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Comparison of Lower Trapezius Muscle Thickness In Patients With and Without Scapular Dyskinesis Measured With Diagnostic Ultrasound

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COMPARISON OF LOWER TRAPEZIUS MUSCLE THICKNESS IN PATIENTS WITH AND WITHOUT SCAPULAR DYSKINESIS MEASURED WITH DIAGNOSTIC ULTRASOUND

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by

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ABSTRACT

Context: Dyskinesis has been linked to deficits in muscular strength and neuromuscular control of the scapular stabilizers. Often, when treating overhead athletes with pathological shoulders, Athletic Trainers focus on rotator cuff and scapular muscle strength to find resolution, yet the role of the lower trapezius strength in scapular dyskinesis is not well understood. **Objective:** To identify differences among varying levels of scapular dyskinesis on lower trapezius muscle thickness and strength. To identify the relationship between lower trapezius muscle thickness and strength with varying levels of scapular dyskinesis . To identify the relationship between pain and function within varying levels of scapular dyskinesis. **Design:** Ex-post-factor descriptive design. **Setting:** Indiana State University Applied Medicine Research Center. **Participants:** Fifty participants (age=25.18±5.90y; mass=71.67±13.15kg; height=173.5±10.2in; males=23/50, 46%, females=27/50, 64%; right-handed=48/50, 96%, left-handed=2/50, 4%) completed the study. **Interventions:** We evaluated scapular dyskinesis using the clinical visualization technique identifying each scapula as normal, with subtle or with obvious dyskinesis. Participants, depending on body mass, lifted a 3lb (mass<150lb [68kg]) or 5lb (mass>150lb [68kg]) weight overhead in flexion (5 repetitions) and abduction (5 repetitions), while a trained clinician observed for normal scapulohumeral rhythm, dysrhythmia, or scapular winging. Participants completed the Penn Shoulder Scale, a reliable and internally consistent self-report questionnaire with subscales on pain (0-30 points) and function (0-60 points). **Main Outcome Measures:** We evaluated strength with a hand-held dynamometer (microFET2,

Hoggan Scientific, ±1%) with a single arm outstretched overhead in a "Y" position. The strength testing was performed at the same time as the diagnostic ultrasound (GE LOGIQ®e 2008) measurement of muscle thickness. We used separate one way analyses of variance to examine the size and strength of the lower trapezius and compared it over three levels of scapular dyskinesis to identify the differences in the dominant limb (DL) and non-dominant limb (NDL). We used a Spearman rho correlation to determine the relationship between scapular dyskinesis, muscle strength, and muscle thickness in DLs and NDLs. We conducted Kruskal-Wallis non-parametric one-way analyses of variance to compare pain and function subscales over the three levels of scapular dyskinesis in dominant and non-dominant limbs. **Results:** We did not identify any significant differences between DL scapular dyskinesis visual inspection categories on the strength ($F_{2,49}$=0.596, p=0.555, 1-β=0.93) and thickness variables ($F_{2,48}$=0.714, p=0.495, 1-β=0.51). We did not identify any significant difference between NDL scapular dyskinesis visual inspection categories on the strength ($F_{2,49}$=2.382, p=0.103, 1-β=0.96) and thickness variables ($F_{2,47}$=0.631, p=0.537, 1-β=0.54). We identified no significant correlation between DL or NDL scapular dyskinesis and strength (DL Spearman's rho= -0.160, p=0.266; NDL Spearman's rho=-0.106, p=0.466) or thickness (DL Spearman's rho=-0.175, p=0.230; NDL Spearman's rho=-0.091, p=0.537). We did identify a significant and strong relationship between DL strength and thickness (Spearman's rho=0.706, p<0.001) and a significant and moderate relationship between NDL strength and thickness (Spearman's rho=0.414, p=0.003). : We did not identify any significant differences for pain (χ2=5.561, df=2, p=0.062, 1-β=1.00) among the normal (n=15, mean=29.40±1.68), subtle (n=14, mean=28.93±2.73) or obvious (n=21, mean=27.43±3.74) dyskinesis levels in the dominant limb. We did not identify any significant differences for function (χ2=1.386, df=2, p=0.500, 1-β=1.00) among the normal (n=15,

mean=58.20±3.32), subtle (n=14, mean=59.00±1.47) or obvious (n=21, mean=56.86±5.97) dyskinesis levels in the dominant limb. We did not identify any significant differences for pain ($\chi2$=0.937, df=2, p=0.626, 1-β=0.99) among the normal (n=11, mean=27.64±4.18), subtle (n=15, mean=29.33±1.50) or obvious (n=24, mean=28.79±2.00) dyskinesis levels in the non-dominant limb. We did not identify any significant differences for function ($\chi2$=0.391, df=2, p=0.822, 1-β=0.91) among the normal (n=11, mean=58.09±2.21), subtle (n=15, mean=58.40±2.29) or obvious (n=24, mean=58.54±2.09) dyskinesis levels in the non-dominant limb. **Conclusion:** Our findings suggest that lower trapezius strength and thickness have little impact on the presence of scapular dyskinesis. As such, neuromuscular control should be studied to better understand the multifactorial issue of scapular dyskinesis. Our findings also confirmed our hypothesis that muscle strength and thickness are strongly correlated, particularly in the dominant limb. Also, without the exacerbation of overhead activity, dyskinesis may be subclinical yielding little to no pathologic consequences.

PREFACE

Like many of my other classmates, I wanted to develop a project that would be clinically applicable and possibly change clinical practice. When I first began graduate school I was unsure of what I wanted for my research. There were so many captivating topics to explore and questions I wished to answer. With the help of my thesis chair we were able to develop a clinically relevant topic. Through the help of my committee and research assistants we were able to put together a clinically relevant research project that may change the way some athletic trainers clinically practice. I put a lot of work into this research and am very proud of my accomplishments and will never forget the hard work and long nights that went into this.

ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION

The shoulder is a complex series of joints providing significant mobility at the expense of stability. The scapula provides several biomechanical advantages providing mobility, particularly at the glenohumeral joint. During humeral elevation, the upper and lower trapezius work together with the serratus anterior, to produce the upward rotation, external rotation, and posterior tilt necessary for normal scapular kinematics. [1, 2] Without proper scapular mechanics, the glenohumeral joint produces a decreased range of motion and in overhead throwing athletes will result in altered or pathologic performance.

Scapular dyskinesis is the visible alterations in scapular position and motion patterns[3] occurring due to changes in activation of the scapular stabilizing muscles.[4] Scapular dyskinesis can lead to several adverse effects on the shoulder including loss of internal and external rotation leading to winging. Winging demonstrates weakness of the rhomboids and trapezius muscles.[4] These abnormal scapular motions can lead to further stresses on both the labrum and the glenohumeral ligaments which will put the athlete at a higher risk for shear injuries or strains.[4] Posterior impingement is a common secondary injury to scapular dyskinesis and without treatment can result in posterior labral fraying and an unstable glenohumeral joint.[5] In other words, scapular dyskinesis and resultant impingement are potentially harmful to the overhead throwing athletes and methods used to identify these muscular weaknesses carry average diagnostic abilities. Additional methods of analysis may be helpful to the sports medicine clinician.

