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Shoulder External Rotator Eccentric Training For Subacromial Pain Syndrome

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Shoulder External Rotator Eccentric Training For Subacromial Pain Syndrome

by

Eric J. Chaconas

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Nova Southeastern University
College of Health Care Sciences
Physical Therapy Department

2015

College of Health Care Sciences
Department of Physical Therapy

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

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Abstract

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Background and Purpose: Rotator cuff weakness has been associated with subacromial pain syndrome (SAPS). The purpose of this study was to determine the effect of eccentric training, isolated to the shoulder external rotators, on strength, strength ratios, range of motion, upper quarter balance, pain, perceived function and global change. **Methods:** Forty-Four participants, 19 females (mean age 46), with greater than 3 months of shoulder pain were randomized into two groups. The experimental group performed an external rotator eccentric training exercise (ETER) for three sets of 15 and a scapular retraction exercise, with a resistance band, for 2 sets of 10, once daily for six weeks. The control group utilized a general exercise program (GE), consisting of active range of motion and scapular retraction, with a resistance band, each for two sets of 10, once daily for six weeks. Dependent variables were compared within and between groups at baseline, week 3, and week 6. **Results:** The factorial ANOVA demonstrated a significant difference for external rotation strength comparing the interaction between group and time ($p<.001$, ETER mean .160, GE mean .120). The factorial ANOVA did not demonstrate a significant difference for the upper quarter y balance test ($p=.07$- $p=.32$) and active range of motion ($p=.17$ - $p=.77$). The Mann-Whitney U test demonstrated significant differences for average pain ($p=.022$, median change ETER -2, GE -1), worst pain ($p=.001$, median change ETER -4, GE 0), Western Ontario rotator cuff index ($p<.001$, median ETER 91.40, GE 73.90), and global change ($p<.001$, median ETER +5, GE 0). Significant between group differences were not identified for the ANOVA, or ANCOVA controlling for worst pain, upon testing the internal rotator to external rotator ($p=.46$, $p=.55$), and abductor to external rotator ($p=.32$, $p=.42$) strength ratios. **Conclusions:** This study identified the efficacy of eccentric training of the external rotators for individuals with SAPS, as evidenced by significant improvements for external rotation strength, pain, function and global change when compared to a control group. **Recommendations:** Integrating eccentric training for the external rotators among individuals diagnosed with SAPS of greater than three months onset may improve outcomes including pain, strength, and function.

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CHAPTER 1: INTRODUCTION

OVERVIEW

Shoulder pain affects up to 67% of the adult population at some point in their lifetime.[1] Although the etiology of shoulder pain is variable a consensus of evidence has implicated subacromial pain syndrome (SAPS) as a primary source.[2] SAPS has also been referred to as subacromial impingement syndrome (SAIS) affecting multiple tissues in the shoulder including the tendons of the supraspinatus, infraspinatus, long head of the biceps as well as structures such as the subacromial bursa.[3, 4] The subacromial space comprises the humeral head inferiorly and undersurface of the acromion process, acromioclavicular joint and coracoacromial ligament for the superior border. When the subacromial space is compromised, from conditions such as SAIS, the affected tissues can become painful, thickened, reactive and degenerated.[5, 6] The supraspinatus tendon in particular, due to its proximity to the acromion often demonstrates signs of degeneration, associated with weakness, pain, and functional limitations during activities requiring overhead elevation. Moreover, pathological tendon changes can lead to tears in time with 97% of spontaneous complete tendon ruptures demonstrating signs of degeneration.[7, 8]

Two primary theories describe the underlying mechanism responsible for SAPS. The first theory is intrinsic impingement and has been described as “tension overload of the rotator cuff resulting in a degenerative process within the tendon.”[9] This tissue overload and subsequent damage has been postulated to be the cause of osteophyte formation, muscle imbalances, and aberrant biomechanics which in turn may lead to SAPS.[4,9] The second theory is extrinsic impingement and occurs due to tendon swelling and degeneration resulting from mechanical compression between the head of the humerus and undersurface

of the acromion.[5] This mechanical compression is thought to be caused by abnormal acromion shape, subacromial bursitis, impaired scapulothoracic and glenohumeral biomechanics that result from muscle imbalances caused by motor control impairments and muscle weakness.[4, 5] Two of the more common muscle imbalances associated with SAPS reside in the strength of the abductors versus external rotators and internal rotators versus external rotators.[10, 11] These imbalances are responsible for impairing shoulder elevation as a result of an abnormal deltoid to rotator cuff force couple.[10] When this force couple becomes disturbed the deltoid muscle creates an excessive superior glide of the humeral head while the rotator cuff is unable to provide a sufficient compressive and stabilizing effect for the head of the humerus in the glenoid fossa.[12] Muscle imbalances between the deltoid to rotator cuff and stronger internal rotators to, typically weaker, external rotators have been associated with SAPS.[13] Interventions prescribed to address the signs and symptoms of SAPS, improve function and reverse the degenerative cascade to the supraspinatus tendon, could be effective for patients experiencing SAPS. Although a variety of interventions have been described in the literature,[14] eccentric training could be considered as a worthwhile intervention for those experiencing symptoms of SAPS.[15, 16]

Eccentric training is a form of exercise in which muscle tissue lengthens because the force generated through the muscle contraction is less than the resistive force acting upon it.[17] Studies suggest eccentric training is efficacious for decreasing symptoms, improving function and normalizing tendon structure, for patients with tendinopathy at the Achilles,[18, 19] patella,[20] lateral elbow[21] and posterior tibialis[22] tendons. Moreover, studies examining clinical outcomes for patients with SAPS demonstrate favorable results when eccentric training is utilized as an intervention.[15, 16, 23-27] Chapter 1 will focus on the

problem and the need for the current study to determine the efficacy of frequency eccentric training for the shoulder external rotators (ETER) in subjects with SAPS.

PROBLEM STATEMENT

SAPS has been associated with weakness of the shoulder external rotators compared to healthy controls.[13] The effects of eccentric training, isolated to the shoulder external rotators, for patients experiencing SAPS has not been studied with a randomized controlled trial. The presence of tendon degeneration and rotator cuff weakness, in these individuals, provides a strong argument for the use of eccentric training to the external rotators (infraspinatus, supraspinatus and teres minor muscles).

RESEARCH PURPOSE

Eccentric training to the shoulder external rotators in patients with SAPS has not been thoroughly investigated. Prior research has examined a variety of eccentric supraspinatus and external rotator exercises but no studies target the external rotators in isolation. The purpose of this investigation is to examine the effects of ETER in subjects with SAPS. Identifying specific exercise protocols for individuals with SAPS will provide evidence to help clinicians select the best interventions.

The effects of ETER were quantified by examining the following dependent variables: (1) body weight adjusted mean isometric shoulder strength values measured in force kilograms (2) strength ratios for internal/external rotation, external rotation/abduction, (3) Pain free active range of motion (AROM) (4) Numeric Pain Rating Scale (NPRS), (5) Upper Quarter Y-Balance test (UQYBT), (6) Western Ontario Rotator Cuff Index (WORC) and (7) Global Rating of Change (GROC). The dependent

variables were used to investigate the research questions and hypotheses established in this research study.

RESEARCH QUESTIONS AND HYPOTHESES

This investigation determined if a significant difference was found in the dependent variables (isometric strength values, strength ratios, range of motion, global rating of change, shoulder function and pain) between individuals with SAPS who underwent a six week ETER protocol versus a general shoulder exercise protocol. The following research hypotheses (H1-H6) were tested with this investigation.

Research Question #1 - Does ETER improve mean bodyweight adjusted shoulder external rotation strength in participants with SAPS?

Research Hypothesis #1 (H1) - A significant improvement in mean bodyweight adjusted shoulder external rotation strength will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #2 - Does ETER improve internal rotator to external rotator and shoulder abductor to external rotator isometric strength ratios in participants with SAPS?

Research Hypothesis #2 (H2) - A significant improvement in shoulder internal rotator to external rotator and shoulder abductor strength to external rotator strength ratios will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #3 - Does ETER improve self-reported pain and function in participants with SAPS?

Research Hypothesis #3 (H3) - A significant improvement in self-reported pain measured by the numeric pain rating scale and function measured by the Western Ontario Rotator Cuff Index will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #4 – Does ETER improve active shoulder range of motion (abduction, flexion, external rotation, and internal rotation) in participants with SAPS?

Research Hypothesis #4 (H4) – A significant improvement in pain free active shoulder range of motion will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #5 - Does ETER improve upper extremity closed kinetic chain performance in participants with SAPS?

Research Hypothesis #5 (H5) - A significant improvement in upper extremity closed kinetic chain performance as measured by the upper extremity y balance test will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #6 – Does ETER improve patient perceived global change of condition as measured by the Global Rating of Change Scale?

Research Hypothesis #6 (H6) – A significant improvement in global change measured by the Global Rating of Change Scale will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

RELEVANCE AND SIGNIFICANCE

Shoulder pain is a prevalent condition resulting in a significant loss of function and disability.[1] In the United Kingdom the prevalence of shoulder pain increased linearly with age and 13.6% of those patients were still reporting to a healthcare provider with shoulder pain three years after initial consultation.[28] Impingement of the rotator cuff tendons is thought to be the most common cause of shoulder pain comprising 44%-65% of all shoulder pain reports.[29,30,31] Roquelaure et al[32] prospectively followed 2,685 working individuals, including both physically demanding and non-physically demanding occupations, over a one year period and found pathology of the rotator cuff to be the most common upper extremity musculoskeletal condition. Virta et al[33] investigated the cost of healthcare utilization for patients with shoulder pain in Sweden. The authors found that physiotherapy care accounted for 60% of the total healthcare cost in this cohort of patients. In the United States the medical treatment of shoulder pain was found to cost up to 7 billion dollars during the year 2000.[34]

While the positive clinical outcome of eccentric training for SAPS is promising further investigation is warranted. Eccentric shoulder protocols, including those investigated by Bernhardsson et al,[23] Camargo et al,[24] and Jonsson et al[25] utilized a variety of exercises focusing on loading the supraspinatus tendon and shoulder abductors. Exercises targeting shoulder abduction may have been improperly selected in many of these investigations as the abnormal deltoid to rotator cuff muscle imbalance is further

accentuated with this type of exercise selection. Bernhardsson et al[23] in a case series investigated the effect of eccentric supraspinatus and infraspinatus exercises performed twice a day for 12 weeks among ten individuals diagnosed with SAPS. Results identified significantly improved pain with a median reduction of 30 points, out of 100, on the visual analog scale and improved function at 9 points, out of 30, on the patient specific functional scale ($p=.008$). The Bernhardsson et al[23] study is limited by the small sample size and single arm design. Camargo et al[24] in a case series investigated the effect of twice a week eccentric exercises to the shoulder abductors on 20 subjects with shoulder impingement syndrome and reported significant improvements in pain as measured with the visual analog scale ($p<.05$), function using the disabilities of the arm shoulder hand (DASH) ($p<.05$) and strength measured isokinetically ($p<.05$) at a 6-week follow up. In another case series, Jonsson et al[25] studied eccentric loading of the supraspinatus in 9 patients with chronic shoulder impingement syndrome on a waiting list for shoulder surgery. Exercises were performed twice a day, every day for 12 weeks. In five of the patients significant improvement in pain occurred with a mean improvement of 44 points on the visual analog pain scale ($p<.05$). Functional gains were found with a mean Constant Score improvement of 15 points ($p<0.05$). Also, of clinical and economic significance was all five patients canceling their scheduled surgical procedures. The exercise chosen by Jonsson et al[25] was performed using a pulley system in order for the heavy load to be assisted overhead with the contralateral upper extremity (Figure 1.1).

Figure 1.1 Shoulder abductor eccentric training with internal rotation

This movement has some significant limitations due to the inherent reproduction of the impingement testing position with shoulder abduction and internal rotation.[35] Moreover, the abduction movement combined with internal rotation maximizes the deltoid force while reducing the muscle function of the rotator cuff.[36] This exercise might not be the best option for many patients with SAPS due to the potential development of shoulder pathology inherent in the exercise.

While all three studies demonstrated favorable outcomes the single group design makes drawing a causal effect of these interventions challenging. Two randomized controlled trials have investigated the outcomes of eccentric training for SAPS.[15, 16] Holmgren et al[16] compared the effect of eccentric training combined with traditional exercises to a control group of nonspecific unloaded exercises in 97 subjects with shoulder impingement syndrome who were on a waiting list for subacromial decompression surgery. Exercises for the experimental group consisted of side-lying external rotation and seated abduction performed eccentrically and additional isotonic exercises targeting the external rotators, serratus anterior and periscapular muscles as well as stretching to the posterior shoulder joint. Control exercises consisted of

movement without resistance including shoulder abduction, flexion, scapular retraction, cervical spine retraction and stretching to the upper trapezius and pectoralis major. After 12 weeks of daily exercises the experimental group had a significant improvement in shoulder function, using the Constant Shoulder Function Score and Disabilities of the Arm Shoulder and Hand (DASH), night pain levels measured by the Visual Analog Scale (95% confidence interval) and global change compared to the control group ($p<.001$). No significant differences were reported when comparing between group changes for resting pain or pain with activity. Hallgren et al[27] published the one year follow up to the Holmgren et al[16] study and found a significant difference ($p<.001$) with 63% of participants from the control group receiving shoulder surgery compared to only 24% from the group performing eccentric training. While results from this experimental trial are promising the combined abduction and external rotation eccentric exercises utilized in the experimental group make drawing specific conclusions related to the efficacy of eccentric training alone challenging. Abduction eccentric training may further perpetuate abnormal shoulder strength ratios whereas the external rotation training in isolation could be the more favorable intervention. Additionally, all participants received corticosteroid injection prior to beginning the exercise programs which potentially could pose a threat to external validity, as injections prior to rehabilitation has not been established as a standard of care for SAPS. In a randomized clinical trial, Maenhout et al[15] investigated the effects of shoulder abductor eccentric training, using a dumbbell, on 61 subjects with SAPS. The control group performed traditional internal and external rotation strengthening exercises with a resistance band for three sets of 10 one time per day, for 12 weeks. The experimental group performed these same exercises with the addition of a

heavy load shoulder abduction eccentric exercise for three sets of 15 twice daily. (Figure 1.2).

Figure 1.2 Shoulder abductor full can eccentric exercise is initiated with an overhead press and then eccentric lowering occurs in the plane of the scapulae over a 5 second period of time

Load for the eccentric exercise was established by monitoring participant shoulder symptoms and increasing the weight used once the exercise could be performed pain free. Both the eccentric training and standard shoulder exercise groups demonstrated significant improvements in isometric strength for abduction, internal and external rotation at 12 weeks. Moreover, both groups demonstrated improved pain and functional ability at 12 weeks (<0.001). One limitation to this study is that the shoulder abductors were a primary focus of eccentric training which, could have further facilitated an abnormal ratio of deltoid to rotator cuff strength, perpetuating any existing pathological shoulder joint mechanics. This abnormality was evident with the experimental group significantly improving abduction strength compared to the control group. It has been proposed that training the shoulder with an emphasis on abduction further facilitates the abnormal ratio of deltoid to rotator cuff strength, thereby leading to SAPS.[37] Another

limitation present in all of the aforementioned studies is that shoulder function has not been measured with physical performance upper extremity functional tests as a dependent variable, thus limiting the interpretation of functional performance in these subjects.

This investigation compared ETER in positions found to strengthen the supraspinatus, infraspinatus and teres minor versus a general shoulder exercise program. Participants were randomly assigned to either an experimental group or control group. The investigation utilized ETER as the independent variable and compared that to a control group performing general shoulder exercises. The eccentric exercise was standing external rotation with a resistance band in which the contra lateral arm provides assistance to end range external rotation and then an eccentric lowering motion occurs back to the starting position. (Figure 1.3).

Figure 1.3 Standing external rotation eccentric exercise is initiated by the contralateral arm assisting the concentric portion of external rotation and then the eccentric lowering occurs to return back to the starting position over a three second period of time

The experimental group performed the specific eccentric interventions daily, one time per day, 3 sets of 15 repetitions with a 2 minute rest period in between sets. This specific eccentric exercise dosing and frequency has been established as appropriate in prior research.[16, 38] Resistance was determined during clinical visits in which patients

were prescribed the level of resistance band based upon ability to perform exercises with correct technique, no increase in pain compared to rest and ability to perform 15 repetitions without rest. All eccentric exercises were performed with a slow 3-second lowering phase consistent with Holmgren et al.[16] In addition to the ETER exercise participants in the experimental group also performed a scapular retraction exercise with resistance band for 2 sets of 10 each day and cross body horizontal stretch for 3 repetitions of 30 to 45 seconds every day as described by Holmgren et al.[16]

The control group performed active movement without resistance including shoulder abduction and flexion, once daily, for 2 sets of 20 repetitions each with a two minute rest between exercises as described by Holmgren et al.[16] The control group also performed the scapular retraction exercise with a resistance band for 2 sets of 10 repetitions and the cross body horizontal adduction stretch for 3 repetitions of 30 to 45 seconds each.

PRACTICAL APPLICATION OF THE FINDINGS

Exercise protocols using eccentric training have been found to benefit patients with SAPS, however, further study is necessary due to the paucity of quality investigations.[14] Identifying the efficacy of specific protocols can provide direction for clinicians when prescribing exercises for patients with SAPS. The results of this project will contribute to the body of knowledge for clinical decision making related to interventions for individuals with SAPS. Moreover, the results of this investigation can be compared to those of prior studies examining eccentric and traditional exercise interventions for patients with SAPS, to further develop the knowledge of how to best manage this condition. An eccentric program targeting the shoulder external rotators

could be more beneficial compared to prior investigations targeting the abductors,[15, 16] as shoulder strength ratios would be normalized in this investigation. This dissertation will provide an advancement in the clinical science related to the role that eccentric training has in the rehabilitation of musculoskeletal disorders and the shoulder complex.

SCOPE OF INVESTIGATION

This project required a significant number of resources. Patients were recruited through flyers and advertisements in local health clubs, medical offices, and universities. The primary investigator performed a history and physical examination on all patients to determine patient inclusion into the investigation and collected baseline and outcome measure data. A blinded research assistant provided all interventions for patients enrolled in the investigation. Additional resources were utilized such as a computer equipped with statistical software, instruments to collect strength and shoulder functional performance data, and resistance bands for participants to use for home exercises. Data collection was performed at the University of St. Augustine where the primary investigator is employed.

DEFINITION OF TERMS

Eccentric Training: An exercise by which a muscle contraction occurs during a lengthening movement.

External Rotators: Muscles of the shoulder rotator cuff responsible for lateral rotation of the glenohumeral joint. Includes the supraspinatus, infraspinatus and teres minor.

Extrinsic Impingement: Tendon swelling and degeneration resulting from mechanical compression between the head of the humerus and under-surface of the acromion.[5] This

mechanical compression is thought to be caused by faulty scapulothoracic and glenohumeral biomechanics that result from muscle imbalances and motor control impairments.

Internal Rotators: Muscles of the shoulder responsible for medial rotation. Includes the subscapularis, pectoralis major, latissimus dorsi, and teres major.

Intrinsic Impingement: Tension overload of the rotator cuff resulting in a degenerative process within the tendon.[9]

Rotator Cuff: Muscle and tendon complex around the shoulder consisting of supraspinatus, infraspinatus, teres minor and subscapularis.

Strength Ratio: Amount of force created by one muscle divided by the amount of force created by another muscle.

Subacromial Pain Syndrome (SAPS): Mechanical abrasion of the subacromial structures including the supraspinatus, infraspinatus, long head of the biceps, as well as structures such as the subacromial bursa, against the anterior undersurface of the acromion and coracoacromial ligament.[39]

Tendinopathy: An overuse tendon injury, resulting in pain and loss of function, by which the tendon structure is altered due to increased thickness and/or areas of tissue breakdown[40].

SUMMARY

To summarize, SAPS is a common shoulder disorder often associated with supraspinatus tendinopathy due to impingement in the space between the head of the humerus and the undersurface of the acromion. This mechanical compression is thought to be caused by impaired scapulothoracic and glenohumeral biomechanics that can result

from muscle imbalances and motor control impairments. The most common muscle imbalances associated with SAPS are the deltoid versus rotator cuff and external versus internal shoulder rotators.

Prior research has found that eccentric training for the shoulder is effective for patients with SAPS.[15, 16, 23-25] The limitations to these studies include either single arm designs, a focus on eccentric loading of the shoulder abductors resulting in faulty shoulder biomechanics, and a lack of functional performance outcome measures. Further investigation on the role of eccentric training, specifically to the shoulder external rotators, in patients with SAPS is warranted. This investigation will contribute to the evidence base for clinical decision making related to interventions for individuals with SAPS.

Specifically, this investigation: (1) Determined if ETER improved external rotator to internal rotator and external rotator to abductor strength ratios in participants with SAPS. (2) Determined if ETER improved shoulder pain free active range of motion in participants with SAPS. (3) Determined if ETER improved self-reported pain and function in participants with SAPS. (4) Determined if ETER improved upper extremity functional ability in participants with SAPS.

The results of this investigation can be compared to those of prior studies examining eccentric and traditional exercise interventions for patients with SAPS, to further develop the knowledge of how to best manage this condition.

CHAPTER 2: LITERATURE REVIEW

INTRODUCTION

Subacromial pain syndrome (SAPS) is a common shoulder condition affecting multiple tissues including the tendons of the supraspinatus, infraspinatus, long head of the biceps and subacromial bursa.[3, 4] This disorder is thought to occur from approximation between the head of the humerus and undersurface of the acromion due to a variety of factors.[4] Biomechanical shoulder impairments such as muscle weakness, motor control abnormalities and joint mobility loss are often considered in relation to SAPS.[5] Impairments such as abnormal muscle strength ratios have been established as potential contributors to SAPS.[13] These abnormal strength ratios include the shoulder abductors to external rotators and external to internal rotator muscle imbalances.[41, 42] Exercise, as an intervention, has been found to benefit patients with SAPS, however, further study is needed due to the paucity of quality investigations.[14] The purpose of this chapter is to review the literature pertaining to the diagnosis and management of SAPS. A detailed review of the risk factors leading to SAPS and the muscles that optimize shoulder kinematics will be provided. Moreover, the specific function of each muscle will be discussed with an emphasis on abnormal muscle ratios and shoulder dysfunction. Lastly, an in depth review of the current evidence pertaining to the role of eccentric training for individuals with SAPS will be presented.

DIAGNOSIS OF IMPINGEMENT SYNDROME

Neer[39] described SAPS as a "mechanical abrasion of the subacromial structures against the anterior undersurface of the acromion and coracoacromial ligament." The

diagnosis of SAPS results from the physical examination and history. Patients often describe a gradual onset of lateral and anterior shoulder pain resulting from overhead activity and functional tasks.[43] Individuals experiencing SAPS often report pain worsening with increased upper extremity elevation movements compared to rest.[4] The clinical examination includes a multitude of physical tests and measures that have been purported to indicate the presence of SAPS. Most tests attempt to incriminate the disorder by either contracting the injured supraspinatus and infraspinatus muscle/tendon complexes or compressing them between the humeral head and undersurface of the acromion. While single tests have not been found to result in sufficient clinical accuracy, a cluster of the following tests improves the diagnostic accuracy of the physical examination for SAPS.[44]

Jobe and Moynes[45] originally described the empty can test as a strength assessment of the supraspinatus muscle. The test has been described in the literature with a variety of names including the Jobe test,[46] empty can test,[47] and supraspinatus strength test.[35] While variations in test names have been described, the performance of the test is consistently the same. The empty can test is performed with the examiner placing the patient's arms at 90 degrees of elevation in the plane of the scapulae (30 degrees of horizontal adduction) and subsequently applying a downward force to the arm as a means of determining the amount of shoulder strength and the presence of symptoms. The examiner then maintains the arm in the plane of the scapulae but has the patient internally rotate the shoulder so that the thumbs are pointing downward. The examiner then provides a downward pressure on the patient's arms, a second time, while the patient

resists this force. A positive test result includes shoulder pain or weakness during resistance in the second position (Figure 2.1).

Figure 2.1 Empty can test start and finish positions

The position of internal rotation in the plane of the scapulae is proposed to place a greater amount of force through the supraspinatus tendon. If the patient reports pain in the second position the test should be considered positive for pathology of the supraspinatus muscle or tendon. Park et al[35] investigated the diagnostic accuracy of the empty can test and found it useful for ruling in rotator cuff disease and impingement syndrome, (specificity 89.5%, +Likelihood ratio (LR) 4.2, Post-test probability .89, sensitivity 44%, -LR .63).

Kessel et al[48] initially described the painful arc test as a test to detect SAPS and more specifically supraspinatus tendinopathy. The test is performed by having the patient abduct the arm in the coronal plane with a positive test being present when the

patient reports reproduction of shoulder symptoms between 60 and 120 degrees of abduction (Figure 2.2).

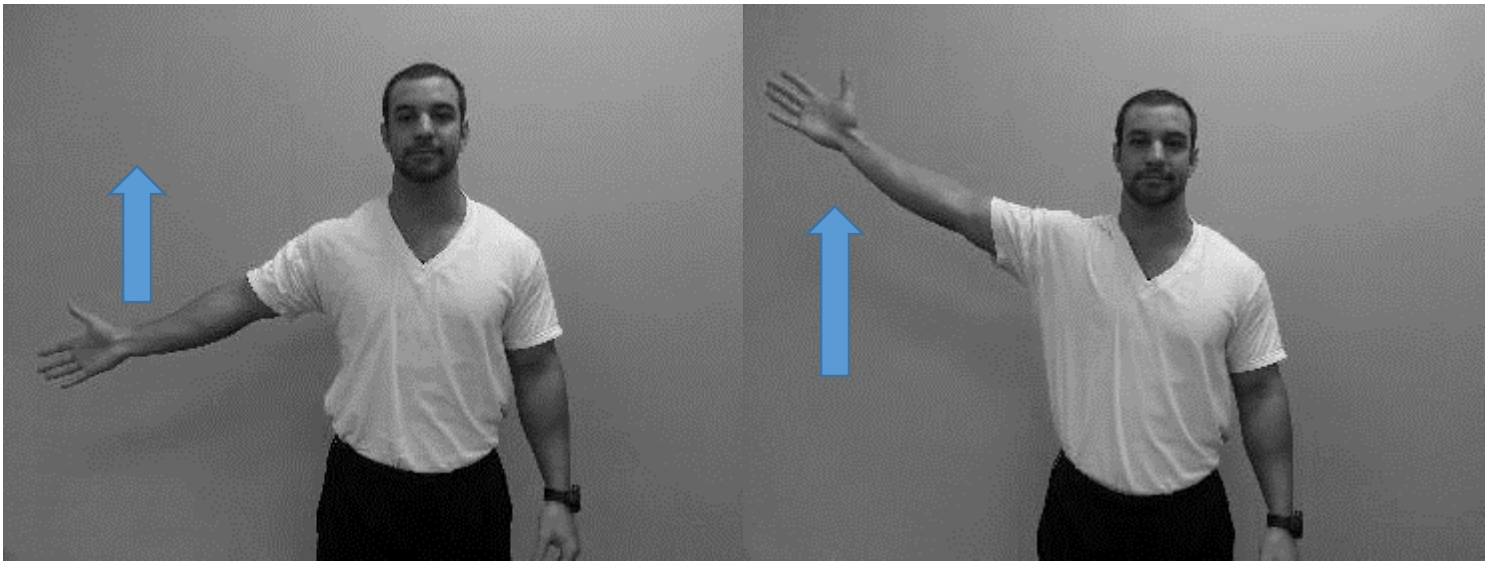


Figure 2.2 Painful arc test conducted in the coronal plane

Diagnostic accuracy of the painful arc test has been reported (sensitivity 73.5%, specificity 81.1%, +LR 3.89, –LR .32 and post-test probability .88).[35] Moreover, Calis et al[49] identified the painful arc test as being more valuable to incriminate patients with SAPS compared to ruling out the condition (sensitivity 33%, specificity 81%, +LR 1.73, -LR .82).

The external rotation resistance test (infraspinatus muscle test) has been described as a test to incriminate injury to the shoulder external rotators.[35, 50] The external rotation test is performed with the examiner placing the patients arm in neutral rotation with the elbow by the side at 90 degrees of flexion. The examiner applies a resistance against the patients arm in order to facilitate an external rotation contraction by the patient (Figure 2.3).[35]

Figure 2.3 External rotation resistance test

The resisted external rotation test has demonstrated good diagnostic accuracy to rule in SAPS (sensitivity 41.6%, specificity 90.1%, +LR 4.2, -LR .65 and post-test probability .89).[35]

The Neer impingement test was originally described by Neer[39] in 1983. The test is conducted with the patient seated while the examiner raises the affected arm into flexion with one hand while the other hand prevents the scapulae from moving. The examiner provides an upward force, on the humerus, to end-range attempting to reproduce the patients shoulder pain (Figure 2.4).

Figure 2.4 Neer impingement test

A positive test is recorded if the patient reports shoulder pain during or at the end range of the movement. Park et al[35] determined the Neer test to be most useful in ruling out rotator cuff tendinitis and subacromial bursitis. (Sensitivity 85.7% and Specificity 49.2%). When the Neer test is negative an examiner can be fairly confident that the patient does not have SAPS due to the provocative nature of this test.

Hawkins and Kennedy[51] described a test to detect SAPS in which the examiner places the patients shoulder in 90 degrees of flexion and full internal rotation while

stabilizing the scapulae. This position is thought to compress the greater tubercle of the humerus against the undersurface of the acromion. A positive Hawkins-Kennedy test results if the patient describes pain at the end-range position (Figure 2.5).

Figure 2.5 Hawkins-Kennedy impingement test

A recent systematic review with meta-analysis found both the Neer test and Hawkins-Kennedy have a fair ability to rule out SAPS with limited use for ruling in the condition.[44] Park et al[35] reported similar findings with diagnostic accuracy values that favored ruling out SAPS (sensitivity 71.5%, specificity 66.3%).

Palpable tenderness at the supraspinatus and infraspinatus are often used in clinical practice as diagnostic tests for SAPS. Mattingly and Mackarey[52] investigated the most accurate positions, for shoulder tendon palpation, which resulted in the maximum tendon exposure with the least amount of overlying tissue. The study was performed on 24 shoulders of 12 human cadavers (6 female, age range 55-92). The supraspinatus was optimally palpated with the shoulder in a position of full adduction, extension and internal rotation, similar to a hand to back position. The supraspinatus was then accessed one finger width below the anterior aspect of the acromion adjacent to the acromioclavicular joint (Figure 2.6).

