventions were provided following the first visit.

The second visit of the study occurred 48-72 hours following the initial assessment. The current NPRS score was obtained prior to the shoulder strength testing. Next, the PI performed two trials of shoulder ER strength tests separated by a one-minute break. The procedure of shoulder ER strength testing and EMG setup were exactly the same as described earlier. The third visit of the study occurred 6-7 days from the initial assessment (the first visit). Again, the current NPRS score was obtained prior to the shoulder ER strength testing. The same procedure was performed for shoulder ER strength testing.

Data Analysis

All statistical analysis was performed using IBM SPSS Statistics Version 22.0 (IBM Corp., Armonk, New York). Means and standard deviations were calculated for participant characteristics (age, height, weight, body mass index, duration of shoulder pain, DASH score, and FABQ score), as well as the outcome measures

(NPRS score, shoulder ER strength, and shoulder EMG data). To compare differences in participants' characteristics and baseline outcome measures between groups, independent *t*-tests were performed for the ratio data and chi-square tests for the categorical data ($p < 0.05$). $ICCs_{(2,2)}$ were calculated to determine the within-day and between-day test-retest reliability using the data collected from the first 10 participants with SAIS.

Using Delsys EMGWorks Analysis 4.0 (Delsys Inc., Natick, MA), a root mean square (RMS) value of the middle 3 of the 5-second EMG recording was extracted for each of the shoulder MVIC and resting trials. Next, each EMG RMS value during MVIC was normalized to the EMG RMS value during resting using the following formula and was expressed in percent (%): (RMS during MVIC/RMS during resting) x 100% (Ettinger, Weiss, Shapiro, & Karduna, 2016). The normalized data was then included in the statistical analysis.

A 2 (group) x 7 (time) RM ANOVA was performed to analyze shoulder ER strength data (torque in N*m). Three separate 2 (group) x 7 (time) RM ANOVAs were performed to analyze the normalized EMG RMS values for the MDELT, INFR, and SUPR muscles, respectively. Another 2 (group) x 7 (time) RM ANOVA was used to analyze the NPRS scores. The alpha level for all of statistical analyses was set at 0.05. If a significant interaction was observed, post-hoc tests were performed.

CHAPTER IV

RESULTS

The purpose of this study was to examine the effectiveness of cervicothoracic junction (CTJ) manipulation as compared to placebo in patients with subacromial impingement syndrome (SAIS) on: (a) shoulder muscle strength of external rotation (ER) using hand-held dynamometry (HHD), (b) electromyographic (EMG) amplitudes of the middle deltoid (MDELT), supraspinatus (SUPR), and infraspinatus (INFR) muscles, and (c) pain level. This chapter contains a summation of the participants and outcome measures collected during the one-week clinical trial.

Participants

All participants were recruited by word-of-mouth and flyer distribution from the campus of the University of North Texas Health Science Center and from the surrounding Fort-Worth community. A total of 38 adult participants were screened for eligibility between July 2015 and April 2017. Six of those were excluded from the study because they did not meet all of the inclusion criteria. Two of these six participants had a history of rotator cuff surgery, two received chiropractic treatment for their cervical spine three months prior to testing, and two did not have at least three of five positive shoulder impingement tests during the initial screening. The remaining 32 participants were enrolled in the study and were randomly allocated to one of the two intervention groups. All enrolled participants

completed the study over a one-week period of time. In total, 16 participants were included in the manipulation group and 16 participants were included in the control group. Figure 1 is a consort diagram summarizing the enrollment, randomization, and analysis portions of the study.

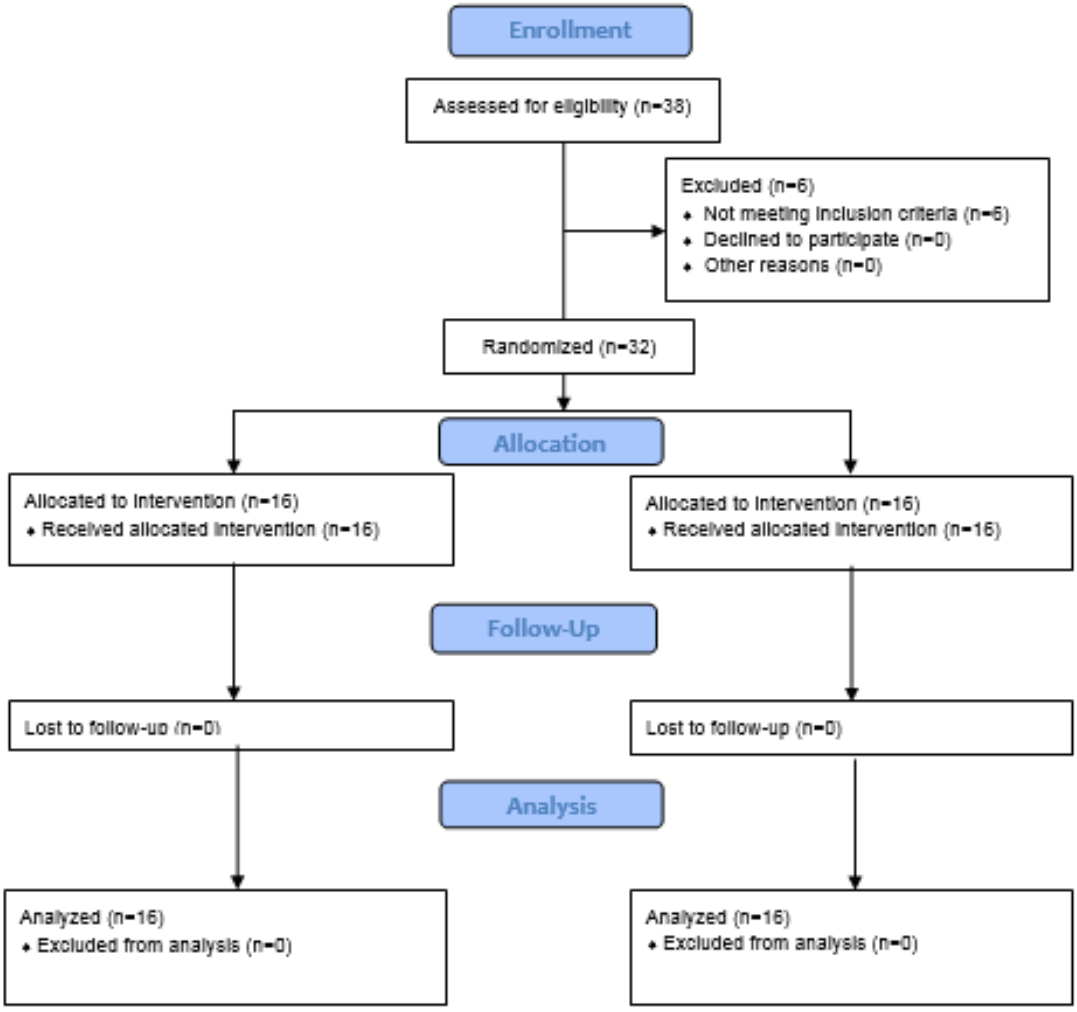

Figure 1. The consort diagram for enrollment, randomization, and analysis.

Table 1 shows a description of participants' characteristics at baseline that includes age, sex, height, weight, body mass index (BMI), duration of shoulder pain in weeks, hand dominance, disability level, and fear-avoidance level, as well as their baseline outcome measurements. There was no significant difference between groups at baseline for any of the variables ($p \geq 0.05$). The majority of the participants in this study were female (n = 19) as compared to 13 males. Although there were slightly more females and fewer male participants in the manipulation group as compared to the placebo group, the difference was not significant ($p = 0.72$). The average age of the participants in this study was 43.3 ± 12.8 years, which is the common age range for SAIS to occur (Brantingham et al., 2011). With regard to pain, participants had an average NPRS score of 4.7 which indicates a moderate pain level. However, both groups had low Disability of the Arm, Shoulder and Hand Questionnaire scores (28.7 ± 14.5 in the manipulation group, 22.6 ± 9.6 in the placebo group), indicating a low level of patient-reported upper extremity disability without significant functional restriction. In addition, both groups had low Fear Avoidance Belief Questionnaire Physical Activity (FABQ-PA) scores (physical activity subscale: 18.1 ± 6.1 in the manipulation group, 17.3±6.8 in the placebo group), indicating a low level of fear avoidance behavior with activity due to shoulder pain. In summary, participants in both groups were similar in age, height, weight, BMI, duration of shoulder pain, NPRS score, DASH scores, and both the work and physical activity subscale scores for the FABQ.

