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An Electromyographic Study of Upper Trapezius, Lower Trapezius, and Serratus Anterior Muscle Activity during Traditional and Modified Muscle Testing Positions

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AN ELECTROMYGRAPHIC STUDY OF UPPER TRAPEZIUS, LOWER
TRAPEZIUS, AND SERRATUS ANTERIOR MUSCLE ACTIVITY DURING
TRADITIONAL AND MODIFIED MUSCLE TESTING POSITIONS

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Department of Physical Therapy, School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of Doctor of Physical Therapy

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2006

This Scholarly Project, Submitted by Jace Everett, Mike Fowler, Jason Haak, and Robby Luck in partial fulfillment of the requirements for the degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Graduate School Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.


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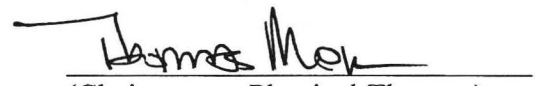

(Chairperson, Physical Therapy)

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ABSTRACT

Purpose: The purpose of this study is to assess the muscle activity of the shoulder joint force couple induced by the upper trapezius, lower trapezius, and serratus anterior to determine if they are more effectively recruited during the traditional exercise position of forward shoulder elevation in 145° of shoulder abduction versus a modified position of shoulder external rotation while in 80° of shoulder abduction and 90° of elbow flexion

Methods: Nine participants took part in this randomized study in which EMG data was collected during 4 exercise trials of 10 repetitions each on the right shoulder. EMG activity was monitored in the upper trapezius, lower trapezius, upper serratus anterior, and lower serratus anterior in the standard manual muscle testing position for the lower trapezius and a modified position with and without a two pound hand weight. The modified position had the shoulder in 80° of shoulder abduction with the elbow flexed to 90°, and palm facing the floor.

Results: All subjects were able to complete the study except one who was excluded due to data corruption. Not surprisingly, more EMG activity was found in the four muscles for positions using weight compared to the no weight position regardless of the testing position implemented. The EMG activity, in the modified position, is decreased in the upper trapezius and lower serratus when compared to the standard position. This is true regardless of the presence of the two pound weight. In the lower trapezius and the upper serratus there is no significant difference between the modified and standard positions regardless of the presence of the two pound weight.

Conclusion: The modified position recruits similar motor units in the lower trapezius and upper serratus. There is a significant reduction in EMG activity in the upper trapezius and lower serratus when comparing modified and standard testing positions.

CHAPTER I

Introduction

The current testing position for the lower trapezius at 145° of shoulder abduction has been hypothesized to cause shoulder impingement and pain. Pain will often limit muscle contraction and therefore the standard testing position of the lower trapezius may result in a decreased force output. The muscles that are commonly affected with shoulder pathology are the rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis).

The structure of the shoulder joint allows for a great deal of motion. While the joint structure is designed for increased motion, the lack of the structure requires greater muscular input for stability. The muscles around the shoulder complex work as a force couple whereby each muscle is required to participate in the overall movement. The three main muscles of the force couple include the upper and lower trapezius, and the serratus anterior.¹² The first force acts in a vertical and upward direction to counteract the weight of the shoulder girdle.⁵ The other two forces supply the rotary couple, one starting from the acromion process in a medial direction, and the other from the inferior angle in an outward or forward direction, in which this last force comes predominately from the serratus anterior.⁵

In order for the entire shoulder complex to perform properly all four parts have to move in what Codman termed scapulothoracic rhythm.⁷ As the humerus begins

movement in any plane, all four joints have to move a specific distance at a specific time. The success of scapulohumeral rhythm is a must for two main reasons. First, motion of the scapula maintains the optimal length/tension balance as the humerus is elevated, and secondly with the total motion split up between four joints the glenohumeral joint is able to reach maximum movement, while maintaining stability.¹³

The possibility of impingement at the subacromial bursa presents a problem for the clinician assessing muscle strength or initiating resistance training for the scapular musculature. To avoid impingement, all muscles of scapula and shoulder movement need to be assessed and treated. The common testing position for the lower trapezius is 145 degrees of abduction. Because overhead movements of the upper extremities increase the chance of impingement due to a decrease in subacromial space, the traditional position is a likely position for impingement to occur. It is believed that an alternative position can reduce impingement, while having the same treatment effect on the force couple surrounding the scapula. The alternate position occurs with the patient in a prone position with the arm at 80 degrees of abduction, elbow flexed to 90 degrees, and externally rotated. While the alternate position may diminish the potential for impingement, it is unknown whether the alternate position recruits the shoulder force couple to an optimal degree.