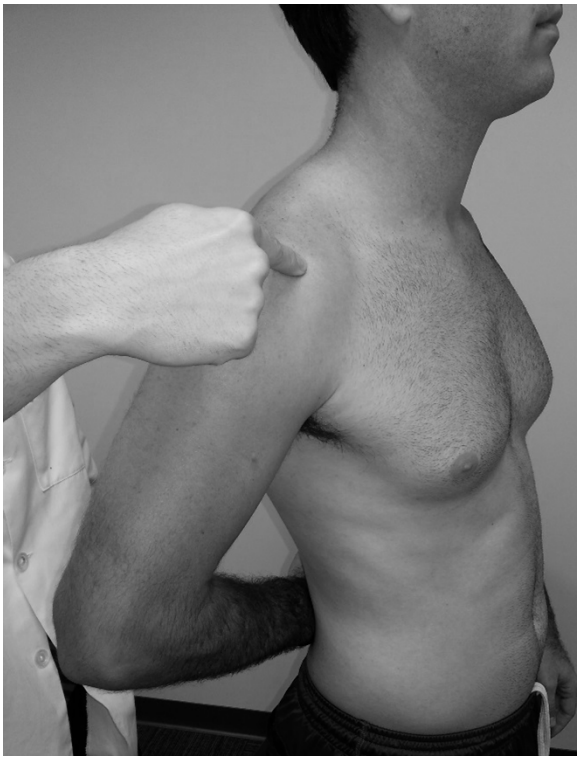


Figure 2.6 Supraspinatus tendon palpation with patients hand behind back

To most accurately identify the infraspinatus through palpation the shoulder is placed in a position of flexion to 90 degrees, horizontal adduction to 10 degrees and 20 degrees of external rotation.[52] The infraspinatus tendon is then located one finger width below the posterior and lateral corner of the acromion (Figure 2.7).

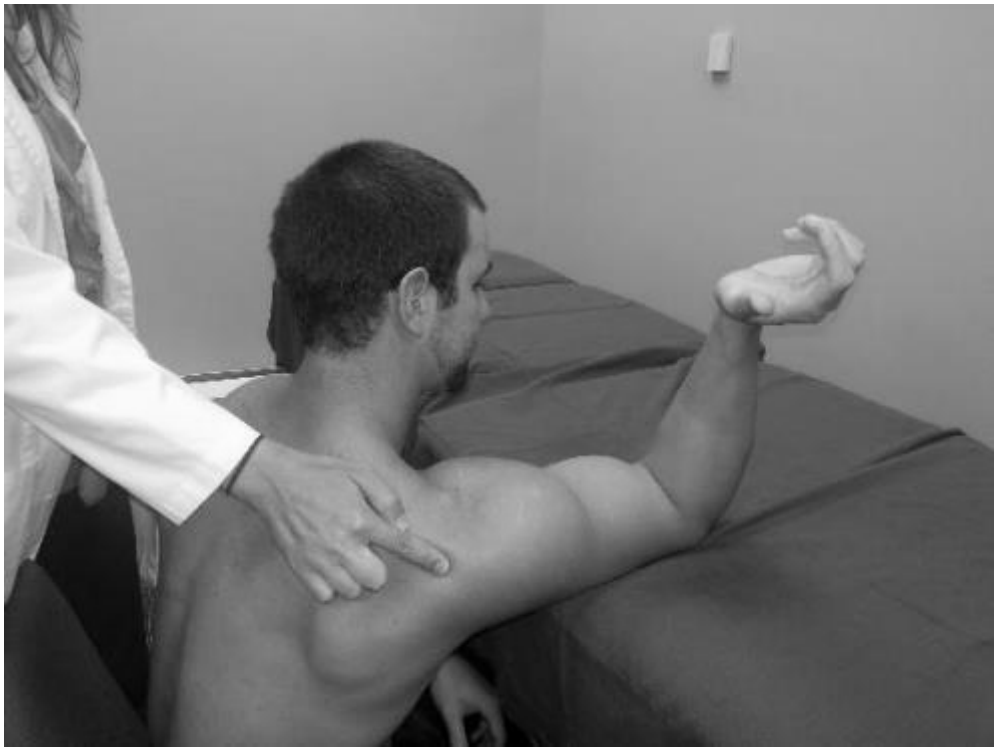


Figure 2.7 Infraspinatus tendon palpation

Toprak et al[53] investigated the diagnostic accuracy of palpable tenderness to the supraspinatus and infraspinatus for SAPS resulting in rotator cuff tendinopathy and bursitis. The palpation tests were compared to the Neer impingement and Hawkins-Kennedy impingement tests. Palpation to the supraspinatus demonstrated superior accuracy for ruling out SAPS (specificity 41% at 95% Confidence Interval (CI) 18%-64%, sensitivity 92% CI 78%-95%) compared to both the Neer (specificity 52% CI 30%-73%, sensitivity 80% CI 67%-89%) and Hawkins-Kennedy tests (specificity 47% CI

26%-69%, sensitivity 67% CI 53%-78%). Palpation for tenderness to the infraspinatus is less accurate in ruling in or out SAPS (specificity 66% CI 54%-76%, sensitivity 33% CI 6%-79%). A limitation to the accuracy of the palpation tests could have been that a standardized position to maximally expose each tendon was not described.

Michener et al[50] examined a variety of clinical tests to detect SAPS and found positive likelihood ratios greater than 2.0 for the painful arc (+LR 2.25 95% CI, 1.33-3.81), empty can (+LR 3.90 95% CI, 1.5-10.12) and the external rotation resistance test (+LR 4.39 95% CI 1.74-11.07). One can conclude from the diagnostic accuracy research of SAPS that the condition can be detected with positive painful arc, empty can, palpable supraspinatus tenderness and external rotation resistance tests while the absence of the disorder is probable when negative Neer impingement and Hawkins-Kennedy tests are present. Palpable tenderness of the infraspinatus could be utilized to enhance the physical examination but is not supported by the diagnostic accuracy literature. Caution should be used for clinical application of single tests to detect SAPS with appropriate diagnostic accuracy.[44] A detailed patient history and cluster of examination tests can be a clinically effective method to diagnose SAPS.[44] Studies examining the efficacy of exercise in the management of SAPS have successfully utilized clusters of these aforementioned tests to determine the diagnosis of SAPS and participant inclusion criteria.[15, 16] The summary of metrics for each physical examination test to diagnose SAPS is provided in Table 2.1.

Table 2.1 Diagnostic accuracy metrics for SAPS physical examination tests

Physical Examination Test	Metrics to rule in condition	Metrics to rule out condition
Empty Can	Specificity 89.5%, +LR 4.2, post test probability .89	Sensitivity 44%, -LR .63
Painful Arc	Specificity 81.1%, +LR 3.89, post test probability .88	Sensitivity 73.5%, -LR .32
External Rotation Resistance	Specificity 90.1%, +LR 4.2, post test probability .89	Sensitivity 41.6%, -LR .65
Neer Impingement	Specificity 49.2%	Sensitivity 85.7%
Hawkins - Kennedy	Specificity 66.3%	Sensitivity 71.5%
Supraspinatus Palpation	Specificity 41%	Sensitivity 92%
Infraspinatus Palpation	Specificity 66%	Sensitivity 33%

Abbreviation legend: Likelihood ratio (LR)

IMPINGEMENT SYNDROME RISK FACTORS

Impingement syndrome of the subacromial space can be attributed to a variety of extrinsic and intrinsic factors. Extrinsic factors can originate from impairments of the upper quarter and include the scapulothoracic and glenohumeral regions. Moreover, structural, habitual and activity-based factors can also contribute to SAPS. These factors are all centered upon the phenomenon that the relationship between the acromion and humeral head is compromised in a manner as to compress the tissues of the supraspinatus tendon and subacromial bursa.

During upper extremity elevation, from 30 to 60 degrees, a superior translation of the humerus occurs in relation to the glenoid fossa of 1-3mm.[54] However, this superior movement does not normally increase significantly above 60 degrees of elevation as the humerus remains centered on the glenoid.[55] Individuals experiencing symptoms

consistent with SAPS demonstrate altered kinematics during upper extremity movements. Ludewig and Cook[56] compared the shoulder kinematics of construction workers with shoulder pain to those without symptoms. Humeral and scapulae movement was measured with a three dimensional tracking system with markers attached to the skin. Workers with shoulder pain demonstrated significantly more anterior translation of the humerus during elevation. Further evidence that support such claims is advanced by Chen et al[55] who investigated the differences in humeral kinematics viewed by plain film radiography during elevation during different arm positions. The images were taken before and after an exercise fatigue protocol targeting the rotator cuff. A significant increase in humeral head superior migration was noted during all positions of elevation after the muscle fatigue exercises were performed. One can conclude from these findings that a dysfunctional rotator cuff may result in abnormal shoulder mechanics and potentially SAPS. Extrapolation of these findings may be challenging as the kinematics of fatigued healthy shoulders may differ from those experiencing SAPS. Hughes et al[57] measured compression in various areas of the shoulder joint using pressure transducers in cadavers. Pressure levels were greatest for compressing the supraspinatus between the humerus and acromion during shoulder movements including external rotation coupled with extension and elevation. Greatest levels were noted at the coracoacromial ligament during abduction and internal rotation. These results help determine potentially provocative positions of the glenohumeral joint but the role these positions have in the active process of SAPS is not definitive.

The scapulothoracic articulation plays a critical role for normal shoulder kinematics. In healthy subjects it has been found that the scapula moves, on average, 50

degrees in upward rotation, 30 degrees of posterior tilting and 24 degrees of external rotation during scapular plane elevation.[58] Abnormal scapular kinematics during glenohumeral elevation in individuals diagnosed with SAPS has been well established in multiple studies.[59-63] While several studies utilize a wide variety of methodologies, the consensus is that diminished scapular upward rotation, posterior tilting and external rotation occurs in patients with SAPS during upper extremity elevation.[64] Scapular elevation is required for elevation of the acromion during upper arm movements and the posterior tilt must occur for sufficient space between the humeral head and anterior acromion. Any reduction in these scapular movements may result in a decreased subacromial space and potential for compression of the associated soft tissues.

Structural Causative Factors

Structural factors related to SAPS include the morphology of the acromion and coracoacromial ligament. A variety of acromion morphology measurements can be obtained using plain film radiograph imaging. The four common assessments of acromion morphology have been proposed as depicted in (Figure 2.8).[65-67]

Acromion slope and tilt are described according to Kitay et al[65] Slope is the curve angle of the acromion determined by a longitudinal axis from the posterior/inferior acromion straight through the anterior/superior aspect. Acromion tilt is described as the angle between the posterior/inferior acromion through the inferior coracoid process and the posterior/inferior acromion through the anterior/inferior acromion. Lateral acromion angle is described according to Banas et al[67] as the angle between the glenoid fossa and inferior/lateral acromion.

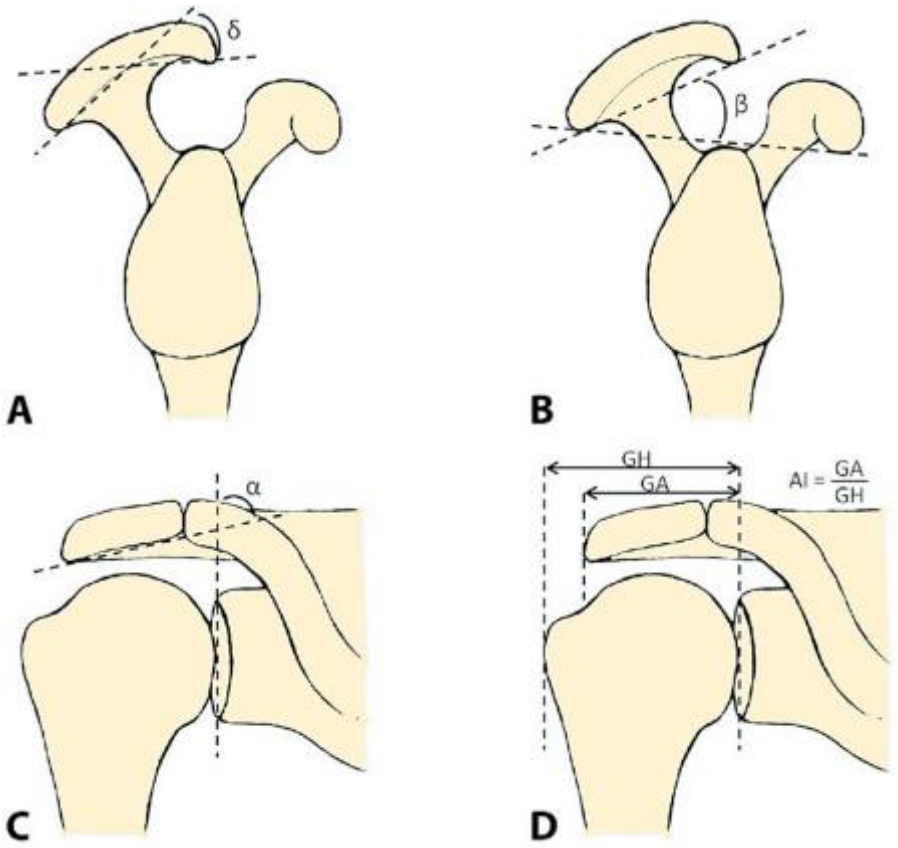


Figure 2.8 Structural parameters of acromion shape A) Anterior/posterior acromion slope B) Anterior/posterior acromion tilt C) Lateral acromion angle D) Acromion index (glenoid to acromion distance divided by glenoid to humerus distance © Nordic Orthopaedic Federation 2013 Balke et al.[68] permission of use granted per non-commercial use, distribution and reproduction.

The acromion index is described according to Nyffeler et al[66] This measurement can help determine the amount of lateral acromial over coverage and is measured as the glenoid to acromion distance divided by the glenoid to lateral humerus distance. Abnormal acromion shape is considered a risk factor for SAPS and rotator cuff tear if >.70.[68]

Hamid et al[69] examined the relationship between acromion shape, including slope angle and tilt, with rotator cuff disease. No association was found between an abnormal shape of the acromion and rotator cuff disease. However, these authors did determine

that a subacromial bone spur was strongly associated with a rotator cuff tear. Balke et al[68] examined the relationship between abnormalities in acromion shape between 50 participants in each of the following categories, full thickness supraspinatus tears, SAPS and a control without shoulder pain. Participants with a large lateral acromion angle and high acromion index were associated with having a higher prevalence of SAPS.

Coracoacromial ligament thickening has also been proposed as a structural factor related to SAPS but limited evidence exists to support this theory. Coracoacromial ligament thickening has been associated with rotator cuff tears as visualized with advanced imaging techniques[70] and in cadavers.[71, 72]

A decreased subacromial space due to structural factors may be associated with SAPS but surgical correction is not recommended in the routine treatment of this condition.[73] Subacromial decompression is a surgical procedure by which the undersurface of the acromion and coracoacromial ligament is partially excised and debrided. When comparing subacromial decompression to supervised exercise in the management of SAPS, evidence does not support long term benefit of one procedure over the other.[74-76] These results demonstrate the need to acknowledge that SAPS is a dynamic condition involving shoulder movement and to a lesser degree structural abnormalities.

Habitual and Activity Related Factors

Several risk factors related to activity and daily habits should be considered when discussing SAPS. Tangtrakulwanich and Kapkird[77] investigated the presence of risk factors between 111 participants with SAPS and 191 participants without SAPS as a control group. Participants completed activity questionnaires to determine presence of

risk factors and SAPS was confirmed with diagnostic injection. Smoking tobacco was found to increase risk of SAPS by 6.8 times compared to participants who did not smoke. Sleeping in the sidelying position was also found to elevate risk of SAPS by 3.7 times. It should be noted that while an association has been demonstrated between these activities and SAPS causality has not been established. Body mass index, age and sex were not associated with SAPS in this investigation.

Svendsen et al[78] examined the association between workers performing tasks in the overhead position and rotator cuff injury. The study sample consisted of 136 workers employed in physically demanding occupations. These individuals were examined with magnetic resonance imaging techniques to determine the exposure to response relationship. When the worker consistently performed tasks with the arm elevated above 90 degrees a 1.27 odds ratio that SAPS would develop was present at the 95% confidence interval (1.02-1.60).

Shoulder Internal Rotation Mobility Impairments

Posterior shoulder tightness (PST) can be associated with a loss of internal rotation and has been associated with thickening of the posterior component of the glenohumeral joint capsule.[79] Tyler et al[80] investigated range of motion loss in both patients with SAPS and those with no shoulder pain. Individuals with SAPS in the dominant arm were more likely to have PST compared to those with no shoulder pain. Moreover, when an individual was experiencing SAPS in the non-dominant arm a loss of both internal and external rotation was present. These findings suggest that PST is more closely related to SAPS in the dominant arm, which requires further investigation.

Multiple correlations between the presence of PST and motion loss in patients with shoulder pain exist for individuals involved in both athletic activity and work related activity.[79-83] These clinical observations provide insight into the prevalence of PST and its association with shoulder pain but the mechanisms behind this phenomenon have proven elusive. One study design to examine the roll of PST in shoulder kinematics includes observation of surgically induced PST on fresh cadavers. Harryman et al[84] examined humeral head translation differences in seven fresh cadaver shoulders. After surgically induced PST was created an increase in anterior translation was noted with flexion and horizontal adduction. Moreover, this increased movement occurred earlier in the range of motion. Muraki et al[85] investigated contact pressure in the subacromial space, in 9 fresh cadavers, before and after inducing posterior capsule tightness. Contact pressures were recorded for all shoulder motions. Posterior capsule tightness demonstrated the greatest increase in contact pressure at the lesser tuberosity of the humerus. These findings suggest that the critical structures involved in SAPS may not be necessarily associated with posterior capsule tightness but further investigation is needed. Several limitations should be considered concerning this study design, including the surgically induced posterior capsule tightness on cadavers. It is plausible that PST could result in SAPS but a cause and effect relationship has not been established.[86-88]

Shoulder Muscle Strength Imbalances

One factor thought to be associated with shoulder injury is a muscular strength imbalance. Two predominant theories exist related to the glenohumeral joint which includes the ratio of shoulder abductor to external rotator and internal to external rotator muscle strength. The deltoid muscle, a shoulder abductor, provides an upward directed

force upon shoulder elevation and must be counterbalanced by a properly functioning rotator cuff.[89] During active abduction the rotator cuff provides a compressive action on the humeral head into the glenoid fossa increasing stability of the joint.[90] This synchronous muscular balance is termed the deltoid to rotator cuff force couple and is a critical component to healthy shoulder elevation. This force couple can be altered when rotator cuff strength is impaired. The resultant imbalance of weaker rotator cuff to stronger deltoid results in a superior migration of the humeral head, leading to compression between the humeral head and acromion.[91, 92]

Deutsch et al[92] compared the humeral head position of painful and non-painful shoulders in different positions of abduction. Plain film radiographs demonstrated increased superior movement of the humeral head in participants with either SAPS or rotator cuff tear. Moreover, when comparing humeral head position in those with SAPS compared to complete rotator cuff tear, both groups had an equal amount of superior humerus movement. No changes in humeral head position were noted in those without shoulder pain. These findings demonstrate that the presence of pain or causative muscle weakness can be just as detrimental to shoulder kinematics as an abnormal functioning and torn supraspinatus tendon.

Clisby et al[10] investigated the effects of external loads, during upper extremity elevation, on shoulder muscle activation in patients with SAPS. Higher loads were found to preferentially activate the middle deltoid over the infraspinatus compared to lower levels of external load. These results can infer that when increased loads are elevated, by the upper extremity, the contribution to increased humeral head superior migration may increase. These findings are consistent with Terrier et al[93] who investigated the effects of

supraspinatus deficiency on humeral head translation with a three dimensional computer model. In the aforementioned investigation an increase in upward migration 1.6 times greater than normal occurred when the model accounted for a deficient supraspinatus compared to a fully functioning rotator cuff.

The external to internal rotator muscle balance is another important strength ratio in the shoulder. The stronger internal rotators are comprised of pectoralis major, latissimus dorsi and subscapularis. The weaker external rotators include supraspinatus, infraspinatus and teres minor. The strength imbalance between these two groups of muscles can create abnormal biomechanics during shoulder function. This abnormal ratio of rotator cuff strength has been associated with SAPS and shoulder injury.[13, 42, 94-98] Additionally, many activities tend to precipitate a bias for this abnormal ratio of rotator cuff strength. Kolber et al[11] found abnormal rotator cuff ratios in recreational weight training participants compared to a control group that did not participate in weight training. Several sports tend to favor internal rotation strength and thus magnify any muscle imbalance between the strong internal rotators and weak external rotators. This unfavorable rotator cuff strength ratio has been demonstrated in baseball pitchers,[94-96] swimmers,[97] and female badminton players.[99]

The abnormal ratio of internal rotation strength to external rotation strength can also be predictive of shoulder injury. Eduard et al[41] found that in team handball players a higher injury risk of shoulder injury was present when a weak external rotator to strong internal rotator muscle imbalance exists. Forthomme et al[42] examined isokinetic strength profiles of volleyball players to determine risk factors for injury. Increased eccentric

rotator cuff strength (internal and external rotators) was found to be the greatest protective factor in reducing shoulder injury risk.[42]

Normative values of internal to external rotation strength have been described in the literature with varying results.[100] Hughes et al[100] investigated the strength ratios of several shoulder motions including internal and external rotation. Participants ranging in age from 20 to 78 years old were examined for isometric strength ratios in different shoulder positions. Internal to external strength ratios were reported at 0.60 with the arm in the position of 15 degrees of abduction and 0.73 with the arm in the position of 90 degrees of abduction. Findings in this study include the positive relationship of age to the strength ratio. Older participants had a stronger ratio of external to internal rotation strength when tested at 90 degrees of shoulder abduction. This may be due to the loss of internal rotation strength in the test position, possibly associated with age. Normative strength ratios of internal to external ratios have also been reported with isokinetic testing. Ivey et al[101] found a 3:2 ratio of internal to external rotation strength with isokinetic testing on individuals with no shoulder pain. Warner et al[98] found a 30% greater level of internal rotation strength compared to external rotation in asymptomatic individuals.

Another area of interest pertaining to shoulder function is the muscular control of the scapulothoracic articulation. Prior research has identified scapular muscular activation and strength imbalances to be associated with SAPS.[102-105] Impaired motor control of the scapula could alter the base from which the glenohumeral joint functions resulting in SAPS.[106] Moreover, normal scapular kinematics provide sufficient space between the acromion and head of humerus during functional upper extremity

movements. The ability of the scapula to upwardly rotate and retract during arm movement is largely dependent upon the function of the scapular muscles. It is not clear whether scapular strength impairments are the cause or a result of SAPS but significant associations exist.[107]

Smith et al[102] investigated the ratio of upper versus lower trapezius muscle fiber activation with surface electromyography (EMG). Sixteen subjects with SAPS were compared to 32 asymptomatic subjects. A significant difference was found with greater upper trapezius activation compared to lower trapezius in subjects with SAPS compared to controls. Cools et al[104] compared activation of the upper, middle and lower trapezius, in subjects with SAPS and those without shoulder pain, during isokinetic testing for shoulder external rotation and abduction. A significant increase for upper trapezius activation was found with shoulder movements and a decrease in lower trapezius activation during abduction and middle trapezius activation during external rotation. Phadke and Ludewig[108] compared scapular muscle activation in subjects both with and without SAPS during an arm elevation activity. Earlier activation of the upper trapezius was demonstrated in those participants with SAPS compared to the control group.

These investigations demonstrate the need for rehabilitation of an individual with SAPS to address the motor control impairments of the muscles controlling the scapulae. Rehabilitation should include improving motor control and activation of the lower trapezius and middle trapezius while decreasing the emphasis of the upper trapezius.

EXERCISES FOR KEY SHOULDER MUSCLES

The prime muscles of the shoulder complex that play a critical role in healthy upper extremity function are the shoulder external rotators and scapular muscles creating

retraction, posterior tilt and upward rotation. Knowledge pertaining to the function of these muscles is of primary concern for clinicians rehabilitating individuals with SAPS. Clinicians must be aware of the movement each muscle is responsible for, the best methods to create maximal volitional contractions of muscles with exercise and the effects that these muscles have on joint biomechanics. Through EMG, isokinetic, isotonic and isometric research data clinicians can confidently prescribe specific exercises to maximize clinical benefit. In some cases high EMG activity provides a negative effect to the rehabilitation process as muscles that are responsible for aberrant motion could be recruited in excess. The purpose of the following section is to review each muscle from an anatomical, biomechanical and functional perspective.

Infraspinatus

The infraspinatus muscle functions as an external rotator. As an external rotator the infraspinatus muscle plays an integral role in normal shoulder function. The importance of this function is magnified in patients with SAPS who have been found to lack infraspinatus activation between 60 and 90 degrees of elevation.[109] This decreased infraspinatus function in patients with SAPS should be addressed with specific exercise selection. Selective activation of the infraspinatus muscle can best be achieved by performing the side lying wiper exercise (SWE).[110] SWE has been found to maximize infraspinatus muscle activity and concurrently provide minimal recruitment to the deltoid and middle trapezius muscles.[110] To perform the SWE a side lying position is assumed with the humerus flexed to ninety degrees and internally rotated. The individual moves the humerus into external rotation while the humerus rests on the opposite arm (Figure

2.9). Drawbacks to performing the SWE are the position of impingement that is created towards the later phase of the lowering motion.

Figure 2.9 Sidelying wiper exercise start/finish and middle range (picture to right) positions

With the humerus flexed to 90 degrees, 45 degrees of internal rotation will reproduce the position of the Hawkins-Kennedy test.[51] This position could approximate the greater tubercle of the humeral head into the undersurface of the acromion leading to shoulder pain. Therefore the SWE should be performed in a limited range of motion for the eccentric phase or not performed in individuals presenting with SAPS. An alternative exercise, also demonstrating high EMG activity of the infraspinatus is side lying (Figure 2.10) or standing (Figure 2.11) external rotation.[111]

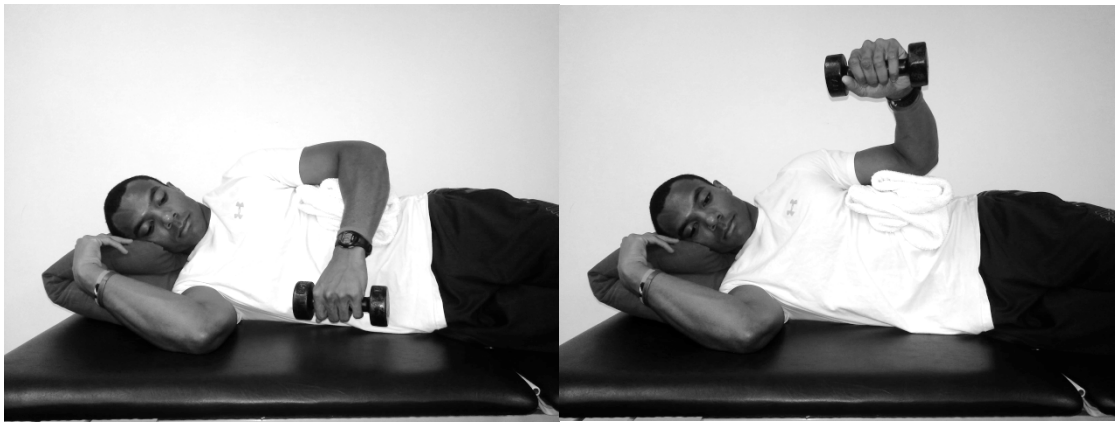


Figure 2.10 Sidelying external rotation exercise start/finish and middle range positions

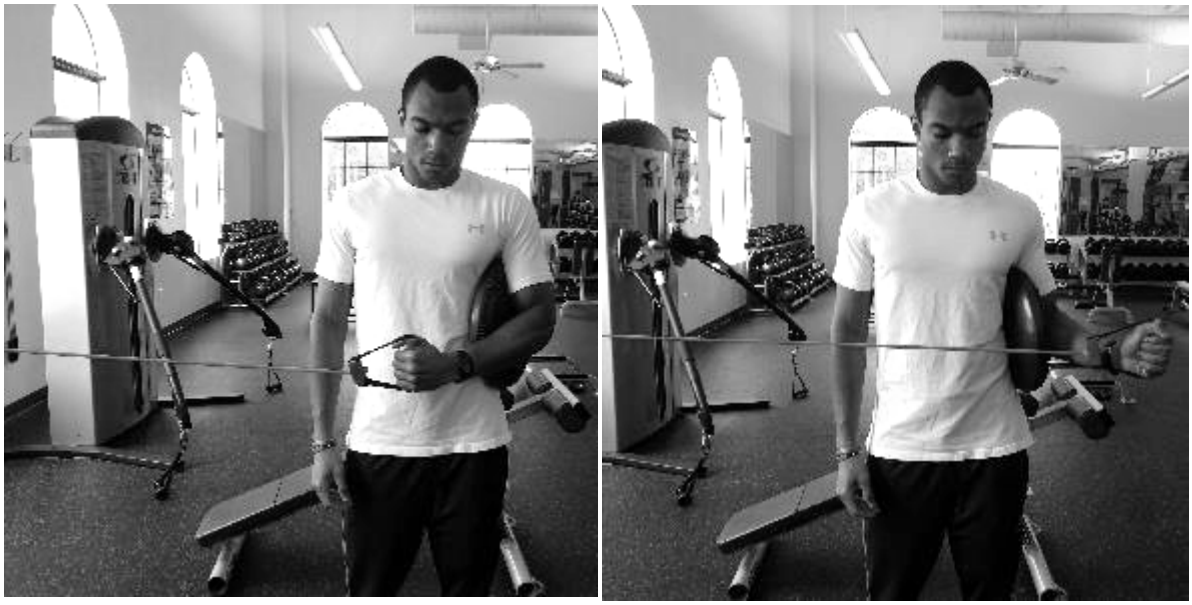


Figure 2.11 Standing external rotation exercise start/finish and middle range positions

These exercises are performed with the humerus in a neutral position. A towel roll is placed between the humerus and trunk for shoulder support while the shoulder performs an external rotation movement. The use of a towel roll between the humerus and trunk

has been described as an important component for proper shoulder external rotation exercise technique.[112] One benefit of using the towel roll is the contraction of the adductors while performing the external rotation movement can facilitate an inferior glide of the humeral head, increasing the subacromial space.[113] These shoulder external rotation exercises could be favorable because they do not demonstrate the potential for detrimental stress on the shoulder joint or soft tissues.