Table 1

Participant Characteristics at Baseline (Mean ± SD)

	All Participants (n=32)	Manipulation Group (n=16)	Placebo Group (n=16)	*p* value
Sex (female/male)	19/13	12/4	7/9	0.072
Age (years)	43.3±12.9	43.4±13.4	43.3±12.7	0.979
Height (cm)	1.7±0.1	1.7±0.0	1.7±0.0	0.339
Weight (kg)	79.8±15.3	76.4±4.4	83.1±3.1	0.219
BMI (k/m2)	28.6±5.4	27.8±5.5	29.3±5.2	0.408
Hand dominance (right/left)	26/6	14/2	12/4	0.365
Duration of symptoms (weeks)	5.2±2.6	4.9±2.4	5.4±2.8	0.332
NPRS	4.7±0.8	4.7±0.8	4.7±0.8	0.948
DASH	25.7±12.5	28.7±14.5	22.6±9.6	0.167
FABQ				
Physical activity	17.7±6.4	18.1±6.1	17.3±6.8	0.704
Work	5.0±7.2	5.5±7.9	4.44±6.6	0.682
Shoulder ER Strength (N·m)	6.5±2.8	5.6±2.5	7.6±2.9	0.765
Normalized EMG (%)				
MDELT	366.8±194.7	388.3±204.9	345.3±186.0	0.539
SUPR	330.1±172.0	346.7±164.6	313.5±182.9	0.594
INFR	291.9±157.7	272.2±136.0	311.7±179.1	0.488

Note. BMI = Body Mass Index. NPRS = Numeric Pain Rating Scale. DASH = Disabilities of the Arm, Shoulder and Hand Questionnaire. FABQ = Fear Avoidance Beliefs Questionnaire. EMG = Electromyography. Independent *t*-tests were performed to compare groups for ratio data and chi-square tests for categorical data ($p < 0.05$).

Reliability Analysis

The first 10 participants, regardless of treatment group, were tested twice on the first visit for shoulder ER strength testing using HHD and simultaneous surface EMG (SEMG) recording of three shoulder muscles for within-day reliability. No assigned intervention (CTJ manipulation or placebo) was administered on this visit. All 10 of these participants returned within 24 hours for between-day reliability of the same shoulder ER strength testing and simultaneous SEMG recording. The within-day test-retest reliability was excellent for the maximal voluntary isometric contraction (MVIC) of shoulder ER using a hand-held dynamometer with an intraclass correlation coefficient ($ICC_{2,2}$) of 0.979. The within-day test-retest reliability was also excellent for the SEMG of all three muscles (MDELT, SUPR, and INFR), with ICCs ranging from 0.907 to 0.973. The between-day test-retest reliability for the MVIC of shoulder ER was excellent, with an ICC of 0.958. Lastly, the result also showed that the between-day test-retest reliability for the SEMG of all three muscles was good-to-excellent, with ICCs ranging from 0.879 to 0.897. Table 2 lists the ICC values for the within-day and between-day test-retest reliability.

Table 2

Intraclass Correlation Coefficients (ICC) for the Within-day And Between-day Test-retest Reliability of Maximal Voluntary Isometric Contraction of Shoulder External Rotation and Simultaneous Electromyographic Recording (n = 10)

$ICC_{2,2}$ (95% CI)	Within-day Reliability	Between-day Reliability
MVIC of shoulder ER	0.979 (0.924, 0.994)	0.958 (0.844, 0.989)
MDELT	0.961 (0.855, 0.989)	0.897 (0.617, 0.972)
SUPR	0.973 (0.901, 0.993)	0.892 (0.600, 0.971)
INFR	0.907 (0.655, 0.975)	0.870 (0.517, 0.965)

Note. ER = External Rotation. HHD = Hand-held dynamometry. MDELT = Middle Deltoid. SUPR = Supraspinatus. INFR = Infraspinatus. 95% CI = 95% Confidence Interval.

Outcome Measures

The outcome measures collected in this study included shoulder ER strength as measured by a hand-held dynamometer, muscle activity as measured by SEMG, and pain intensity as measured by the Numerical Pain Rating Scale. The MVIC of shoulder ER strength, SEMG of the MDELT, SUPR, and INFR muscles, and NPRS scores were collected at baseline, immediately, 15 minutes, 30 minutes, and 45 minutes on the second visit for the first 10 participants, who participated in the

concurrent reliability study, and on the first visit for the remaining 22 participants. All participants returned for a follow-up visit two days after intervention and for their last follow-up visit 6 days after intervention. Tables 3 to 5 displays the means and standard deviations for the MVIC of shoulder ER strength, normalized SEMG values (%) of the three muscles, and NPRS scores at baseline and for each assessment period respectively.

Table 3

*Averaged Maximal Voluntary Isometric Contraction (Mean ± SD) of Shoulder External Rotation Using Hand-held Dynamometry (*N·m*)*

	All (n=32)	Manipulation group (n=16)	Placebo group (n=16)
Baseline	6.5±2.8	5.6±2.5	7.6±2.9
Immediately	6.6±2.5	5.9±2.2	7.4±2.6
15 minutes	6.8±2.6	6.2±2.6	7.5±2.4
30 minutes	7.0±2.7	6.2±2.5	7.8±2.7
45 minutes	7.0±2.8	6.2±2.5	7.8±3.0
48-72 hours	6.9±2.6	6.4±2.8	7.5±2.4
Day 6-7	7.1±2.4	6.5±2.0	7.7±2.8

Table 4

Averaged Normalized Electromyographic (EMG) Amplitudes (mean ± SD, percent) during the Maximal Voluntary Isometric Contraction (MVIC) of Shoulder External Rotation at Seven Time Points

	All (n=32)	Manipulation group (n=16)	Placebo Group (n=16)
MDELT			
Baseline	366.8±193.7	388.3±204.9	345.3±160.0
Immediately	349.5±165.7	383.1±182.9	315.9±144.5
15 minutes	361.9±183.7	387.6±205.6	336.1±161.5
30 minutes	370.3±198.8	420.5±229.3	320.1±153.9
45 minutes	352.0±196.7	341.6±181.4	362.4±216.4
48-72 hours	391.0±213.6	496.8±231.2	285.3±130.2
Day 6-7	342.9±171.3	365.4±169.9	320.4±175.2
SUPR			
Baseline	330.0±172.0	346.7±164.6	313.5±186.0
Immediately	373.1±247.6	393.6±239.0	352.6±144.5
15 minutes	373.5±215.3	416.3±234.1	331.0±192.6
30 minutes	355.7±223.4	384.6±224.1	326.7±226.1
45 minutes	354.7±222.8	447.4±253.9	324.3±173.5
48-72 hours	354.7±197.7	324.9±178.4	384.4±217.0
Day 6-7	330.6±184.0	304.3±152.1	356.9±146.2
INFR			
Baseline	291.9±157.7	383.1±182.9	311.7±179.1
Immediately	323.3±205.4	342.2±214.1	304.3±201.5
15 minutes	323.8±206.9	350.2±235.8	297.3±177.1
30 minutes	302.5±148.5	304.9±151.5	300.0±150.3
45 minutes	309.5±185.0	329.6±172.8	289.4±200.0
48-72 hours	336.5±224.5	341.2±236.0	331.8±220.0
Day 6-7	275.7±132.5	247.6±115.0	303.8±146.2

Note. MDELT = Middle Deltoid. SUPR = Supraspinatus. INFR = Infraspinatus. Normalized EMG amplitude = (RMS during MVIC/RMS during resting) x 100%. RMS = Root mean square.

Table 5

Numerical Pain Rating Scale (NPRS) Scores of Current Pain Intensity at Baseline and Six Post-intervention Time Points (mean ± SD)

Outcome Measure	All (n=32)	Manipulation Group (n=16)	Placebo Group (n=16)
Baseline	4.4±0.9	4.4±0.8	4.2±1.0
Immediate	3.9±1.0	4.0±1.1	3.8±0.8
15 minutes	3.7±0.8	3.6±0.8	3.8±0.8
30 minutes	3.5±0.8	3.4±0.8	3.7±0.7
45 minutes	3.5±0.7	3.5±0.8	3.5±0.6
48-72 hours	3.7±0.7	3.8±0.8	3.6±0.6
Day 6-7	3.5±0.7	3.5±0.6	3.4±0.7

Note. Pain intensity was assessed with the Numeric Pain Rating Scale (NPRS).