Problem Statement

There is limited research assessing the most effective position to recruit optimal motor units during exercise for the upper trapezius, lower trapezius, and serratus anterior. A previous study found a significant difference in total and average lower trapezius muscle activity between the traditional position without weight and the traditional and

modified positions with weight. More importantly an earlier study found no difference between EMG activity between the alternate and standard position----implying that both positions could recruit the lower trapezius to the same extent.

Purpose of the Study

The purpose of this study is to assess the muscle activity of the shoulder joint force couple induced by the upper trapezius, lower trapezius, and serratus anterior to determine if they are more effectively recruited during the traditional exercise position of forward shoulder elevation in 145° of shoulder abduction versus a modified position of shoulder external rotation while in 80° of shoulder abduction and 90° of elbow flexion.

Significance of Study

This study is significant to the field of physical therapy and physical therapy research because it will better define the recruitment patterns of the shoulder force couple generators. An effective alternative position for shoulder testing and training could provide physical therapists and their clients with an effective training position while minimizing the potential of subacromial impingement. An effective alternate position could result in faster rehabilitation with similar strength outcomes. While the effectiveness of the alternative position on the lower trapezius has been identified, the role of the alternative position on the entire shoulder joint force couple has not been investigated.

Research Questions

- 1) Is there a significant difference in total EMG recruitment of the upper trapezius, lower trapezius and serratus anterior between the modified muscle testing position compared to the traditional position when tested with or without weight?
- 2) Is there a significant difference in average EMG activity of the upper trapezius, lower trapezius, and serratus anterior between the modified muscle testing position compared to the traditional position when tested with or without weight?

Hypothesis

Null Hypothesis: There is NO significant difference in average EMG recruitment of the upper trapezius, lower trapezius, and serratus anterior between the modified muscle testing position and traditional testing position when tested with or without weight.

Alternative Hypothesis: There is a significant difference in average EMG recruitment of the upper trapezius, lower trapezius, and serratus anterior between the modified muscle testing position and traditional testing position when tested with or without weight.

Chapter II

Literature Review

The shoulder complex is formed from four parts including the glenohumoral(GH), acromioclavicular(AC), sternoclavicular(SC), and the scapulothoracic(ST) joint, which is technically a fascial articulation. So it is not sufficient to speak about either the glenohumoral, or scapulothoracic joints as separate entities because they work together as a unit.⁵ As the upper extremities are set into motion, whether passively or actively, the four parts of the shoulder complex must work together in order to prevent impairments. The glenohumoral joint functions for the most part to provide mobility, which means it is lacking in stability.¹² The scapulothoracic joint on the other hand uses surrounding musculature and a firm base to provide stability and controlled mobility to the glenohumoral joint.⁹

The glenohumeral (GH) joint is made up of the head of the humerus, which sits in the glenoid fossa of the scapula. Because of the labrum, which forms the outer ring of the glenoid fossa, only 50% of the humeral head is in actual contact with the scapula at any given moment. The labrum also deepens the glenoid cavity increasing the overall mobility of the GH joint.⁹ Other important components of the GH joint include the rotator cuff muscles (subscapularis, supraspinatus, infraspinatus, and teres minor), the multiple ligaments surrounding the joint to provide stability, and the deltoid muscle, which is a prime mover involved with all actions of the GH joint.

The scapulo-thoracic (ST) articulation provides a pivoting point for the humerus, and more importantly stability while the humerus is in motion. The stability of the ST joint is also very important as it needs to move in a controlled manner to prevent abnormal motion of the entire shoulder complex.¹ Abnormal motion can result in injury to the shoulder complex. If one part of the complex isn't moving properly, the chance of impingement increases dramatically. The surrounding musculature of the scapula provides most of this stability. The stabilizing musculature includes the levator scapulae, rhomboids (major and minor), pectoralis (major and minor), serratus anterior, and trapezius (upper, middle, and lower).^{9,12}

The major role of the acromioclavicular (AC) and sternoclavicular (SC) joints is to provide motion on their particular axis, which in turn provides range of motion (ROM) to the shoulder complex.¹² Although these joints do not seem to have any motion during observation, they contribute approximately 60 degrees of the normal ROM of the shoulder.¹²