One of the most common causes of scapular dyskinesis is loss of muscle function specifically in the lower trapezius.[4] It is difficult to isolate the lower trapezius muscle during gross manual muscle tests,[6] and as such, alternative methods from strength assessments are evaluated in the literature. Research suggests that muscle thickness is related to muscle strength.[7-9] Some evidence suggests strength training over a period of just seven and a half weeks resulted in strength gains, improved muscular power and significant hypertrophy.[9] Thus far, magnetic resonance imaging, and computed tomography are considered to be the gold standard for measuring muscle thickness. However, diagnostic ultrasound has also demonstrated relative accuracy in comparison to the gold standard in muscle thickness measurements.[10] Moreover, diagnostic ultrasound has shown strong reliability (ICC=0.90-0.99) for measuring the lower trapezius muscle thickness.[11]

Research Question

What differences exist between levels of scapular dyskinesis and muscle size, strength, and pain of the lower trapezius?

Purpose Statement

The purpose of this study is to evaluate the differences between levels of scapular dyskinesis and muscle size, and strength, of the lower trapezius and general shoulder pain and function.

Hypotheses

Based on previous literature linking muscular strength to thickness, and scapular dyskinesis to lower trapezius weakness, we hypothesize that those demonstrating scapular dyskinesis will possess smaller lower trapezius muscles.

CHAPTER 2

REVIEW OF LITERATURE

Scapular Anatomy

The shoulder complex is a very elaborate combination of joints and articulations including the glenohumeral, acromioclavicular, and sternoclavicular joints, and the scapulothoracic articulation.[12] The muscles of the shoulder are then broken down into two groups, ones that are responsible for scapulothoracic articulation and those that move the humerus at the glenohumeral joint.[13] Glenohumeral motions include flexion, extension, abduction, adduction, internal and external rotation, and circumduction while muscles work in collaboration resulting in multidirectional motion at the scapula including, internal and external rotation, upward and downward rotation, and anterior and posterior tilt.[14] The muscles acting on the scapula have two separate functions, controlling the glenoid fossa, located on the scapula, to allow increased range of motion, and to fixate the scapula allowing for a fixed based during contraction of the rotator cuff muscles. Muscles inserting on the vertebral border and responsible for retracting the scapula include the rhomboid major and the rhomboid minor. The levator scapulae inserts on the superior medial angle of the scapula and is responsible for elevation and downward rotation. The trapezius muscle divided into three sections inserting onto the scapular spine. This muscle altogether is responsible for depression and retraction of the scapula.[13]

The trapezius muscle is a large triangular muscle with an origin extending from the base of the skull down the cervical and thoracic vertebrae and an insertion along the spine of the scapula.[15] This muscle is a main stabilizer of the scapula and is broken down into three sections, upper, middle, and lower, each responsible for different scapular motions. The lower portion of the trapezius muscle, coupled with the upper trapezius and rhomboids, is a primary mover in elevation of the scapula.[6] However it is impossible to isolate the lower trapezius when making strength assessments during scapular movements. Alone the lower trapezius is responsible for downward rotation and depression of the scapula.[4]

Scapular dyskinesis is a term used when dealing with visible alterations in scapular position and motion patterns[3] occurring due to changes in activation of the scapular stabilizing muscles.[4] Scapular motions such as winging can be noticed even at rest, the superior medial border of the scapula can be exposed due to weak serratus anterior muscle while winging of the inferior border of the scapula results from weakness in the trapezius muscle.[16] During humeral elevation, the upper and lower trapezius work together with the serratus anterior, to produce upward rotation, external rotation, and posterior tilt necessary for normal scapular kinematics. [1, 2]Although there is some question on the actual reliability of some testing for the detection scapular dyskinesis, a study by McClure showed with good reliability that scapular dyskinesis can be detected through visual inspection. A positive scapular dyskinesis test would show visible scapular winging or dysrhythmia. [17] In this study scapular dyskinesis is assessed using a rating scale of one to three. A rating of one is described as a person with no abnormality at all. A rating of two is given to those individuals that have a mild abnormality, which are those that are not always noticeable. A three will be given to those individuals with obvious deformity, one that is visibly noticeable 3/5 times or those that present with winging of greater than 1 inch off of the thorax. Scapular dyskinesis can also result from posterior shoulder tightness. Another study assessed scapular motion in two separate ways. One involved 4 classifications while the other was a 2 classification method and also a more simplified version of the 4 classification method.[18] The 4 classification method included having the patient engage in humeral elevation three to five times while the clinician observed the medial and superior scapular borders. A type I dyskinesis pattern is given to those patients with a noticeable prominence of the inferior medial scapular angle and would be associated with excessive anterior tilting of the scapula. A type II dyskinesis pattern is one with a noticeable prominence of the entire medial border and would be associated with excessive scapular internal rotation. A type III dyskinesis pattern is a prominence of the superior scapular border and would be associated with excessive upward translation of the scapula. A type IV pattern is characterized as normal and shows no abnormal motions during humeral elevation. The two type method shows "yes" or "no". Types 1 through three from the 4 type method were grouped into yes while the type 4 or "normal" would be given a no.[18]

There are some other quantitative methods of assessing scapular motion, but they tend to demonstrate only moderate validity and reliability. The lateral scapular slide test (Figure 2a and b) includes taking a measurement from the inferior border of the scapula to the spinous process of the thoracic vertebra in the same horizontal plane.[4] This is done with the arms in three different positions of humeral elevation. The first position is relaxed with arms hanging to the sides, the next is with the patients arms on their waist, and the last measurement is taken with the patients arms in 90 degrees of humeral elevation.[4] The scapular assistance test (Figure 3) evaluates scapular and acromial involvement in subacromial impingement. In this test the clinician actually assists the scapular throughout the motion during humeral elevation.[4] The scapular retraction test (Figure 4) involves the clinician manually stabilizing the scapula on the thorax which allows for decreased impingement symptoms during scapular elevation.[4] All of these tests have demonstrated average intertester reliability.

Scapular dyskinesis can lead to several adverse effects on the shoulder including loss of internal and external rotation leading to winging. Winging demonstrates weakness of the rhomboids and trapezius muscle.[4] These effects can lead to further stresses on both the labrum and the glenohumeral ligaments which will put the athlete at a higher risk for shear injuries or strains.[4] Posterior impingement is a common secondary injury to scapular dyskinesis and without treatment can results in posterior labral fraying and an unstable glenohumeral joint.[5] In other words, scapular dyskinesis and resultant impingement are potentially harmful to the overhead throwing athletes and methods used to identify these muscular weaknesses carry average diagnostic abilities. Additional methods of analysis may be helpful to the sports medicine clinician.

Neuromuscular Control

Neuromuscular control is the interaction of nervous and muscular systems to create coordinated movement. [19] A very common cause of scapular dyskinesis is loss of neuromuscular control, specifically with the lower fibers of the trapezius muscle. [4] The lower trapezius and the serratus anterior muscles are the most susceptible to inhibition due to other painful conditions around the shoulder. [20] The lower trapezius muscle is an extremely important part of normal scapular motion, particularly elevation, in that without the proper activation of this muscle the scapula cannot maintain its center of motion.