Supraspinatus

The supraspinatus muscle functions as a shoulder abductor and external rotator.[114] Significant debate has occurred regarding the best position to obtain maximal strength of the supraspinatus comparing the full can with thumb up, (Figure 2.12) versus empty can with thumb down, (Figure 2.13) positions during scapular elevation.[115]

Figure 2.12 Full can thumb up exercise start/finish and middle range positions

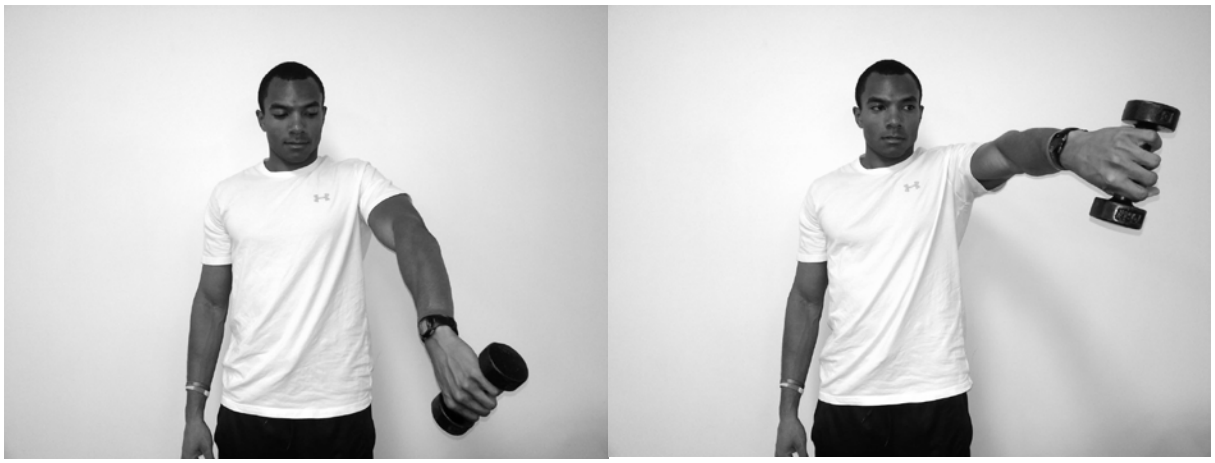


Figure 2.13 Empty can thumb down exercise start/finish and middle range positions

The full can position has been demonstrated in multiple investigations to provide an equal level of muscular activity, to the supraspinatus, compared to the empty can position.[116, 117] The limitation to the elevation exercise in the empty can position is that a greater amount of humeral force is directed superiorly, possibly resulting in an increased likelihood of subacromial impingement.[36] The full can exercise demonstrates significant levels of supraspinatus activity but the concomitant deltoid recruitment could potentially further exacerbate any abnormal deltoid to rotator cuff ratio. Therefore, the full can exercise may be deemed more appropriate compared to the empty can exercise for supraspinatus strengthening for individuals with SAPS.

Dark et al[118] investigated the EMG activity level of shoulder muscles during low, medium and high load external rotation movements with the humerus in 0 degrees of elevation (arm by the side position). The infraspinatus was recruited with the greatest percentage of maximum voluntary isometric contraction (MVIC) during the external rotation movement with the supraspinatus demonstrating significant levels of activity as

well. Supraspinatus activity increased significantly from 15% (3) to 51% (14) MVIC ($p<.001$) when comparing the low load versus high load movements. Infraspinatus MVIC increased from 40% (7) to 70% (14) MVIC ($p<.001$). The results of this investigation demonstrates the strong role the supraspinatus plays in the external rotation exercise with the arm by the side as well as the significant increase in supraspinatus muscle activity that can occur during a heavier loaded movement.

Stabilization of the humerus against the glenoid is another important function of the supraspinatus that can also be a beneficial result of external rotator training. Tardo et al[119] investigated the electromyographic activity of the shoulder muscles during an external rotation exercise at 90 degrees of abduction. The authors compared muscle activity with the shoulder supported, partially supported and unsupported. Results demonstrated that the supraspinatus plays a much stronger stabilization role with the humerus unsupported during the external rotation exercise at 90 degrees of abduction.

Trapezius

The trapezius contains muscle fibers that span different directions from the upper cervical spine to the mid thoracic spine. The lower fibers are responsible for upwardly rotating, depressing, posterior tilting and externally rotating the scapulae during arm elevation.[120] Ludewig et al[59] found the scapular movement of external rotation and posterior tilting increased the subacromial space therefore the lower trapezius should be considered as a critical muscle in relation to the management of SAPS. Exercises found to result in a high level of lower trapezius fiber activation are the prone row, prone horizontal abduction at 90 and 135 degrees of abduction with external rotation of the shoulder, and external rotation at 90 degrees of abduction in prone.[37] Exercises found to

maximize activation of the middle trapezius are the prone row and horizontal abduction with external rotation.[37]

Serratus Anterior

The serratus anterior muscle functions to protract and upwardly rotate the scapulae.[121] This muscle is critical in the rehabilitation of SAPS as it has been found to also posterior tilt and externally rotate the scapulae during arm elevation.[121] Exercises found to maximize serratus anterior muscle activity include the D1 flexion above 90 degrees of shoulder elevation,[122] scapular punches,[123] and the push up plus exercise.[124]

Rhomboids

The rhomboids are responsible for scapular retraction, downward rotation and elevation.[125] Standing shoulder external rotation with the humerus both at 0 and 90 degrees of abduction has been demonstrated to elicit a high amount of EMG activity.[123] Moreover, external rotation with a resistance band and the humerus at 90 degrees of abduction elicited a stronger contraction of the rhomboids compared to scapular rows at high, middle and low angles.[123]

EXERCISE FOR SUBACROMIAL PAIN SYNDROME

Exercise can be considered a standard of care, first line intervention for individuals experiencing SAPS. Variations of exercise interventions for SAPS have been demonstrated to be effective including supervised exercise, unsupervised home program exercise and multi-modal interventions by a physical therapist.[14] No significant, long term difference has been demonstrated between these different management approaches but efficacy of exercise over placebo treatment or no treatment has been established.[14] Moreover, when comparing exercise versus surgery for SAPS and rotator cuff

tendinopathy no significant difference exists in short term and long term follow up.[74, 126] While a variety of exercise protocols demonstrating effectiveness exist, a clearly defined best method of resisted exercise has yet to be established.

Exercise to Restore Shoulder Muscle Imbalance

Malliou et al[127] compared 3 training methods to investigate the best method to restore rotator cuff muscle imbalances. Each group performed several exercises training both the external and internal rotators with one using multi-joint shoulder exercises such as overhead press and reverse pull ups, a second group performing the same exercises with dumbbells and a third group performing isolated isokinetic rotator cuff training. The greatest improvement in external rotator to internal rotator muscle imbalance was found in the group performing the isolated rotator cuff exercises. Neiderbacht et al[128] investigated the effects of external rotation training in healthy female tennis players. Participants who underwent an external-rotation training program had a significant improvement in eccentric external rotator strength compared to concentric internal rotation strength. These findings suggest that isolated external rotator strengthening is indicated for individuals presenting with muscle imbalances of the rotator cuff.

Exercises to restore the muscle imbalance of the scapular muscles should maximize recruitment of the lower trapezius and serratus anterior while minimizing recruitment of the upper trapezius. Cools et al[129] compared 12 commonly performed scapula motor control movements to determine the best exercises to be performed for optimal lower trapezius to upper trapezius muscle recruitment. The four exercises found to best regain optimal scapular muscle imbalance were side lying external rotation, side

lying forward flexion, prone horizontal abduction with external rotation and prone shoulder extension.

ECCENTRIC TRAINING FOR SHOULDER PAIN

Shoulder eccentric training as an intervention in the management of SAPS has been examined by five clinical trials.[15, 16, 23-25] These investigations have utilized a variety of training protocols, specific exercises, doses, experimental and non-experimental methodology as described in (Table 2.2). The following section describes each investigation in detail, the limitations and conclusions that can be drawn from the results.

Bernhardsson et al[23] recruited 11 participants, five males and six females, with SAPS from two different primary care medical clinics in Sweden. Mean participant symptom duration was 12 months and the average patient age was 54 years. Participants were included in this study if they had 3 of the following 5 tests positive. Neer Impingement, Hawkins-Kennedy, Jobe test, painful arc of abduction between 60 to 120 degrees and tender to palpation on the supraspinatus or infraspinatus insertions. Participants were then verified to have SAPS with diagnostic ultrasound examination but no details pertaining to the performance, interpretation or validity of this test was provided. The design of this study was quasi experimental with the patients acting as their own control group. Outcome measures were taken at baseline and again three weeks later after no intervention. This control phase data was then compared to outcomes after 12 weeks of eccentric training. It should be noted that the sample size was small (N=11) and two patients were lost to follow up in this investigation. The authors reported one participant dropping out of study during week three due to excessive

pain and another during week 8 because of an acute trauma. Pain and function were measured using the visual analog scale, patient specific scale, constant shoulder score and Western Ontario Rotator Cuff Index (WORC). As a component of the constant shoulder score for shoulder function isometric strength was tested, using a hand held dynamometer, in the standing position for abduction at 90 degrees in the plane of the scapulae with the elbow extended and forearm pronated. Participants were seen for an average 4.6 visits and instructed to perform a home exercise program for three sets of 15, two times per day. Exercises performed included a warm up of shoulder shrugs and retraction, upper trapezius stretch and sidelying infraspinatus and supraspinatus eccentric exercises with dumbbells. Load was progressed based on symptom reproduction with participants instructed to increase load until symptoms were present not exceeding a 5 on the 0-10 numeric pain rating scale. Patients were followed for compliance, two times per week, either in the clinic or via telephone and were instructed to keep a log for recording exercise adherence. Results identified significantly improved pain with a median reduction of 30 points, out of 100, on the visual analog scale and improved function at 9 points, out of 30, on the patient specific functional scale ($p=0.008$) and improved WORC from 51% to 71% ($P=0.021$). The Bernhardsson et al[23] study is limited by the small sample size and single arm design. The first 3 weeks, no intervention control phase, of this investigation resulted in a trend in pain reduction for 6 of the 10 subjects included in the final data analysis. It is unknown whether these subjects would have continued to experience reduced pain without the addition of eccentric training as an intervention.

Camargo et al[24] in a case series, investigated the effect of twice a week eccentric exercises to the shoulder abductors on 20 subjects with SAPS. Isokinetic eccentric

resistance training was utilized with no other interventions or exercises performed by the participants. After 6 weeks of training the results demonstrated significant improvements in pain as measured with the visual analog scale ($p<0.05$), function using the disabilities of the arm shoulder and hand (DASH) ($p<0.05$) and abduction strength measured isokinetically ($p<0.05$). The mean improvement in DASH score from initial assessment (18.78) to final assessment (5.49) 6 weeks post completion of the intervention program demonstrated a moderate effect size ($p<0.05$). Jonsson et al[25] in a case series, studied eccentric loading of the supraspinatus in 9 patients with chronic shoulder impingement syndrome on a waiting list for shoulder surgery. Exercises were performed twice a day, every day for 12 weeks. In five of the patients significant improvement in pain occurred with a mean improvement of 44 points ($p<0.05$). Functional gains were found with a mean Constant Score improvement of 15 points ($p<0.05$). Also of both clinical and economic significance was all five patients canceling their scheduled surgical procedures. The exercise chosen by Jonsson et al[25] was performed using a pulley system in order for the heavy load to be assisted overhead with the contralateral upper extremity. This movement has some significant limitations due to the inherent reproduction of the empty can impingement testing position with shoulder abduction and internal rotation.[5] Moreover, equal supraspinatus EMG activity has been demonstrated with both the empty can and full can positions for this exercise negating any potential benefit for the empty can exercise.[116] Shoulder elevation in the plane of the scapulae with the internally rotated position might not be the best option for many patients with SAPS due to the potential development of shoulder pathology inherent in the exercise.

While all three of these studies demonstrated favorable outcomes, the single group design creates threats to internal validity making interpretation of these results challenging. Two randomized controlled trials have investigated the outcomes of eccentric training for SAPS.[15, 16] Holmgren et al[16] compared the effect of eccentric training, to the shoulder external rotators and abductors, combined with scapulae exercises and manual therapy to a control group of non-specific unloaded exercises in 97 subjects with shoulder impingement syndrome. Exercises for the experimental group included side-lying external rotation and standing abduction performed eccentrically and additional isotonic exercises targeting the external rotators, serratus anterior and periscapular muscles. Control exercises consisted of active range of motion exercises without resistance including shoulder abduction, flexion, scapular retraction, cervical spine retraction and stretching to the upper trapezius and pectoralis major. Upon conclusion of 12 weeks of daily exercises the experimental group had significantly improved in shoulder function, using the Constant shoulder function score and DASH, pain levels measured by the visual analog scale (95% confidence interval) and global change compared to the control group ($p<0.001$). At one year follow up need for surgery was significantly lower ($p<0.001$) in the experimental group (24%) compared to the control group (63%). The multimodal exercises and manual therapy techniques utilized in the experimental group make drawing specific conclusions related to the efficacy of eccentric training alone challenging. Additionally, all participants received corticosteroid injection prior to beginning the exercise programs that potentially could pose a threat to external validity.

In a randomized clinical trial, Maenhout et al[15] investigated the effects of shoulder abductor eccentric training on 61 subjects with SAPS. The control group performed traditional internal and external rotation strengthening exercises with a resistance band for three sets of 10, one time per day, for 12 weeks. The experimental group performed these same exercises with the addition of a heavy load shoulder abduction eccentric exercise for three sets of 15 twice daily. Both the eccentric training and standard shoulder exercise groups demonstrated significant improvements in isometric strength for abduction, internal rotation and external rotation at 12 weeks ($P<0.001$). Moreover, both groups demonstrated improved pain and functional ability at 12 weeks ($P<0.001$). One limitation of this study is that the shoulder abductors were the primary focus of eccentric training which could have further facilitated an abnormal ratio of deltoid to rotator cuff strength, perpetuating any existing pathological shoulder joint mechanics. It has been suggested that training the shoulder with an emphasis on abduction further facilitates the abnormal ratio of deltoid to rotator cuff strength, thereby leading to SAPS.[37] Another limitation present was that the examining researcher was not blinded to participant group allocation.

Table 2.2 Eccentric Training for Shoulder Impingement Research

Investigation	Bernhardsson 2011	Carmargo 2012	Holmgren 2012 Hallgren 2014	Jonsson 2006	Maenhout 2012
Subjects	N=10, one intention to treat	N=20	N=97	N=9	N=61
Symptom duration	12 (9.1) months	2.8 (2.9) years	Median 24(6-120) 12 (6-156)	41 months	At least 3 months
Age (yr)	54 (8.6)	34.2 (10.2)	52(9)/52(8)	54	40.2 (12.9) 39.4 (13.1)

Sampling	Purposive: 2 primary care clinics (Sweden)	Purposive: PT wait list (Brazil)	Purposive: orthopaedic office (Sweden)	Purposive: surgery wait list (Sweden)	Purposive: orthopaedic office (Belgium)
Inclusion criteria	-Age 18-65 -VAS >30mm -3/5 Neer impingement, Hawkins-Kennedy (HK), Jobe test, painful arc 60-120 abduction Tender to palpation supraspinatus or infraspinatus insertion -ultrasound confirmation, poorly described	-Diagnosed by PT and confirmed by orthopaedic surgeon -3/5 Neer, HK, Jobe, Speed, Gerber tests -All pts had active abduction painful, ultrasound confirmation and rule out tears	-Age 30-65 -SAPS diagnosis by ortho surgeon, wait list for surgery. -Shoulder pain of 6 month duration, not responding to conservative (exercise) treatment -3/5 Neer painful arc sign, Jobe test, HK, Patte test, Neer impingement -ultrasound confirmation did include some partial and full tears	-Neer, HK, -ultrasound confirmation	-Age over 18 -anterolateral shoulder pain -painful arc -2/3 Neer, HK, Jobe -2/4 resistance full can, abduction 90, abduction 0, ER/IR
Design	Single arm, patient is own control with 3 weeks no intervention	Single arm, patient is own control with 4 weeks no intervention	Random allocation, 2 groups (specific exercise vs unspecific (control), blinded examiner,	Single arm with no control	Random allocation, 2 groups (traditional and eccentric vs traditional) -no blinding
Dependent variables	-VAS -Patient-specific functional scale For 3 activities that the person participated in 10 pts x 3 =0-30 scale -Constant score -Western Ontario rotator cuff index -isometric strength abduction standing 90 deg	-DASH -isokinetic abduction in scapular plane for acceleration time, peak torque and total work	-VAS -Constant score -DASH -European quality of life -5 point GROC and continued desire for surgery post exercise -Decision to undergo sub-acromial decompression one year post intervention	-VAS -Constant score	-Improvement 5 point Likert -Shoulder pain and disability index -isometric strength, abduction scapular plane 0, 45, 90 IR/ER neutral

	in plane of scapulae, elbow extended forearm pronated				
Frequency and dose	-Mean total visits 4.6 (1.4) - 3 sets of 15 twice a day -12 weeks every day home exercise program (HEP) -load increased symptoms (5/10 VAS)	-12 total visits, 2x week for 6 weeks -no HEP	7 visits, 1x a week for first 2 weeks, every other week for 10 weeks -HEP every day x2 first 8 weeks then 1x per day for 4 weeks -3 sets of 15 -load increased (5/10 VAS) -if pain persisted > 1 day subject decreased load -Manual therapy in clinic for post capsule and pectoralis stretch. -control: non specific not progressed abduction, elevation, retraction of cervical spine, shoulder stretch	HEP 3x15 twice a day, every day for 12 weeks -load increased to create pain	-PT session 1x week for 6 weeks, 2x week for 6 weeks. -all 12 weeks HEP
Intervention	5 exercises, shoulder shrug, scapular retraction (warm up) upper trapezius stretch, side lying supraspinatus and infraspinatus with dumbbell	Isokinetic eccentric training to the shoulder abductors 3 x 10	All received corticosteroid injection, 2 weeks later exercise prescription, all had posture and condition education. -2 eccentric full can with pulley first 8 weeks, concentric/eccentric last 4 weeks,	Eccentric empty can exercise with pulley for concentric portion	Traditional (control) IR and ER with resistance band, 2x per day, 3 sets of 10, 2 sec con, iso, ecc -Load based on no more pain than at rest increased load when pain was reduced

			Sidelying ER eccentric first 8 weeks, concentric/eccentric last 4 weeks. - concentric/eccentric scap retraction Week 0-12 theraband band, supine punch first 8 weeks, push up plus last 4, bilateral ER with thera band week 5-8, then at 90 degrees of flexion ER last 4 Post shoulder stretch Week 0-12		-all patients received PT treatment including patient education, manual therapy, scapulothoracic mobilization, scapula setting, posture correction - Experimental performed traditional and 3x15 2x per day eccentric full can -painful but no more than 5 on VAS. Pain after exercise not exceeding 5 and subsides following morning -load increased when pain was reduced

Results	Pre/Post 12 weeks: Shoulder Constant Score improvement from 44 to 69 points. WORC 51% to 71%. Pain VAS 57 to 29. PSFS 13 to 25.	Pre/Post 6 weeks: DASH 18.78 to 5.49 Isokinetic strength peak torque Nm 3.75 improvement.	Pre/Post 12 weeks: Constant Score improvement from 48.5 to 72.5. DASH 30 to 16. VAS rest 15 to 10 VAS activity 61 to 25 VAS night 46 to 15 Decision to undergo surgery 63% compared to only 24% of control group.	Pre/Post 12 weeks: Constant Score improved for those satisfied 65 to 80. VAS 62 to 18.	Pre/Post 12 weeks: SPADI 42 to 17. Isometric strength 90 degrees abduction (newtons) 64.7 to 78.0.

Abbreviation legend: Visual Analog Scale (VAS), Hawkins Kennedy test (HK), Physical Therapist (PT), External rotation (ER), Internal rotation (IR), Disability of the Arm Shoulder and Hand outcome measure (DASH), Patient specific Functional Scale (PSFS), Shoulder Pain and Disability Index (SPADI), Home exercise program (HEP).

SUMMARY

SAPS is a common shoulder disorder often associated with supraspinatus tendinopathy due to compression in the space between the head of the humerus and the undersurface of the acromion. This mechanical compression is thought to be caused by impaired scapulothoracic and glenohumeral biomechanics that can result from muscle imbalances and motor control impairments. The most common muscle imbalances associated with SAPS are the deltoid versus rotator cuff and external versus internal shoulder rotators.[96, 109] Exercise protocols using eccentric training have been found to benefit patients with SAPS but further study is indicated due to the paucity of quality investigations.[14] Identifying the efficacy of specific protocols can provide direction for clinicians when prescribing exercises for patients with SAPS. The results of this project

will contribute to the evidence base for clinical decision making related to interventions for individuals with SAPS. Moreover, the results of this investigation can be compared to those of prior studies examining eccentric and traditional exercise interventions for patients with SAPS, to further develop the knowledge of how to best manage this condition. Individuals with SAPS would benefit from increased awareness of efficacious treatment options in the management of SAPS. It is the purpose of this study to determine if improved pain, range of motion, shoulder strength ratios and function occurs when participants with SAPS perform an eccentric training protocol for the shoulder external rotators compared to a general shoulder exercise program.

CHAPTER 3: METHODOLOGY

INTRODUCTION

This chapter outlines the methodology used to investigate the research questions and hypotheses of this dissertation project. Methods used to recruit participants and determine group assignment along with inclusion and exclusion criteria will be described. Data collection methods will be discussed, including the validity and reliability of selected measurements. This chapter will also describe the interventions, independent variables, and data analysis methods that was utilized in this study. This investigation was registered with the United States National Institutes of Health (clinicaltrials.gov identifier: NCT02153827)

RESEARCH QUESTIONS AND HYPOTHESES

This investigation evaluated differences between dependent variables (isometric strength values in kilograms (kgs.), strength ratios, pain free active range of motion (ROM), global rating of change (GROC), shoulder function and pain) for individuals with subacromial pain syndrome (SAPS) who underwent a shoulder eccentric training external rotator (ETER) protocol versus a general shoulder exercise protocol (GE). The following research hypotheses (H1-H6) were tested with this investigation.

Research Question #1 - Does ETER improve mean bodyweight adjusted shoulder external rotation strength in participants with SAPS?

Research Hypothesis #1 (H1) - A significant improvement in mean bodyweight adjusted shoulder external rotation strength exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #2 - Does ETER improve internal rotator to external rotator and shoulder abductor to external rotator isometric strength ratios in participants with SAPS?

Research Hypothesis #2 (H2) - A significant improvement in shoulder internal rotator to external rotator and shoulder abductor strength to external rotator strength ratios will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #3 - Does ETER improve self-reported pain and function in participants with SAPS?

Research Hypothesis #3 (H3) - A significant improvement in self-reported pain measured by the numeric pain rating scale and function measured by the Western Ontario Rotator Cuff Index (WORC) exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #4 – Does ETER improve AROM (abduction, flexion, external rotation, and internal rotation) in participants with SAPS?

Research Hypothesis #4 (H4) – A significant improvement in pain free AROM exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #5 - Does ETER improve upper extremity closed kinetic chain performance in participants with SAPS?

Research Hypothesis #5 (H5) - A significant improvement in upper extremity closed kinetic chain performance as measured by the upper extremity Y balance test exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #6 – Does ETER improve patient perceived global change of condition as measured by the GROC?

Research Hypothesis #6 (H6) – A significant improvement in global change measured by the GROC exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

RESEARCH DESIGN OVERVIEW

This investigation was a randomized controlled trial to determine the efficacy of eccentric training of the shoulder external rotators for individuals with SAPS. The purpose of this study was to determine if a significant difference exists between the dependent variables (strength ratios, range of motion, global rating of change, shoulder function and pain) and subjects with SAPS who undergo, the independent variable, ETER

versus a control group performing a general shoulder exercise protocol. The dependent variables investigated in this research project are listed below.

1. Mean bodyweight adjusted shoulder strength values (bodyweight in kilograms /strength in kilograms) for the shoulder external rotators.
2. Shoulder Strength Ratio in kilograms Internal Rotator/External Rotator (IR/ER) and Abductor/External Rotator (ABD/ER).
3. Shoulder Pain free active range of motion (AROM)
    a. Abduction
    b. Flexion
    c. External rotation
    d. Internal rotation
4. Shoulder Function
    a. Western Ontario Rotator Cuff Index (WORC)
    b. Upper Quarter Y-Balance Test (UQYB)
5. Shoulder Pain and change of condition
    a. Numeric Pain Rating Scale (NPRS)
    b. Global Rating of Change (GROC)

The dependent variables were compared between the ETER group versus a control group performing general shoulder exercises. Currently there is a paucity of scientific evidence to support the use of eccentric training of the shoulder external rotators for individuals with SAPS.

RECRUITMENT AND SELECTION OF PARTICIPANTS

Sample size was estimated using *a priori* power analysis based upon the 8% between group, functional outcome measure, difference reported by Holmgren et al.[16] After 12 weeks of eccentric training the positive experimental group change was reported as clinically meaningful for a successful outcome ($p<.001$).[16] This dissertation utilized the WORC which should be considered ordinal level data because an absolute zero score does not exist and meaningful fractions cannot be derived from this measurement tool. The non-parametric Mann Whitney U was used to compare between group differences by dividing *a priori* power analysis results by the asymptotic relative efficiency (ARE) of .955.[130] Statistical power was estimated using the G* Power 3 software application.[131] G Power is a commonly used power analysis program for *a priori* procedures in scientific research.[132] With an effect size of .36, significance level of $P<.05$, statistical power set at $P = 0.80$, and division by the ARE of .955, it was estimated that a total study sample size of 42 participants was needed for this dissertation.

An additional investigation, separate from this dissertation, will concurrently be conducted to measure long term (6 months) response to ETER. This supplementary investigation would require a total sample size of 68 in order to protect from attrition and make comparisons to long term follow up studies of eccentric training for individuals with SAPS.[15, 16, 26]

Participants were recruited through purposive sampling to the University of St. Augustine faculty clinic where the primary investigator is employed. Individuals with shoulder pain were made aware of the opportunity to participate in the investigation by publicly displayed flyers (Appendix A). Participants were then screened by the primary

investigator and informed of the opportunity to participate in the study. Internal review board (IRB) approval was obtained by Nova southeastern University (Appendix B), where the primary investigator is enrolled as a PhD student, and the University of St. Augustine (Appendix C) where data collection occurred. Participants were presented with the details of the investigation and asked to sign the Nova Southeastern University informed consent form (Appendix D) prior to enrollment in the investigation.

Inclusion Criteria

Inclusion criteria for participation in this investigation consisted of:

1. Presence of non-acute shoulder pain (greater than 3 months duration).
2. Three out of the 6 following tests positive, Neer impingement, Hawkins-Kennedy impingement, empty can test, resisted external rotation test, palpable tenderness at the insertion of the supraspinatus or infraspinatus, and painful arc from 60° to 120° during active abduction.
3. Age over 18 years old.
4. Sufficient ability to read English as required for completing questionnaires as evidenced by self report.

Exclusion Criteria

Exclusion criteria included:

1. Red flags noted in the patient's Medical Screening Questionnaire (MSQ) (Appendix E) (i.e. tumor, fracture, metabolic diseases, rheumatoid arthritis, osteoporosis, prolonged history of corticosteroid use)
2. Full thickness supraspinatus or infraspinatus tendon tear as determined by a positive drop arm test, lag sign or rent test.

3. Shoulder adhesive capsulitis as evidenced by a limitation in passive motion for all shoulder planes of movement.
4. Having an upper extremity amputation.
5. Individuals having a history of surgery to the cervical spine or involved upper extremity for a musculoskeletal, neurological or dermatological condition for which they received post-operative care during the time of data collection.
6. Pending legal action regarding their shoulder pain.
7. Inability to comply with treatment and follow up schedule.
8. Insufficient English language skills to complete all questionnaires as evidenced by self report.

INSTRUMENTATION

Data collection required the use of the following instruments: (1) the micro*FET2*© hand-held dynamometer (HHD) (Figure 3.1) and a (2) standard 12" plastic goniometer (Figure 3.2)

Figure 3.1 MicroFET2 hand-held dynamometer

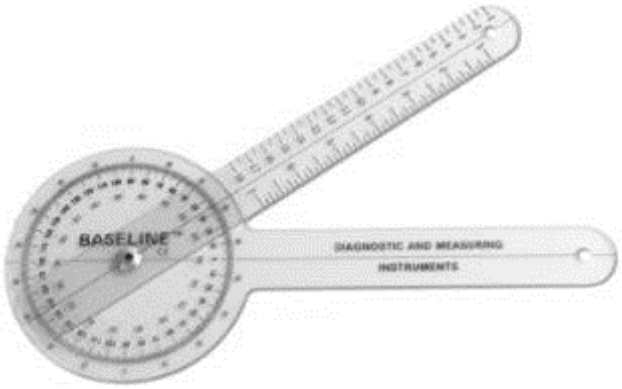


Figure 3.2 Standard 12" goniometer

Hand-Held Dynamometer

Strength values were measured using the micro*FET2*© HHD (Hoggan Health Industries, West Jordan, Utah). The HHD displays maximum force and duration of resistance testing on a digital liquid crystal display and according to the manufacturer the device is accurate within +/-2%. The HHD was calibrated by the manufacturer prior to use. Reliability of HHD has been established as good to excellent.[133] This investigation utilized shoulder internal and external rotation strength testing with a stabilization device (Figure 3.3) as described by Kolber et al.[134] Reliability of using the micro*FET2,* with a stabilization device, for measuring strength of the internal and external rotators of the shoulder in kilograms has been established as high with test-retest trials finding Intra class correlation coefficients of (3,1) = 0.971-0.972.

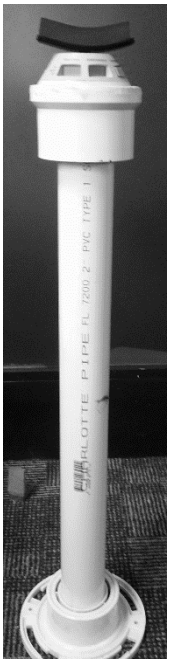


Figure 3.3 Stabilization device for isometric strength testing

Goniometry

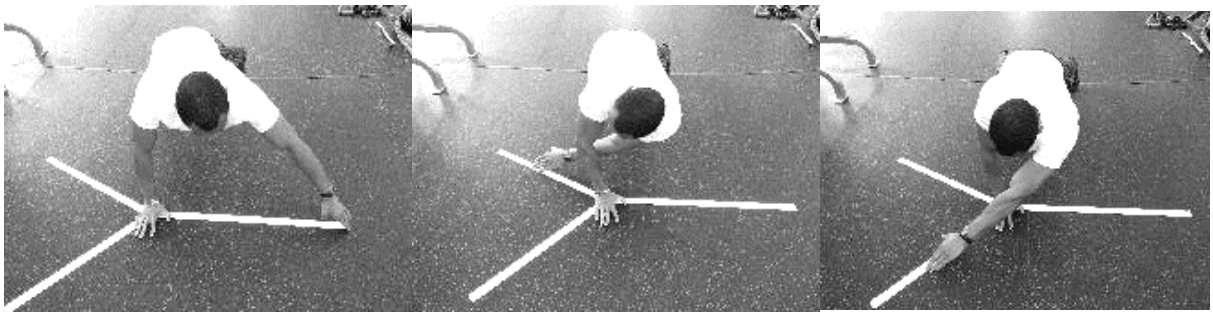
AROM was tested with a standard 12-inch goniometer and procedures outlined by Riddle et al[135] The reliability of goniometry for shoulder AROM has been previously established in the literature.[135-137] Muir et al[136] found AROM to be reliable with inter-rater standard error of measurement 6°to 9° and intra-rater standard error of measurement 4° to 7° for shoulder motions. Moreover, minimal clinical difference was calculated from 11° to 16° for one evaluator and 14° to 16° for multiple evaluators. Hayes et al[137] established good reliability for goniometry of flexion, abduction and external rotation in subjects with shoulder pain and dysfunction.