In order for the entire shoulder complex to perform properly, all four parts have to move in what Codman termed "scapulothoracic rhythm".⁷ As the humerus begins movement in any plane, all four joints have to move a specific distance at a specific time. In the first 90 degrees of abduction, the GH joint accounts for 60 degrees and the ST joint accounts for 30 degrees.¹² Of this 30 degrees, 20-25 degrees comes from clavicular elevation at the SC joint and 5-10 degrees from upward rotation at the AC joint.¹² From 90-180 degrees of glenohumeral motion, the ST joint accounts for another 30 degrees of movement.¹² Of this 30 degrees, 5 degrees comes from clavicular elevation at the SC joint and 20-25 degrees from upward rotation at the AC joint.¹² Of the total normal range

of motion(ROM) in abduction of 180 degrees, the ST joint accounts for 1/3 of the movement, leaving 2/3, or 120 degrees of motion occurring at the GH joint.¹² The success of scapulohumoral rhythm is a must for two main reasons. First, motion of the scapula maintains the optimal muscle length/tension balance as the humerus is elevated, and secondly the total motion is split up between four joints, the GH joint is able to reach maximum movement, while maintaining stability.¹³

Three main muscles of the shoulder complex are considered a force couple. The muscles included in the force couple are the upper and lower trapezius, and the serratus anterior.¹² The force provided by the upper trapezius acts in a vertical and upward direction to counteract the weight of the shoulder girdle.⁵ The other two forces supply the rotary component, one starting from the acromion process in a medial direction, and the other from the inferior angle in an outward or forward direction, in which this last force comes predominately from the serratus anterior.⁵ Inman et al⁵ states the upper trapezius muscle serves a supportive role during resting position until 35 degrees of elevation. From 35-140 degrees the upper trapezius is a more effective rotator with maximum power at 90 degrees.¹ From 140-180 degrees, the upper trapezius has a decreasing role as an upward rotator, because it must balance the inferior pull of the lower trapezius.¹ An additional purpose of the upper trapezius is to elevate the clavicle during the early phases of abduction.¹² On the other hand, research has indicated that the upper trapezius has its first initial increase in muscle activity as soon as the arm begins to elevate¹ This statement makes the opposite observation in that the upper trapezius serves no supportive role during a resting state.

The lower trapezius shows little activity up until 90 degrees of elevation, at which point the activity level increases drastically through the end of elevation.¹ The lower portion of the scapular rotary force couple is made up of the lower trapezius and lower digitations of the serratus anterior.⁵ Of the lower part of the force couple, the lower trapezius is reported as a more active component in abduction when compared to flexion as the lower trapezius has to relax allowing the scapula to move forward.⁵ At this point the lower digitations of the serratus take over for the lower force couple.⁵

The serratus anterior exhibits a gradual increase in muscle activity throughout upper extremity elevation.¹ Some studies have divided the serratus anterior into upper and lower digitations, showing that each has its own distinctive roles.³ According to Ekstrom et al,³ the lower serratus anterior has increased EMG activity with upward scapular rotation when compared to the upper serratus. They also stated the upper serratus anterior is more active during scapular protraction, but not significantly different than the lower serratus anterior.³

One of the main problems facing physical therapists in the clinic has to do with manual muscle testing and resistance training for the scapular musculature. This is due to the possibility of impingement in the subacromial space. The scapulothoracic musculature is being ignored when dealing with common shoulder injuries. Most of the focus for shoulder programs is on the rotator cuff muscles, which are only a part of the overall picture. Because of this practice of setting aside the lower half of the shoulder complex, the patients aren't receiving total treatment, which leads to further impairment. All muscles pertaining to the shoulder complex have to be assessed and treated. This will allow the shoulder complex to function properly, meanwhile decreasing the chance of

impingement. At this time the common testing position for the lower trapezius is 145 degrees of abduction. Because overhead movements of the upper extremities increase the chances of impingement due to a decrease in the subacromial space, the traditional position is a likely position for impingement to occur.⁷ Many injuries or dysfunctions can increase the chance of impingement. Impingement has been linked to inflammation in the suprahumoral space, inhibition of rotator cuff muscles, damaged rotator cuff tendons, and altered kinematics which cause a decrease in the subacromial space not allowing ample movement.⁷ Other possible causes of impingement include excessive anterior or superior translations of the humeral head on the glenoid fossa, inadequate lateral rotation of the humerus, and decrease in the normal scapular upward rotation and posterior tipping on the thorax, all occurring during humoral elevation.⁷ All of these possible causes tend to alter the scapulohumeral rhythm from the optimal position and therefore lead to further impairment.