There are four basic elements to reestablishing neuromuscular control: proprioceptive and kinesthetic sensation, dynamic joint stabilization, reactive neuromuscular control and functional motor patterns. [19] Kinesthesia and proprioception involve the body's ability to determine the position of joint in space during motion. Techniques for kinesthetic and proprioceptive control include joint repositioning, functional range of motion, and closed kinetic chain exercises. Dynamic joint stabilization includes the muscles ability to anticipate and react to different joint loads. Dynamic joint stabilization techniques include closed kinetic chain exercises on unstable surfaces, eccentric loading, and balance training. Reactive neuromuscular control focuses mainly on the stimulation of the reflexes and transporting that to information to the skeletal muscle. Exercises such as plyometrics, or balance reacquisition, are considered reactive neuromuscular control. Functional motor patterns is the last element in reestablishing neuromuscular control and include exercises such as bio-feedback or sport-specific drills, that are designed to prepare an athlete for return to play. [19] In the previous section, we described the means for visually inspecting the scapula to identify scapular dyskinesis. In that description, the presence of dysrhythmia is one of the primary components to a diagnosis of subtle or obvious deformity. As such, the neuromuscular control over the scapula is a major factor in identifying and managing dyskinesis.

Muscle Thickness Related to Strength

Research suggests that muscle thickness is related to muscle strength.[7-9] Some evidence suggests strength training over a period of just seven and a half weeks resulted in strength gains, improved muscular power and significant hypertrophy.[9] The study was designed to look at the effect of the speed of contraction and its effects on strength, muscular power, and muscle hypertrophy. Eighteen male subjects completed a seven and a half week training program. Eight of the participants produced fast concentric contractions while the other ten participants focused on slow controlled movements. Both groups showed significant improvements in muscle strength, power and hypertrophy and showed no significant differences between the two training regimes. In another study, 48 healthy untrained volunteers participated in a bilateral quadriceps/hamstrings strength training program. Strength was measured using a knee extension and knee flexion ergometer. Muscle thickness was determined using B-mode ultrasound and the muscle was measured at three different points. Subjects were separated randomly into a non-exercising control group, or one of two training groups. The training groups completed three bilateral training sessions per week. The control group was instructed not to do any type of training for the 14 week period. Muscle strength and muscle thickness were both assessed when the study was completed. Results of the study showed increases in both muscle strength and muscle thickness showing the relationship between the two variables.[8]

Strength and Muscle Thickness Testing

Many different techniques can be used to study muscle strength, power, and thickness. These methods include biofeedback, isokinetic measures, magnetic resonance imaging and computed tomography scans. Diagnostic ultrasound is a relatively new method in this field of research however and has proven to be very accurate in comparison to the gold standard in muscle thickness measurements.[10] When dealing with strength assessments using isotonic and isokinetic machines it is very difficult to isolate certain muscles particularly in the shoulder girdle where there are a lot of different muscles that act at once for a number of different motions. There is some preliminary research[21] also suggests that potential for isolating thickness with the ability to translate the information into outcomes related to strength. When looking at muscle size and comparing diagnostic ultrasound imaging with the gold standards, computed tomography scanning and magnetic resonance imaging, ultrasound showed great correlation with the two.[10] Also a huge advantage diagnostic ultrasound has over the other methods of diagnostic imaging is it is much more cost effective.[10] We cannot isolate the lower trapezius muscle to assess strength therefore muscle thickness measured by diagnostic ultrasound can be used as an indicator of muscle strength in comparing lower trapezius strength in those participants with scapular dyskinesis and participants without.

Diagnostic Ultrasound

Diagnostic ultrasound or ultrasonagraphy is a relatively new imaging tool that exposes the body to high frequency sound waves through a transducer that produces pictures in real time.[22] Diagnostic ultrasound produces images when pulses of ultrasound from the transducer produce echoes at tissue or organ boundaries. [23] Resolution is the smallest distance that can be discriminated within an ultrasound image. Higher frequency transducers produce higher resolutions; however when the frequency increases the depth that the waves can penetrate decreases. The lower the frequency transducers produce lower resolutions but are able to penetrate much deeper. [22] This tool is used in effectively imaging and evaluating the musculoskeletal system with the understanding that the closer the structures are to the surface the clearer the image will be. [22] Some images on the ultrasound screen will appear brighter than other images, this all has to do with the angle at which these ultrasound waves are emitted. Some structures in the body are more hyperechoic, meaning they show a higher reflective pattern where others show a lower reflective pattern, which is known as hypoechoic. The angle at which the ultrasound waves are projected also play a key role in the way an image will appear on the screen. Images appear hyperechoic when the ultrasound waves are perpendicular to the structure, and hypoechoic when ultrasound waves are more oblique.[22]

There is evidence to suggest that diagnostic ultrasound is reliable for measuring the lower trapezius.[11] The lower trapezius muscle size of 16 asymptomatic patients were measured through the use diagnostic ultrasound by three separate investigators. All measurements were taken 3cm lateral to the spinous process and then again 1cm medial to the first location. The results indicated a good inter-rater reliability both with the lateral medial and combined measurements with ICCs of .96 (95% CI: 0.90 to 0.98), .90 (95% CI: 0.78 to 0.96), and .99 (95% CI: 0.99 to 1.0) respectively for the use of diagnostic ultrasound to determine muscle size (Figure 5a).[11] A systematic review took a number of different studies and compared the use of diagnostic ultrasound with MRI and CT scanning, the gold standard for measuring, and results depict the two different tools correlate highly with the cross sectional area determined by MRI.[8]

Population Characteristics of UE Strength

When looking at muscle size and strength it is important to take into account many different factors including gender, limb dominance, athlete or non-athlete and also whether or not that athlete plays a lower extremity sport or an upper extremity sport. When looking at muscle size and comparing it among males and females research shows males have a higher average cross-sectional area then do women when looking at upper extremity muscles.[24] Based on other research we can infer that men have more upper extremity strength then women on average.[7-9]When dealing with limb dominance some results of many different research articles show mixed appear inconclusive when talking about whether or not limb dominance is related to strength. Some studies show that limb dominance shows no differences in strength. [25] A separate research study shows that limb dominance does in fact play a role in strength.[26] Another factor that is worth looking at is comparing athletes that play sports where the upper extremity are used more frequently than the sports where the lower extremity is more frequently used. This study comparing the muscles in the shoulder girdle between rugby players and soccer players has shown that there is a significant difference in strength between upper extremity athletes, that play rugby, and the non-upper extremity athletes, that play soccer. [27]

Conclusion

Dyskinesis is the term used to describe abnormal scapular motions during humeral motion. Dyskinesis can be caused by several factors including postural issues including kyphosis or cervical lordosis.[17] However the most common cause of dyskinesis is related to the inhibition of muscular activation or loss of neuromuscular control. The lower trapezius muscle, a significant muscle when dealing with normal scapular motion, is often the most susceptible to inhibition.[4] Strength and neuromuscular activation, particularly of the lower trapezius, is a significant factor when dealing with patients with scapular dyskinesis. it is impossible to isolate the lower trapezius when making strength assessments during scapular movements. [4]

CHAPTER 3

METHODS

Research Design

This study is an ex-post-factor descriptive design to evaluate the differences between levels of scapular dyskinesis and muscle size and of the lower trapezius as well as shoulder pain, and function.