Upper Quarter Y-Balance Test (UQYB)

The UQYBT is a test to assess single arm stability and mobility in a closed chain position and was performed as described by Gorman et al.[138] The test was performed with the participant in the push-up position. A single arm was used to stabilize while the

other arm performed a reaching motion in three directions, relative to the participants free hand. The participant moved the free hand as far as possible in the medial, superolateral and inferolateral directions (Figure 3.4).

Figure 3.4 Upper Quarter Y Balance Test for medial, superolateral, and inferolateral directions



For each direction the length of reach was recorded in centimeters. The participant was allowed three practice trials and then three testing trials were performed to determine the distance sum. Limb length was taken into consideration and normalized by taking the total excursion distance and dividing it by 3 times the limb length. The UQYBT has been found to have excellent test-retest reliability at ICC = 0.90 and does not demonstrate a significant difference between testing dominant versus non-dominant upper extremities.[139] The UQYBT has not been examined for reliability specifically in the population of individuals diagnosed with SAPS and the testing protocol in this investigation differs from the referenced reliability study as floor tape is used rather than a plastic measurement apparatus. Therefore the measurement protocol used in this investigation underwent a pilot (N=18) test-retest reliability analysis. Reliability testing was conducted by instructing the participants in the testing protocol and allowing 4 practice sessions in each direction. Participants were then asked to rest for 3 minutes before repeating the test. A 1:3 work to rest ratio has been suggested as appropriate for

avoiding the effects of fatigue during a high intensity upper extremity closed chain test.[140] Three minutes was chosen as the rest time because the average total time to complete the UQYBT in all directions was 9 minutes. Participants were provided another 3 minute rest and performed the UQYBT a second time in order to compare results. In order to minimize bias the examiner was unable to view the data collection form and verbalized all test results to a research assistant who recorded the data.

SELF REPORT MEASURES

All subjects completed several commonly used instruments to assess pain, function and condition change in patients with shoulder pain.

Numeric Pain Rating Scale (NPRS)

The NPRS is an 11 point scale to quantify the intensity of pain with 0 quantifying no pain and 10 representing "worst imaginable pain" (Appendix F). The NPRS has been demonstrated to be a reliable and valid measure of pain intensity.[141-143] The minimal clinically important difference (MCID) of the NPRS has been demonstrated to range from 1-3 points by investigations of patients with shoulder pain.[143, 144]

Global Rating of Change (GROC)

The GROC was used as described by Jaeschke et al[145] (Appendix G). This outcome measure asks the participant to rate their overall perception of improvement. The GROC contains a 15 point scale ranging from -7 "a very great deal worse", to 0 "about the same", to +7 "a very great deal better". A change of (+3) points on the GROC has been described as the MCID and associated with meaningful improvement in a patients perceived quality of life.[145]

Western Ontario Rotator Cuff Index (WORC)

The WORC (Appendix H) is a condition specific, self-report measure, originally described by Kirkley et al.[146] This disease specific outcome measure contains 21 items in five categories including physical symptoms, sports/recreation, work, lifestyle and emotion. Each item is measured on a visual analog scale (VAS) in which the level of response is marked on a blank line anchored on each end ranging from "no difficulty" to "extreme difficulty." The total maximum raw score is 2100mm. Higher scores denote more severe disability with lower scores representing less severe disability. For simplicity the WORC score was converted to a percentage by inverting the raw score, dividing by 2100 and multiplying by 100. An example is provided as a raw score of 1850 – 2100 = 250 / 2100 = 11.9 x 100 = 11.9%. When a WORC score is converted to a percentage, lower scores identify more disability with a higher percentage correlating with higher quality of life and shoulder function. The WORC has demonstrated high internal consistency, reliability and good construct validity for individuals with SAPS.[147, 148] MCID has been reported for the WORC at 275mm or 13%.[149]

PROCEDURES

Individuals meeting the inclusion criteria were provided an informed consent form (Appendix D) approved by the Institutional Review Board for Nova Southeastern University and the University of St. Augustine for Health Sciences. Once informed consent was obtained participants were brought to a private examination room located on the campus of the University of St. Augustine to complete questionnaires and perform all tests and measures. The primary investigator conducted all examination procedures.

Questionnaires and Demographics

Participants who met the inclusion criteria and agreed to participate by signing the informed consent form were then provided with a demographic questionnaire (Appendix I). Following completion of the demographic questionnaire participants completed the MSQ (Appendix E), NPRS (Appendix F) and WORC (Appendix H).

Tests and Measurements

All participants received several tests and measures that are routinely performed in standard clinical practice. The three tests to exclude participants from the investigation were conducted first including the drop arm, lag sign and rent tests. A positive result from any of the aforementioned tests to identify tendon tears resulted in the participant being excluded from the study. If negative results were found with the three tendon tear tests the primary investigator then performed the Neer impingement, Hawkins-Kennedy impingement, empty can test, resisted external rotation test, palpable tenderness at the insertion of the supraspinatus or infraspinatus, and painful arc tests. The results of these tests were then recorded on a data collection sheet (Appendix K), the therapist providing treatment was blinded to any of the information collected on this sheet during the entire time of this investigation. The treating physical therapist is board certified in orthopaedic physical therapy with 8 years of experience and was trained in all aspects of the study protocol.

Strength Testing. All isometric strength measurements were performed consistent with the protocol described by Kolber et al.[11, 134] Participants were provided with instructions and illustrations for all testing positions prior to strength test performance. For all tests the participant assumed the seated position with the back

supported by an armless chair. A stabilization belt was applied to the participant's torso to restrict movement during the tests. Strength tests were performed in consecutive order for 3 repetitions, with an isometric hold time of approximately 6 seconds each. One practice session was performed prior to each test in order to familiarize the participant with the test and ensure proper form. Participants were instructed to push into the HHD at the command "ready set go" by the investigator and to gradually increase the amount of force effort over a 2 second time frame. The participant was instructed to provide their best effort for the duration of the 6 second total time. Peak force for each trial was recorded in pounds and then converted to kilograms by dividing the value in pounds by 2.2046. A 10 second rest between trials occurred and the highest strength value of the three trials, for each position, was recorded. If the third trial effort was greater than the first and second the participant was asked to perform a 4th trial due to the potential for best effort to have not yet been obtained. Mean peak strength levels were calculated and adjusted for bodyweight. Strength ratios were then determined by dividing the peak strength value of one measurement by the peak value from another measurement.

Internal Rotation/External Rotation. Internal and external rotation strength testing was performed according to the protocol described by Kolber et al.[134] This

protocol demonstrates high reliability with ICC (3,1) = 0.97 for within session trials.[134] The participant was seated in an armless chair with the spine supported against the chair back. The contralateral upper extremity rested on the lap and both feet flat on the floor. A stabilization device was used to provide immovable resistance to support the HHD in the same manner as described in prior investigations.[134] The arm was placed at 90 degrees of elbow flexion, neutral rotation and supported away from the body with an arm support at 30 degrees of abduction with a support wedge (Figure 3.5).

Figure 3.5 Support wedge to maintain arm at 30 degrees of abduction

A belt was placed around the participant's trunk and arm to prevent compensations into shoulder abduction during testing. The stabilization device was then placed against the wall while the HHD contacted the participant's dorsal aspect of the distal forearm for external rotation and volar aspect for internal rotation. The participant then applied pressure against the HHD in this position during testing (Figure 3.6).

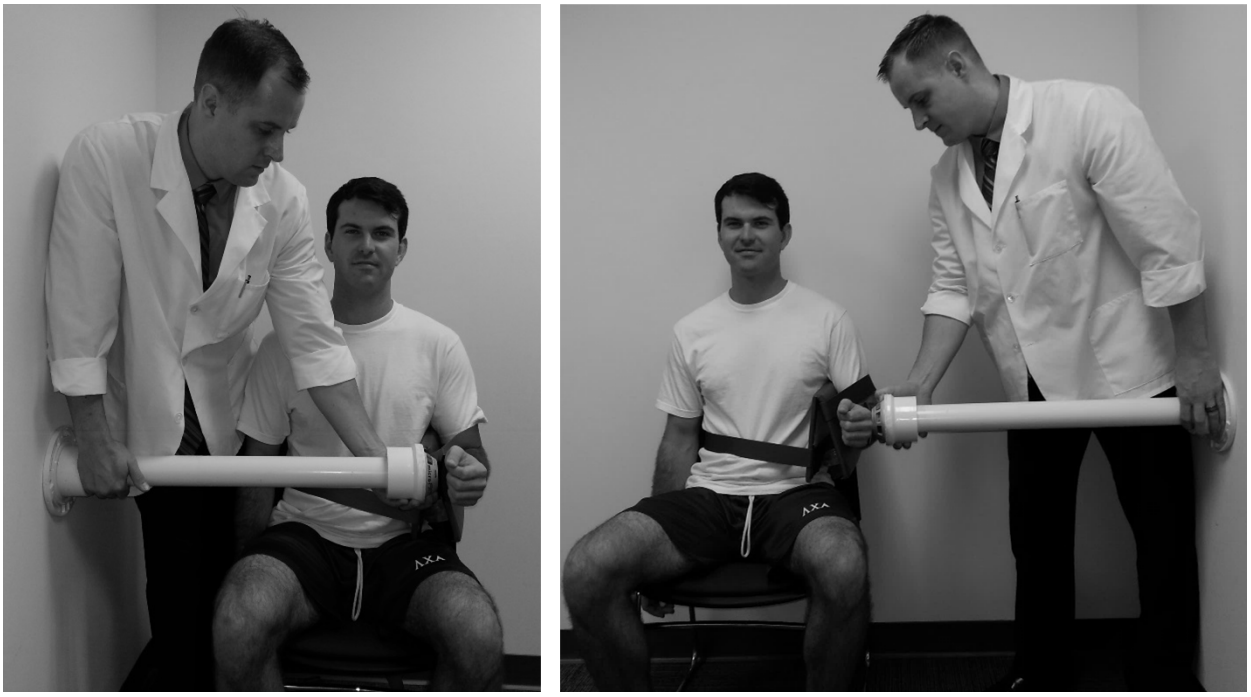


Figure 3.6 Internal rotation and external rotation strength testing positions

Abduction strength testing. The abductors were tested for isometric strength following the internal and external rotators. The abductors were tested in the same position, seated, secured to the back of an armless chair. The tested arm was elevated to 20 degrees in the scapular plane with the elbow bent to 90 degrees and forearm in a neutral position. The HHD was placed against the participant's lateral epicondyle of the distal humerus while the stabilization device was placed against the wall for support. The participant stabilized their body with the contralateral arm grasping the chair. The verbal

instruction was given to provide maximum pressure against the HHD in this position (Figure 3.7).

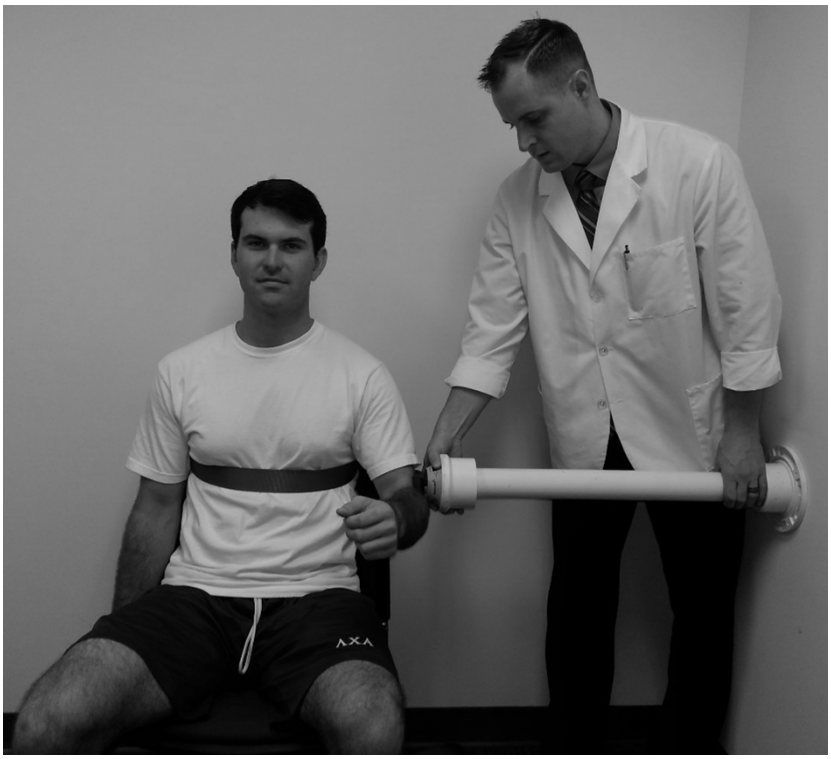


Figure 3.7 Abduction strength testing position

Active Range of Motion Testing. Following strength testing, AROM was assessed for the participant's painful shoulder. The motions that were tested include abduction, flexion, extension, external rotation and internal rotation. The procedures used for measuring shoulder AROM with the clear plastic universal goniometer were consistent with those described by Riddle et al.[135] Participants were verbally and passively guided in the movement to be performed for one repetition prior to testing. Participants were then asked to perform the movement actively until limited AROM or pain was

experienced. If the participant performed the movement with compensation or incorrect form they were provided verbal and tactile cues to correct the movement.

Flexion active range of motion. Flexion was measured with the participant seated in an armless chair with a belt around the torso and chair. The shoulder was actively elevated in the sagittal plane to the pain free end range without compensation. The goniometer axis was placed along the lateral humerus 2.5 cm inferior to the lateral process of the acromion. The movement arm aligned along the humerus pointed to the lateral epicondyle and the stationary arm was maintained in a position parallel to the trunk. (Figure 3.8)

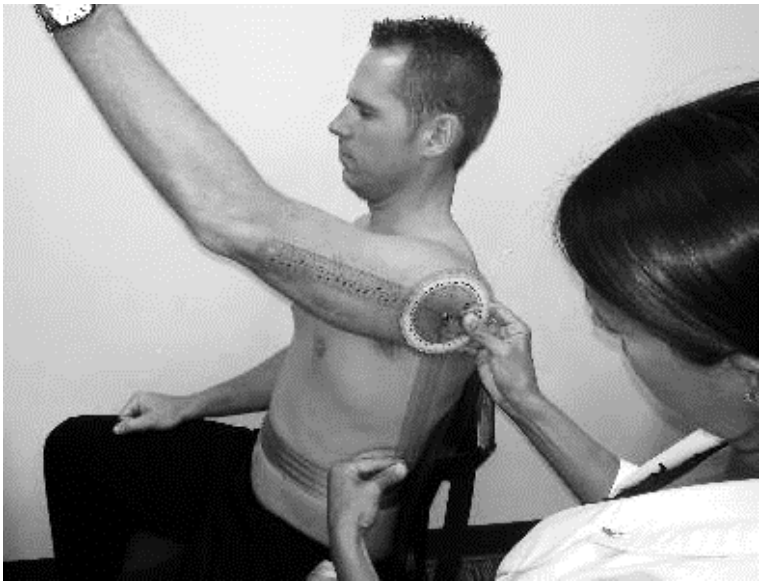


Figure 3.8 AROM flexion measurement position

Abduction active range of motion. Abduction was measured with the participant seated in an armless chair with a belt around the torso and chair. The participant actively elevated the arm in the coronal plane with the thumb pointed to the ceiling until pain or

limitation occurs. The goniometer axis was placed 1.3 cm inferior and lateral to the coracoid process with the stationary arm parallel to the sternum. The movement arm maintained a position parallel to the long axis of the humerus pointing toward the medial epicondyle (Figure 3.9).

Figure 3.9 AROM abduction measurement position

External rotation active range of motion. External rotation was tested in supine with the arm abducted to 90 degrees and elbow flexed to 90 degrees. The participant was instructed to maintain the back flat against the table. A towel roll was placed under the humerus to maintain a neutral humerus position level with the acromion process. The participant was asked to rotate the arm into external rotation until pain or limitation occurs. The axis of the goniometer was placed along the olecranon process of the ulna, with the movement arm aligned with the long axis of the ulna and the stationary arm perpendicular to the ceiling (Figure 3.10)

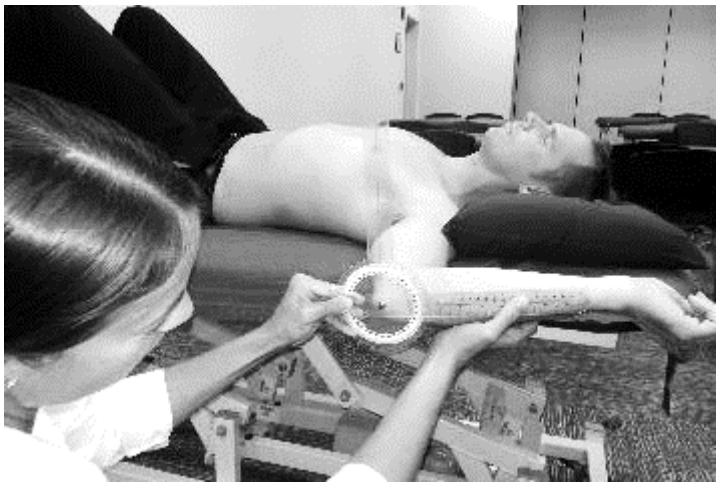


Figure 3.10 AROM external rotation measurement position

Internal rotation active range of motion. Internal rotation was measured in the prone position with the tested arm supported on the table at 90 degrees of abduction and 90 degrees of elbow flexion. A towel roll was used to support the humerus and ensure neutral alignment of the humerus relative to the trunk. The participant was asked to rotate the shoulder internally until pain or limitation occurs. The axis of the goniometer was placed on the olecranon process of the ulna, with the movement arm along the ulna and stationary arm perpendicular to the floor (Figure 3.11).

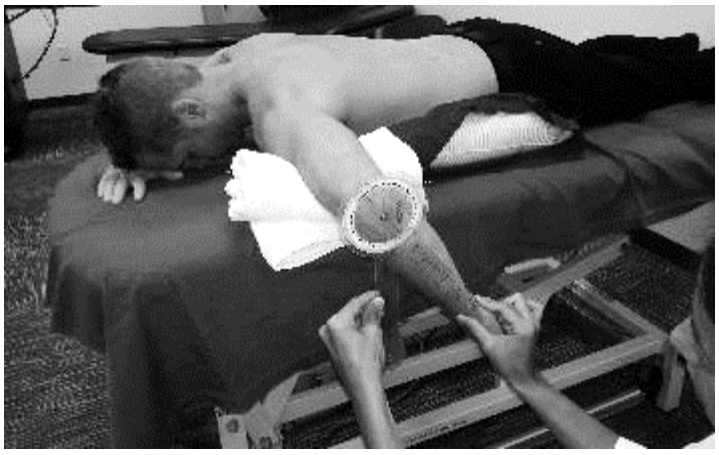


Figure 3.11 AROM internal rotation measurement position

Closed Chain Shoulder Function Testing. Following range of motion assessment the upper quarter Y balance test was performed. The participants arm length was assessed, in centimeters, in the standing position with the arm pointing straight down toward the floor. In order to obtain limb length, a tape measure was placed at the most lateral aspect of the acromion process and runs the length of the arm to the most distal point of the middle finger. The participant then assumed the push up position with the involved arm located on axis of the Y balance measuring tape. This arm was used to stabilize while the other arm performed the reaching motion in three directions. The participant moved the free hand as far as possible in the medial, superolateral and inferolateral directions. For each direction the length of reach was recorded in centimeters. The participant was allowed three practice trials and then three testing trials to determine the distance sum. Limb length was taken into consideration and normalized by taking the total excursion distance and dividing it by 3 times the limb length. Pilot reliability testing was performed for the UQYBT prior to the start of this investigation.

Participant Group Allocation

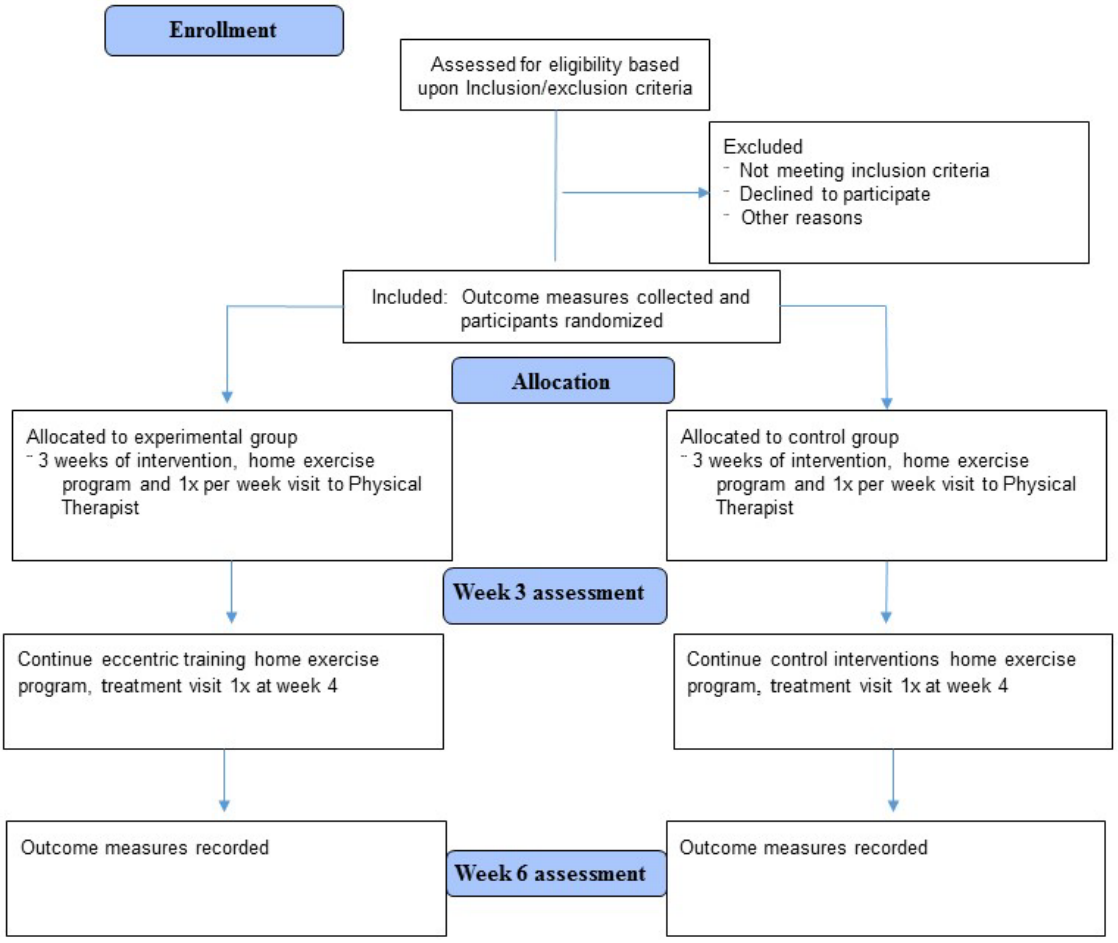
Upon completion of all questionnaires, physical examination and outcome measure data collection participants were then randomized to group assignment by a research assistant. A simple randomization strategy using a table of random numbers was utilized (Appendix J). The research assistant blindly placed a pencil on the page of random numbers until the pencil contacted a number. Contacting an even number allocated the participant into the experimental group and contacting an odd number into the control group. The group allocation of the participant was written down by the research assistant and sealed in a white opaque envelope. Only the research assistant providing the

intervention component of this investigation opened this envelope and was able to view the participant group allocation. The primary investigator (performing examination and deciding on participant inclusion) was blinded to this group assignment process and documentation.

Interventions

After the participant was provided with a group allocation status the treating physical therapist saw the patient for the first of four visits. The study design is outlined in (Figure 3.12)

Figure 3.12 Study flow diagram



All participants maintained an exercise diary (Appendix L) to record adherence to the home program. This exercise diary was submitted to the treating therapist, upon each scheduled visit, for verification of home exercise program adherence. Both the treatment and control group interventions are listed in (Table 3.1) and described below.

Table 3.1 Interventions for experimental and control group

Experimental Group Interventions		Control Group Interventions	
Exercise	Dose	Exercise	Dose
Eccentric external rotator with 3 second eccentric phase using resistance band	3 sets of 15 repetitions performed once daily	Active range of motion in standing with no resistance for flexion in the sagittal plane and abduction in the coronal plane	2 sets for 10 repetitions each once daily
Scapular retraction using resistance band	2 sets of 10 repetitions performed once daily	Scapular retraction using resistance band	2 sets of 10 repetitions once daily
Cross body horizontal adduction stretch in the standing position	3 repetitions, 30-45 seconds each performed once daily	Cross body horizontal adduction stretch in the standing position	3 repetitions, 30-45 seconds each once daily

Treatment Protocol: Experimental Group

Participants assigned to the experimental group were seen by the treating physical therapist for a total of 4 visits. Prior research on eccentric training for SAPS has demonstrated effectiveness after an average of 4.6 treatment visits to a physical therapist.[23] This exercise was performed in the standing position with a towel placed

between the elbow and trunk. The contralateral arm assisted in the concentric phase to achieve a position of external rotation and then the involved arm performed an isolated eccentric movement back to the starting position. Dosing consisted of 3 sets of 15 repetitions with a two minute rest between sets. The specific eccentric exercise was performed one time per day, seven days a week. The contralateral arm was removed and the resistance slowly returned to the starting position over a three second count consistent with prior investigations[16] (Figure 3.13).

Figure 3.13 Standing eccentric external rotation exercise

The eccentric exercise to be used in this study was performed without an increase in resting symptoms. The *TheraBand™ system of progressive resistance* (The Hygienic Corporation, Akron, OH) was used to provide resistance for the eccentric exercises. Load was increased by resistance band thickness (color coded) from Green, Blue, Black, Silver, Gold. Each participant was given a 4 foot length band and instructed in home program use. If a participant reported an increase in pain from rest while performing the exercise a reduced load was prescribed until the pain level was the same or less compared to resting pain levels.

In addition to the aforementioned eccentric exercise the experimental group performed an isotonic scapular retraction exercise. The exercise was performed with the participant standing with both hands grasping either end of the resistance band affixed to a stationary object located at waist height. The bands were pulled back by retracting both scapula to end range scapular adduction as pictured in (Figure 3.14)

Figure 3.14 Scapular retraction exercise

The resistance band used for this scapular retraction exercise was the same band as used in the eccentric external rotation exercise. The exercise was performed for 10 repetitions, once daily. This dosing strategy was based upon the investigation by Struyf et al,[150] detecting significant changes in pain and function from performing the dosing strategy of 10 repetitions of a scapular muscle exercise in participants with SAPS. In addition to the above scapular exercise, all participants performed a cross body horizontal adduction stretch (Figure 3.15).

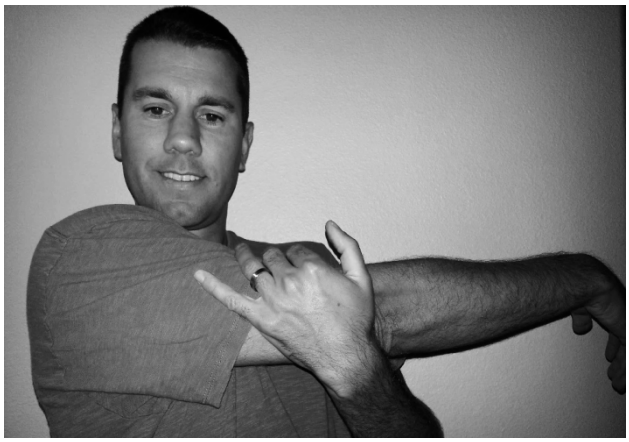


Figure 3.15 Cross body horizontal adduction stretch

The stretch was held for 3 repetitions of 30-45 seconds each. This stretching protocol and dosing strategy was used by Holmgren et al[16] with favorable results. The horizontal adduction cross body stretch has been proposed to target the posterior shoulder and can help prevent a loss of shoulder mobility potentially associated with eccentric shoulder exercises. Moreover, a loss of internal rotation shoulder mobility has been associated with SAPS and maintaining appropriate range of motion can be beneficial for shoulder health.[80]

All participants attended one session per week for 4 weeks and then a final outcome measure visit during week number 6. Treatment sessions consisted of exercise technique review and resistance load progression based upon the successful ability to complete 3 sets of 15 repetitions without an increase in symptoms. Participants were progressed to the next level of resistance for any exercise when the participant demonstrated the ability to perform three or more additional repetitions of the current resistance level with proper form and no increase in symptoms. If any adverse event occurred including a significant increase in participant symptoms (greater than 3 point

increase on the NPRS) the subject was instructed to cease any exercise performance for one week. A 3 point increase in pain rating as measured by the NPRS exceeds minimal change and can be considered significant.[144] After the rest time was completed and pain levels subsided the participant was evaluated by the physical therapist to determine readiness to return to exercise protocol. If the participant had not experienced a reduction in symptoms the participant would have been referred to a local orthopaedic physician.

Treatment Protocol: Control Group

Participants allocated to the control group performed a once daily, general exercise program consisting of 2 sets of 10 repetitions for shoulder flexion, and abduction. In addition these participants performed the same cross body horizontal adduction stretch and resistance band scapular retraction exercise with the same method and dosing as the experimental group. All participants attended one session per week for 4 weeks and then a final treatment visit during week number 6. A research assistant who is an orthopaedic board certified physical therapist conducted all treatment visits of the above described protocol. The visit occurred during week 1,2,3, and 4. If any adverse event occurred including a significant increase in participant symptoms (greater than 3 point increase on the NPRS) the subject was instructed to cease any exercise performance for one week. After the duration of the week the participant was evaluated by the physical therapist to determine readiness to return to exercise protocol. If the participant had not experienced a reduction in symptoms the participant would have been referred to a local orthopaedic physician.

DATA ANALYSIS

Collected data was transferred to the program statistical package for the social sciences (SPSS statistical program Version 22.0 for Windows) for analysis. The intraclass correlation coefficient model 3,1 used for the reliability analysis of the ratio level UQYBT data. The correlation coefficient was evaluated using the following criteria, .00-.25 little to no relationship, .25-.50 fair relationship, .50-.75 moderate to good relationship, and greater than .75 indicated excellent reliability.[151] Baseline between group differences for demographics including weight, age, and duration of shoulder pain were analyzed using the independent samples t test. Baseline pain levels and WORC scores were analyzed with the non-parametric Mann-Whitney U test to determine if a significant difference between groups existed.