Shoulder External Rotation Strength of Shoulder Muscles

The average values of the two MVIC trials of the shoulder ER (N*m) were used for statistical analysis. The repeated measure (RM) ANOVA result did not show a significant group by time interaction (p = 0.103) or main effect of time (p = 0.129) (Figure 2). The Greenhouse-Geisser statistics was reported because the Mauchly's test for sphericity was significant (p = 0.0001). Mauchly's test is a test used to assess the homogeneity of samples for repeated testing.

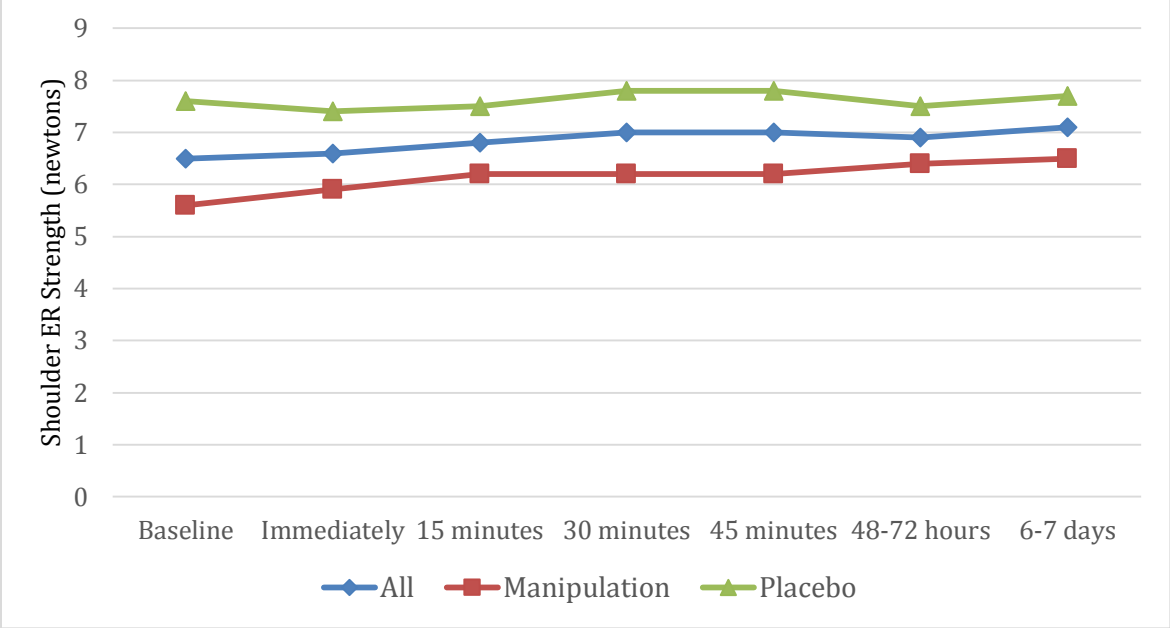

Figure 2. *Average shoulder external rotation (ER) strength (*N·m*) for all participants, the manipulation group, and the placebo Group*

Electromyographic Amplitude of Shoulder Muscles

The average values of the normalized EMG amplitude in percent [normalized EMG amplitude = (RMS during MVIC/RMS during resting) x 100%] were used for all statistical analyses. Three separate RM ANOVAs were utilized to analyze data for the EMG RMS values (%) of the three muscles, respectively. The Greenhouse-Geisser statistics were reported for the MDELT muscle because Mauchly's test for sphericity was significant (p = 0.0001). The RM ANOVA results showed a significant group by time interaction for the MDELT (p = 0.014) (Figure 3), but not for the SUPR (p = 0.553) (Figure 4) and INFR (p = 0.888) (Figure 5) muscles. Figure 3 illustrates the significant group by time interaction of the MDELT between the 30 minutes to 6-

7 days after intervention. Therefore, three post-hoc 2 (group) x 2 (time) RM ANOVAs were performed and showed a significant difference between groups from 48-72 hours to 6-7 days after intervention (p = 0.002), but no significant difference between groups: from 30 to 45 minutes after intervention (p = 0.087), and from 45 minutes after intervention to 48-72 hours later (p = 0.650). The results indicated that the significant changes occurred on the second visit (48-72 hours after intervention) with the intervention group having significant increased MDELT muscle activity, coinciding with the placebo group having significantly reduced the MDELT muscle activity.

An exploratory analysis revealed one outlier existed in the EMG data of the MDELT muscle. Following the removal of the one outlier, a subsequent 2 (group) x 7 (time) RM ANOVA was performed with a significant interaction still present for the MDELT muscle (p = 0.010). Therefore, three post-hoc 2 (group) x 2 (time) RM ANOVAs were performed to examine the differences between groups with the single outlier removed from the analysis: 1) from 30 to 45 minutes after intervention (p = 0.186), 2) from 45 minutes after intervention to 48-72 hours later (p = 0.006), and from 48-72 hours to 6-7 days after intervention (p = 0.007). The results of removing the outlier showed that the significant changes occurred between 45 min after intervention and the second visit (48-72 hours after intervention), with the manipulation group having significantly increased MDELT muscle activity, coinciding with the placebo group having significantly reduced the MDELT muscle

activity. However, these significant changes at the second visit (48-72 hours after intervention) disappeared at the last visit (6-7 days after intervention). Lastly, there was no significant main effect of time for any of the muscles (p = 0.989 for MDELT, p = 0.892 for SUPR, p = 0.813 for INFR).

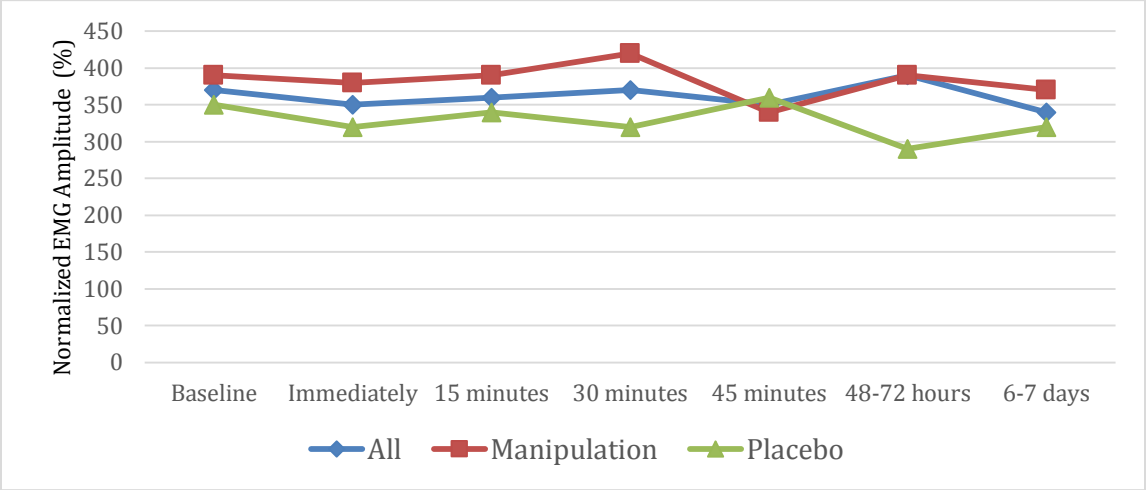

Figure 3. *Average normalized electromyographic amplitudes (%) for the middle deltoid muscle: all participants, the manipulation group, and the placebo group*