Participants

We performed a power analysis to determine that we need three equal size groups (n=50/group). This will yield strong power ($1\text{-}\beta=0.92$) and effect size ($\eta 2=0.75$). After completing an informed consent to participate, each participant will complete a health history survey to describe previous injuries and pain characteristics. None of these factors will limit the potential participants from the study.

Instrumentation

Health Questionnaire

Each of the participants will take a brief survey with regard to their previous injuries, sport participation, and pain characteristics.

Scapular Dyskinesis Assessment

We used one trained rater with 11 years of clinical experience and advanced specialization in shoulder and scapular pathologies. The practitioner will assess each scapula individually using a rating scale of normal, subtle, and obvious based on the studies by McClure and Tate. [17, 28] A rating of normal will indicate no unilateral abnormality. A rating of subtle deformity will indicate a mild abnormality, those that are not always noticeable (nor noticeable in 2 or fewer repetitions). Obvious deformity (Figure 2) indicates noticeable abnormality (visible in 3 or more repetitions or winging greater than 1 inch off the thorax). Level of scapular dyskinesis will be recorded with the participant code and limb, but this information will be blind to the primary investigator evaluating muscle thickness with diagnostic ultrasound.

Diagnostic Ultrasound

Diagnostic ultrasound or ultrasonagraphy is a relatively new imaging tool that exposes the body to high frequency sound waves through a transducer that produces pictures in real time.[22] Evidence suggests that diagnostic ultrasound has good inter-rater reliability of ICCs of .96 (95% CI: 0.90 to 0.98), .90 (95% CI: 0.78 to 0.96), and .99 (95% CI: 0.99 to 1.0) for measuring the lower trapezius thickness at the lateral, medial, and combined locations.[11] Further, a systematic review comparing diagnostic ultrasound with MRI suggests these tools have an excellent correlation of 0.95.[8] The primary investigator (AV) will measure the thickness of the lower trapezius muscle using the diagnostic ultrasound. The primary investigator will record the patient code and limb on each image and store the image on a USB drive to be analyzed at a later date.

Procedures

We will recruit active, healthy males and females from the University and surrounding community. Participants will be expected to attend only one session where we will inform them of the purpose of the study and procedures and complete data collection. Upon signing the informed consent, participants will complete the health questionnaire. Data in the questionnaire will be used for post hoc statistical analysis and not as exclusionary criteria in the study. Following, one of three trained clinicians will assess the participant for the presence of scapular dyskinesis bilaterally. The primary investigator (AV) will then measure the thickness of their lower trapezius muscle using the diagnostic ultrasound. The primary investigator will record the patient code and limb on each image and store the image on a USB drive to be analyzed at a later date.

Statistical Analysis

We will use a one way analysis of variance (ANOVA) to assess the size of the lower trapezius muscle and compare it over three different levels of scapular dyskinesis to identify the differences among groups.

CHAPTER 4

MANUSCRIPT

Introduction

The purpose of this study was to compare and contrast the muscular strength and thickness of the lower trapezius with characteristics of pain and dysfunction of those with varying degrees of scapular dyskinesis. The shoulder is a complex series of joints providing significant mobility at the expense of stability. The scapula provides biomechanical advantages providing mobility, particularly at the glenohumeral joint but at the same time is susceptible to instability. During humeral elevation, the upper and lower trapezius work together with the serratus anterior, to produce the upward rotation, external rotation, and posterior tilt necessary for normal scapular kinematics.[14, 15] Without proper scapular mechanics, the glenohumeral joint will produce a decreased range of motion and in overhead throwing athletes this will result in altered or pathologic performance.

Scapular dyskinesis is the visible alteration of scapular position and motion patterns[12] occurring due to changes in activation of the scapular stabilizing muscles.[4] Scapular dyskinesis might include the loss of external rotation around the vertical axis leading to winging, which occurs when the medial border of the scapula rotates away from the trunk and spine. Winging demonstrates weakness of the rhomboids and trapezius muscles.[4] These effects can lead to increased compression on the labrum posteriorly and stretch on the glenohumeral ligaments anteriorly increasing the risk for injury.[4] Likewise, posterior impingement is a common secondary injury due to scapular dyskinesis. Without treatment or retraining of the scapular stabilizers, may result in posterior labral fraying and an unstable glenohumeral joint.[18] Thus, scapular dyskinesis and resultant impingement are potential precursors to injury in the overhead throwing athlete.

One of the most common theoretical causes of scapular dyskinesis is loss of muscle function specifically in the lower trapezius.[4] Isolating the lower trapezius muscle during gross manual muscle tests is difficult,[5] and most methods to identify muscular weakness in the clinical setting are diagnostically disadvantages. Research suggests that muscle thickness is related to muscle strength.[1-3] Some evidence suggests strength training over a period of just seven and a half weeks results in strength gains, improved muscular power and significant hypertrophy.[3] Thus far, magnetic resonance imaging, and computed tomography are considered to be the gold standard for measuring muscle thickness. However, diagnostic ultrasound has also demonstrated relative accuracy in comparison to the gold standard in muscle thickness measurements.[7] Moreover, diagnostic ultrasound demonstrates a strong reliability (ICC=0.90-0.99) for measuring the lower trapezius muscle thickness.[23] Scapular dyskinesis is the pathologic motion of the scapula and can lead to subsequent debilitating injury or performance. The condition is considered a result of muscular weakness and a lack of muscular synchrony to produce arthrokinematic motion at the scapula and concommittant humeral elevation; upper and lower trapezius, and serratus anterior. Objectively measuring strength is difficult, given the limitations of clinical assessment. Therefore, alternative measures may aid clinician assessment of muscular strength. In combination with assessments for pain and dysfunction, a clinician may be better poised to effectively evaluate scapular dyskinesis prior to failure of other structures like the labrum and joint capsule. The purpose of this study was to compare and contrast the muscular strength and thickness of the lower trapezius with characteristics of pain and dysfunction of those with varying degrees of scapular dyskinesis.

Methods

Research Design

We used an ex-post-factor descriptive design to compare and contrast the muscular strength and thickness of the lower trapezius with characteristics of pain and dysfunction of those with varying degrees of scapular dyskinesis.

Participants

Fifty participants (age=25.18±5.90y; mass=71.67±13.15kg; height=173.5±10.2in; males=23/50, 46%, females=27/50, 64%; right-handed=48/50, 96%, left-handed=2/50, 4%) completed the study. After completing an informed consent to participate, each participant completed a health history survey to describe previous injuries and pain characteristics. None of these factors were used to exclude participants from the study.

Instrumentation

Health Questionnaire

Each of the participants took brief survey with regard to their previous injuries, sport participation, and pain characteristics.