Normality of data for the entire sample of subjects, the GE and ETER groups were analyzed with skewness, kurtosis and the Shapiro-Wilk W test. The skewness and kurtosis calculations measure symmetry for the distribution of data. Skewness determines the magnitude of dispersion in the positive or negative direction with Kurtosis indicating the overall spread of data.[151] A skewness value of 0 indicates perfectly even distribution with higher and lower numbers indicating a distribution in a positive or negative direction. An excess kurtosis value of 0 indicates a perfectly normal distribution. Higher kurtosis values indicate the data variability is from a few extreme differences from the mean and lower numbers indicate most of the data consists of many modest differences from the mean.[151] The Shapiro-Wilk W test was also utilized to determine if the study sample was normally distributed. A p value of less than .05 for the

Shapiro-Wilk W test indicates the population of data is not normally distributed and greater p values indicate normal distribution.

The 2-way factorial ANOVA statistic analyzed the interaction between treatment group and time. Treatment group (ETER versus GE) was the between subjects variable and time (week 0, week 3 and week 6) was the within subjects variable. Separate ANOVAs were performed for external rotation strength, range of motion, and the UQYBT as the dependent variables. For each ANOVA, the result of interest was the 2-way (group/time) interaction. Interactions were analyzed with a Bonferroni corrected alpha of .00625 at all outcome measure collection time points for the data. This Bonferroni correction was utilized due to the use of multiple ANOVA's for the eight dependent variables at the interval or ratio level of measurement (alpha .05/8=.00625). The effect size of partial eta squared was also utilized to compare the interaction between group and time for the factorial ANOVA. Partial eta squared values are suggested as small (0.01), medium (0.09) and large (0.25).[151]

The non-parametric Mann-Whitney U test was used to analyze between group differences and the Friedman's ANOVA for within group differences for all ordinal level data including the NPRS, shoulder strength ratios and WORC. The ordinal GROC data was analyzed comparing between group data for week 3 and week 6 using the non-parametric Mann-Whitney U test.

SUMMARY

This chapter detailed the methodology that was used to conduct this investigation of two different shoulder training protocols, for individuals with SAPS. Substantial thought and preparation occurred in order to ensure appropriate selection of measurement

tools and research design to maximize the rigor of this investigation. A high level of internal validity was ensured through selection of reliable instruments along with continued observance to the testing protocols. The use of a control group to compare outcomes to the experimental group as well as blinded randomization and allocation of participants to either of these two groups reduced the threats to internal validity. A blinded examiner conducted all outcome measurements and was unaware of participant group allocation. External validity was ensured by using a time frame for clinical interventions and a home program duration similar to those commonly utilized by physical therapists for individuals with SAPS. Individuals with SAPS were recruited from the community similar to what commonly occurs in clinical practice.

CHAPTER 4: RESULTS

INTRODUCTION

Chapter four will discuss the results of this investigation on eccentric training for subacromial pain syndrome (SAPS). The dependent variables consisting of isometric shoulder strength, strength ratios, pain free active range of motion (AROM), global rating of change (GROC), shoulder function and pain were measured at baseline, after three weeks and six weeks of eccentric shoulder training. These outcome measures will be presented and compared to a control group performing general shoulder exercises (GE). Additionally, within group measures will be described for data collection time points when indicated. All data analysis were conducted using the statistical package for the social sciences (SPSS statistical program Version 22.0 for Windows).

PARTICIPANTS

Sixty-five individuals presenting with shoulder pain were recruited for participation in this investigation over a sixteen month time period. Seven individuals were excluded due to having a physical characteristic from the exclusion criteria and fourteen individuals failed to meet the positive examination findings from the inclusion criteria. Forty-four individuals with SAPS aged 23-76 (mean 46.16, median 47.50) met the inclusion criteria and provided consent to participate in this investigation. Group assignment after randomization revealed 21 subjects participating in the GE group and 23 in the eccentric training to the external rotators (ETER) experimental group. Skewness, Kurtosis and the Shapiro-Wilk W test were used to determine normality of all baseline variables for the two groups of subjects. Two participants from the GE group requested

to cease participation in the study, due to worsening symptoms, during treatment week 2 and therefore intention to treat analysis was utilized for the comparison of results for these two subjects at week 3 and week 6.

Statistical analysis using the independent samples *t* test was conducted for the baseline interval and ratio data consisting of age, weight in kilograms, height in centimeters, and number of months for shoulder pain onset. Participant height was recorded in inches and then converted to centimeters by multiplying the inches value by 2.54. Weight was recorded in pounds and converted to kilograms by dividing the value in pounds by 2.2046. Body mass index (BMI) was calculated by dividing weight in kilograms by the squared value of height in meters. The analysis revealed no significant differences between the experimental and control groups for the variables of age (p=.264), weight (p=.694), height (p=.893), BMI (p=.528) and shoulder pain onset duration (p=.763). The mean, standard error of the mean (SEM), 95% confidence intervals (95%CI), range, Skewness and Kurtosis were reported for age, weight, height, BMI and shoulder pain onset duration and listed in Table 4.1. Shoulder pain onset did not reach statistical significance with the independent samples *t* test (p=.763). The assumption for normality of distribution (Shapiro-Wilk W test control p<.001, experimental p<.001) was not met and therefore the Mann-Whitney U test was also used to analyze between group differences. Median comparison for pain onset duration (control 17 months, experimental 21 months, p=1.000) and body mass index (BMI) (p=.733) did not reach significance with the Mann-Whitney U test for between group median comparison.

Table 4.1 Demographic Characteristics of Participants

Characteristic		Total (44)	GE (21)	ETER (23)	P
Age (years)	Mean (SEM)	46.16(2.607)	49.24(3.756)	43.35(3.599)	.264*
	95% CI	40.90-51.42	41.40-57.07	35.88-50.81	
	Range	23-76	23-76	23-73	
	Skewness	.069	-.122	.256	
	Kurtosis	-1.405	-1.157	-1.571	
	Shapiro-Wilk	.004	.240	.008	
Weight (kg)	Mean (SD)	81.01(2.505)	82.06(3.907)	80.05(3.273)	.694*
	95% CI	75.96-86.06	73.91-90.21	73.26-86.84	
	Range	51.26-117.03	54.43-108.86	51.26-117.03	
	Skewness	.046	-.111	-.201	
	Kurtosis	-.773	-1.371	.251	
	Shapiro-Wilk	.382	.131	.742	
Height (cm)	Mean (SD)	171.88(9.69)	171.67(9.025)	172.07(10.462)	.893*
	95% CI	168.93-171.99	167.56-175.77	167.54-176.59	
	Range	150-195	150-188	150-195	
	Skewness	-.133	-.526	.073	
	Kurtosis	.108	.235	.935	
	Shapiro-Wilk	.752	.807	.986	
Body Mass Index	Mean (SD)	27.30(4.710)	27.78(5.734)	26.85(3.612)	.528*
	95% CI	25.87-28.73	25.18-30.40	25.29-28.41	
	Range	19.66-43.34	19.66-43.43	20.02-35.14	
	Skewness	.969	.929	.432	
	Kurtosis	1.843	1.226	.306	
	Shapiro-Wilk	.031	.205	.840	
Pain onset duration (months)	Mean (SD)	52.20(12.313)	48.29(16.62)	55.78	.763*
	95% CI	27.37-77.04	13.61-82.96	17.75-93.81	
	Range	3-280	3-280	3-280	1.00¶
	Skewness	2.028	2.185	2.022	
	Kurtosis	2.900	4.010	2.826	
	Shapiro-Wilk	.000	.000	.000	

*Independent *t*-test

¶Independent Median test

Abbreviation legend: Standard error mean (SEM), Confidence Interval (CI), Standard deviation (SD), centimeters (cm).

Among the participants, 19(43%) were female and 25(57%) were male with 10 females and 13 males in the ETER experimental group and 9 females and 12 males in the

GE control group. Hand dominance data was collected with 36(82%) reporting their right upper extremity to be dominant and 8(18%) reported their left upper extremity to be dominant. Eighteen participants (41%) reported the non-dominant arm to be the painful shoulder with 8 in the GE group and 10 in the ETER group. Twenty-six participants (59%) reported the dominant arm to be the painful shoulder with 13 in the ETER group and 13 in the GE group. The Chi-square test revealed no significant differences between groups for either gender (p=.967, phi=-.006), hand dominance (p=.887, phi=.021) or painful shoulder/matching dominant upper extremity (p=.717, phi=-.055).

Initial variables, comprising the ordinal level of measurement, including pain severity on average (Avg), worst pain, best pain, shoulder function as measured by the WORC and strength ratios for internal rotation to external rotation and abduction to external rotation were all compared between groups with mean, standard error of mean, median, 95% confidence intervals, Skewness, Kurtosis and the Shapiro-Wilk W test conducted for normality of distribution and listed in Table 4.2.

Table 4.2 Ordinal Level Baseline Variables

Variable		**Total (44)**	**GE (21)**	**ETER (23)**	**P***
Avg Pain	Mean (SEM)	3.55(.282)	3.33(.361)	3.74(.432)	.617
	Median	3	3	3	
	95% CI	2.98-4.12	2.58-4.09	2.84-4.64	
	Range	1-8	1-7	1-8	
	Skewness	.659	.435	.685	
	Kurtosis	-.029	-.282	-.173	
	Shapiro-Wilk	.009	.299	.077	
Worst Pain	Mean (SEM)	6.98(.301)	6.95(.475)	7.00(.388)	.802
	Median	7	7	7	
	95% CI	6.37-7.58	5.96-7.94	6.20-7.80	
	Range	2-10	2-10	3-10	
	Skewness	-.557	-.862	-.140	

	Kurtosis	-.079	.024	-.133	
	Shapiro-Wilk	.026	.052	.165	
Best Pain	Mean (SEM)	1.43(.229)	1.29(.286)	1.57(.355)	.651
	Median	1	1	1	
	95% CI	.97-1.89	.69-1.88	.83-2.30	
	Range	0-6	0-4	0-6	
	Skewness	1.479	.889	1.668	
	Kurtosis	2.197	-.158	2.579	
	Shapiro-Wilk	.000	.003	.000	
WORC	Mean (SEM)	65.33(2.304)	64.50(3.140)	66.10(3.408)	.716
	Median	65.59	64.00	69.28	
	95% CI	60.69-69.98	57.94-71.05	59.03-73.17	
	Range	34.42-91.33	39.62-90.38	34.42-91.33	
	Skewness	-.108	.075	-.261	
	Kurtosis	-.785	-.594	-.805	
	Shapiro-Wilk	.412	.843	.594	
IR/ER Strength Ratio	Mean (SEM)	1.15(.036)	1.10(.052)	1.20(.048)	.226
	Median	1.15	1.04	1.17	
	95% CI	1.08-1.22	.99-1.21	1.10-1.30	
	Range	.68-1.68	.68-1.67	.83-1.64	
	Skewness	.266	.317	.315	
	Kurtosis	-.147	.546	-.590	
	Shapiro-Wilk	.754	.640	.540	
ABD/ER Strength Ratio	Mean (SEM)	1.18(.051)	1.07(.081)	1.27(.058)	.080
	Median	1.25	1.05	1.29	
	95% CI	1.07-1.28	.90-1.24	1.15-1.39	
	Range	.29-1.95	.29-1.75	.74-1.95	
	Skewness	-.216	-.058	.202	
	Kurtosis	.167	-.278	.565	
	Shapiro-Wilk	.723	.919	.569	

***Mann-Whitney U Test for significant difference between groups**

Abbreviation legend: Standard error mean (SEM), Confidence Interval (CI), Average (Avg), Western Ontario Rotator Cuff Index (WORC), Internal rotation (IR), External rotation (ER), Abduction (ABD).

The non-parametric Mann-Whitney U test was used for between group comparisons demonstrating no significant difference for ordinal level baseline variables at the $p>.05$ significance level.

Baseline variables comprising the interval or ratio level of measurement including bodyweight adjusted shoulder strength, the UQYBT and shoulder AROM were all compared between groups with 95% confidence intervals, Skewness, Kurtosis and the Shapiro-Wilk W test conducted for normality of distribution and listed in Table 4.3.

Table 4.3 Interval and Ratio Level Baseline Variables

Variable		Total (44)	GE (21)	ETER (23)	P*
Bodyweight Adjusted External Rotation Strength	Mean (SEM)	.132(.004)	.131(.006)	.134(.005)	.697
	Median	.130	.132	.128	
	95% CI	.124-.140	.117-.144	.123-.145	
	Range	.073-.182	.073-.182	.092-.182	
	Skewness	-.025	-.233	.361	
	Kurtosis	-.708	-.762	-.867	
	Shapiro-Wilk	.517	.678	.374	
Bodyweight Adjusted Internal Rotation Strength	Mean (SEM)	.152(.007)	.142(.008)	.162(.010)	.147
	Median	.154	.155	.153	
	95% CI	.139-.166	.125-.160	.141-.183	
	Range	.071-.253	.071-.206	.081-.253	
	Skewness	.170	-.415	.203	
	Kurtosis	-.305	-.621	-.698	
	Shapiro-Wilk	.774	.484	.676	
Bodyweight Adjusted Abduction Strength	Mean (SEM)	.158(.009)	.143(.015)	.171(.011)	.123
	Median	.153	.131	.168	
	95% CI	.140-.176	.113-.173	.150-.193	
	Range	.040-.280	.040-.280	.081-.253	
	Skewness	.155	.475	.162	
	Kurtosis	-.472	-.071	-1.005	
	Shapiro-Wilk	.667	.607	.341	
Medial UQYBT	Mean (SEM)	1.06(.028)	1.046(.046)	1.073(.034)	.634
	Median	1.10	1.119	1.100	
	95% CI	1.005-1.116	.951-1.141	1.004-1.142	
	Range	.61-1.32	.61-1.31	.67-1.32	
	Skewness	-1.038	-.919	-.1.161	
	Kurtosis	.369	-.256	1.510	
	Shapiro-Wilk	.000	.017	.007	
Superior/Lateral UQYBT	Mean (SEM)	.555(.024)	.537(.039)	.5717(.030)	.483
	Median	.548	.520	.570	
	95% CI	.506-.604	.455-.619	.509-.634	
	Range	.32-.86	.32-.86	.36-.86	
	Skewness	.381	.429	.540	
	Kurtosis	-.912	-1.125	-.620	

	Shapiro-Wilk	.036	.071	.217	
Inferior/Lateral UQYBT	Mean (SEM)	.648(.021)	.611(.029)	.682(.030)	.097
	Median	.680	.640	.710	
	95% CI	.605-.691	.549-.673	.620-.743	
	Range	.35-.87	.35-.82	.39-.87	
	Skewness	-.601	-.481	-.916	
	Kurtosis	-.647	-.633	-.161	
	Shapiro-Wilk	.014	.301	.020	
Flexion ROM	Mean (SEM)	151(3.459)	149(6.333)	154(3.318)	.524
	Median	159	158	160	
	95% CI	145-159	136-163	147-161	
	Range	52-180	52-180	108-174	
	Skewness	-2.223	-2.074	-1.259	
	Kurtosis	7.382	5.622	1.728	
	Shapiro-Wilk	.000	.001	.025	
Abduction ROM	Mean (SEM)	147(4.911)	148(7.719)	147(6.381)	.963
	Median	157	160	155	
	95% CI	138-157	132-164	134-161	
	Range	84-182	88-180	84-182	
	Skewness	-.794	-.756	-.914	
	Kurtosis	-.836	-1.145	-.340	
	Shapiro-Wilk	.000	.001	.007	
ER ROM	Mean (SEM)	79(2.249)	77(3.627)	81(2.754)	.342
	Median	83	82	85	
	95% CI	75-84	69-85	76-87	
	Range	42-110	42-104	48-110	
	Skewness	-.851	-.820	-.736	
	Kurtosis	.637	.005	1.588	
	Shapiro-Wilk	.004	.060	.064	
IR ROM	Mean (SEM)	59(2.014)	59(2.843)	59(2.907)	.883
	Median	61	62	56	
	95% CI	55-63	53-65	53-65	
	Range	25-88	25-88	36-86	
	Skewness	-.147	-.505	.116	
	Kurtosis	.020	1.838	-.912	
	Shapiro-Wilk	.733	.381	.407	

*Independent *t*-test

Abbreviation legend: Standard error mean (SEM), Confidence Interval (CI), Upper quarter y balance test (UQYBT), Range of motion (ROM), External rotation (ER), Internal rotation (IR).

No statistical differences ($p<.05$) in the baseline variables were noted between groups for body weight adjusted strength values, shoulder range of motion and the UQYBT.

Kurtosis, skewness and the Shapiro-Wilk W test revealed several baseline variables that did not meet the assumption of normality and therefore the non-parametric Mann Whitney U test was utilized to compare mean ranks in these instances. External rotation strength (p=.379), Internal rotation strength (p=.951), flexion range of motion (p=.976), abduction range of motion (p=.487), external rotation range of motion (p=.472), medial UQYBT (p=.991), superior lateral UQYBT (p=.318) and inferior lateral UQYBT (p=.053) all demonstrated no statistically significant differences between groups with the non-parametric Mann Whitney U test.

RELIABILITY ANALYSIS

Prior investigations have established reliability for the measurement protocols used in this investigation as cited previously. The upper quarter Y balance test has not been investigated for reliability, utilizing the modifications in this investigation, therefore a reliability analysis was performed as described in the methods section. Test-retest reliability analysis using the Intra-class correlation coefficient (ICC) model 3,1 are listed in Table 4.4.

Table 4.4 UQYBT Measurement Protocol Reliability

Measurement	**Subjects**	**ICC Model 3**	**95% CI**
Medial UQYBT	N=18	.87	.45-.96
Superior/Lateral UQYBT	N=18	.96	.88-.98
Inferior Lateral UQYBT	N=18	.92	.79-.96

Abbreviation legend: Intra-class correlation coefficient (ICC), Confidence Interval (CI), Upper quarter y balance tests (UQYBT).

The UQYBT reliability analysis demonstrates excellent agreement but caution should be taken when interpreting these results for the medial direction due to the wide confidence intervals.

RESEARCH QUESTIONS AND HYPOTHESES RESULTS

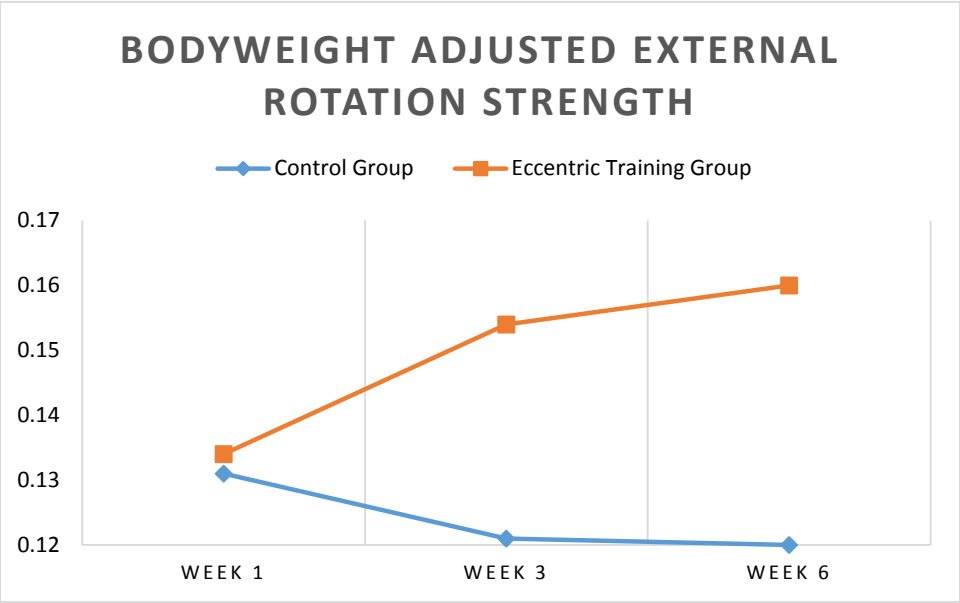
Research Question #1 - Does ETER improve mean bodyweight adjusted shoulder external rotation strength in participants with SAPS?

Research Hypothesis #1 (H2) - A significant improvement in mean bodyweight adjusted shoulder external rotation strength exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #1 Results

Bodyweight adjusted external rotation strength was calculated by dividing strength by bodyweight, in kilograms, for each participant. Bodyweight adjusted strength values should be considered ratio level data as they contain a fixed zero and meaningful fractions can be derived from the data.[151] The factorial repeated measures analysis of variance (ANOVA) with a Bonferroni correction was used to analyze strength differences for the interaction between group and time. This factorial ANOVA was also used for the dependent variables, range of motion and the upper quarter y balance test, and therefore a Bonferroni corrected alpha was set to .00625. The assumption of equal variance for time and group comparisons was met after analysis using Mauchly's test of sphericity ($p=.14$). The interaction between group assignment and time was significant ($p<.001$) and displayed in Figure 4.1

Figure 4.1 Body Weight Adjusted External Rotation Strength Time/Group Interaction



The interaction between group and time was statistically significant (p<.001) with a large effect size of .46. Between group effects reached statistical significance (p=.010) with a large effect size of .15. Results for bodyweight adjusted external rotation strength values are listed in Table 4.5.

Table 4.5 Data Analysis of Adjusted External Rotation Strength Values (Mean Strength / Bodyweight) Main Effects for the Interaction Between Group and Time

Group	Week 0	Week 3	Week 6	F*	P*	Effect Size¶
ETER (N=23) Mean(SEM) 95% CI	.134(.006) .122-.145	.154(.007) .139-.169	.160(.007) .145-.174	17.53	<.001	.46
GE (N=21) Mean(SEM) 95% CI	.131(.006) .119-.143	.121(.008) .105-.137	.120(.008) .105-.135			

*Factorial Repeated Measures ANOVA Interaction Between Group and Time
¶Partial eta squared

Abbreviation legend: Eccentric training to the external rotators group (ETER), Standard error of mean (SEM), Confidence interval (CI), General exercise group (GE).

Research Question #2 - Does ETER improve internal rotator to external rotator and shoulder abductor to external rotator isometric strength ratios in participants with SAPS?

Research Hypothesis #2 (H1) - A significant improvement in shoulder internal rotator to external rotator (IR/ER) and shoulder abductor strength to external rotator (ABD/ER) strength ratios will be found in participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #2 Results

Shoulder strength ratios were calculated by dividing internal rotation scores by external rotation scores and abduction scores by external rotation scores in kilograms. These strength ratios do not have an absolute zero and meaningful fractions cannot be derived from the scores indicating ordinal level data. The non-parametric Friedman's analysis of variance test was used to compare within group changes and the non-parametric Mann Whitney U was used to compare strength ratio values between groups. Results for IR/ER and ABD/ER strength ratios of both groups are listed in Table 4.6.

Table 4.6 IR/ER and ABD/ER Strength Ratio Results

Ratio	Group(N)	Week 0 Median Ratio	Week 3 Median Ratio	Week 6 Median Ratio	Median difference within groups baseline to week 6
IR/ER	ETER (N=23) Interquartile Range	1.17 .98-1.35	1.13 .98-1.33	1.08 .93-1.31	-.09
	GE (N=19) Interquartile Range	1.04 .96-1.27	1.08 .96-1.37	1.11 1.02-1.41	+.07
ABD/ER	ETER(N=23) Interquartile Range	1.30 1.09-1.37	1.23 1.13-1.48	1.29 1.02-1.49	-.01

	GE (N=19) Interquartile Range	1.05* .80-1.35	1.38* .91-1.34	1.59* .92-1.41	+.54

*Statistically Significant at p<.05 Friedman's ANOVA Within Groups
¥Statistically Significant at p<.05 Mann-Whitney U Between Groups

Abbreviation legend: Internal rotation (IR), External rotation (ER), Eccentric training to the external rotators group (ETER), General exercise group (GE), Abduction (ABD).

Significantly higher abduction to external rotator (p=.012) strength ratios were identified in the general exercise participants when comparing within group mean ranks from week 0 to week 3 and 6. The general exercise group did not demonstrate significant within group changes for internal rotator to external rotator strength ratios (p=.114). The eccentric training group did not demonstrate significant within group changes in strength ratios for internal rotator to external rotator (p=.296) and abductor to external rotator mean ranks (p=.119). No significant difference was identified when comparing changes between the ETER and GE groups for all time points (IR/ER Week 0 p=.226, IR/ER week 3 p=.716, IR/ER week 6 p=.459, ABD/ER Week 0 p=.080, ABD/ER week 3 p=.169, ABD/ER week 6 p=.318).

Research Question #3 - Does ETER improve self-reported pain and function in participants with SAPS?

Research Hypothesis #3 (H3) - A significant improvement in self-reported pain as measured by the numeric pain rating scale and function measured by the Western Ontario Rotator Cuff Index exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #3 Results – The non-parametric Friedman's analysis of variance test was used to compare within group changes and the non-parametric Mann Whitney U

test was used to compare values for average pain, worst pain and best pain between the ETER and GE groups. Pain level results are reported in Table 4.7 and displayed in Figure 4.2

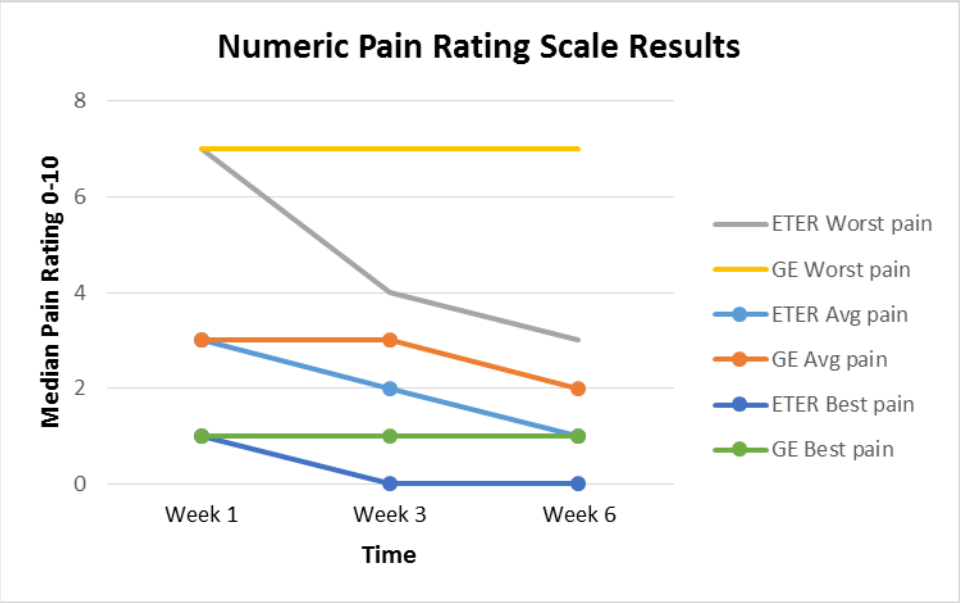
Table 4.7 Numeric Pain Rating Scale Results

Pain Measure	**Group**	**Week 0 Median NPRS**	**Week 3 Median NPRS**	**Week 6 Median NPRS**	**Median difference within groups baseline to week 6**
NPRS Average	ETER (N=23)	3	2	1¥	-2.00*
	Interquartile Range	2.00-5.00	1.00-2.00	.00-2.00	
	GE (N=19)	3.00	3.00	2.00	-1.00
	Interquartile Range	2.00-4.50	1.00-5.00	1.00-4.50	
NPRS Worst	ETER (N=23)	7	4.00	3.00¥	-4.00*
	Interquartile Range	6.00-8.00	3.00-7.00	1.00-6.00	
	GE (N=19)	7.00	7.00	7.00	.00
	Interquartile Range	6.00-9.00	5.00-8.00	4.00-8.50	
NPRS Best	ETER (N=23)	1.00	.00¥	.00	-1*
	Interquartile Range	.00-2.00	.00-1.00	.00-2.00	
	GE (N=19)	1.00	1.00	1.00	.00
	Interquartile Range	.00-2.00	.00-2.50	.00-2.00	

*Statistically Significant at p<.05 Friedman's ANOVA Within Groups
¥Statistically Significant at p<.05 Mann-Whitney U Between Groups

Abbreviation legend: Numeric pain rating scale (NPRS), Eccentric training to the external rotators group (ETER), General exercise group (GE).

Figure 4.2 Numeric Pain Rating Scale Results for Average Pain



Abbreviation legend: Eccentric training to the external rotators group (ETER), General exercise group (GE), Average (Avg).

Significant differences were identified within the ETER group when comparing average pain ($p<.001$), worst pain ($p<.001$) and best pain ($p=.004$) mean rank values between week 0, week 3 and week 6. The GE group did not demonstrate significant within group differences for average pain ($p=.262$), worst pain ($p=.876$) and best pain ($p=.245$) when comparing results between week 0, week 3 and week 6. A significant difference was identified when comparing the ETER group to the GE group for average pain ($p=.022$) and worst pain ($p=.001$) after 6 weeks of treatment. No significant difference was identified for changes in best pain values when comparing the ETER group to the GE group ($p=.478$) after 6 weeks of treatment. Week 3 between group differences for pain values demonstrated a trend toward statistical significance with lower

ETER group values for average pain (p=.091), worst pain (p=.051) and best pain (p=.050).

The Western Ontario Rotator Cuff Index (WORC) is a measure of patient reported shoulder function and therefore has no absolute zero value and can be considered ordinal level data. The non-parametric Friedman's analysis of variance test was used to compare within group changes in WORC scores and the non-parametric Mann Whitney U test was used to compare WORC values between groups. WORC score results are reported in Table 4.8 and displayed in Figure 4.3.