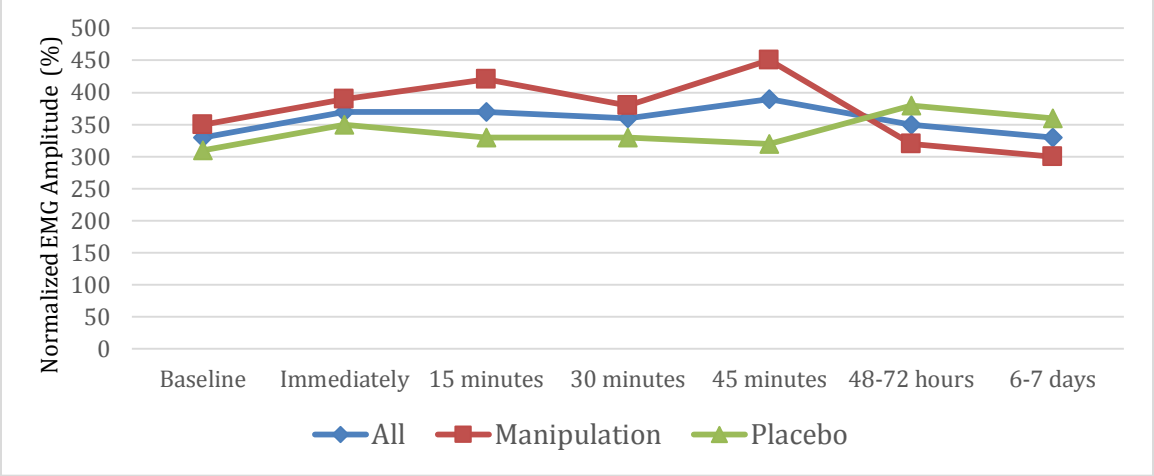

Figure 4. *Average normalized electromyographic (EMG) amplitudes (%) for the supraspinatus muscle: all participants, the manipulation group, and the placebo group*

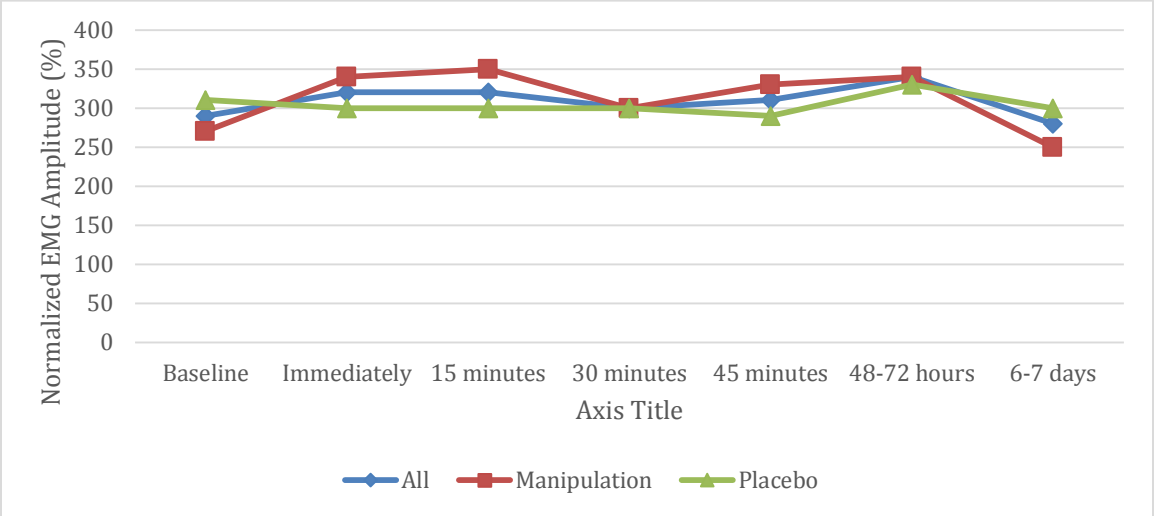

Figure 5. *Average normalized electromyographic (EMG) amplitudes (%) for the infraspinatus muscle: all participants, the manipulation group, and the placebo group*

Pain Intensity using NPRS

The 2 (group) x 7 (time) RM ANOVA was used to analyze current pain intensity as determined by the NPRS. The Greenhouse-Geisser statistics were reported because Mauchly's test of sphericity was significant ($p = 0.0001$). The ANOVA results revealed no significant group by time interaction ($p = 0.942$), but a significant main effect of time ($p = 0.0001$), indicating that all participants had a significant change in pain over time. Post-hoc pair-wise comparisons showed the significant change occurred from baseline to all other time periods: between baseline and immediately post intervention ($p = 0.006$), 30 minutes post intervention ($p = 0.004$), 45 minutes post intervention ($p = 0.003$), 48-72 hours post intervention ($p = 0.005$), and 6-7 days post intervention ($p = 0.0067$), respectively. Post-hoc pair-wise comparisons also revealed a significant increase between 45 minutes and 48-72 hours post intervention ($p = 0.033$), as well as a significant decrease between 48-72 hours and 6-7 days post intervention ($p = 0.020$).

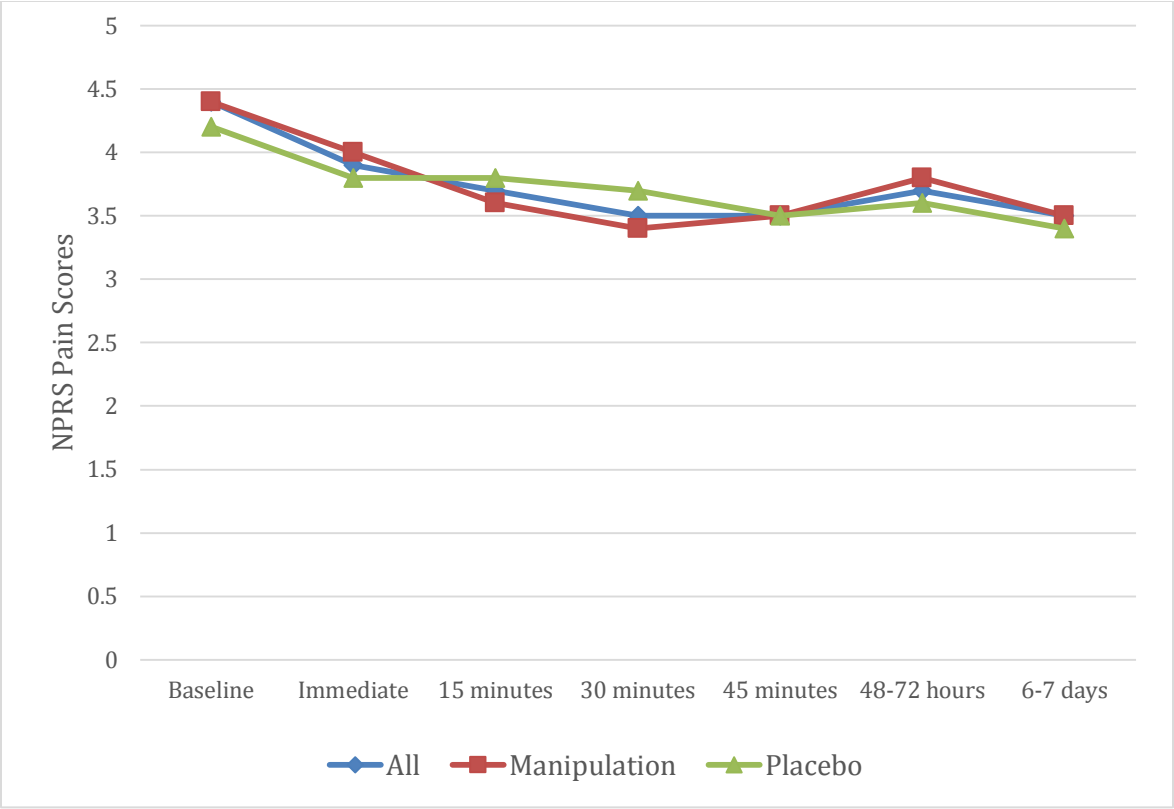

Figure 6. *Average Numerical Pain Rating Scale (NPRS) scores over time: all participants, the manipulation group, and the placebo group*

CHAPTER V

DISCUSSION

The purpose of this study was to examine the effectiveness of cervicothoracic junction (CTJ) manipulation as compared to placebo in patients with subacromial impingement syndrome (SAIS) on: (a) shoulder muscle strength of external rotation (ER) using hand-held dynamometry (HHD), (b) electromyographic (EMG) amplitude of the middle deltoid (MDELT), supraspinatus (SUPR), and infraspinatus (INFR) muscles, and (c) pain level. This chapter contains a summary and discussion of the participant characteristics, hypothesis testing, results, conclusions, limitations, and recommendations for future studies.