Scapular Dyskinesis Assessment

One trained practitioner with 11 years of experience and advanced training in shoulder/scapular functional assessment performed the visual inspection of scapular dyskinesis. The practitioner assessed each scapula individually using a rating scale of normal, subtle, and obvious based on McClure and Tate.[17, 28] Each participant was asked to complete five repetitions of bilateral, active, weighted shoulder flexion and bilateral, active, weighted shoulder abduction to assess scapular dyskinesis. Subjects were rated on a scale based on three rating normal, subtle, or obvious while completing the abduction movements. During abduction, the participant held either a three pound weight, if under 150 pounds, or a five pound weight if over 150 pounds. A rating of normal indicated no unilateral abnormality. A rating of subtle deformity indicated a mild abnormality, those that are not always noticeable (nor noticeable in 2 or fewer repetitions). The obvious deformity classification (Figure 2) indicated noticeable abnormality (visible in 3 or more repetitions or winging greater than 1 inch off the thorax). The practitioner recorded level of scapular dyskinesis with the participant code and limb, but this information was blind to the primary investigator evaluating muscle thickness with diagnostic ultrasound.

Diagnostic Ultrasound

Diagnostic ultrasound or ultrasonagraphy is a relatively new imaging tool that exposes the body to high frequency sound waves through a transducer producing pictures in real time.[22] Evidence suggests that diagnostic ultrasound has good inter-rater reliability of ICCs of .96 (95% CI: 0.90 to 0.98), .90 (95% CI: 0.78 to 0.96), and .99 (95% CI: 0.99 to 1.0) for measuring the lower trapezius thickness at the lateral, medial, and combined locations.[11] Further, a systematic review comparing diagnostic ultrasound with MRI indicates these tools have a good correlation of 0.95.[8] The primary investigator measured the thickness of the lower trapezius muscle using the diagnostic ultrasound. The primary investigator recorded the patient code and limb on each image and stored the image on a USB drive to be analyzed at a later date.

Hand Held Dynamometer

We used a handheld dynamometer (microFET2, Hoggan Scientific, ±1%) to assess muscle strength of the lower trapezius. One study testing strength of hip abductors show this specific dynamometer to be a useful measure of strength with ICCs of 0.88 (95% CI: 0.577 to 0.969) and 0.942 (95% CI: 0.796 to 0.985) among two different raters.[29]

Penn Shoulder Score

The Penn Shoulder Score(PSS) is a questionnaire consisting of a total of 24 questions used to assess shoulder pain (3 questions), satisfaction (1 question), and function (20 questions). Studies show the Penn shoulder score to be the most reliable measure of pain satisfaction and function for the shoulder.[30] The PSS is one of two test in the study that takes into account all three factors of pain, satisfaction, and function, however the reliability is much higher. With a test retest reliability for each of the variables being 0.88 for pain, 0.93 for satisfaction, 0.93 for function, and a 0.94 as a whole for the PSS.[30]

Procedures

We recruited 50 active, healthy males and females from the University and surrounding community. Participants were expected to attend only one session where we informed them of the purpose of the study and procedures and completed data collection. Upon signing the informed consent, participants completed the health questionnaire. Data in the questionnaire was used for post hoc statistical analysis and not as exclusionary criteria in the study. Following, the trained clinicians assessed the participant for the presence of scapular dyskinesis bilaterally. The patient laid down prone on the treatment table so the primary investigator could then measure the thickness of the participant's lower trapezius muscle using the diagnostic ultrasound. The DU head was placed over the lower trapezius muscle at the origin over the spinous process and was held long enough to get a strength measurement and take a picture. We evaluated strength with a hand-held dynamometer (microFET2, Hoggan Scientific, ±1%) with a single arm outstretched overhead in a "Y" position in a "make" test, or isometric hold against an immovable brace attached to the dynamometer. The strength testing was performed, by an assistant, at the same time as the diagnostic ultrasound (GE LOGIQ®e 2008) measurement of muscle thickness. The research assistant recorded the strength assessment, independent of the diagnostic image. The primary investigator recorded the patient code and limb on each image and stored the image on a USB drive. The primary investigator analyzed the image with the DU software at that time to determine the thickness measurement. Participants completed the Penn Shoulder Scale, a reliable and internally consistent self-report questionnaire with subscales on pain (0-30 points) and function (0-60 points).

Statistical Analysis

Levene's statistic suggested our sample was heterogeneous and as such, we analyzed our data using parametric statistics, with the exception of the pain variables. We used separate one way analyses of variance to examine the size and strength of the lower trapezius and compared it over three levels of scapular dyskinesis to identify the differences in the dominant limb (DL) and non-dominant limb (NDL). We used a Spearman rho correlation to determine the relationship between scapular dyskinesis, muscle strength, and muscle thickness in DLs and NDLs. We did not find a heterogeneous sample for the assessment of pain, so we conducted Kruskal-Wallis non-parametric one-way analyses of variance to compare pain and function subscales over the three levels of scapular dyskinesis in dominant and non-dominant limbs.

Results

Scapular Dyskinesis

We identified no significant differences between DL scapular dyskinesis visual inspection categories on the strength ($F_{2,49}$=0.596, p=0.555, 1-β=0.93) and thickness variables ($F_{2,48}$=0.714, p=0.495, 1-β=0.51). We identified no significant difference between NDL scapular dyskinesis visual inspection categories on the strength ($F_{2,49}$=2.382, p=0.103, 1-β=0.96) and thickness variables ($F_{2,47}$=0.631, p=0.537, 1-β=0.54). We identified no significant correlation between DL or NDL scapular dyskinesis and strength (DL Spearman's rho= -0.160, p=0.266; NDL Spearman's rho=-0.106, p=0.466) or thickness (DL Spearman's rho=-0.175, p=0.230; NDL Spearman's rho=-0.091, p=0.537).

Strength and Thickness

We did identify a significant and strong relationship (Figure 6) between DL strength and thickness (Spearman's rho=0.706, p<0.001) and a significant and moderate relationship (Figure 7) between NDL strength and thickness (Spearman's rho=0.414, p=0.003).

Pain

We identified no significant differences for pain (χ^2=5.561, df=2, p=0.062, 1-β=1.00) among the normal (n=15, mean=29.40±1.68), subtle (n=14, mean=28.93±2.73) or obvious (n=21, mean=27.43±3.74) dyskinesis levels in the dominant limb. We also discovered no significant differences for function (χ^2=1.386, df=2, p=0.500, 1-β=1.00) among the normal (n=15, mean=58.20±3.32), subtle (n=14, mean=59.00±1.47) or obvious (n=21, mean=56.86±5.97) dyskinesis levels in the dominant limb. We identified no significant differences for pain (χ^2=0.937, df=2, p=0.626, 1-β=0.99) among the normal (n=11, mean=27.64±4.18), subtle (n=15, mean=29.33±1.50) or obvious (n=24, mean=28.79±2.00) dyskinesis levels in the non-dominant limb. We discovered no significant differences for function (χ^2=0.391, df=2, p=0.822, 1-β=0.91) among the normal (n=11, mean=58.09±2.21), subtle (n=15, mean=58.40±2.29) or obvious (n=24, mean=58.54±2.09) dyskinesis levels in the non-dominant limb.