The effects of impingement on the scapular muscles includes increased upper trapezius activity from 60-180 degrees with 4.6 kg of resistance, decreased serratus anterior activity from 0-180 degrees, and increased lower trapezius activity from 60-180 degrees.⁷ Also seen with the decrease in serratus activity is a decrease in posterior tipping of the scapula, resulting in an increase in impingement.⁷

An alternative position may reduce impingement, while having the same treatment effect on the force couple surrounding the scapula. This alternate position places the patient in a prone position with the affected arm at 80 degrees of abduction, elbow flexed to 90 degrees, and externally rotated. However, it remains to be seen whether the alternate position is able to recruit the entire force couple as well as the

standard testing position. A study to determine the level of EMG activity in the scapular muscles in a variety of positions observed the EMG activity of the upper trapezius showed only 16% of the maximum contraction, the serratus anterior produced 56% of maximum contraction, and the lower trapezius showed 72% of maximum contraction.⁴ Accordingly, the alternative position proposed by this study should work well with the lower trapezius, provide fair results for the serratus anterior, but very little activity should be seen in the upper trapezius. On the other hand, if the alternative position described in this study does not elicit similar activity patterns in all three muscles, alternative positions could be contemplated for the upper trapezius and serratus anterior. The alternate position produces a relatively large amount of activity in the lower trapezius, which is a positive for reducing impingement during lower trapezius strengthening or testing.⁴

In addition to EMG analysis, the Lateral Scapular Slide Test will be added to assess scapular motion during the four test movements. Kibler has studied scapular positioning in relation to glenohumeral motion and believes that altered scapular positioning can lead to altered shoulder biomechanics.⁶ Scapular positioning is affected only by its muscular attachments because it has no bony or ligamentous attachments that secure it directly to the axial skeleton. Altered scapular kinematics and positioning can lead to alterations of shoulder movements and eventually shoulder pathologies.

The intention of our study is to use electromyography to assess the activity of the scapulohumeral muscles separately. The subjects will perform 4 different types of movement, while recording their muscular activity through the use of electrodes placed over the upper, and lower trapezius, and serratus anterior. The four positions include the traditional testing position for the lower trapezius, which is lying prone, while abducting

the upper extremity to 145 degrees, with and without weight. The other two testing positions include the alternative position, which entails the subject lying prone, at a slight angle compared to the table, and then positioning the upper extremity in 80 degrees of abduction, including lateral rotation of the shoulder, and 90 degrees of elbow flexion, with and without weight. Each subject will perform 30 cycles/minute for each position, while EMG activity is recorded for the trapezius (upper and lower), and the serratus anterior.

The purpose is to determine if the alternate position results in similar recruitment patterns as the traditional position. If the alternate position mirrors the traditional position it would mean that the alternate position (where there is a smaller chance of impingement) could be used to perform the same exercises and testing. Thus the lower trapezius, upper trapezius, and serratus anterior could be trained in the alternative position rather than the standard position. Ideally, less impingement should lead to faster recovery and improvement.

CHAPTER III

METHODS

Subjects

Nine healthy students from the University of North Dakota volunteered as subjects for this study. Inclusion criteria included no history of right shoulder pathology while exclusion criteria were shoulder pathology or an allergy to latex or isopropyl alcohol. Shoulder pathology for this study was defined as any condition that required physician intervention. Inclusion and exclusion criteria were determined by a questionnaire that was completed prior to subject testing, along with demographics for each subject including: age, height, weight and hand dominance. Informed consent was obtained from all subjects by asking each subject to complete an informed consent form (Appendix A) prior to participating in the study. A copy of the consent form was provided to each individual participant. This study was approved by the Institutional Review Board of the University of North Dakota (Project IRB-200505-373 Appendix B).

Instrumentation

The EMG data was collected using a Noraxon Telemetry 900 telemetry unit (Noraxon USA, Scottsdale, AZ). Information was collected, transmitted, and converted to a digital form by an analog to a digital interface board installed in the computer. The

digitized EMG signals were analyzed using the MyoResearch XP software package (version 1.03.15 Noraxon USA).