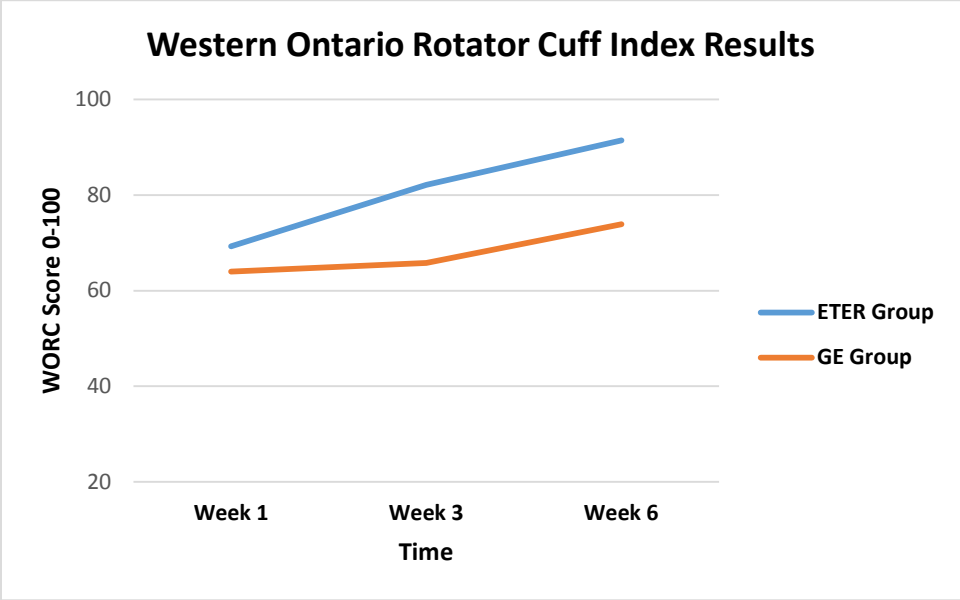
Table 4.8 Western Ontario Rotator Cuff Index Results

Group	**Week 0 Median WORC**	**Week 3 Median WORC**	**Week 6 Median WORC**	**Median difference within groups baseline to week 6**
ETER (N=23)	69.29	82.10	91.40	+22.11*
Interquartile Range	50.66-78.90	68.70-81.14	85.04-97.86	
GE (N=19)	64.00	65.76	73.90	+9.90
Interquartile Range	52.40-75.50	51.33-72.49	55.80-79.28	

*Statistically Significant at p<.05 Friedman's ANOVA Within Groups
¥Statistically Significant at p<.05 Mann-Whitney U Between Groups

Abbreviation legend: Western Ontario rotator cuff index (WORC), Eccentric training to the external rotators group (ETER), General exercise group (GE).

Figure 4.3 Western Ontario Rotator Cuff Index Results



Abbreviation legend: Eccentric training to the external rotators group (ETER), General exercise group (GE), Western Ontario rotator cuff index (WORC).

Significant differences were identified within the ETER group when comparing mean rank WORC scores between week 0, week 3 and week 6 ($p<.001$). The GE group did not demonstrate significant differences in WORC scores between week 0, week 3 and week 6 ($p=.148$). Between group comparisons identified a significant difference in WORC scores for week 3 ($p=.001$) and week 6 ($p<.001$).

Research Question #4 – Does ETER improve active shoulder range of motion (abduction, flexion, external rotation, and internal rotation) in participants with SAPS?

Research Hypothesis #4 (H4) – A significant improvement in pain free active shoulder range of motion exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #4 Results – Range of motion has an absolute zero and meaningful fractions can be derived from these values classifying them as ratio level data. The factorial repeated measures analysis of variance was used to analyze the interaction between group and time for range of motion data. This factorial ANOVA was also used for the dependent variables of, external rotation strength and the upper quarter y balance test, therefore a Bonferroni corrected alpha was set to .00625.. Mauchly's test of sphericity was violated for abduction (p=.036). Due to the violation of the assumption of sphericity mean comparisons for the group and time interaction for abduction are reported after the Greenhouse-Geisser correction for the F statistic and p value. Results for range of motion values in both groups are listed in Table 4.9.

Table 4.9 Data Analysis for AROM

AROM	**Group**	**Week 0 Mean (SEM)**	**Week 3 Mean (SEM)**	**Week 6 Mean (SEM)**	**F**	**p***	**Effect Size¶**
Flexion	ETER	153.91 (4.82)	157.57 (4.11)	166.70 (2.98)			
	95% CI	144.19-163.64	149.27-165.87	160.68-172.72			
					.256	.776	.01
	GE	149.43 (5.04)	149.14 (4.30)	160.52 (3.12)			
	95% CI	139.26-159.60	140.46-157.83	154.22-166.82			
Abduction	ETER	147.35 (6.87)	155.87 (7.07)	167 (6.52)			
	95% CI	133.48-161.22	141.60-170.14	154.45-180.77	1.851	.169	.04
	GE	147.81 (7.19)	148.52 (7.40)	151.05 (6.83)			
	95% CI	133.29-162.33	133.59-163.46	137.27-164.82			
Internal Rotation	ETER	58.83 (2.82)	59.04 (3.01)	63.78 (2.03)			
	95% CI	53.14-64.51	52.98-65.11	59.68-67.89			
					1.291	.286	.06
	GE	69.83 (2.82)	58.04 (3.01)	59.04 (2.13)			
	95% CI	53.48-65.38	52.13-64.83	54.75-63.34			
External Rotation	ETER	81.48 (3.11)	83.78 (3.04)	86.70 (2.37)			
	95% CI	75.20-87.76	77.66-89.91	81.91-91.49			
					1.564	.222	.07
	GE	77.14 (3.26)	76.38 (3.18)	77.14 (2.48)			
	95% CI	70.57-83.72	69.97-82.79	72.13-82.16			

*Factorial Repeated Measures ANOVA Interaction Between Group and Time
¶Partial eta squared

Abbreviation legend: Standard error mean (SEM), Eccentric training to the external rotators group (ETER), General exercise group (GE), Confidence interval (CI), Analysis of Variance (ANOVA).

None of the range of motion results identified a statistical significant difference for interaction between group and time negating an indication for pairwise comparison. Moreover, the small F statistic and effect sizes support the null hypothesis that range of motion does not significantly improve when comparing ETER to GE after three and six weeks of treatment.

Research Question #5 - Does ETER improve upper extremity closed kinetic chain performance in participants with SAPS?

Research Hypothesis #5 (H5) - A significant improvement in upper extremity closed kinetic chain performance as measured by the upper extremity Y balance test (UQYBT) exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #5 Results – The UQYBT has an absolute zero and meaningful fractions can be derived from these values classifying this as ratio level data. The factorial repeated measures analysis of variance was used to analyze the interaction between group and time for UQYBT values. This factorial ANOVA was also used for the dependent variables of, external rotation strength and range of motion, therefore a Bonferroni corrected alpha was set to .00625. Results for UQYBT in both groups are listed in Table 4.10.

Table 4.10 Data Analysis for Upper Quarter Y Balance Test

Test	**Group**	**Week 0 Mean (SEM)**	**Week 3 Mean (SEM)**	**Week 6 Mean (SEM)**	**F**	**p***	**Effect Size**
Medial UQYBT	ETER 95% CI	1.07 (.033) 1.00-1.14	1.15 (.045) 1.06-1.25	1.21 (.051) 1.10-1.31			

	GE 95% CI	1.05 (.045) .95-1.14	1.02 (.050) .92-1.13	1.28 (.057) .91-1.15	2.906	.066	.12
Superior /Lateral UQYBT	ETER 95% CI	.57 (.034) .50-.64	.66 (.028) .60-.73	.69 (.028) .63-.75	2.701	.079	.11
	GE 95% CI	.54 (.035) .46-.61	.55 (.030) .49-.61	.57 (.030) .51-.63			
Inferior/ Lateral UQYBT	ETER 95% CI	.68 (.029) .62-.74	.73 (.028) .66-.78	.73 (.026) .67-.78	1.169	.321	.05
	GE 95% CI	.61 (.030) .55-.67	.62 (.029) .56-.67	.61 (.027) .55-.66			

*Factorial Repeated Measures ANOVA Interaction Between Group and Time
Abbreviation legend: Standard error mean (SEM), Eccentric training to the external rotators group (ETER), General exercise group (GE), Confidence interval (CI), Analysis of Variance (ANOVA), Upper quarter y balance test (UQYBT).

None of the UQYBT results identified a statistical significance for interaction between group and time negating an indication for pairwise comparison. Moreover, the small F statistic and effect sizes support the null hypothesis that UQYBT scores do not significantly improve when comparing ETER to GE after three and six weeks of treatment.

Research Question #6 – Does ETER improve global change of condition as measured by the Global Rating of Change Scale?

Research Hypothesis #6 (H6) – A significant improvement in global change measured by the Global Rating of Change Scale exists for participants who perform ETER compared to those performing a general shoulder exercise protocol.

Research Question #6 Results – The Global Rating of Change (GROC) is a measure of patient reported change after treatment and therefore has no absolute zero value and can be considered ordinal level data. The non-parametric Mann Whitney U test was used to

compare GROC, mean rank, values between groups at week 3 and week 6 data collection time points. Results for global rating of change in both groups are listed in Table 4.11.

Table 4.11 Data Analysis for Global Rating of Change Scores

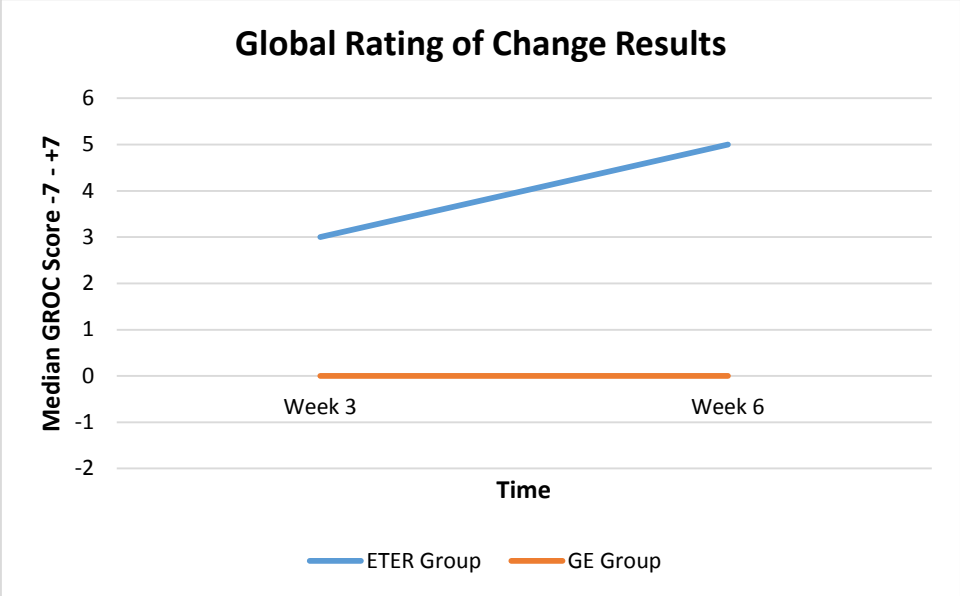
Group	**Week 3 Median GROC**	**Week 6 Median GROC**
ETER (N=23)	+3.00*	+5.00*
Interquartile Range	+1.00-+5.00	+4.00-+6.00
GE (N=19)	0.00*	0.00*
Interquartile Range	-2.00-+1.50	0.00-+3.00

*Statistically Significant at p<.05 Mann-Whitney U Between Groups

Abbreviation legend: Global rating of change (GROC), Eccentric training to the external rotators group (ETER), General exercise group (GE).

Significant differences were identified between groups for GROC scores at week 3 (p=.001) and week 6 (p<.001). GROC scores for both the ETER and GE groups are displayed in Figure 4.4.

Figure 4.4 Global Rating of Change Results



Abbreviation legend: Global rating of change (GROC), Eccentric training to the external rotators group (ETER), General exercise group (GE).

SUMMARY

Forty four individuals with SAPS aged 23-76 (mean 46.16, median 47.50) met the inclusion criteria and participated in this investigation. Group assignment after randomization revealed 21 subjects participating in the GE group and 23 in the ETER experimental group. Statistical analysis using the independent samples *t* test was conducted and the analysis revealed no significant differences between the experimental and control groups for the variables of age ($p = .264$), weight ($p = .694$), height ($p = .893$), BMI ($p = .528$) and shoulder pain onset duration ($p = .763$). Shoulder pain onset did not meet the assumption of normality of distribution (Shapiro-Wilk W test control $p < .001$, experimental $p < .001$) therefore the Mann-Whitney U test was also used to analyze between group differences. Median comparison for pain onset duration (control 17 months, experimental 21 months) did not reach significance with the Mann-Whitney U test ($p = 1.000$).

After the second week of interventions 2 participants from the GE group requested to cease participation in the study due to worsening symptoms. Intention to treat analysis was utilized for the data analysis of week 3 and week 6 for these 2 subjects.

The factorial repeated measures ANOVA was used to analyze strength differences, AROM and the UQYBT for the interaction between group and time. A Bonferroni corrected alpha was set to .00625. The interaction between group and time was statistically significant for external rotation strength ($p < .001$). None of the AROM or UQYBT results identified a statistical significant difference for the interaction between group and time negating an indication for pairwise comparison.

Friedman's ANOVA for within group repeated measures did not identify statistical significance $p<.05$ for the ETER group comparisons of ER/IR and ER/ABD at week 0, week 3 or week 6. The control group did demonstrate significant worsening strength ratios for the abductor to external rotator mean ranks ($p=.012$). No significant difference was identified when comparing changes between the ETER and GE groups for all time points using the Mann Whitney U for between group differences (IR/ER Week 0 $p=.226$, IR/ER week 3 $p=.716$, IR/ER week 6 $p=.459$, ABD/ER Week 0 $p=.080$, ABD/ER week 3 $p=.169$, ABD/ER week 6 $p=.318$).

Significant differences were identified within the ETER group when comparing average pain ($p<.001$), worst pain ($p<.001$) and best pain ($p=.004$) mean rank values between week 0, week 3 and week 6. The GE group did not demonstrate significant differences for average pain ($p=.262$), worst pain ($p=.876$) and best pain ($p=.245$) when comparing differences between week 0, week 3 and week 6. A significant difference was identified when comparing the ETER group to the GE group for average pain ($p=.022$) and worst pain ($p=.001$) after 6 weeks of treatment. No significant difference was identified for changes in best pain values when comparing the ETER group to the GE group ($p=.478$) after 6 weeks of treatment.

Significant differences were identified within the ETER group when comparing mean rank WORC scores between week 0, week 3 and week 6 ($p<.001$). The GE group did not demonstrate significant differences in WORC scores between week 0, week 3 and week 6 ($p=.148$). Between group comparisons identified a significant difference in WORC scores for week 3 ($p=.001$) and week 6 ($p<.001$). Significant differences were identified between groups for GROC scores at week 3 ($p=.001$) and week 6 ($p<.001$).

CONCLUSION

The primary purpose of this investigation was to compare outcomes of individuals with SAPS who performed ETER, for six weeks, versus a control group who utilized a GE program for six weeks. The ETER group demonstrated significant improvements, compared to the GE group, for external rotation strength, numeric pain rating scores, shoulder function as reported on the WORC index and patient perceived global rating of change. Internal rotation to external rotation strength ratios, abduction to external rotation strength ratios, pain free active range of motion and the upper quarter Y balance tests did not demonstrate significant changes within or between the ETER and GE groups. The GE group did not demonstrate any within group significant improvements for any of the dependent variables examined in this investigation. These results provide preliminary evidence for the efficacy of a 6 week ETER program for individuals with SAPS of greater than 3 month onset.

CHAPTER 5: DISCUSSION

INTRODUCTION

The focus of this final chapter will be on interpreting the results of the current investigation and relating them to the existing literature on eccentric training for subacromial pain syndrome (SAPS). When possible, dependent variable data from prior studies will be discussed and compared to the results from the present investigation. The research questions and hypotheses will be discussed along with the results and implications for clinical practice.

A precise and comprehensive determination will be made whether the findings from this investigation support or reject the established hypotheses. A discussion regarding future research plans on this topic will also be presented.

Research Question #1

The goal for research question #1 was to determine if bodyweight adjusted strength changes would occur to the shoulder external rotators after 6 weeks of eccentric training (ETER). Moreover, this data was compared to the control group who performed a general shoulder exercise program (GE) without eccentric training. The results indicated that a significant difference ($p<.001$) occurred in bodyweight adjusted external rotation strength (ERS) for the ETER group when comparing week 0 (.134) to week 3 (.154) and week 6 (.160). A significant difference ($p<.001$) and large effect size (.46) was identified when comparing the interaction between group and time as the GE group did not substantially change from week 0 (.131) to week 3 (.121) and week 6 (.120).

The mean ERS for all of the individuals evaluated in this investigation at baseline was .132. Prior research reveals several interesting comparisons for normative ERS

values. Kolber et al[11] found mean bodyweight adjusted ERS values of .144 in a group of 60 individuals participating in recreational weight training and .137 in a control group of 30 individuals. Westrick et al[152] investigated the isometric bodyweight adjusted strength values for active college age individuals comparing gender and arm dominance. Mean ERS for the dominant arm were higher in both males (.20) and females (.16) compared to the non-dominant arm in each gender respectively (.19) and (.15). While the difference between males and females was significant ($p<.001$) the difference between the dominant and non-dominant arm did not reach statistical significance. Age related changes in isometric ERS values have been identified in prior investigations[153, 154] and could be one contributing factor to lower mean strength values in the current investigation. Moreover, it should be noted that this dissertation and the study conducted by Kolber et al[11] utilized identical testing protocols and the protocol utilized by Westrick et al[152] was not described.

Another contributing factor to lower ERS values for the current investigation could be the presence of SAPS. The current understanding of SAPS is that it can be precipitated by weakness to the shoulder external rotators.[13] Kolber et al[155] found an inverse relationship between participation in external rotation strengthening exercises and clinical signs of SAPS, in an active weight training population. Moreover, Reddy et al[109] identified a correlation between decreased infraspinatus muscle activity for individuals with SAPS. These findings potentially reveal the importance of integrating external rotation strengthening exercises to prevent SAPS.

The possibility of pain influencing strength values in this dissertation requires further statistical analysis of the results. To control for the covariate of pain an analysis

of covariance (ANCOVA) was conducted and compared to an analysis of variance for ERS at week 3 and week 6. The results demonstrate a significant difference between groups at week 3 when controlling for average pain (p=.010) and worst pain (p=.010). Week 6 results demonstrate a significant between group difference for average pain (p=.001) and worst pain (p=.002). These results demonstrate that average and worst pain values do not influence the statistically significant difference in ERS when comparing the ETER and GE groups.

The current investigation revealed a dramatic improvement in the mean ERS values comparing baseline (.134) to 3 weeks (.154) and 6 weeks (.160) in the ETER group. Strength improvements are often correlated with increases in muscle hypertrophy and cross sectional muscle size after long term exposure to training, most commonly occurring after eight weeks.[156] Long term strength changes can also be attributed to improvements in tendon stiffness which has been documented to occur after 14 weeks of training.[157] Contributing factors to the dramatic increase in strength after three weeks, are likely to be attributed to short term neurological changes. The acute strength changes demonstrated in the current investigation could be a result of increased motor unit recruitment. Exercise training has a positive effect on motor unit recruitment and could reverse the effects on muscular strength inhibition in the injured population of individuals, in a relatively short period of time.[158]

A two minute rest time between sets of ETER was appropriate and may have contributed to the improved ERS. ETER is a moderate intensity exercise with one set lasting between 40 and 60 seconds. The energy system primarily utilized for this level of intensity and duration is likely a combination of phosphagen and fast glycolysis. The

phosphagen system supplies adenosine triphosphate (ATP) to the muscle tissue for energy during resistance exercise.[17] Glycolysis is the process by which ATP is produced from a breakdown of carbohydrates. During resistance exercise ATP depletion will ensue resulting in fatigue. ATP replenishment occurs during the rest time between sets of resistance training. Baechle and Earle[17] have established a one to three ratio of work to rest time for moderate intensity exercise lasting between 60 and 180 seconds. The rest time of two minutes between sets of ETER was appropriate based on these guidelines and likely contributed to the ERS improvements.

Comparison of bodyweight adjusted external rotation isometric strength values to prior investigations on shoulder eccentric training is challenging as there is a paucity of ERS reported in prior investigations examining eccentric training for SAPS. The Maenhout et al[15] research study utilized a similar strength testing protocol as the current investigation but reported strength values in newtons and did not adjust for the bodyweight of each participant. The data reported by Maenhout et al[15] could be converted from newtons to kilograms and adjusting average strength values for mean bodyweight values in kilograms. Bodyweight adjusted external rotation strength values, after the above calculations, reported by Maenhout et al[15] reveal .121 for the group that underwent eccentric training compared to .122 for the control group, at baseline. Eccentric training to the supraspinatus did reveal an improvement to .137 after 6 weeks and .140 after 12 weeks for the eccentric training group. In comparison the control group improved to .133 after 6 weeks and .136 after 12 weeks of general shoulder exercise training. While the within group change for both groups between week 0 compared to week 6 was statistically significant ($p<.001$), these results were reported as not significant

when comparing the eccentric group to the control group. The mean strength values for the eccentric training group in the Maenhout et al[15] study is substantially lower than those reported in the current investigation and are likely due to the differences in the interventions provided. Maenhout et al[15] utilized traditional concentric resistance training for external and internal rotation in both the experimental and control groups. Moreover, dosing for the resistance load was based on symptom response with load increasing as pain decreased as opposed to dosing based on strength improvements. The additional eccentric exercise for the experimental group was scapular plane abduction which did not result in a significant effect, when comparing to the general exercise group, on isolated external rotation strength. This lack of significant external rotation strength improvement could be a reason that Maenhout et al[15] did not identify a significant improvement in shoulder pain and function after 12 weeks of eccentric training compared to the control group. Also important to note was the lack of within group statistical significant improvements between week 6 and 12. This could support the notion that an additional 6 weeks of shoulder eccentric training may not be necessary to appreciate significant shoulder strength improvements for individuals with SAPS.

The results of this dissertation reveal a superior improvement to external rotation strength in comparison to the results reported by Maenhout et al[15] The results from this investigation could have a more beneficial impact on rotator cuff strength and shoulder biomechanics after eccentric training isolated to the external rotators.

Research Question #2

The goal for research question #2 was to determine if internal rotator to external rotator (IR/ER) and shoulder abductor to external rotator (ABD/ER) strength ratios

improved after 6 weeks of ETER. Lower strength ratios denote an improvement with a more normalized strength imbalance between the two muscle groups. Within the ETER group median IR/ER values from week 0 (1.17) to week 3 (1.13) and week 6 (1.08) did not reach statistical significance (p=.296) but a trend towards an improved ratio was identified. Within group changes for the ETER group for ABD/ER improved from week 0 (1.30) to week 3 (1.23) and worsened at week 6 (1.29). The within group changes for ETER did not reach statistical significance (p=.119) for the ABD/ER strength ratio. The GE group demonstrated a non-significant (p=.114) trend toward worsening for IR/ER of 1.04 in week 0 to 1.08 in week 3 and 1.11 in week 6. For ABD/ER statistically significant (p=.012) worsening occurred in the GE group from 1.05 in week 0 to 1.38 in week 3 and 1.59 in week 6. While the differences between groups are notable comparisons for both strength ratios, at all time points, did not reach statistical significance of $p<.05$.

A possible explanation for the lack of between and within group differences for the strength ratios of IR/ER and ABD/ER could be the absolute strength values for abduction and internal rotation. The experimental group improved abduction strength values from a mean of .171 at the initial visit to .201 at the week six data collection time point. The control group demonstrated minimal improvement of .143 to .144 over the same six week treatment time frame. These differences identified a trend when comparing the interaction between group and time with the factorial ANOVA but not reaching statistical significance (p=.05) with the Bonferroni correction of .00625 applied. Internal rotation values also improved for the experimental group from .162 to .183 compared to no improvement for the control group from .142 to .142 demonstrating a

trend but not reaching statistical significance for the interaction between group and time (p=.035) with the Bonferroni corrected alpha applied.

These improvements in abduction, external rotation and internal rotation strength values for the ETER group could have resulted from a variety of factors. One such mechanism could be related to physiological processes of the endocrine and autocrine systems in response to heavy load eccentric training. Testosterone, growth hormone, and cortisol are influenced by resistance training and can result in strength alterations for skeletal muscle.[17] Testosterone enhances both protein synthesis and neurotransmission causing greater force production of muscle tissue. Growth hormone increases amino acid and protein synthesis resulting in muscle hypertrophy after resistance training. Growth hormone also enhances circulating insulin like growth factor - I (IGF-I) which stimulates greater protein synthesis through satellite cell fusion within a muscle fiber. Satellite cells are muscle specific stem cells that aide in skeletal muscle regeneration and play a critical role for strength and hypertrophy enhancement. Eccentric training results in satellite cell activation and proliferation which has a positive regenerative effect on the muscle tissue.[159,160] Moreover, low velocity eccentric training of the elbow flexors has been identified to increase growth hormone levels immediately post exercise in untrained women.[161] Upper extremity eccentric training has resulted in greater IGF-I and growth hormone responses compared to concentric training in men.[162,163] Cortisol is a catabolic hormone that has the opposite effect on muscle tissue by decreasing protein synthesis resulting in atrophy.[17] Eccentric training has resulted in lower cortisol levels post exercise compared to concentric training.[164,165] The body of knowledge surrounding eccentric training indicates that enhanced function of the endocrine system results in

greater strength gains for skeletal muscle tissue. It is possible that ETER influences these endocrine and autocrine systems creating greater overall shoulder strength explaining the improved strength values for abduction and internal rotation.

Internal rotation strength could also be influenced by the utilization of the scapular row exercise in this research study. Meyers et al[123] assessed fine wire electromyography of the shoulder muscles during the scapular row exercise using a resistance band. The subscapularis muscle demonstrated 68.9% of the maximal voluntary isometric contraction during the row exercise. The subscapularis functions as a shoulder internal rotator and the use of a scapular row could potentially influence the IR/ER strength ratio values.

Another factor that could influence strength ratio results could be the presence of pain. When participants experience pain in the shoulder during a muscle testing procedure it may result in decreased effort or muscular force. The ANCOVA was utilized to analyze strength ratio results while controlling for the covariate of pain. Between group IR/ER values did not reach statistical significance for week 3 ($p=.753$) or week 6 ($p=.549$) when the covariate of worst pain was controlled for. Moreover, between group comparison for ABD/ER ratios did not reach statistical significance for week 3 ($p=.216$) or week 6 ($p=.416$) when the covariate worst pain is controlled for. While pain may affect strength testing in some cases the between group comparisons using an ANCOVA for this sample of patients did not demonstrate a significant influence.

Strength ratios between the ETER and GE groups identified between group differences that did not reach statistical significance. Although not significantly different at the $p<.05$ level a trend for the between group differences was identified. The use of

the more stringent non-parametric Mann-Whitney U for between group differences and relatively small sample size may have resulted in a type II error. The Mann-Whitney U was utilized due to the ordinal level data and a post hoc power analysis cannot be computed based on mean ranks. A post hoc power analysis was conducted by taking the mean for each strength ratio in the ETER group and subtracting from each strength ratio in the GE group. This data was then divided by the entire sample standard deviation for each strength ratio. These results were then entered into the G* Power 3 software application.[131] G Power is a commonly used power analysis program for post hoc procedures in scientific research.[132] The results identified post hoc power for the ABD/ER and IR/ER strength ratios ranging from .05-.27. Statistical power at the .80 level is commonly advocated to reduce the likelihood of type II error. This theory supports the idea that the statistical significance comparison between groups for strength ratios could possibly be present if a larger sample size can be recruited.

Prior investigations conducted by Camargo et al[24] and Maenhout et al[15] collected data for shoulder strength values before and after eccentric training but Camargo reported only isokinetic values for abduction and Maenhout did not calculate strength ratios. Camargo et al[24] only examined the movement of abduction without comparison to external rotation or internal rotation. Abduction strength values did improve slightly for the pre and post testing comparison but these changes did not reach statistical significance. The dosing parameters for the Camargo et al[24] investigation consisted of 3 sets of 10 repetitions performed 2 times per week for 6 weeks. The intervention may not have been substantial enough to demonstrate strength changes. Maenhout et al[15] did report strength values for abduction, internal rotation and external rotation before and

after the eccentric intervention but did not report strength ratios. The testing protocols between this current investigation and that described by Maenhout et al[15] differed slightly in that the current investigation utilized a chair with back support, straps to stabilize the participants trunk and a support wedge to maintain a consistent shoulder position. Maenhout et al[15] had the participant use the contralateral arm for support and tested internal and external rotation with the arm against the body instead of supported in 30 degrees of abduction. The comparison of these two investigations should be done with caution due to the discrepancy in testing protocols. Strength ratios can be calculated based on the raw strength data, in newtons, presented by Maenhout et al.[15] For the eccentric training group ABD/ER for week 0 was (.858), week 6 (.845) and week 12 (.850). The general exercise control group reported week 0 (.818), week 6 (.903) and week 12 (.901). Without statistical analysis it is challenging to interpret this data but it is interesting to note that the strength ratios for ABD/ER did not change considerably. This may be due to the inclusion of abduction, external rotation and internal rotation resistance exercises all into the experimental group. An expectation of worsening ABD/ER strength ratios, due to the heavy load eccentric exercise for the abductors, could certainly be considered but these results do not support that theory. Results of IR/ER strength ratios for Maenhout et al[15] demonstrated improvements for the eccentric training group from week 0 (1.468) to week 6 (1.341), but not to from week 6 to week 12 (1.343). The general exercise group improved from week 0 (1.427) to week 6 (1.361) and week 12 (1.348). These changes could be considered minimal but without statistical analysis a comparison is not able to be completed.

While not statistically significant, this dissertation demonstrates a trend toward favorable shoulder muscle strength changes after ETER. These changes exceed changes demonstrated in the prior investigations conducted by Maenhout[15] and Camargo[24] and could likely be a result of the intervention protocol utilized. This current investigation utilized an external rotation only eccentric protocol whereas the prior comparison studies utilized abduction as the eccentric training exercise. The abduction exercise didn't demonstrate a noteworthy worsening of calculated strength ratios but an accurate comparison may not be possible due to discrepancy in testing protocols and types of measurement utilized.

Research Question #3

Participant Self-Reported Pain Scores

The goal of research question #3 was to compare self-reported pain and function in participants with SAPS before and after a 6 week ETER training program. These results were also compared to the GE group who only participated in a general shoulder exercise program without eccentric training. Three categories of pain were reported, best pain, worst pain and average pain on the 0-10 numeric pain rating scale (NPRS). Our results demonstrated that after 6 weeks the ETER group improved by a median 2 points for average pain, 4 points for worst pain and 1 point for best pain. These within group changes were significant at the $p<.05$ level. Between group changes for average and worst pain at week 6 improved significantly at the $p<.05$ level in favor of the ETER group. Best pain also improved in favor of the ETER group but only reached statistical significance at the week 3 time point due to a ceiling effect of 0/10 median score value.

Minimal clinical important difference (MCID), for the NPRS for individuals with shoulder pain, was reported by Michener et al[144] to be 2.17. Mintken et al[143] reported the MCID for the NPRS in patients with shoulder pain to be 1.1. These results demonstrate a spectrum of meaningful change in a variety of shoulder conditions. Our results exceed both levels of meaningful change and particularly the more conservative level reported by Michener et al[144] for the worst pain value. This comparison identified meaningful change for average pain and worst pain in the ETER group for our investigation. The GE group did not achieve MCID with only a 1 point improvement in average pain. Neither group achieved MCID for best pain as the initial median pain value of 1 was too low.