Discussion

Scapular Dyskinesis

The results of this study demonstrate that no significant correlation exists between strength and thickness of the lower trapezius and scapular dyskinesis. This is the first study observing the relationship between these variables. Given that a majority of the literature attributes scapular winging to either muscular weakness or a loss of neuromuscular control,[31] our findings may indicate strength has little to do with the presence of dyskinesis.

If we review the neuromuscular control literature, the findings may be consistent with abnormal functional movement patterns associated with and without pain at the knee and ankle.[31] Neuromuscular control is the interaction of nervous and muscular systems to create coordinated movement.[19] A lack of neuromuscular control may be caused by a number of different issues including pain, weakness, and a lack of use for an extended period of time. Pain or dysfunction in even one muscle of the force couple controlling scapular arthrokinematic motion may cause resultant abnormal motion at the glenohumeral joint. The lower trapezius and the serratus anterior muscles are the most susceptible to inhibition due to other painful conditions around the shoulder.[20] Studies [4] suggest a pathologic relationship between the force couple and neuromuscular control; however literature evaluating this relationship is lacking.

Some would argue, although not evident in our participants, pain and dyskinesis (pathologic motion regardless of joint) are directly related. Others have demonstrated both the absence of pain and joint effusion may still yield a lack of neuromuscular control.[31] The presence of uncoordinated motion without pain occurred within our participations; however, neither previous injury nor current pain was prevalent in our participants. If pain is present and the precursor to pathology, it is likely that dyskinesia and lack of neuromuscular control are linked through an arthrogenic muscular response to protect the injured joint.

Strength and Thickness

We found results consistent with other studies relating to the link between muscular strength and muscular thickness.[7-9] A strong and significant correlation was identified between dominant limb muscular strength and muscular thickness and a moderate and significant correlation for the non-dominant side. Although we did not compare limbs, as this was not the scope of this investigation, differences between dominant and non-dominant limb strength have been identified in the literature.[26] Interestingly, we observed a stronger relationship between strength and thickness in the dominant limb, which raises some additional questions for future research.

As previously stated, we identified a lack of relationship between strength and thickness with scapular dyskinesis. The findings suggest a significant body of theoretical research and common clinical practice focused on retraining the strength of the lower trapezius to avoid scapular dyskinesis and its concomitant or secondary injuries may be an ineffective strategy. The literature demonstrates that development of a new therapeutic paradigm that focuses on facilitating neuromuscular control may better serve to restore patient function.[31]

Pain

Pain or function had no bearing on scapular dyskinesis in this healthy, non-overhead throwing population. Although previous literature[4] suggests that alterations in scapular motion are caused by pain and loss of function, we were unable to replicate the findings. Scapular dyskinesis may not always cause pain; however when a person with scapular dyskinesis is required to perform overhead motion, it may be likely that the presence of dyskinesis will yield a different outcome. Some research offers evidence of pain and scapular dyskinesis developing from training.[32] The functional stability paradigm (Figure 8) suggests that injury leads to proprioceptive deficits, leading to a loss of neuromuscular control, leading to functional instability which again leads back to further injury or re-injury. Some inconsistency in the literature regarding the direct association between pain and scapular dyskinesis exists, but our results suggest no relationship in healthy, non-overhead throwing volunteers.

Limitations

We did not distinguish between overhead throwing athletes and non-overhead throwing athletes, which may create differences as injury and pain are more common for sports that primarily use upper extremities. Potential exists for changes in results when treating patients with a pathology compared to healthy individuals. In this case we studied both populations. Lastly we only measured strength and thickness for one of the muscles in the force couple that is responsible for scapular movement. Any muscles in the force couple not firing correctly, or being weak could potentially throw off normal scapular kinematics which is why it may be important to look at other muscles in the force couple.

Conclusions

Because scapular dyskinesis precedes other debilitating injuries, understanding the root of the problem is crucial to clinical practice. We know from the results of this study that scapular dyskinesis is not solely caused by a lack of strength or thickness of the lower trapezius. Our findings lead to more questions, particularly regarding neuromuscular control of the scapular stabilizers and force couple. Future research should focus on coordinated strength and movement of the scapular force couple to identify the cause of scapular dyskinesis. With more information about the cause, more potential prevention and treatment strategies can be explored.

Figure 1. Obvious Scapular Dyskinesis during Humeral Flexion.

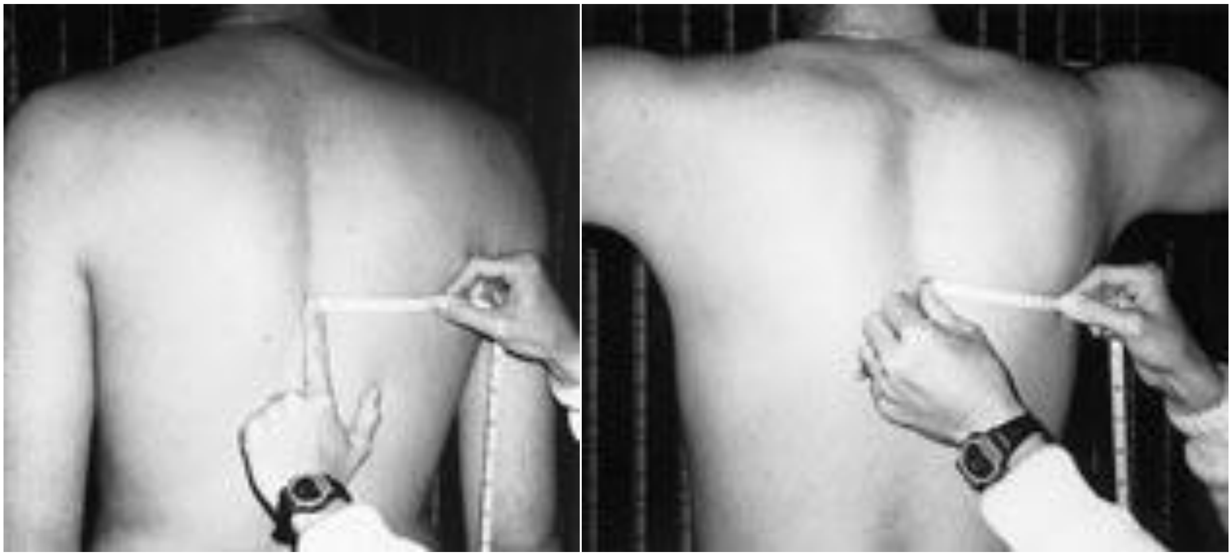

Figure 2. Lateral Scapular Slide Test in a relaxed position (a) and in 90 degrees of humeral elevation (b).

Figure 3. Scapular Assistance Test.

Figure 4. Scapular Retraction Test.