Results of Hypothesis Testing

Hypotheses 1 and 2

Research Quetion1: Would participants with SAIS who receive a CTJ manipulation have an increase in shoulder ER muscle strength more than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention?

Research Question 2: *Would all participants with SAIS have an increase in shoulder ER muscle strength immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days after receiving a CTJ manipulation or a placebo intervention?*

There was no significant difference between groups over time for shoulder ER muscle strength. Because no significant difference was found, Hypothesis 1 was rejected. Therefore, Null Hypothesis 1 was accepted for the result of shoulder ER muscle strength. These findings suggest that the CTJ manipulation or placebo manipulation used in the study had no effect on ER muscle strength over time. In addition, there was no significant main effect of time. Therefore, Hypothesis 2 also was rejected and the null hypothesis was accepted. This result suggests that neither a CTJ manipulation nor a placebo intervention had any effect on the shoulder ER strength over one week.

Hypotheses 3 and 4

Research Question 3: Would participants with SAIS who receive a CTJ manipulation have an increase in EMG amplitude of the MDELT, SUPR, and INFR muscles more than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention?

Research Question 4: Would all participants with SAIS have an increase in shoulder EMG amplitude of the MDELT, SUPR, and INFR muscles immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days after receiving a CTJ manipulation or a placebo intervention?

Similar to the shoulder ER strength finding, there was no significant difference between groups over time for the shoulder EMG amplitudes of the SUPR and INFR muscles. In addition, there was no main effect of time for any of EMG

amplitudes of these two muscles. Because no significant differences were found, both Hypothesis 3 and 4 for these two muscles were rejected. Therefore, the null hypotheses were accepted for the normalized EMG amplitude of the SUPR and INFR muscles. However, there was a significant group by time interaction for MDELT (p = 0.014). Therefore, Hypothesis 3 for the MDELT muscle was accepted. A post-hoc analysis revealed the significant change occurred between 45 min after intervention and the second visit (48-72 hours after intervention), with the manipulation group having significantly increased MDELT muscle activity, coinciding with the placebo group having significantly reduced the MDELT muscle activity. This finding suggests that CTJ manipulation appeared to have the same effect on the MDELT muscle activity as a placebo intervention one the same day, but CTJ manipulation seemed to have a delayed effect on increasing the MDELT muscle activity 48-72 hours later. However, this effect disappeared after one week.

Hypothesis 5 and 6

Research Question 5: Would participants with SAIS who receive a CTJ manipulation have a decrease in the perception of shoulder pain, more than those who receive a placebo intervention immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days post intervention?

Research Question 6: Would all participants with SAIS have a decrease in the perception of shoulder pain immediately, 15 min, 30 min, 45 min, 48-72 hours, and 6-7 days after receiving either a CTJ manipulation or a placebo intervention?

Because the results revealed no significant group by time interaction, Hypothesis 5 was rejected for the perception of shoulder pain and the null hypothesis was accepted. However, there was a significant main effect of time, indicating that a significant change in pain occurred in all participants over time. Therefore, Hypothesis 6 was accepted.

Discussion of Findings

Participant Characteristics

No significant differences were found between groups for sex, age, height, weight, BMI, hand dominance, and duration of symptoms. Although there were more female participants in this study, the difference between the number of male and female participants was not significant. Therefore, this factor is unlikely to have affected the results. In addition, there was no significant difference in all other participant characteristics and baseline outcome measures between groups, thus indicating the make-up of these two groups were similar. The results also showed that the average age (43.3 ± 12.8 years) and moderate pain intensity (NPRS score: 4.4±0.9) of the participants in this study were common presentations seen in the outpatient orthopedic clinics (Brantingham et al., 2011). Therefore, the participants enrolled in this study were considered a good representation of patients with SAIS who seek rehabilitation care.

Shoulder External Rotation Muscle Strength

The results of this study showed that neither a CTJ manipulation nor a placebo intervention affected shoulder ER strength immediately after the intervention or one week after the intervention. Previous studies (Boyles et al., 2009, Strunce et al., 2009) have shown shoulder pain reduction and shoulder range of motion (ROM) improvement immediately after CTJ manipulation. Shoulder ROM improvement was hypothesized as a result of pain reduction. In this study, although pain reduction was found for all participants, pain reduction did not seem to have a similar effect on shoulder ER strength as it did on shoulder ROM. Arguably, the participants' shoulder ROMs could be affected with the intervention in this study. However, shoulder ROMs were not measured because the interests of the study were muscle strength and activation. Given that no studies have examined the differences in shoulder ER muscle strength between pre and post CTJ manipulation in patients with SAIS, the result of shoulder ER strength could not be compared directly with previous studies on CTJ manipulation. However, a study by Cleland et al. (2004) revealed a greater improvement in lower trapezius strength after a manipulation performed on the lower thoracic spine as compared to a placebo intervention in a group of 40 asymptomatic participants. Although no studies have specifically examined the relationship between shoulder ER strength and CTJ manipulation, the work by Cleland et al. (2004) may imply a short-term

improvement in muscle strength of scapular muscles following thoracic manipulation.

The maximal voluntary isometric contraction (MVIC) values of shoulder ER strength have been reported to be approximately 9.53 N·m for asymptomatic individuals and 8.22 N·m for patients with SAIS (Zanca, Saccol, Oliveira, & Mattiello, 2013). The shoulder ER strength in patients with SAIS is considerably lower than that in asymptomatic individuals, suggesting that shoulder ER strength may be a meaningful outcome measure for assessing treatment effects.

The fatigue factor could not be overlooked for this study because five trials of the shoulder MVIC tests were performed within 45 minutes on the same day. The participant may not recover from the previous MVIC strength test during the subsequent MVIC strength test. Repeated strength test at maximum level could have had a negative impact on the results of subsequent shoulder strength tests. However, fatigue did not seem to occur during the five repeated shoulder ER MVIC tests in this study because the shoulder ER strength values were not decreased, rather than slightly increased from the baseline MVIC to the last MVIC test: 6.5±2.8, 6.6±2.5, 6.8±2.6, 7.0±2.7, and 7.0±2.8 N·m.

Shoulder EMG Amplitude

Similar to the results of shoulder ER strength, the results of the normalized EMG RMS data showed that neither a CTJ manipulation or a placebo intervention affected the SUPR and INFR muscle activity immediately after the intervention or

one week after the intervention. Interestingly, the manipulation group had a significantly increase in MDELT muscle activity in contrast with that of the placebo group, who had a significant reduction of the MDELT muscle activity during the time periods from 48-72 hours and 6-7 days. A study by Dunning and Rushton (2009) demonstrated an increase in EMG activity of the biceps muscle following cervical manipulation. Dunning and Rushton (2009) speculated that the change muscle activity of the biceps muscle, supplied primarily by C5 and C6, was a result of cervical spinal manipulation. However, the neurophysiological change (i.e. facilitation of inhibition) of muscle activity associated with spinal manipulation has often been found immediately after the manipulation. In this study, the delayed changes of the MDELT muscle activity occurred 2-3 days after the intervention as well as a distinctly different change of the MDELT muscle activity was noted in the manipulation group versus the placebo group. Moreover, these changes disappeared 6-7 days after intervention. In addition, it is also noted that these delayed changes only occurred in the MDELT muscle, which is a prime mover for shoulder elevation, but did not occur in the SUPR and INFR muscles, which are shoulder stabilizers. Because no other studies have examined the differences in shoulder EMG between pre and post CTJ manipulation in patients with SAIS, the results of shoulder EMG strength could not be compared directly with previous studies on CTJ manipulation.

The normalization method utilized in this study has been used in other studies, namely using the equation of (%) = (RMS during MVIC/RMS during resting) x 100% (Ettinger et al., 2013). The MVIC is the most common and reliable normalization method for studies examining submaximal EMG tasks (Ettinger et al., 2013). However, because the MVIC was used to represent the shoulder ER strength in this study, an alternative normalization was warranted. Therefore, the EMG activity during resting was chosen in this study as the normalization method. In addition, the within-day and between-day reliability of the EMG data collected from the first 10 participants was shown to be good. As shown by the results of the reliability part of this study, the ICCs revealed good between-day reliability of the EMG recording for the DELT, SUPR, and INFR muscles. Many factors could affect EMG recording, such as location of electrode placement, skin impedance, and environmental interference. Therefore, the between-day reliability of EMG recording is usually only poor-to-fair even though a normalization method is used (Bandholm et al., 2006; De Luca, 1997). According to Bandholm et al. (2006), the average between-day reliability for shoulder EMG assessment were fair with ICC values ranging from 0.50 to 0.65, much lower than the ICC values found in our study.