Prior reports for eccentric training of the shoulder report a wide range of initial pain scores and improved pain scores after eccentric training. Bernhardsson et al[23], Holmgren et al[16] and Jonsson et al[25] all reported pain values using the visual analog scale (VAS) with Camargo et al[24] and Maenhout et al[15] not reporting pain scores. The visual analog scale is comparable to the NPRS as both pain reporting tools demonstrate similar responsiveness and have correlated in prior reports.[166] Bernhardson et al[23] reported VAS improvements from 57 to 29 before and after 12 weeks of eccentric shoulder training. Converting these results for comparison to the NPRS identifies a 2.8 median improvement in pain scores. These results reported by Bernhardson et al[23] are comparable to our results for average pain improvement after training. Differences noted are that Bernhardsson et al[23] recruited individuals with at least one year of chronic shoulder pain and resting VAS scores of at least 30. It appears that Bernhardsson et al[23] had a sample of individuals with more severe pain levels upon initial examination whereas our sample had initial ratings of 3 and final ratings of 0 for average pain.

Holmgren et al[16] reported VAS scores of 15 to 10 at rest, 61 to 25 with activity and 46 to 15 for night pain after 12 weeks of shoulder eccentric training. One year post intervention[27] those individuals that did not go on to receive surgery maintained lower VAS scores of 2 at rest, 15 with activity and 11 for night pain. It was identified that individuals in the control group who did not undergo surgery also improved to 5 for resting pain, 12 for activity pain and 11 for night pain. These categories for reporting differ from our average, worst and best pain. Comparison of our results to these are challenging because participants are being asked different questions regarding pain. Moreover, the sample of individuals in the Holmgren et al[16] investigation were on a wait list for surgery and may represent a different clinical scenario within the diagnosis of SAPS. Severity of pathology also makes comparisons challenging with 35% of the individuals included in the eccentric training group reported to have an ultrasound imaging confirmed partial or full thickness rotator cuff tear. These participants had also failed prior rehabilitation exercise programs before inclusion in the research investigation.

Jonsson et al[25] reported VAS improvements of 62 to 18 after eccentric training of the shoulder. The authors did not report the category of this pain report but it appears to be average pain. The 4.4 point improvement is larger than our results for average pain but the sample of participants recruited by Jonsson et al[25] differed compared to our sample in that they had a higher baseline pain and were on wait list for surgery. Comparison of our pain scores and prior investigations on shoulder eccentric training reveal similar magnitude of change for average pain but our sample had less severe initial pain levels upon initial examination compared to those reported by Jonsson et al[25],

Bernhardsson et al[23] and Holmgren et al.[16] An important feature from our exercise protocol was that pain was not reproduced during the interventions. We asked participants to conduct exercises without increasing symptoms which is in direct contrast to the prior investigations on shoulder eccentric training.

Participant Reported Function

We utilized the Western Ontario Rotator Cuff Index (WORC) to measure participant reported shoulder function. We identified a significant improvement ($p<.001$) from the week 0 median score of 69.29%, week 3 score of 82.10% and week 6 score of 91.40% in the ETER group. Between group comparisons also revealed significant differences ($p<.001$) in favor of ETER with only a 9.90% point improvement after 6 weeks of intervention for the GE group. MCID for the WORC has been reported to be 13%.[149] We identified a 22.11% improvement for the ETER group which far exceeded MCID compared to the GE group. Prior investigations on shoulder eccentric training utilize a variety of patient report functional measures. We chose the WORC because it is a disease specific tool unique to individuals with SAPS and rotator cuff tendinopathy. Of the prior investigations on eccentric training for SAPS only Bernhardsson et al[23] utilized the WORC. Bernhardson et al[23] reported a 20% improvement in WORC scores after 12 weeks of eccentric training, going from 51% to 71%, exceeding the MCID. The initial and final reported functional scores of the Bernhardson et al[23] investigation are lower than the scores we identified in our investigation supporting the fact that the two samples of participants differed in initial symptom severity and self-reported functional ability.

Camargo et al[24] and Holmgren et al[16] utilized the Disabilities of the Arm Shoulder and Hand Questionnaire (DASH). When the DASH is converted to a 100 point scale it

can be compared to the WORC.[148] Holmgren et al[16] provided DASH scores converted to the 100 point scale and identified improvements in DASH scores from 30 to 16 which did reach statistical significance compared to the 6 point mean improvement for the control group but p values were not reported for statistical significance testing. This improvement in function was not as substantial as our results but did exceed the MCID of 10.5[167] for the DASH score. Camrago et al[24] reported DASH scores after the conversion to a 100 point scale at 4 different time points. DASH scores were recorded 4 weeks before treatment, at the start of treatment, after 6 weeks of treatment and again 6 weeks after the conclusion of treatment. Mean DASH scores steadily declined from 18.78 to 5.49 in the Camargo et al[24] investigation. For comparison to our results we examined the DASH score on week 0 of eccentric training and immediately after treatment week 6 in that study. Camargo et al[24] identified a mean improvement of 4.58 points on the DASH from 14.28 to 9.70. These scores do not exceed MCID and are markedly smaller than the results we identified after 6 weeks of ETER. Caution should be taken when comparing our results for shoulder function to that of Holmgren et al[16] and Camargo et al[24] as the WORC and DASH contain different items and scoring methods.

Maenhout et al[15] utilized the Shoulder Pain and Disability Index (SPADI) which is scored on a 100 point scale and can be compared to the WORC. The MCID for the SPADI has been reported as 18 points.[168] Maenhout et al[15] identified significant within group changes ($p<.001$) when comparing week 0 mean SPADI scores of 42 to the week 6 scores of 25.4 and week 12 scores of 17. The 25 point change, after 12 weeks of eccentric training, is comparable to the 31.39% change we identified after 6 weeks of ETER. What is very interesting about the results reported by Maenhout et al[15] is that the

general exercise group had a larger 29.8 improvement in SPADI scores, of 44.3 to 14.5, compared to the group who underwent eccentric training. This may be due to the interventions utilized in the Maenhout et al[15] investigation. The general exercise group did receive external rotation strengthening exercises compared to the experimental group which also received shoulder abduction eccentric loading. This method of integrating eccentric loading for abduction may not have been as beneficial due to the possible negative effects for shoulder mechanics compared to just external and internal rotation strengthening exercises.

Jonsson et al[25] measured shoulder function with the Constant Score. The Constant Score is a 100 point scale but integrates physical exam measures including strength and range of motion and results cannot be accurately compared to the WORC. These measures demonstrate similar reliability and responsiveness to change[148] but differences between scores vary due to incompatible items and scoring methods.

Research Question #4

The goal of research question #4 was to determine if an improvement in pain free active shoulder range of motion (AROM) would occur after 6 weeks of ETER. AROM did not significantly improve for any movements after 6 weeks of ETER and when compared to the GE group no significant differences were identified. The null hypothesis was not rejected in our investigation of ETER. Prior investigations of shoulder eccentric training have not reported range of motion values as a dependent variable. Holmgren et al[16] and Jonsson et al[25] utilized the Shoulder Constant Score which has a AROM component but that specific data was not reported in either investigation. Our results indicate very high initial AROM values and may have suffered from a ceiling effect.

Moreover, the posterior shoulder stretch utilized by both the GE and ETER groups in this research study did not include any stabilization of the scapulae. Salamh et al[169] examined the effects of the horizontal adduction stretch with and without scapular stabilization on internal rotation range of motion values. Participants included female volleyball players with internal rotation deficits recording a baseline mean value of 40 degrees. A between group significant difference (p=.006) was identified when comparing the mean internal rotation value of 51 degrees for the group that received scapular stabilization compared to a mean internal rotation angle of 43 degrees for the group that received the stretch without stabilization.[169] These results demonstrate the importance of integrating scapular stabilization when using a posterior shoulder stretch to improve internal rotation mobility. The absence of scapular stabilization for the horizontal adduction stretch in this research study may have contributed to the lack of internal rotation improvement. Our results also demonstrate a trend towards improved abduction for the ETER group of 20 degrees and that change does exceed the prior reports of shoulder range of motion MCID.[137] It is possible that our AROM results are susceptible to a type II error as the post hoc calculated power for all motion ranges from .05 to .44.

Research Question #5

The goal of research question #5 was to determine the effects from 6 weeks of ETER on the upper quarter y balance test (UQYBT). The null hypothesis was not rejected when comparing within group changes after 6 weeks of ETER and in comparison to the GE control group. To our knowledge no other investigations have examined the effects of exercise treatment on UQYBT scores. The UQYBT is a relatively new procedure for assessing single arm stability and mobility in a closed chain

position. Our experience of conducting the UQYBT over several sessions for all participants was that individuals need to have a significant amount of trunk and abdominal strength to perform the test. We hypothesize that isolated shoulder exercises may not address the strength and coordination skills required to improve UQYBT scores.

Research Question #6

The goal for research question #6 was to determine the effects from 6 weeks of ETER on self-perceived global rating of change (GROC) and compare these results to that of the GE group. The results of this study rejected the null hypothesis and supported the research hypothesis of a significant difference in GROC scores for the ETER group compared to the GE group. The ETER group demonstrated improvements in GROC scores of +3 at 3 weeks and +5 at 6 weeks. A significant difference ($p<.001$) was present between groups as the GE group did not improve on the GROC after 6 weeks.

Several prior investigations examining eccentric training of the shoulder have reported global change scores. Holmgren et al[16] utilized the GROC and reported a significant difference ($p<.001$) with 69% of individuals who completed the eccentric training program reported large GROC improvements compared to only 24% in the general exercise group. The authors did not report descriptive statistics for the GROC scores making a comparison of these results to ours challenging.

Maenhout et al[15] utilized a measurement of self-perceived improvement but it was a 6 point scale and the results could not be directly compared to those of the GROC. Participants in both the eccentric training group and general exercise group improved and these results may be due to the interventions selected as described earlier.

IMPLICATIONS AND RECOMMENDATIONS

Subacromial pain syndrome (SAPS) is a prevalent condition, commonly encountered by medical professionals, often resulting in significant loss of function and disability.[30, 32] The costs associated with the treatment of SAPS are significant with physical rehabilitation comprising a substantial portion.[33, 34] Exercise has been demonstrated as an effective intervention in the management of SAPS but the optimal protocol has not been established in prior research studies.[14] The variability in exercise prescription and clinical outcomes poses an opportunity for more specific shoulder loading programs to be investigated. The results of this investigation have direct implications for the rehabilitation professional seeking a novel exercise program to improve clinical outcomes for individuals presenting with SAPS.

The outcomes of this investigation demonstrate a considerable improvement in external rotation strength, pain, function, and global change after a 6 week shoulder eccentric training protocol. These improvements exceed changes demonstrated by a group only performing a general shoulder exercise program. Moreover, the improvements identified after 6 weeks of ETER in this investigation are superior to the improvements identified in prior research on eccentric training of the shoulder. The results of this investigation support the clinical approach of maximizing load to the shoulder external rotators to improve rotator cuff strength. Moreover, the loading exercise was conducted in a pain free manner which is in direct contrast to prior investigations on shoulder eccentric training. Our results support the idea that clinical outcomes of pain, function and global change improve when exercises target the external rotators and forego loading of the shoulder abductors. Prior investigations may not have

demonstrated the improved outcomes as identified in this study because an emphasis was placed on training the shoulder abductors.

LIMITATIONS AND DELIMITATIONS

Several limitations within this investigation should be discussed. The first is potential bias on the part of the treating physical therapist. This physical therapist was the only clinician to provide treatment in the investigation and could limit the generalizability of our results. A specific protocol for exercise instruction was provided to the treating therapist but his ability to encourage patients in exercises he believes to be more effective could have been present. Moreover, he could demonstrate variable enthusiasm or body language during treatments provided to individuals in the ETER and GE groups. Therapeutic alliance can be described as the collaboration and support between the clinician and patient.[170] This alliance has been demonstrated to influence outcomes for clinical trials of patients with back pain receiving rehabilitative interventions.[170,171] A methodology controlling for therapeutic alliance and utilizing several different treating clinicians at multiple sites would be advantageous. Other questionnaires that determine patient expectations for treatment could be beneficial as well. Outcomes can be influenced by patient expectations for certain interventions and this information should be collected in clinical trials such as this one. Other potential confounding variables include fear avoidance beliefs and pain catastrophizing behaviors that can negatively impact outcomes in patients with musculoskeletal pain.[172,173] These conditions were not included in the general medical questionnaire and it could have been beneficial to utilize a specific psychosocial screening tools as a component of the exclusion criteria.

Another limitation could have been the duration of the eccentric phase for the exercise intervention in this dissertation. We selected three seconds for the eccentric lowering duration of time which was consistent with Holmgren et al.[16] This could potentially have been a limitation as Maenhout et al.[15] utilized 5 seconds for the duration of the eccentric phase. The beneficial results after eccentric training demonstrated by Jonsson et al.[25] and Bernhardsson et al.[23] could be due to greater time under tension but the exact duration was not reported. A greater duration of time under tension could also impact muscular strength changes and could have possibly influenced the results for ERS and the strength ratios of IR/ER and ABD/ER in this research study. Borde et al[174] identified a total time under tension duration of 6 seconds to be a statistically significant ($p<.01$) variable for affecting muscle strength in older adults. Westcott et al[175] identified greater strength gains in middle aged men and women when comparing longer duration time under tension exercise to traditional cadence resistance training. Moreover, exercises that incorporate longer time under tension durations have demonstrated increased muscle protein synthesis[176] and peripheral muscular fatigue[177] often resulting in greater strength gains. This dissertation did demonstrate significant improvements to ERS for the ETER group however strength ratios for IR/ER and ABD/ER did not improve to a statistically significant level. Increasing the time under tension for the eccentric phase could provide additional benefit for improving ERS to a greater extent and improving strength ratios.

The interventions utilized by the control group could potentially not be generalizable to a typical exercise program utilized by an individual experiencing SAPS. AROM for flexion and abduction were utilized and these movements are typically the

most painful and may not be utilized by a treating physical therapist in clinical practice. Moreover, the painful arc movement of abduction between 60 and 120 degrees was a positive test for the inclusion criteria. Including an exercise that closely simulates this painful diagnostic test could have negatively influenced outcomes for participants allocated to the GE group. Two participants elected to cease participation in this investigation during treatment week 2. Both participants had been randomized to the GE group and reported pain during the AROM exercises. Intention to treat was used for these two participants for the week 3 and week 6 outcome measure time points which could have influenced the results for the GE group.

Another limitation could be the possibility of type II error for between group differences in strength ratios, the UQYBT and ROM measurements. This investigation did demonstrate a lack of statistical power for several of these dependent variables and the relatively small sample size is a limitation. Investigations such as this one requiring the involvement of a significant number of human participants with a specific musculoskeletal injury are challenging. This research project was conducted in a small city of only 13,000 residents making it challenging to recruit research participants meeting the inclusion criteria. Another limitation potentially resulting in a reduced number of participants could have been the method for conducting the painful arc test. This research study utilized a strict method for a positive test by mandating that pain was present between 60 and 120 degrees of abduction with pain resolving above that range of motion. The diagnostic accuracy for the painful arc test reported by Park et al[35] and Michener et al[50] did not indicate that pain should resolve above 120 degrees of shoulder abduction. This discrepancy in the classification of a positive test could have limited

some participants that may have met the inclusion criteria and potentially participated in this research study. The sample size for this investigation is a limitation that may require more time to enroll a greater sample of participants presenting with SAPS.

The only strength assessment for the current investigation was isometric strength testing. Cadore et al.[178] examined isometric strength values, peak torque, rate of force development and muscle conduction velocity for individuals participating in eccentric training versus concentric training for six weeks. While both training types identified improvements in all outcome measures isometric strength values demonstrated the only significant improvement for the eccentric group compared to the concentric group. The dramatic changes identified in strength values for the ETER group compared to the GE group in the current investigation could be unique to isometric testing and may not necessarily reflect changes in other strength testing methods.

A delimitation of this investigation is the exclusive use of exercise as an intervention for participants with SAPS. This approach to patient management may not be generalizable to clinical practice where the combination of exercise and manual therapy is superior to exercise alone in the treatment of SAPS.[179] Exercise was used exclusively in this investigation to determine specific cause and effect. Only the single eccentric exercise for the shoulder external rotators was the difference between the ETER and GE groups. This investigation was purposefully designed to establish cause and effect with strong internal validity at the sacrifice of external validity. A more pragmatic study design could provide different results for the dependent variables of AROM, strength ratios and the UQYBT. Moreover, a study design including other interventions to reduce pain could improve the participant's tolerance to exercise loads.

Another delimitation is the inclusion of all participants diagnosed with SAPS without an understanding of tissue pathology for each individual participant or a subgrouping classification for the varying clinical presentations. Significant clinical variability exists between individuals diagnosed with SAPS and one treatment approach is not likely to benefit all of them. A validated classification system for SAPS has not been established but efforts towards narrowing the clinical presentations most likely to benefit from ETER should be considered. Advanced imaging may have been advantageous to determine extent of tendon pathology but may not be clinically feasible in many settings. This investigation took a pragmatic approach for a cost effective and efficient determination of each individual's clinical presentation.

FUTURE RESEARCH

The results of this investigation suggest that eccentric training of the shoulder external rotators (ETER) provides improved rotator cuff strength, pain, shoulder function and patient perceived improvement compared to a general exercise shoulder protocol. Future research should be directed toward the comparison of the ETER protocol to a traditional (concentric) external rotation exercise protocol. Future studies should also include larger samples of individuals experiencing SAPS and long term follow up. Incorporating a sample of patients typically referred to a physical therapy practice can allow for greater generalization of study results.

The clinical examination and diagnosis of SAPS is critically important for future research. The variability in clinical presentation for SAPS likely influences outcomes and a classification system for patient subgrouping could be helpful to determine which types of patients respond most favorably to ETER. Moreover, a determination of the

severity of tissue damage through advanced imaging techniques can also assist in the determination of which individuals should participate in the ETER protocol.

The prescription of exercise dose and progression should be investigated with more detail. The dosing protocol utilized in this investigation of 3 sets of 15 for ETER was utilized in prior shoulder research but its origin could be considered arbitrary and developed from research studies conducted on the Achilles tendon.[38] A progressive protocol with varying dosing strategies based on symptom response and functional status would be more generalizable to clinical practice. Varying the speed, duration, and shoulder positions during ETER in comparison to traditional rotator cuff strengthening exercises should be investigated. Moreover, trials that integrate the use of manual therapy and addressing common impairments of the shoulder region can improve the generalizability to clinical practice.

SUMMARY

Shoulder pain is a common condition often resulting from SAPS.[1,2] The supraspinatus tendon frequently demonstrates signs of degeneration, associated with weakness, pain, and functional limitations during activities requiring overhead elevation. Moreover, pathological tendon changes can lead to tears in time with 97% of spontaneous complete tendon ruptures demonstrating signs of degeneration.[7, 8] Two of the more common muscle imbalances associated with SAPS reside in the strength of the abductors versus external rotators and internal rotators versus external rotators.[10, 11] These imbalances are responsible for impairing shoulder elevation as a result of an abnormal deltoid to rotator cuff force couple.[10] When this force couple becomes disturbed the deltoid muscle creates an excessive superior glide of the humeral head while the rotator cuff is unable to provide a

sufficient compressive and stabilizing effect for the head of the humerus in the glenoid fossa.[12] Muscle imbalances between the deltoid to rotator cuff and stronger internal rotators to, typically weaker, external rotators have been associated with SAPS.[13] Interventions prescribed to address the signs and symptoms of SAPS, improve function and reverse the degenerative cascade to the supraspinatus tendon, could be effective for patients experiencing SAPS. Although a variety of interventions have been described in the literature,[14] eccentric training could be considered as a worthwhile intervention for those experiencing symptoms of SAPS.[15, 16]

Eccentric training can be defined as a form of exercise in which muscle tissue lengthens because the force generated through the muscle contraction is less than the resistive force acting upon it.[17] Studies suggest eccentric training is beneficial for decreasing symptoms, improving function and normalizing tendon structure, for patients with tendinopathy at the Achilles,[18, 19] patella,[20] lateral elbow[21] and posterior tibialis[22] tendons. Moreover, studies examining clinical outcomes for patients with SAPS demonstrate favorable results when eccentric training is utilized as an intervention.[15, 16, 23-27] Eccentric training to the shoulder external rotators in patients with SAPS has not been thoroughly investigated. Prior research has examined a variety of eccentric supraspinatus exercises but none specifically isolate the predominantly weak external rotators with an eccentric movement. The purpose of this investigation is to examine the effects of ETER in subjects with SAPS. Identifying specific exercise protocols for individuals with SAPS could provide evidence to help clinicians select the best interventions.

Sixty-five participants were recruited through purposive sampling to the University of St. Augustine faculty clinic where the primary investigator is employed.

Individuals with shoulder pain were made aware of the opportunity to participate in the investigation by publicly displayed flyers. Participants were then screened by the primary investigator and informed of the opportunity to participate in the study. Inclusion criteria consisted of the presence of non-acute shoulder pain (greater than 3 months duration), 3 out of the 6 following tests positive, Neer impingement, Hawkins-Kennedy impingement, empty can test, resisted external rotation test, palpable tenderness at the insertion of the supraspinatus or infraspinatus, and painful arc from 60° to 120° during active abduction, and age over 18 years old.

Following completion of all paperwork participants were taken through a variety of tests and measures performed by the primary investigator. The dependent variables used to measure the effects of ETER included: (1) body weight adjusted mean isometric shoulder strength values measured in kilograms (2) strength ratios for internal/external rotation, external rotation/abduction, (3) Pain free active range of motion (4) Numeric Pain Rating Scale, (5) Upper Quarter Y-Balance test, (6) Western Ontario Rotator Cuff Index. During follow up evaluations after treatment was conducted the (7) dependent variable of Global Rating of Change was also utilized.

Upon completion of all tests and measures participants were randomized into one of two groups by a blinded research assistant. A control group would perform a twice daily, general exercise program consisting of 2 sets of 10 repetitions for shoulder flexion, extension, and abduction. In addition these participants performed a cross body horizontal adduction stretch and scapular rows with a resistance band. Participants that were randomized to the experimental group performed the above exercises except an eccentric external rotation exercise in lieu of the active abduction, flexion and extension

exercises. The eccentric exercise was conducted with a resistance band and load was determined based on a 15 repetition maximum. Participants in the ETER group performed this exercise twice daily for three sets of 15. All participants attended one session per week for 4 weeks and then a final treatment visit during week number 6. Data for the dependent variables was collected on week 0, week 3 and week 6.

Forty-four individuals with SAPS aged 23-76 (mean 46.16, median 47.50) met the inclusion criteria and participated in this investigation. Group assignment after randomization revealed 21 subjects participating in the GE group and 23 in the ETER experimental group. Statistical analysis using the independent samples *t* test was conducted and the analysis revealed no significant differences between the experimental and control groups for the variables of age ($p = .264$), weight ($p = .694$), and shoulder pain onset duration ($p = .763$). Shoulder pain onset did not meet the assumption of normality of distribution (Shapiro-Wilk W test control $p < .001$, experimental $p < .001$) therefore the Mann-Whitney U test was also used to analyze between group differences. Median comparison for pain onset duration (control 17 months, experimental 21 months) did not reach significance with the Mann-Whitney U test ($p = 1.000$).

After the second week of interventions 2 participants from the GE group requested to cease participation in the study due to worsening symptoms. Intention to treat analysis was utilized for the data analysis of week 3 and week 6 for these 2 subjects.

The factorial repeated measures analysis of variance (ANOVA) was used to analyze strength differences, ROM and the UQYBT for the interaction between group and time. A Bonferroni corrected alpha was set to .00625. The interaction between group and time was statistically significant for external rotation strength ($p < .001$). None

of the range of motion or UQYBT results identified a statistical significant difference for the interaction between group and time negating an indication for pairwise comparison.

Friedman's ANOVA for within group repeated measures did not identify statistical significance $p<.05$ for the ETER group comparisons of ER/IR and ER/ABD at week 0, week 3 or week 6. The control group did demonstrate significant worsening strength ratios for the abductor to external rotator mean ranks ($p=.012$). No significant difference was identified when comparing changes between the ETER and GE groups for all time points using the Mann Whitney U for between group differences (IR/ER Week 0 $p=.226$, IR/ER week 3 $p=.716$, IR/ER week 6 $p=.459$, ABD/ER Week 0 $p=.080$, ABD/ER week 3 $p=.169$, ABD/ER week 6 $p=.318$).

Significant differences were identified within the ETER group when comparing average pain ($p<.001$), worst pain ($p<.001$) and best pain ($p=.004$) mean rank values between week 0, week 3 and week 6. The GE group did not demonstrate significant differences for average pain ($p=.262$), worst pain ($p=.876$) and best pain ($p=.245$) when comparing differences between week 0, week 3 and week 6. A significant difference was identified when comparing the ETER group to the GE group for average pain ($p=.022$) and worst pain ($p=.001$) after 6 weeks of treatment. No significant difference was identified for changes in best pain values when comparing the ETER group to the GE group ($p=.478$) after 6 weeks of treatment.

Significant differences were identified within the ETER group when comparing mean rank WORC scores between week 0, week 3 and week 6 ($p<.001$). The GE group did not demonstrate significant differences in WORC scores between week 0, week 3 and week 6 ($p=.148$). Between group comparisons identified a significant difference in

WORC scores for week 3 ($p=.001$) and week 6 ($p<.001$). Significant differences were identified between groups for GROC scores at week 3 ($p=.001$) and week 6 ($p<.001$).

CONCLUSION

The results from this dissertation identified the efficacy of ETER as evidenced by the significant improvements from week 0 to week 3 and week 6 for external rotation strength, pain, function and global change when compared to a control group who only performed general shoulder exercises. Moreover, the effectiveness was also established based on improvements within the ETER group for the above listed dependent variables.

Prior evidence for eccentric training of the shoulder has provided mixed results with clinical trials not utilizing a control group, emphasizing shoulder abduction training, or integrating a variety of exercises making an establishment of cause and effect challenging.[180] While the positive clinical outcomes from these trials were beneficial, a need for further investigation was warranted. This dissertation compared ETER in positions found to strengthen the supraspinatus, infraspinatus and teres minor versus a general shoulder exercise program. The results of this investigation provide a specific exercise strategy that can be utilized for individuals experiencing SAPS.

Future research should be directed toward the comparison of the ETER protocol to a traditional (concentric) external rotation exercise protocol. Future studies should also include larger samples of individuals experiencing SAPS and long term follow up. Incorporating a sample of patients typically referred to a physical therapy practice can allow for greater generalization of study results.

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APPENDICES

Appendix A Participant Recruitment Flyer

UNIVERSITY OF ST. AUGUSTINE FOR HEALTH SCIENCES **Nova Southeastern University**

REQUEST FOR RESEARCH PARTICIPANTS

Have you been experiencing shoulder pain for more than 3 months?

If so, you may be eligible to participate in a research study titled "Shoulder External Rotator Eccentric Training for Subacromial Impingement Syndrome" Eric Chaconas, Physical Therapist and Assistant Professor at the University of St. Augustine, Department of Physical Therapy is conducting a clinical study on specific exercise techniques for individuals experiencing shoulder impingement syndrome.

This study is investigating measurements of shoulder pain, strength, motion and function before and after the completion of a 6 week exercise program. All measurements and exercises used in this study are routinely used in clinical practice. In other words, we are not performing any type of measurements or exercises that are investigational or experimental.

Participants will be compensated for their time.

If you are interested please contact:

Eric Chaconas PT, DPT, CSCS, FAAOMPT

Phone: (904)-290-1487

Email: echaconas@usa.edu

NOVA SOUTHEASTERN UNIVERSITY
Institutional Review Board
Approval Date: DEC 04 2014
Continuing Review Date: DEC 03 2015

Appendix B Nova Southeastern IRB Form

NOVA SOUTHEASTERN UNIVERSITY

MEMORANDUM

To: Eric Chaconas, PT, DPT
HPD – College of Health Care Sciences

From: David Thomas, M.D., J.D.
Chair, Institutional Review Board

Date: December 18, 2013

Re: *Shoulder External Rotator Eccentric Training for Subacromial Impingement Syndrome*
Protocol No. 12111308Exp.

I have reviewed the revisions to the above-referenced research protocol by an expedited procedure. On behalf of the Institutional Review Board of Nova Southeastern University, *Shoulder External Rotator Eccentric Training for Subacromial Impingement Syndrome* is approved in keeping with expedited review categories #4 and #7. Your study is approved on **December 18, 2013** and is approved until **December 17, 2014.** You are required to submit for continuing review by **November 17, 2014**. As principal investigator, you must adhere to the following requirements:

1) CONSENT: You must use the stamped (dated consent forms) attached when consenting subjects. The consent forms must indicate the approval and its date. The forms must be administered in such a manner that they are clearly understood by the subjects. The subjects must be given a copy of the signed consent document, and a copy must be placed with the subjects' confidential chart/file.

2) ADVERSE EVENTS/UNANTICIPATED PROBLEMS: The principal investigator is required to notify the IRB chair of any adverse reactions that may develop as a result of this study. Approval may be withdrawn if the problem is serious.

3) AMENDMENTS: Any changes in the study (e.g., procedures, consent forms, investigators, etc.) must be approved by the IRB prior to implementation.

4) CONTINUING REVIEWS: A continuing review (progress report) must be submitted by the continuing review date noted above. Please see the IRB web site for continuing review information.

5) FINAL REPORT: You are required to notify the IRB Office within 30 days of the conclusion of the research that the study has ended via the IRB Closing Report form.

The NSU IRB is in compliance with the requirements for the protection of human subjects prescribed in Part 46 of Title 45 of the Code of Federal Regulations (45 CFR 46) revised June 18, 1991.

Cc: Dr. M. Samuel Cheng
Dr. Morey Kolber
Ms. Jennifer Dillon

Institutional Review Board
3301 College Avenue • Fort Lauderdale, Florida 33314-7796
(954) 262-5369 • Fax: (954) 262-3977 • Email: irb@nsu.nova.edu • Web site: www.nova.edu/irb

Appendix C University of St. Augustine IRB Form

UNIVERSITY OF ST. AUGUSTINE
FOR HEALTH SCIENCES

January 24, 2014

Eric Chaconas, PT, DPT
1 University Blvd
St Augustine FL 32086

RE: UR-0122-176 *"Shoulder External Rotator Eccentric Training for Subacromial Impingement Syndrome"*

Dear Dr. Chaconas,

The Chair of the Institutional Review Board (IRB), responsible for the review of research involving human subjects, has reviewed the original proposal, noted the revisions provided by you upon reviewers' request and approved the revised project referenced above. Approval for the project will be for one year, starting January 24, 2014. If a University of St. Augustine For Health Sciences faculty member or student leaves the University prior to completion of a USAHS IRB-approved study, the study may be continued until expiration of that IRB approval. The IRB approval will expire on January 24, 2015.