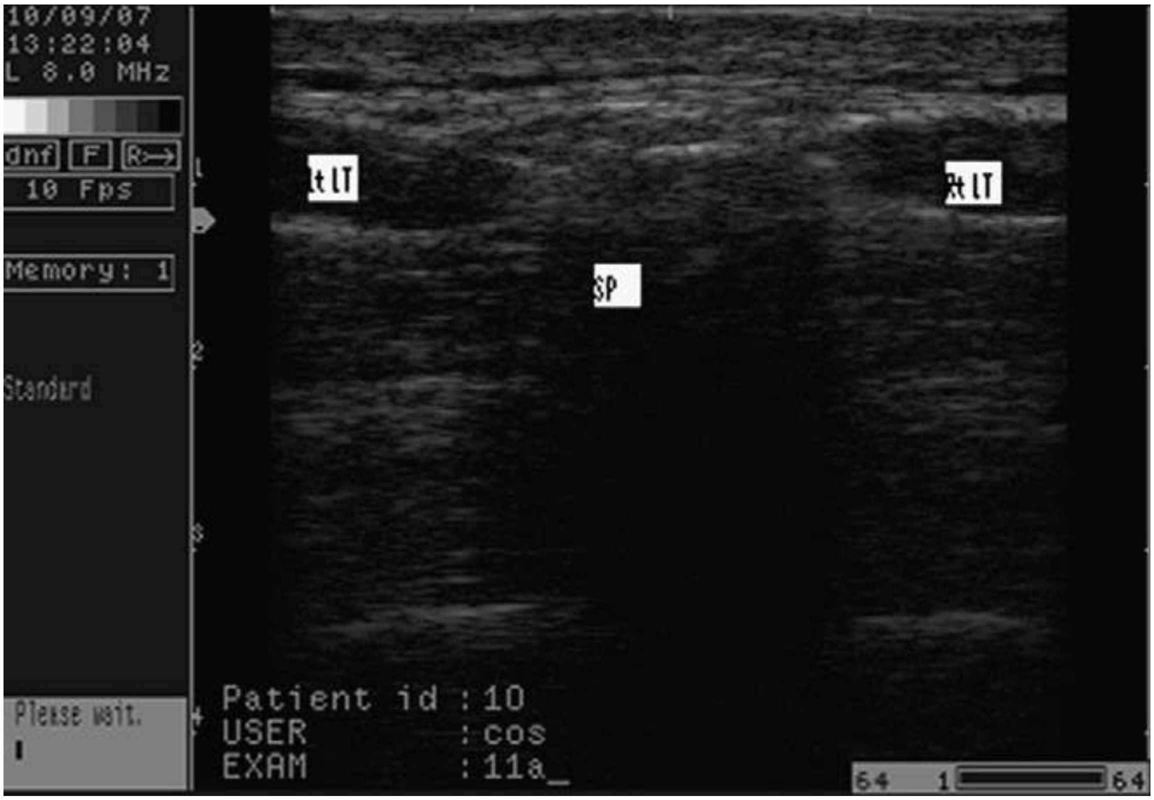

Figure 5. Diagnostic Ultrasound Imaging of Lower Trapezius Muscle at Spinal Level T8.

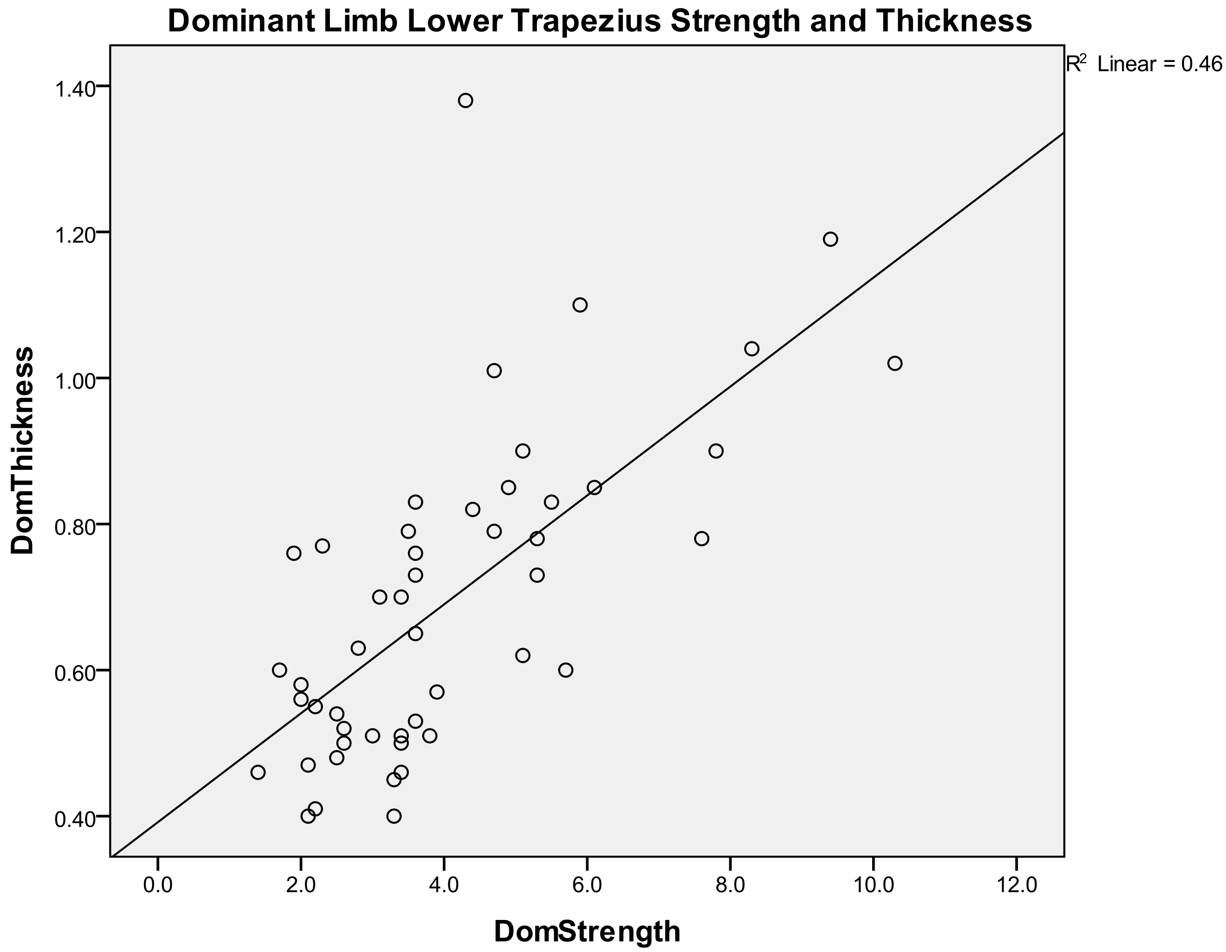

Figure 6. Relationship between Dominant Limb Strength and Thickness.