The EMG value during MVIC as compared to the EMG value during resting was approximately 350-400% larger for the MDELT muscle, 330-370% larger for the SUPR muscle, and 275-337% larger for the INFR muscle. No direct comparison could be made with the previous EMG studies because of the use of different

normalization methods and different shoulder strength tests. However, in a study by Escamilla et al. (2009), shoulder EMG % MVIC was assessed during an isotonic ER exercise performed in standing with the shoulder in 15° abduction. Escamilla et al. (2009) found 11±6% MVIC elicited in the MDELT muscle, 41±37% in the SUPR muscle, and 50±14% in the INFR muscle. The results showed that the INFR EMG activity was elicited the most while the MDELT EMG was elicited the least. Although a similar shoulder ER task was performed in both studies, the different EMG elicitations largely could be due to differences in the shoulder tasks that were performed, i.e., isotonic ER in Escamilla et al.'s study and isometric task in this study.

Shoulder Pain

The results of this study showed that neither a CTJ manipulation nor a placebo intervention affected shoulder pain perception immediately after the intervention or one week after the intervention. However, all participants who either receive a CTJ manipulation or a placebo intervention had significant pain reduction immediately after the intervention, and the pain reduction effect continued to last one week after the post intervention except when the participants returned 48-72 hours after intervention during which time the pain level increased slightly as compared to 45 min after intervention, but was still better than the one at baseline. Interestingly, the pain reduction was again observed one week after intervention. Nevertheless, the change of the NPRS score are not considered clinically significant because the largest difference in pain score occurring from

baseline to the 6-7day follow-up was approximately 0.9, less than the minimal clinical important difference (MCID) for the NPRS of 1.1 or the minimal detectable change (MDC) of 2 (Childs et al., 2005). These results indicate the change in pain scores may not be meaningful to patients.

As in the previous discussion for the results of the shoulder ER strength, pain reduction following spinal manipulation in participants with shoulder pain has been well documented in the literature (Boyles et al., 2009, Strunce et al., 1997). Spinal manipulation appears to have a positive effect on diminishing pain in people presenting with SAIS. However, the results of this study suggest that both CTJ manipulation and placebo CTJ manipulation can have a positive effect on reducing pain in people with SAIS.

Limitations of the Study

The results of this study need to be interpreted with caution while recognizing and acknowledging the limitations of the study. Although this was a randomized controlled trial, this study did not have a true control group. Comparisons were made between two interventions: manipulation versus placebo, but the position and force applied during the placebo intervention could have provided therapeutic effect to these participants, therefore, causing the same pain reduction effects as the CTJ manipulation did. Although adding a true control group would have strengthened the research design of the study, it would not be feasible in most of the orthopedic physical therapy practices in the United States.

The one-week follow-up may have been too short to notice the actual effects of the intervention. Strength and muscle activity are not likely to change from one single intervention. However, it would not be feasible to study the carry-over effects of a single manipulation longer than one week. In fact, rather than a single manipulation a multi-modal approach including spinal manipulation is recommended for the management of patients with SAIS (Boyles et al., 2009; Mintken et al., 2010). In the lack of spinal manipulation in isolation, it is difficult to make any conclusions that spinal manipulation will have an effect on shoulder muscle strength and muscle activity following spinal manipulation.

Another limitation of this study is the small sample size in the study (n = 32). At the beginning of this study, an a priori power analysis showed a minimum of 32 participants would be required to ensure adequate power of 0.80. However, the results of the RM ANOVA analysis in shoulder ER strength revealed an effect size (partial η^2) of 0.13, a very small effect size, and a power of 0.20, a low power. Therefore, it is doubtful that a larger sample size may not result in a significant finding.

Lastly, the manipulation used in the study was performed in the supine position. The supine position was selected for this study to allow the shoulders to be placed in a more comfortable position for participants with SAIS as excessive shoulder ER or elevation are required for the CTJ manipulation performed in both the prone and seated positions. The position of excessive shoulder external rotation

or elevation required with CTJ manipulative techniques in sitting or prone positions represent a significant position of provocation of shoulder pain association with SAIS, which is the rationale for a supine position over the other commonly utilized positions for this technique. Therefore, the results of the study could not be generalized to the prone and seated CTJ techniques.

Conclusion

This clinical trial explored effects of a supine CTJ manipulation on shoulder ER strength, shoulder muscle activity, and shoulder pain perception in participants with SAIS. The results of this study suggested that both CTJ manipulation and placebo interventions would reduce shoulder pain perception in participants with SAIS. However, we do not know if this pain reduction was due to the interventions themselves or the natural healing process, because both groups received intervention. In addition, the results of the study suggest that spinal manipulation does not appear to have a great effect on shoulder ER strength, the SUPR and INFR muscle activity, and shoulder pain perception over one-week.

Recommendations for Future Research

Future studies should examine the effect of CTJ manipulation on quality of life for people with SAIS. There should also be an exploration into the long-term healthcare costs associated with managing episodes of SAIS using CTJ manipulation as a mechanism for enhancing pain relief in people with SAIS. The future studies in this arena could be used to ascertain the most efficacious application of CTJ

manipulation, combined with a comprehensive exercise program, at clinically managing patients with SAIS. Additionally, future studies should include a multidisciplinary and multimodal approach to the clinical management of the dysfunction associated with SAIS to ensure we have a better outcome of the conservative management of this dysfunction.

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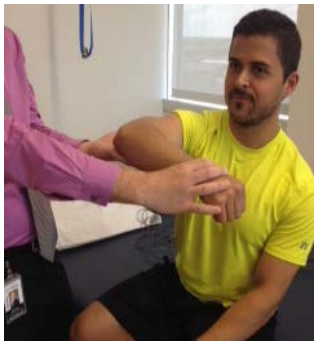
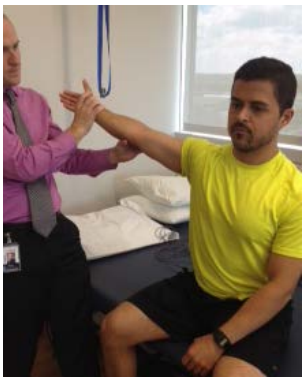
APPENDIX A

Shoulder Examination Tests for Subacromial Impingement Syndrome

Neer's Test: The examiner stabilizes the scapula with a downward force while fully flexing the humerus overhead maximally while applying overpressure. A positive test is reproduction of pain in the superior shoulder (Michener et al., 2009).



Hawkins-Kennedy Test: The examiner flexes the humerus and elbow to 90° and then maximally internally rotates the shoulder. A positive test is reproduction of pain in the anterior shoulder (Michener et al., 2009).



Painful Arc: The examiner asks the patient to actively abduct his/her shoulder and report any pain during abduction. A positive test is the presence of pain noted between 60° and 120° of abduction (Michener et al., 2009).

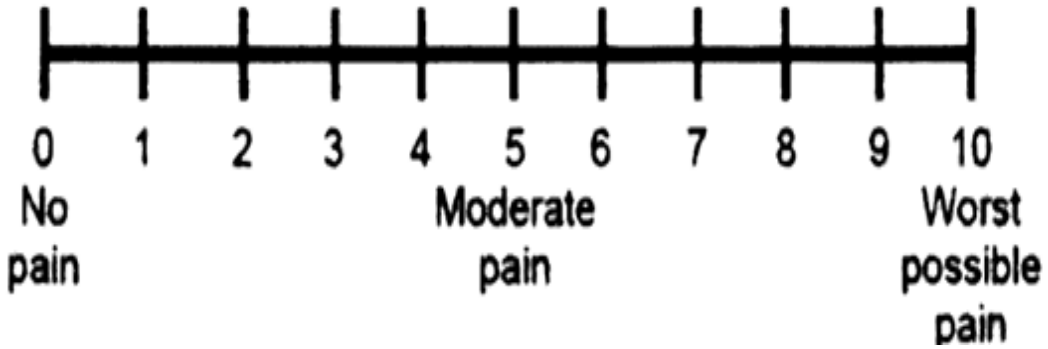
Empty Can Test: The examiner elevates the shoulder to 90° in the plane of the scapula and places the shoulder into internal rotation by asking patient to rotate the thumb toward the floor. The examiner then applies a downward force at the wrist with the individual attempting to resist. A positive test is noted if weakness is present in the involved shoulder (Michener et al., 2009).