Electromyography and Electrode Placement

As shown in Figure 1, 2 hi-lo plinths, with a specially designed U-shaped positioning guide, and a hand switch were positioned prior to the subject entering the room. A hand switch was attached to the plinth with the use of a 2 x 4 board and a metal clamp. The plinth was then adjusted during each exercise trial to allow the subject to strike the hand switch at the end range of shoulder elevation or external rotation. The subject was instructed to lie prone on the adjacent hi-lo plinth and remained in the same position throughout the exercise trials. The subject's mid-back was exposed; care was taken to maintain the subject's modesty. Adhesive electrodes were placed on the lower trapezius, upper trapezius and serratus anterior corresponding motor points. The lower trapezius motor point was defined as the mid-point of a line drawn from the 7th thoracic vertebra to the inferior angle of the scapula (Figure 2). The upper trapezius motor point was defined as being over the muscle belly, 1/2 the distance from the acromion to the seventh cervical vertebra (Figure 2). The serratus anterior motor point was defined as 2 cm below the inferior tip of the scapula in the axillary area at the anterior border of the latissimus dorsi muscle (Figure 3). The ground electrode was placed on the spinous process of the third thoracic vertebra. All EMG sites were marked with a felt tip pen. Excess hair was removed from the sites using an electric razor followed by cleaning of the skin with isopropyl alcohol. Two pre-gelled, self-adhesive electrodes (Noraxon Dual Electrode, Model #272, Scottsdale, AZ) were then applied over the skin at each