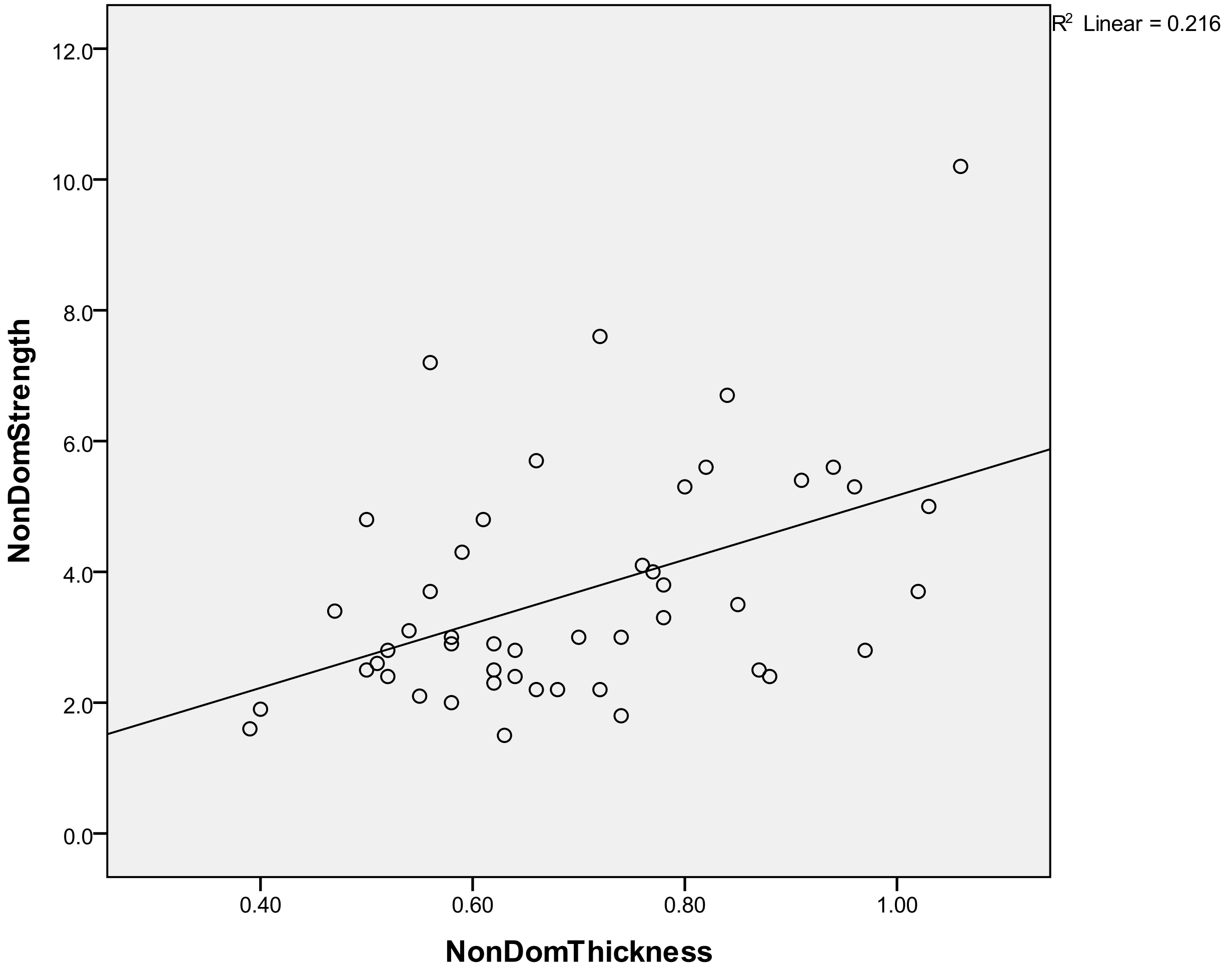

Figure 7. Relationship between Non-Dominant Limb Strength and Thickness.

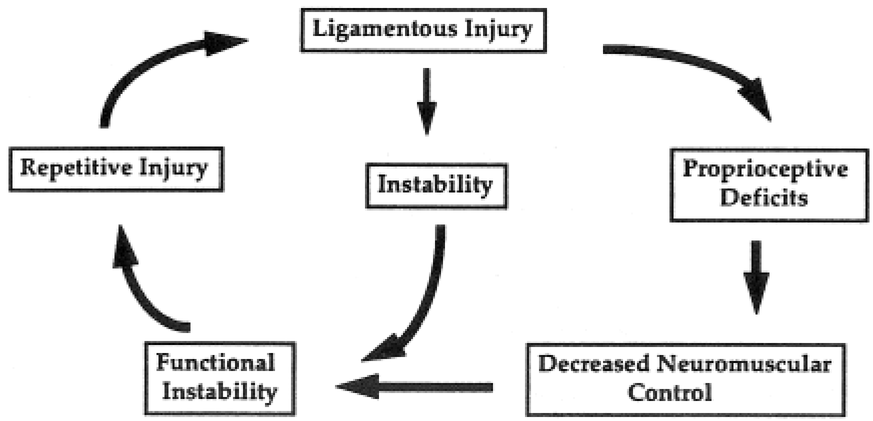

Figure 8. Functional Stability Paradigm.

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APPENDIX A: IRB APPROVAL DOCUMENT

Indiana State University
More. From day one.

Institutional Review Board

Terre Haute, Indiana 47809
812-237-3092
Fax 812-237-3092

DATE:	July 20, 2013
TO:	Alex VanDeusen
FROM:	Indiana State University Institutional Review Board
STUDY TITLE:	[461030-2] COMPARISON OF LOWER TRAPEZIUS MUSCLE THICKNESS IN PATIENTS WITH AND WITHOUT SCAPULAR DYSKINESIS MEASURED WITH DIAGNOSTIC ULTRASOUND
SUBMISSION TYPE:	Revision
ACTION:	APPROVED
APPROVAL DATE:	July 12, 2013
EXPIRATION DATE:	August 20, 2013
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *4*

Thank you for your submission of Revision materials for this research study. The Indiana State University Institutional Review Board has APPROVED your submission. The approval for this study expires on August 20, 2013.

NOTE: Initial approval is for a period of 30 days. In order to obtain continuing approval for a period longer than 30 days the IRB will need to interview a subset of your subjects. If you do not have enough subjects for the IRB to extract a sample you will just need to submit a continuation request before the expiration date listed above. If you have sufficient subjects in the next couple of weeks, please contact Dr. Vicki Hammen so the interviews/contacts can be completed as soon as possible. Your faculty sponsor should be able to provide additional clarifcation if needed.

Prior to the approval expiration date, if you plan to continue this study you will need to submit a continuation request (Form E) for review and approval by the IRB. Additionally, once you complete your study, you will need to submit the Completion of Activities report (Form G).

This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Informed Consent: Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant.

Reporting of Problems: All SERIOUS and UNEXPECTED adverse events must be reported. Any problems involving risk to subjects or others, injury or other adverse effects experienced by subjects, and incidents of noncompliance must be reported to the IRB Chairperson or Vice Chairperson via phone or e-mail immediately. Additionally, you must submit Form F electronically to the IRB through IRBNet within 5 working days after first awareness of the problem.

Please note that any revision to previously approved materials must be approved by the IRB prior to initiation. Please use the appropriate revision forms for this procedure.

Modifications: Any modifications to this proposed study or to the informed consent form will need to be submitted using Form D for review and approval by the IRB prior to implementation.

Please note that all research records must be retained for a minimum of three years. If those research records involve health information, those records must be retained for a minimum of six years.

If you have any questions, please contact Dr. Vicki Hammen within IRBNet by clicking on the study title on the "My Projects" screen and the "Send Project Mail" button on the left side of the "New Project Message" screen. I wish you well in completing your study.