This approval is granted with the understanding that no changes may be made in the procedures to be followed, nor in the consent form(s) to be used, until after such modifications have been submitted to the IRB for review and approval. Please be sure your consent form includes the IRB contact name and telephone number (Dr. Lisa Chase, Chair, University of St. Augustine for Health Sciences Institutional Review Board, 904-826-0084 x1234, lchase@usa.edu). **Researchers must retain a copy of the signed consent form in their files for three years following completion of the project and must provide a copy of the consent form to the subject(s).**

Any unanticipated problems involving risks to human subjects or serious adverse effects must be promptly reported to the IRB.

Two months prior to the expiration of this approval, you will receive notification of the need for updated information to be used for the project's continuing review. When project is completed, please notify the IRB in writing. Thank you.

Sincerely,

Lisa A. Chase

Lisa A. Chase, PhD, PT
Chair, IRB

LC/ck

1 UNIVERSITY BOULEVARD - ST. AUGUSTINE, FL 32086-5783 - (904) 826-0084 - FAX (904) 826-0085 - WEBSITE: *www.usa.edu*

Appendix D Participant Informed Consent Form

NOVA SOUTHEASTERN UNIVERSITY
Health Professions Division
College of Health Care Sciences
Physical Therapy Department

Adult/General Informed Consent form for Participation in the study titled:
Shoulder External Rotator Eccentric Training for Subacromial Impingement Syndrome

IRB protocol # 12111308Exp

Principal Investigator
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Kolber@Nova.edu

For questions/concerns about your research rights, contact:
Human Research Oversight Board (Institutional Review Board)
Nova Southeastern University
(954) 262-5369 /Toll Free: 866-499-0790
IRB@nsu.nova.edu

University of St. Augustine
800-241-1027 ext 1234
ckingry@usa.edu

Data Collection Site:
University of St. Augustine for Health Sciences
1 University Blvd
St. Augustine, Florida 32080

NOVA SOUTHEASTERN UNIVERSITY
Institutional Review Board
Approval Date: DEC 18 2013
Continuing Review Date: DEC 17 2014

What is the study about?

Your participation in this study is for research. The purpose of this study is to determine if people with a certain type of shoulder pain have differences in strength, shoulder motion, function and pain levels after performing different shoulder exercise routines twice a day every day for six weeks.

Why are you asking me?

You have the type of shoulder pain that we think might benefit from different types of shoulder exercises. Sixty-eight people with shoulder pain will be recruited to participate in this study. We have a good understanding that exercise benefits people with your type of shoulder pain but we are not certain if one form of exercise is better than another.

Initials: _____ **Date:** _____

What will I be doing if I agree to be in the study?

This study involves examining your shoulder for pain, strength and function before and after you perform a series of exercises in our clinic and at home for a total of 6 weeks. None of the tests or exercises you will perform are experimental. All questions, tests, measures and treatment will be provided in a private examination room on the campus of the University of St. Augustine. The measurements will be taken during your first visit and again 3 and 6 weeks later, as well as 6 months after the initial measurement session. In addition to these testing sessions you will see a physical therapist for exercise treatment one time per week for 6 weeks. You will be randomly assigned to one of two groups. Each group will perform a series of shoulder exercises routinely done by physical therapists for people with shoulder pain. Once the study is complete the measurements will be compared to see if there is a difference between individuals who perform different types of shoulder exercise programs.

Each session that contains testing and measurements (session 1, week 3, week 6 and 6 months) will last approximately 60 minutes. Sessions held on week 2, 4 and 5 will only last 30 minutes as no testing will be done during those sessions, only exercise treatment. You will be able to ask questions at any time during the study.

First, you will give us information about your height, bodyweight, hand dominance, shoulder pain and medical history. We will then perform 3 screening tests on your shoulder to make sure that you do not have a tendon tear. These tests are named the drop arm test, lag sign and rent test. The drop arm test will be performed with you in the standing position. The tester will raise your arm to the side passively. You will then be asked to slowly lower your arm while the tester determines your ability to control the movement. The next test is the lag sign. The lag sign will be performed with you in the seated position on the edge of a table with your feet flat on the floor. Your arm will be passively positioned away from your body into the motion called external rotation. You will then be asked to hold this position while the tester pushes against your arm attempting to move your arm towards your body. The third test is called the rent test and is also performed with you in the seated position. The tester will hold your arm in a position towards your back. In this position the tester will feel the top of your shoulder while moving your arm back and forth towards and away from your body.

Next you will provide information about how your shoulder pain affects your ability to perform everyday tasks such as lifting your arm, sleeping and performing different movements. This is done by having you complete a questionnaire called the Western Ontario Rotator Cuff Index (WORC). The WORC contains 21 questions related to shoulder function and pain. You will answer each question by marking on the questionnaire how severe your pain or loss of function is currently.

You will then be asked to perform a series of 9 tests to measure your shoulder movement and determine how strong your shoulder is. The tests will use three tools to take your measurements that include a hand-held dynamometer (HHD), a goniometer, and a tape measure on the floor to see how far you can reach. The HHD is used to see how strong your shoulder muscles are.

Initials: _____ **Date:** _____

The HHD fits in the palm of your hand and can measure the strength of muscles by detecting the amount of pressure placed through the device. Another measurement tool called a goniometer will be used to see how much you can move your arm in different directions. A goniometer is a 12 inch device that looks like 2 rulers attached to each other. The goniometer determines how much movement you have in your arm. The third test is a test of arm strength called the upper quarter Y balance test. You perform this test with your hands and feet on the floor and try to reach as far as you can in different directions.

For the first 2 tests you will be seated in a chair with a strap applied around your torso and chair to prevent movement of your body. The tester will place your arm in a specific position and support your arm to make sure your arm stays in the right position. Your arm will be supported with Velcro straps in this position in order to maintain the proper position. You will push against the HHD and it will not move. The HHD will be supported with a piece of plastic against the wall to make sure it does not move. For the third test you will be seated in the same fashion as the first two tests but your arm will be held out in front of you. The tester will hold the HHD and ask you to push against it as hard as you can. For these three tests you will be provided with the command "ready set go."

You will be asked to press as hard as you can into the HHD for 6 seconds no more than 4 times per test. A 10 second rest will occur between each measurement and a 1 minute rest will occur between the different tests.

Following the strength tests the tester will measure some of your shoulder motions. The tester will first move your arm in two different directions, one at a time to familiarize you with the motions that will be measured. The tester will then ask you to raise your arm overhead in front of you to perform a motion called flexion. Once your arm is overhead as much as you are able to raise it the tester will measure how high you raised it with the goniometer. The tester will then ask you to reach your arm out to the side to perform a motion called abduction. Once your arm is overhead as much as you are able to raise it the tester will measure how high you raised it with the goniometer.

After the seated tests are complete you will then lie on a table. In this position the tester will move your arm one time in each direction that will be tested. You will then be asked to move your arm back as if you were reaching back getting ready to throw a ball, this motion is called external rotation. Once you have reached back as far as you can the tester will measure the movement with the goniometer. The tester will then ask you to push your arm back towards the floor as far as you can go. This motion is called shoulder extension. Once you reached back as far as you can the tester will measure the movement with the goniometer. Following the test for extension you will be asked to lie on your stomach on the table. In this position the tester will move your arm one time in each direction that will be tested. This test will measure internal rotation and you will move your shoulder in the opposite motion of external rotation.

Initials: _____ **Date:** _____

Following the goniometer tests you will be asked to perform a test measuring the strength of your arm. This test is called the upper quarter Y balance test. Your arm length will be measured first with you in the standing position and your arm pointing toward the floor. The tester will place a tape measure on the side of your shoulder and down the entire length of your arm to the end of your middle finger. Following the arm length measurement the tester will ask you to assume the push up position on the ground with your arms out in front of you and your hands and feet on the floor.

The arm in which you are feeling pain in the shoulder will stay still in the center of a piece of tape on the floor in the shape of a Y. You will be asked to reach your other arm in the three different directions, the first out to the side, the second to the opposite side and upward, and the third to the opposite side and downward. You will be asked to practice each movement three times prior to testing. Following the movement practice you will be asked to reach as far as possible in each direction without losing your balance. You will perform each movement three times and the tester will measure the distance you have reached.

Upon completion of all questionnaires, tests and measures you will then be introduced to a different researcher. This person is a physical therapist who will provide you with a shoulder exercise program that you will perform during this session. The researcher will instruct you in the performance of these exercises that you will perform on your own every day. These exercises are routinely used by physical therapists for people with shoulder pain. The time required to complete the exercise program will be 10 minutes.

The physical therapist will ask you to perform specific exercises at home every day. You will be asked to schedule follow up visits with this physical therapist once a week for 6 weeks. In addition you will be asked to schedule follow up visits with the tester on week 3, 6 and 6 months after the initial session. Your follow up testing sessions will include performance of the same questionnaires, tests and measures as performed on the initial session with the addition of a questionnaire asking you if your pain is changing. All testing and treatment sessions will occur at the University of St. Augustine.

If at any time you feel your shoulder pain has increased you should contact the primary investigator Eric J. Chaconas so that your exercise program can be modified. If the program modification does not improve your shoulder pain you should contact the primary investigator so that a referral to the appropriate healthcare provider can be made for alternative treatment for your shoulder pain.

Exclusion Criteria

You will not be able to participant in this study if you have any medical conditions that preclude you from performing shoulder exercises, tendon tears, frozen shoulder, upper extremity amputation, pending legal action regarding your shoulder pain, inability to assume the testing positions or inability to comply with the follow up schedule.

Initials: _____ **Date:** _____

What are the dangers to me?

This study contains only minimal risk to you or others directly linked to participation in this study. Procedures used for this study are non-invasive and typically used in clinical practice. The level of exertion expected will be similar to moderate exercise. You may experience soreness in your shoulder or arm muscles after exercising. Your medical history will be obtained by a licensed physical therapist with over 7 years of clinical experience to ensure that you are not at risk for any potentially harmful consequences resulting from your participation.

The procedures or activities in this study may have unknown or unforeseeable risks. If you do experience adverse pain or injury due to participation in this study no compensation for medical treatment will be provided to you. You will be referred to the appropriate healthcare provider but you will be responsible for all medical expenses associated with research-related injuries. **You should contact the primary investigator Eric J. Chaconas, co-investigator Morey J. Kolber or the IRB office at the numbers indicated above for answers to questions about the research and research subjects rights or in the event of a research-related injury.**

Are there any benefits to me for taking part in this research study?

The direct benefits you may experience from participation in this study are improved shoulder motion, strength and reduced pain.

Will I get paid for being in the study? Will it cost me anything?

You will be compensated a total of $100 for completing participation in this study. $20 provided in the form of cash will be given to you upon each completion of all testing and exercises for the initial session, week 3 session and week 6 session. Upon completion of the 6 month follow up testing session you will be compensated $40 in the form of cash payment. You will not have any foreseeable direct costs due to participating in this study.

How will you keep my information private?

All efforts will be made to ensure your privacy. All testing and exercises will be done in a private room, not accessible to individuals not directly involved in the study. You will be assigned a subject number, which will protect your identity.
All information obtained from this study will be stored in locked file cabinet in the principal investigators office. All information is strictly confidential unless disclosure is required by law. IRB and regulatory agencies may however review research records. Since this study is a dissertation, the faculty advisors may also review the research records. All records pertaining to this study will be destroyed, via paper shredder, 3 years after completion of the study.

What if I do not want to participate or I want to leave the study?

You have the right to refuse to participate or to withdraw at any time, without penalty or loss of services you have the right to receive. If you do withdraw it will not affect you in any way. If you chose to withdraw, any information collected about you **before** the date you leave the study will be kept in the research records for 36 months from the conclusion of the study but you may request that it not be used.

Initials: _____ **Date:** _____

you chose to withdraw, any information collected about you **before** the date you leave the study will be kept in the research records for 36 months from the conclusion of the study but you may request that it not be used.

Other Considerations

If significant new information relating to the study becomes available which may relate to your willingness to continue to participate, this information will be provided to you by the investigators.

Voluntary Consent by Participant:

By signing below, you indicate that

- this study has been explained to you
- you have read this document or it has been read to you
- your questions about this research study have been answered
- you have been told that you may ask the researchers any study related questions in the future or contact them in the event of a research-related injury
- you have been told that you may ask Institutional Review Board (IRB) personnel questions about your study rights
- you are entitled to a copy of this form after you have read and signed it
- you voluntarily agree to participate in the study entitled "***Shoulder External Rotator Eccentric Training for Subacromial Impingement Syndrome***"

Participant's Signature: _____ Date: _____

Participant's Name: _____ Date: _____

Signature of Person Obtaining Consent/Witness: _____

Date: _____

NOVA SOUTHEASTERN UNIVERSITY
Institutional Review Board
Approval Date: DEC 18 2013
Continuing Review Date: DEC 17 2014

Initials: _____ **Date:** _____

Appendix E Medical Screening Questionnaire

Subject ID: _____ Date: _____

Age: _____ Gender: _____

I. Have you ever been diagnosed as having any of the following conditions? FILL IN THE APPROPRIATE CIRCLES.

	NO	YES (Diagnosed within the last 12 months)	YES (Diagnosed more than 12 months ago)
1. Lung cancer	O	O	O
2. Breast cancer	O	O	O
3. Prostate cancer	O	O	O
4. Colon cancer	O	O	O
5. Skin cancer	O	O	O
6. Bone cancer	O	O	O
7. Leukemia cancer	O	O	O
8. Lymphoma cancer	O	O	O
9. Other cancer. Please list:			
_____	O	O	O
_____	O	O	O
_____	O	O	O

	NO	YES
10. Chronic urinary tract/bladder infection (3 episodes or more during the past 12 months)	O	O
11. Pneumonia	O	O
12. Bone or joint infection	O	O
13. Pelvic inflammatory disease	O	O
14. Kidney infection	O	O
15. Other infection. Please list: _____	O	O
_____	O	O
_____	O	O

	NO	YES
16. Heart attack	O	O
17. Heart valve problems	O	O
18. Deep venous thrombosis (blood clots in the legs)	O	O
19. Arterial blockage of the legs	O	O
20. High blood pressure	O	O
21. Stroke (including transient ischemic attacks or ministrokes)	O	O
22. Anemia/low blood levels	O	O
23. Asthma	O	O
24. Emphysema	O	O
25. Chemical dependency (eg, alcoholism)	O	O
26. Depression	O	O
27. Tuberculosis	O	O
28. Hypothyroid (low)	O	O
29. Hyperthyroid (high)	O	O
30. Diabetes (diagnosed before age 18 years)	O	O
31. Diabetes (diagnosed after age 18 years)	O	O
32. Multiple sclerosis	O	O
33. Rheumatoid arthritis	O	O
34. Degenerative osteoarthritis or wear-and-tear arthritis	O	O
35. Gout	O	O
36. Ankylosing spondylitis	O	O
37. Hepatitis	O	O
38. Stomach/duodenal ulcers	O	O
39. Epilepsy/seizures	O	O
40. Headaches (more than 1 per week)	O	O
41. Endometriosis	O	O
42. Urinary incontinence	O	O
43. Osteoporosis	O	O
44. Other illnesses diagnosed by a physician.		
Please list: _____ _____	O	O
_____	O	O
_____	O	O

II. Surgeries

	NO	YES (Surgery within last 12 months)	YES (Surgery more than 12 months ago)		NO	YES (Surgery within last 12 months)	YES (Surgery more than 12 months ago
45. Cesarian section	O	O	O	52. Carpal tunnel surgery	O	O	O
46. Hysterectomy	O	O	O	53. Hernia repair	O	O	O
47. Heart surgery (bypass)	O	O	O	54. Tonsillectomy	O	O	O
48. Prostate surgery	O	O	O	55. Other surgeries. Please list:			
49. Appendectomy	O	O	O	_____	O	O	O
50. Gall bladder surgery	O	O	O	_____	O	O	O
51. Bone/joint surgery (total joint replacement, knee or shoulder surgery)	O	O	O	_____	O	O	O

III. During the past week, have you taken any of the following medications not prescribed by a physician?

	NO	YES		NO	YES
56. Advil,[a] Motrin,[b] Aleve,[c] ibuprofen	O	O	61. Decongestants/ antihistamines	O	O
57. Aspirin	O	O	62. Tagamet,[d] Zantac,[d] Pepsid[f]	O	O
58. Tylenol[b]/acetaminophen	O	O	63. Herbal medicines	O	O
			64. Other medications. Please list:		
59. Antacids (eg, Tums,[d] Rolaids[e])	O	O	_____	O	O
			_____	O	O
60. Laxatives	O	O	_____	O	O

IV. During the past week have you taken any of the following PHYSICIAN-prescribed medications?

	NO	YES
65. Aspirin	O	O
66. Anti-inflammatories (eg, Motrin, Naprosyn,[g] Relafen,[d] Orudis[h])	O	O
67. Tylenol/acetaminophen	O	O
68. Muscle relaxers (eg, Valium[i])	O	O
69. Prescribed pain relievers (Darvocet,[j] Darvon,[j] Percocet,[k] Vicodin,[l] Tylenol with codeine)	O	O
70. Birth control pills	O	O
71. Hormone replacement therapy (estrogens/progesterones)	O	O
72. High blood pressure medications	O	O
73. Water pills (diuretics) for reasons other than high blood pressure	O	O
74. Stomach ulcer medications	O	O
75. Heart medications (other than for high blood pressure)	O	O
76. Antibiotics	O	O
77. Thyroid medication	O	O
78. Asthma medication	O	O
79. Antidepressant medication	O	O
80. Insulin	O	O
81. Seizure medication	O	O
82. Decongestants/antihistamines for sinus or allergy problems	O	O
83. Other medications. Please list: _____	O	O
_____	O	O
_____	O	O

V. #84. How many packs of cigarettes do you currently smoke each day on average? Please choose only ONE of the following:

Do not smoke	O
Less than 1 pack per day	O
More than 1 pack per day	O

VI. #85. How many cups of caffeinated beverage do you drink each day?

1 cup of coffee equals 1 cup; 2 cups of tea equals 1 cup; 3 cans of soda equals 1 cup. Please choose only **ONE** of the following answers:

Zero to 2 cups	O
2 cups or more	O

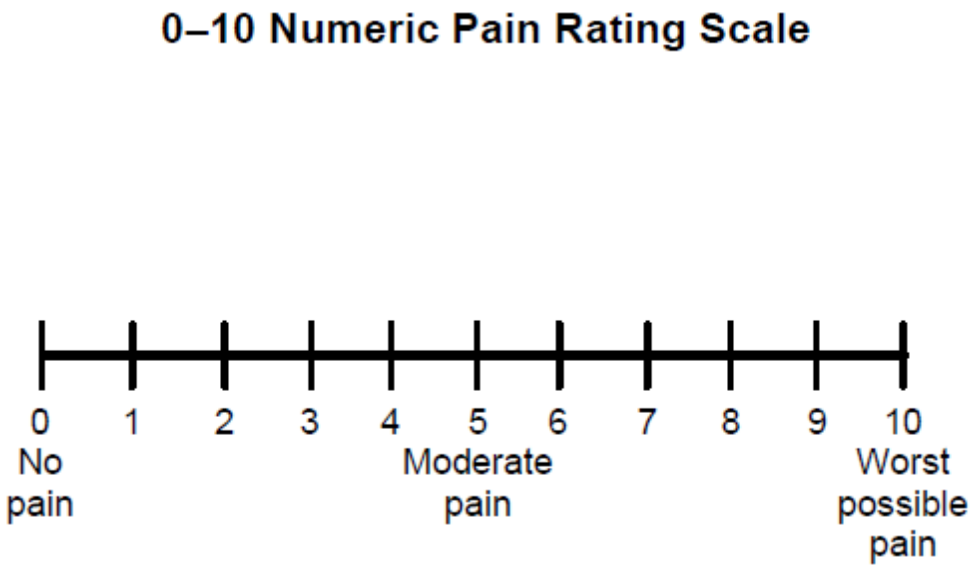
VII. #86. How many days per week do you drink alcohol? Please choose only ONE of the following answers:

Zero	O
Less than 1 day	O
1 – 2 days	O
3 – 4 days	O
5 – 7 days	O

IF YOU DRINK, how much do you drink during an average day? One drink equals one beer or one glass of wine or one shot of hard liquor or mixed drink.

Zero	1 – 3 drinks	4 drinks	5 or more drinks
O	O	O	O

Appendix F Numeric Pain Rating Scale



Appendix G Global Rating of Change Form

Subject #:_____

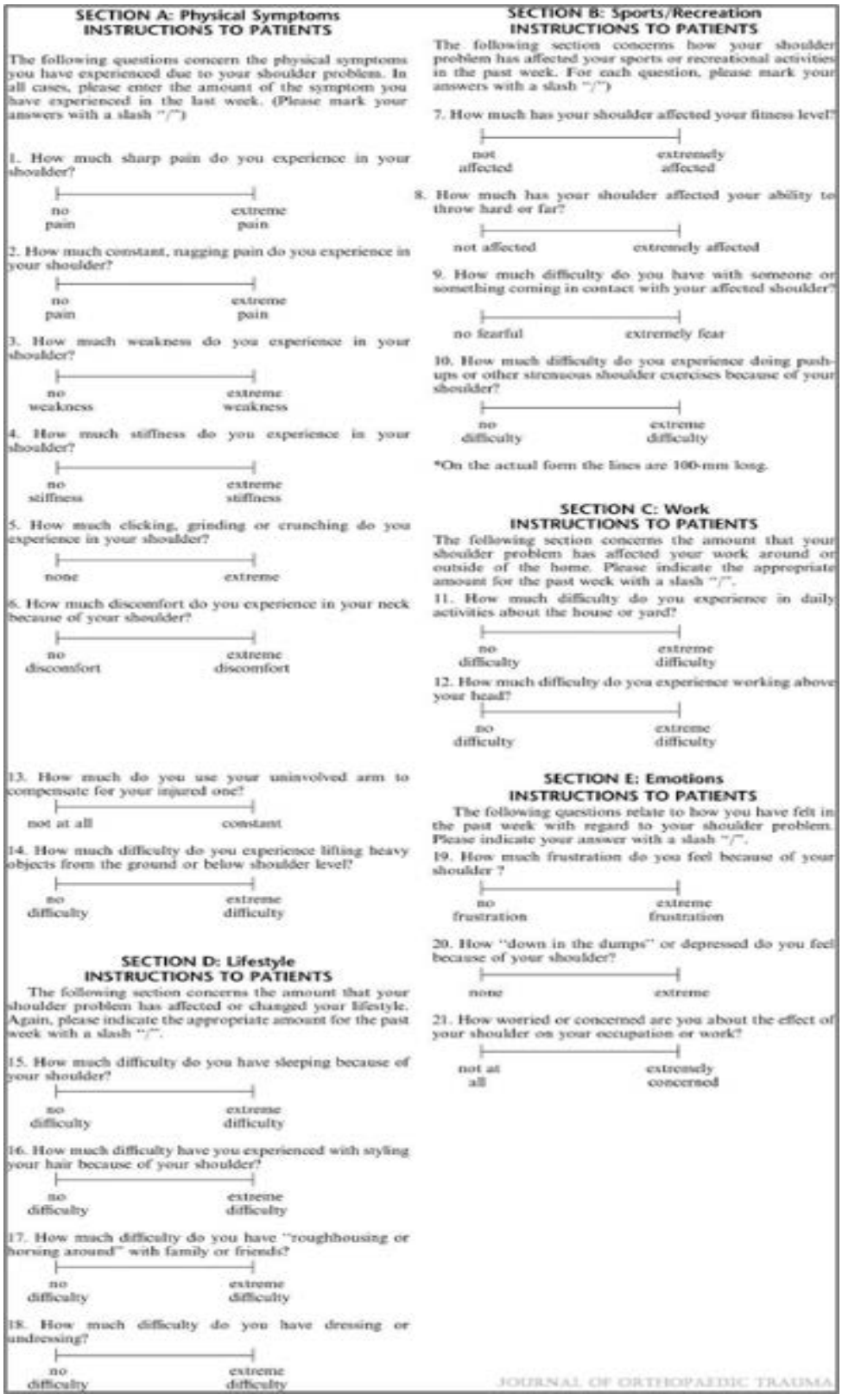
PATIENT GLOBAL RATING

Date:_____/_____/_____
mm dd yy

Please rate the overall condition of your shoulder ***from the time that you began treatment until now*** (check only one):

- ☐ A very great deal worse (-7)
- ☐ A great deal worse (-6)
- ☐ Quite a bit worse (-5)
- ☐ Moderately worse (-4)
- ☐ Somewhat worse (-3)
- ☐ A little bit worse (-2)
- ☐ A tiny bit worse (almost the same) (-1)
- ☐ About the same (0)
- ☐ A very great deal better (+7)
- ☐ A great deal better (+6)
- ☐ Quite a bit better (+5)
- ☐ Moderately better (+4)
- ☐ Somewhat better (+3)
- ☐ A little bit better (+2)
- ☐ A tiny bit better (almost the same) (+1)

Appendix H Western Ontario Rotator Cuff Index



SECTION A: Physical Symptoms
INSTRUCTIONS TO PATIENTS

The following questions concern the physical symptoms you have experienced due to your shoulder problem. In all cases, please enter the amount of the symptom you have experienced in the last week. (Please mark your answers with a slash "/")

1. How much sharp pain do you experience in your shoulder?

no pain — extreme pain

2. How much constant, nagging pain do you experience in your shoulder?

no pain — extreme pain

3. How much weakness do you experience in your shoulder?

no weakness — extreme weakness

4. How much stiffness do you experience in your shoulder?

no stiffness — extreme stiffness

5. How much clicking, grinding or crunching do you experience in your shoulder?

none — extreme

6. How much discomfort do you experience in your neck because of your shoulder?

no discomfort — extreme discomfort

13. How much do you use your uninvolved arm to compensate for your injured one?

not at all — constant

14. How much difficulty do you experience lifting heavy objects from the ground or below shoulder level?

no difficulty — extreme difficulty

SECTION D: Lifestyle
INSTRUCTIONS TO PATIENTS

The following section concerns the amount that your shoulder problem has affected or changed your lifestyle. Again, please indicate the appropriate amount for the past week with a slash "/".

15. How much difficulty do you have sleeping because of your shoulder?

no difficulty — extreme difficulty

16. How much difficulty have you experienced with styling your hair because of your shoulder?

no difficulty — extreme difficulty

17. How much difficulty do you have "roughhousing or horsing around" with family or friends?

no difficulty — extreme difficulty

18. How much difficulty do you have dressing or undressing?

no difficulty — extreme difficulty

SECTION B: Sports/Recreation
INSTRUCTIONS TO PATIENTS

The following section concerns how your shoulder problem has affected your sports or recreational activities in the past week. For each question, please mark your answers with a slash "/")

7. How much has your shoulder affected your fitness level?

not affected — extremely affected

8. How much has your shoulder affected your ability to throw hard or far?

not affected — extremely affected

9. How much difficulty do you have with someone or something coming in contact with your affected shoulder?

no fearful — extremely fear

10. How much difficulty do you experience doing push-ups or other strenuous shoulder exercises because of your shoulder?

no difficulty — extreme difficulty

*On the actual form the lines are 100-mm long.

SECTION C: Work
INSTRUCTIONS TO PATIENTS

The following section concerns the amount that your shoulder problem has affected your work around or outside of the home. Please indicate the appropriate amount for the past week with a slash "/".

11. How much difficulty do you experience in daily activities about the house or yard?

no difficulty — extreme difficulty

12. How much difficulty do you experience working above your head?

no difficulty — extreme difficulty

SECTION E: Emotions
INSTRUCTIONS TO PATIENTS

The following questions relate to how you have felt in the past week with regard to your shoulder problem. Please indicate your answer with a slash "/".

19. How much frustration do you feel because of your shoulder ?

no frustration — extreme frustration

20. How "down in the dumps" or depressed do you feel because of your shoulder?

none — extreme

21. How worried or concerned are you about the effect of your shoulder on your occupation or work?

not at all — extremely concerned

JOURNAL OF ORTHOPAEDIC TRAUMA

Appendix I Demographic Questionnaire

Participant # _____

Shoulder External Rotator Eccentric Training for sub acromial pain Syndrome

Please answer the following questions to the best of your ability. All responses will be kept confidential. If you have and questions regarding this study or completing this questionnaire please contact Eric Chaconas at (443) 336-7094

Date: _____/_____/_____

MM DD YR

1. Age (years): _____
2. Dominant Arm: (Circle one only) Right Left
3. Weight (pounds): _____
4. Height (in) _____
5. Which shoulder do you experience pain: (Circle) Right Left
6. How long have you been experiencing this shoulder pain (months): _____
7. Are you currently under the care of another healthcare provider for this shoulder pain:

   _____. If yes, please describe: _____

   _____

Appendix J Table of Random Numbers

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	8	0	9	4	2	5	2	5	8	2	4	7	1	3	4	7	7	4	3	3	3	6	2	0	1	8	9	7	2	1	3	4
2	3	5	6	3	2	1	9	6	8	2	1	1	9	0	4	5	2	6	1	8	2	7	5	1	2	6	2	7	1	0	9	5
3	1	3	3	0	6	3	3	1	3	7	5	3	9	6	9	3	8	7	3	8	6	8	1	5	1	5	3	8	8	5	4	3
4	3	5	6	5	0	0	1	6	2	2	4	3	6	4	3	2	4	7	9	6	6	0	9	5	5	2	8	3	1	6	2	0
5	7	8	5	0	5	9	2	5	5	5	8	8	7	3	1	1	2	1	9	2	4	5	4	5	3	5	3	0	5	5	8	9
6	4	4	9	0	5	4	1	7	9	7	2	7	6	1	5	3	5	9	0	1	4	8	7	8	9	9	8	0	9	8	7	7
7	6	5	4	5	9	1	0	4	9	3	1	8	8	8	1	9	7	5	3	7	2	7	8	5	9	3	7	3	2	4	4	5
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30	4	6	1	3	8	5	4	9	6	3	6	9	3	2	0	8	5	1	0	9	9	6	8	0	1	1	6	8	6	1	3	3

Appendix K Data Collection Form

Participant # _____ Shoulder: R / L bodyweight (lbs.): _____

Strength (lbs.)

Trial	External Rotation	Internal Rotation	Abduction
Trial 1			
Trial 2			
Trial 3			
Trial 4			

ER/IR Ratio: _____ Abd/ER Ratio: _____

Active Range of Motion

Flexion: _____ Abduction: _____ External Rotation: _____

Internal Rotation: _____ Extension: _____

Upper Quarter Y Balance Test:

Limb length: R_____ L _____

Medial: (1) _____ (2) _____ (3) _____total: _____

Superolateral: (1) _____ (2) _____ (3) _____total: _____

Inferolateral: (1) _____ (2) _____ (3) _____ total: _____

Appendix L Home Exercise Program Diary

Exercise Log Participant #: _____

Date/session	Exercise	Resistance	Sets	Repetitions

Date/session	Exercise	Resistance	Sets	Repetitions