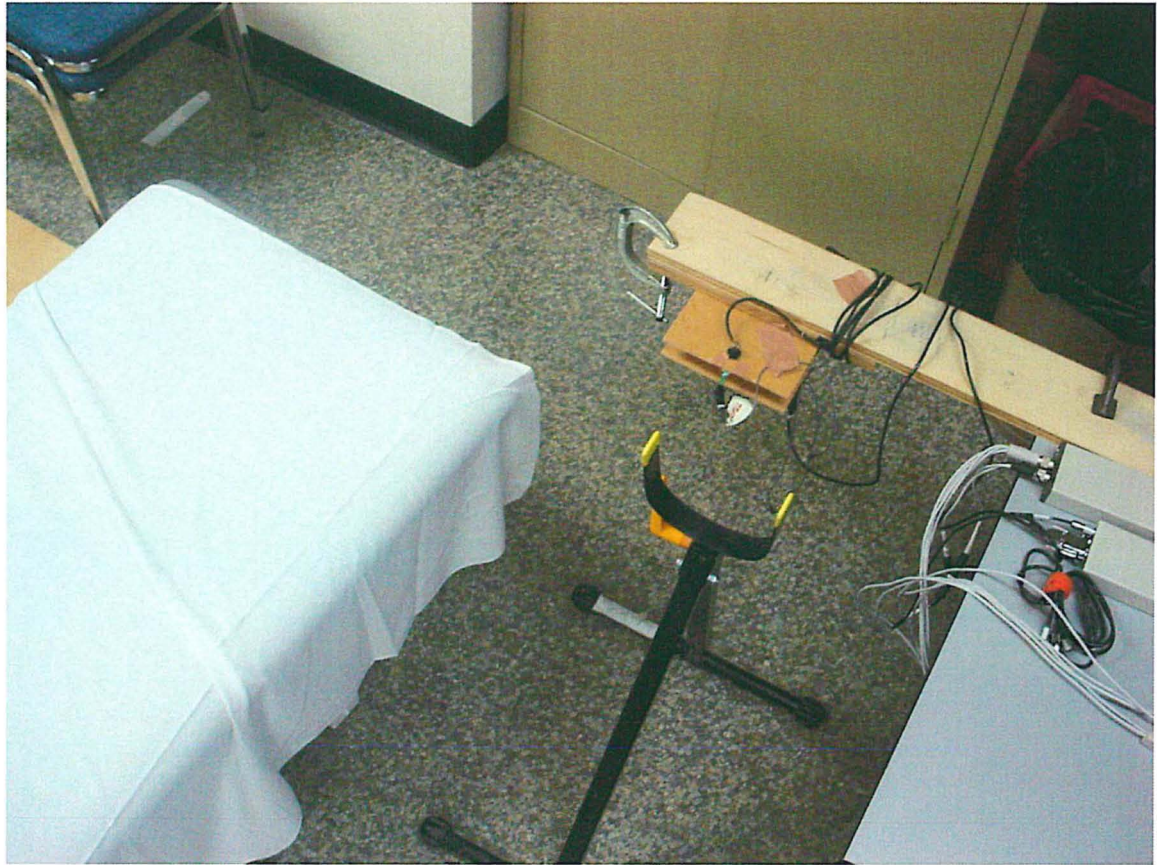


Figure 1. Test equipment, including two hi-lo plinths, a specially designed U-shaped positioning device and a hand switch.

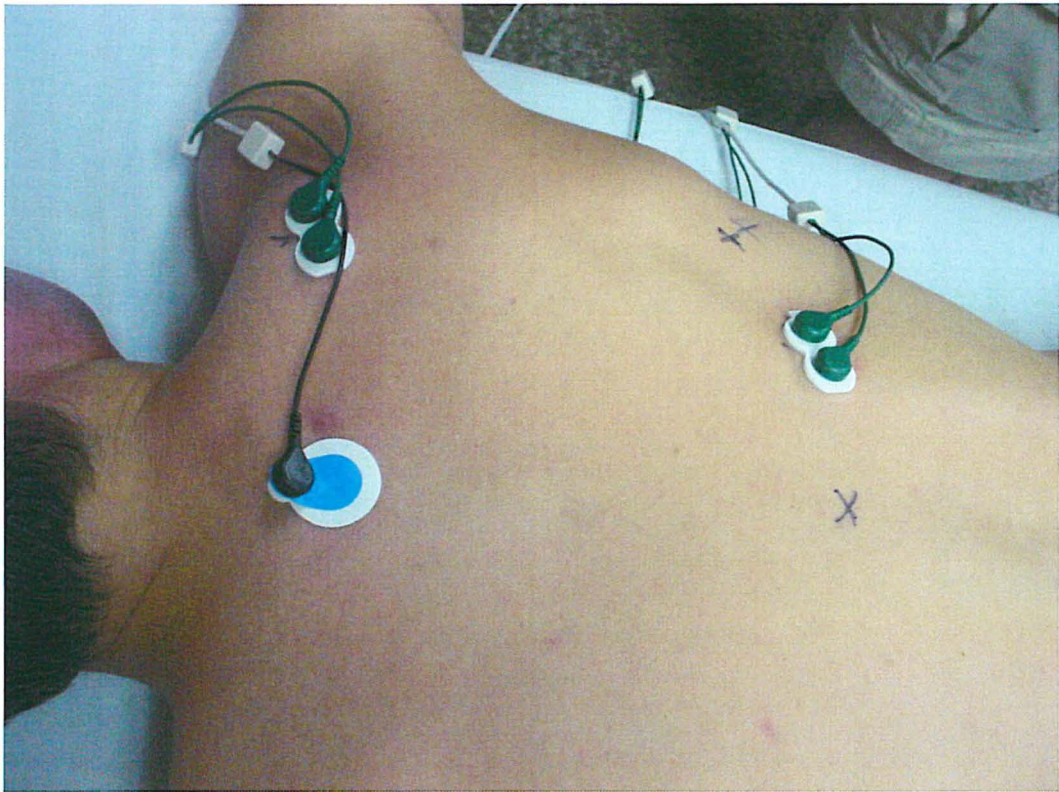


Figure 2. Electrode placement over the motor point of the upper and lower trapezius. A ground electrode was placed over the spinous process of the second thoracic vertebra.