External Rotation Resistance Test: The examiner flexes the elbow to 90° and applies a medially directed force is exerted on the distal forearm to resist shoulder external rotation. A positive test is noted if weakness is present in the involved shoulder (Michener et al., 2009).

APPENDIX B

Numerical Pain Rating Scale (NPRS)

Please circle the number that best corresponds to the number indicating the pain you are currently experiencing, with 0 meaning no pain, 5 being moderate pain, and 10 being worst possible pain.



Appendix C

Participant Demographic Form

Subject ID: _____

Name (Last, First): _____

Age: _____

Gender: M F

Weight: _____

Height: _____

DOB: _____

Race/Ethnicity: _____

Hand Dominance: RIGHT LEFT

MEDICAL HISTORY: _____

_____

PREVIOUS HISTORY OF NECK OR SHOULDER PAIN: _____

_____

PREVIOUS TREATMENT OF NECK OR SHOULDER PAIN:_____

_____

CURRENT PHYSICAL ACTIVITY LEVEL: _____

_____

CURRENT MEDICATIONS: _____

_____

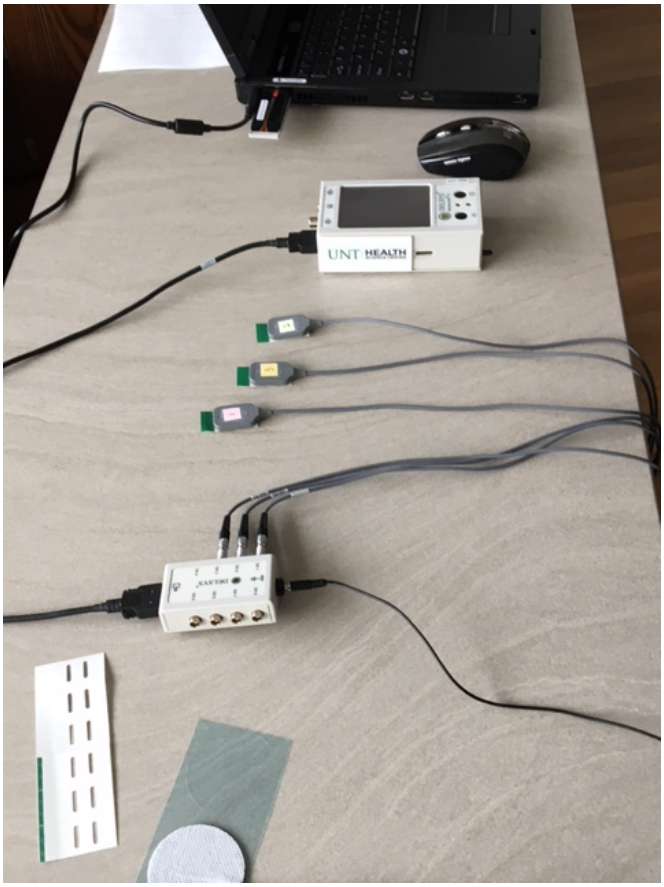
APPENDIX D

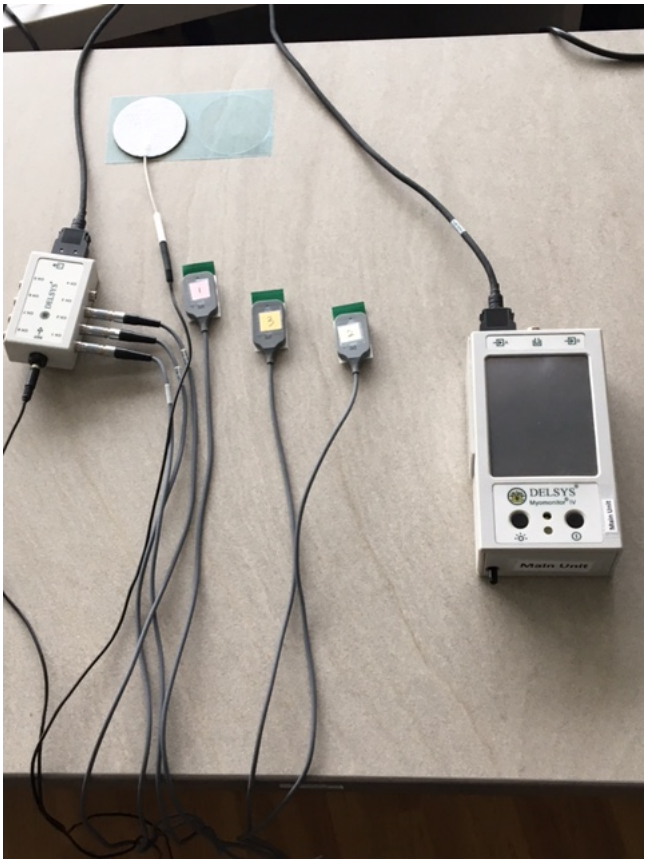
MicroFET Hand-held Dynamometer (HHD)

MicroFET Hand-held Dynamometer

APPENDIX E

Delsys Myomonitor IV Surface Electromyography (EMG) System


UNT HEALTH


DELSYS
Myomonitor IV
Main Unit

APPENDIX F

Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH)

DISABILITIES OF THE ARM, SHOULDER AND HAND

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door.	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g., wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 10 lbs).	1	2	3	4	5
12. Change a lightbulb overhead.	1	2	3	4	5
13. Wash or blow dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover sweater.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g., cardplaying, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g., playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

DISABILITIES OF THE ARM, SHOULDER AND HAND

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A BIT	EXTREMELY
22. During the past week, *to what extent* has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? *(circle number)*	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? *(circle number)*	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. *(circle number)*

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? *(circle number)*	1	2	3	4	5

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. *(circle number)*	1	2	3	4	5

DASH DISABILITY/SYMPTOM SCORE = $\left[\left(\frac{\text{sum of n responses}}{n}\right) - 1\right] \times 25$, where n is equal to the number of completed responses.

A DASH score may not be calculated if there are greater than 3 missing items.

APPENDIX G

Fear Avoidance Beliefs Questionnaire (FABQ)

FEAR AVOIDANCE BELIEF QUESTIONNAIRE

SUBJECT ID:_____

Here are some of the things which some people have told us about their pain. For each statement, please circle any number from 0 to 6 to say how much physical activities such as bending, lifting, walking or driving affect or would affect your shoulder pain.

	COMPLETELY DISAGREE			UNSURE			COMPLETELY AGREE
1. My pain was caused by physical activity.	0	1	2	3	4	5	6
2. Physical activity makes my pain worse.	0	1	2	3	4	5	6
3. Physical activity might harm my shoulder.	0	1	2	3	4	5	6
4. I should not do physical activities which (might) make my pain worse.	0	1	2	3	4	5	6
5. I cannot do physical activities which (might) make my pain worse.	0	1	2	3	4	5	6
The following statements are about how your normal work affects or would affect your shoulder pain.							
6. My pain was caused by my work or by an accident at work	0	1	2	3	4	5	6
7. My work aggravated my pain.	0	1	2	3	4	5	6
8. I have a claim for compensation for my pain.	0	1	2	3	4	5	6
9. My work is too heavy for me.	0	1	2	3	4	5	6
10. My works makes or would make my pain worse.	0	1	2	3	4	5	6
11. My work might harm my shoulder.	0	1	2	3	4	5	6
12. I should not do my normal work with my present pain.	0	1	2	3	4	5	6
13. I cannot do my norami work with my present pain.	0	1	2	3	4	5	6
14. I cannot do my normal work until my pain is treated.	0	1	2	3	4	5	6
15. I do not think that I will be back to my normal work within 3 months	0	1	2	3	4	5	6
16. I do not think that I will ever be able to go back to that work.	0	1	2	3	4	5	6

APPENDIX H

Phone Screening Script

PI: Hello. Thank you for calling about your proposed project for people with shoulder impingement

Potential participant (PP): Hello. I'm calling about participating in your study.

PI: I just have a few questions to ask you to determine your eligibility to participate in my study.

PI: What is your name?

PP: My name is:

PI: What is your age?

PP: My age is:

PI: How long have you had your shoulder pain?

PP: I've had my shoulder pain for:

PI: What is a current rating for your pain, from 0 to 10, with 0 meaning no pain and 10 being the worst pain imaginable?

PP: My current pain rating is:

PI: What is the best rating for your pain, from 0 to 10, with 0 meaning no pain and 10 being the worst pain imaginable?

PP: My best pain rating is:

PI: What is the worst rating for your pain, from 0 to 10, with 0 meaning no pain and 10 being the worst pain imaginable?

PP: My worst pain rating is:

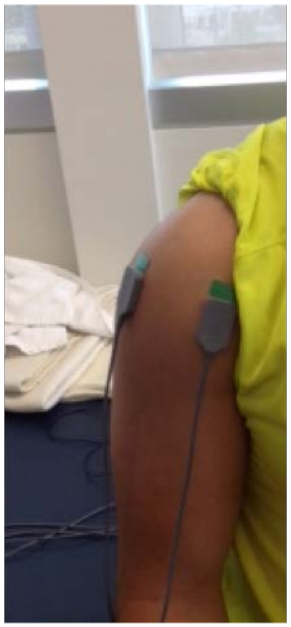
PI: (If meet initial screen requirements for inclusion): You meet my initial screen, can I schedule you for a time to assess your shoulder for possible inclusion in my study?

PI: (If does not meet initial screen requirements for inclusion): Thank you very much for your time and willingness to participate but at this time you do not meet our requirements for participation. Thank you and have a great day.

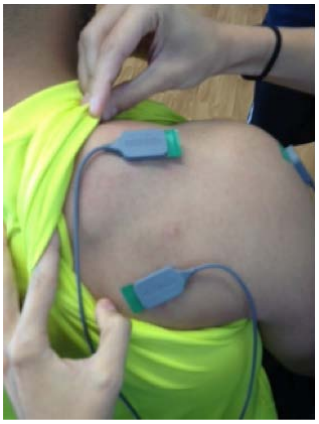
APPENDIX I

Electromyography Electrode Placement

Middle Deltoid (MDELT) electrode


The MDELT electrode will be placed one finger width distal and lateral to the acromion.

Supraspinatus (SUPR) and Infraspinatus (INFR) electrodes


The SUPR electrode was placed above the spine of the shoulder blade in the suprascapular fossa over the muscle belly of the supraspinatus. The INFR electrode was placed 4 cm below the spine of the shoulder blade over the infrascapular fossa.

APPENDIX J

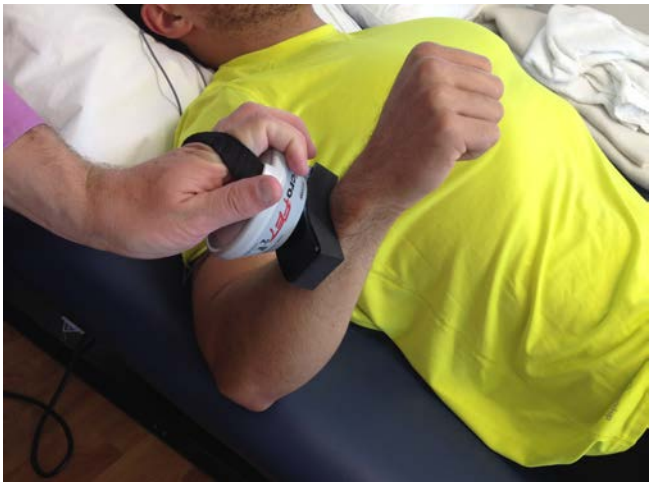
Manual Muscle Test Positions


The abduction manual muscle test to confirm presence of the electrode placement for the middle deltoid and supraspinatus is performed with the participant in sitting. The participant's elbow is flexed to 90° and the examiner applies a force with instructions to the individual to resist the examiner's force.


The external rotation manual muscle test to confirm presence of the electrode placement for the infraspinatus is performed with the participant in sitting. The participant's elbow is flexed to 90° and the examiner applies a force with instructions to the individual to resist the examiner's force.

APPENDIX K

Shoulder Maximal Voluntary Isometric Contraction (MVIC) External Rotation Test Position



Shoulder was placed in 30 degrees of shoulder abduction with elbow flexed to 90 degrees.

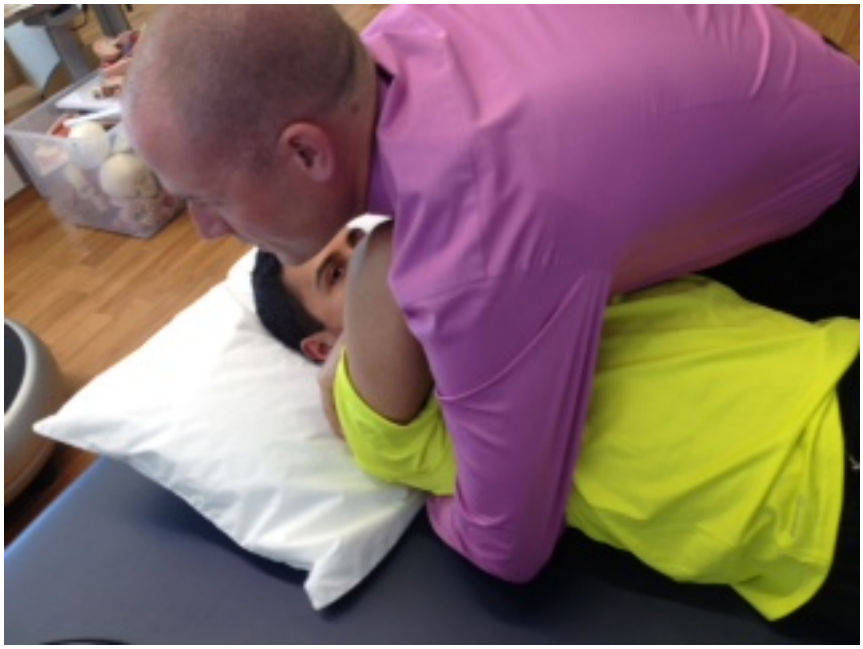
APPENDIX L

Cervicothoracic Junction (CTJ) Manipulation Technique

The manipulative technique was applied to the cervicothoracic junction region by a licensed, skilled physical therapist. The technique involved directing force posteriorly from the therapist through the patient's elbows. The right hand of the therapist was gently lifting the patient's head into a slightly raised position prior to delivery of the thrust.

APPENDIX M

Placebo Manipulation Technique



The placebo manipulation technique was very similar to the prior cervicothoracic junction technique. The placebo technique involved a similar setup to the regular technique but no manipulative thrust was delivered in the placebo group.

APPENDIX N

Active Assistive Range of Motion (AAROM) Shoulder Exercises

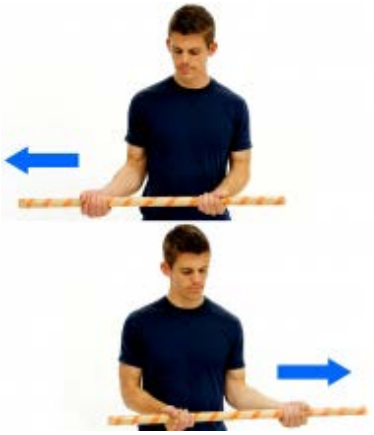
T-bar AAROM shoulder flexion

In the standing position, hold a T-bar with both arms, palms up on the both sides. Raise the T-bar up allowing your unaffected arm to perform most of the effort. Your affected arm should be partially relaxed. Perform 1 set of 15 reps one time per day.

T-bar AAROM shoulder abduction

While holding a T-bar palm face up on the injured side and palm face down on the uninjured side, slowly raise up your injured arm to the side. Perform 1 set of 15 reps one time per day.

T-bar AAROM shoulder external rotation

 In the standing position, hold a T-bar with both hands keeping your elbows bent. Move your arms and T-bar side-to-side. Your affected arm should be partially relaxed while your unaffected arm performs most of the effort. Perform 1 set of 15 reps one time per day.

APPENDIX O

Exercise Tracking Form

Exercise Tracking Form

Participant ID: _____

Place an X in the box each day when you perform these exercises.

Exercise	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
AAROM shoulder flexion with T-bar						
AAROM shoulder abduction with T-bar						
AAROM shoulder external rotation with T-bar						