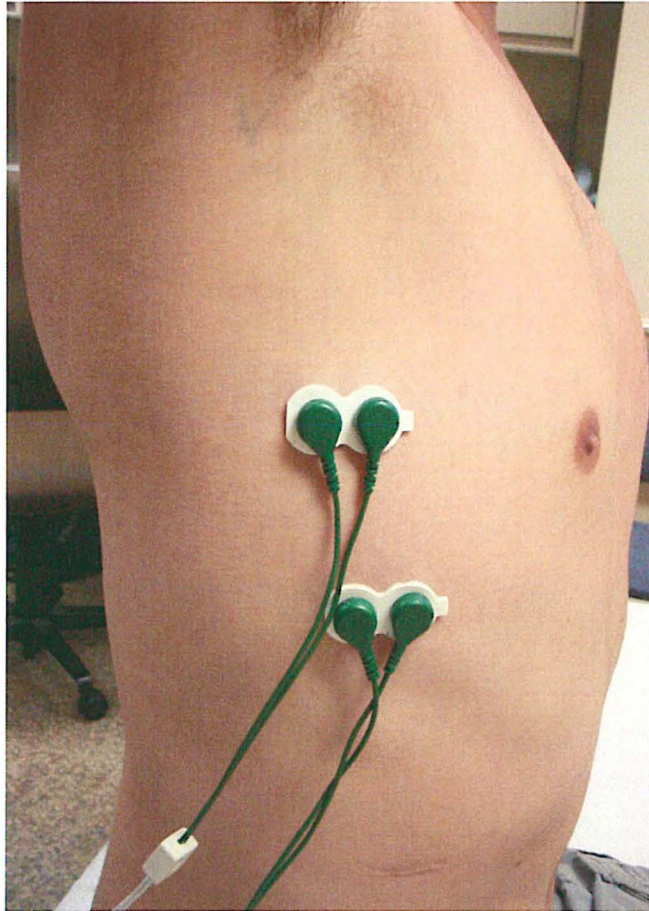


Figure 3 Electrode placement over the motor point of the upper and lower serratus anterior. A ground electrode was placed over the spinous process of the second thoracic vertebra.

corresponding motor point of the respective muscles of the right upper extremity (Figures 2-4). The distance between electrodes was minimized resulting in an inter-electrode distance of 2 cm.

The EMG signals were transmitted to the receiver unit and into a computer for display and future analysis. All electrodes and equipment were removed upon completion of the testing period and the area where the electrodes were attached was cleaned. Each subject was informed that there may be slight redness of the skin following removal of the electrodes; however the redness would only be temporary. There were no reported allergies or unexpected occurrences as a result of the procedure.

Positioning and Procedure

Each subject was given a shoulder training session to learn the proper procedures and techniques used during the trials. During the training session, each subject performed each exercise properly without losing form as well as maintaining the proper cadence. Each subject's right upper extremity was observed and used for all data collection. To allow all landmarks and the scapula to be visible, male subjects performed all tests without clothing on their upper body and female subjects performed all tests in an appropriate open-back halter top.

During each exercise, the subjects contacted a hand switch placed at the subject's maximal elevation and external rotation. The hand switch activation marked the amount of lower trapezius, upper trapezius, and serratus anterior muscle activity at maximal shoulder elevation and external rotation and was used during the analysis of the data to determine the subject's position within the full motion.

An entire cycle is defined as a complete repetition of the exercise from the designated starting position through maximum elevation or maximum external rotation, depending on the position, with a return to the starting position. For testing and graphing purposes, the traditional position without weight was designated position 1, the traditional position with weight designated position 2, the modified without weight was designated position 3, and the modified position with weight was designated position 4.

During the exercise trial in the traditional position, the subject was prone with their head facing the right side. The subject's right humerus was abducted to 145° with the thumb pointed towards the ceiling. The arm was placed into a U-shaped positioning guide to keep the arm in the correct position (Figure 5). The patients were instructed not to rest on or touch the sides of the guide in order to standardize the data. One practice trial was performed with a 2-lb hand weight and a second trial was performed without the 2-lb hand weight.

During the exercises in the modified position, the subject was prone with their head facing towards the right side. The subject's right humerus was abducted to 80° , and the elbow was flexed to 90° with the palm facing the ground. The arm was then placed into the U-shaped positioning guide to keep the arm in the correct position throughout the trial. (Figure 6) External rotation was performed with a 2-lb hand weight and a second trial was performed without the 2-lb hand weight.



Figure 4 Exercise in the traditional position without the 2-lb hand weight.

The Lateral Scapular Slide Test was performed on the right scapula of each subject prior to performing each exercise. All measurements were performed to the nearest millimeter with a metal ruler while the subject was prone lying (Table 3). The linear distance was measured from the medial aspect of the inferior tip of the scapula to the lateral aspect of the nearest spinous process. Position 1 was performed with both of the subjects arms relaxed at their side, position 2 was performed with the subject's right shoulder in 145° of shoulder abduction, and position 3 was performed with the subject's right shoulder in 90° of abduction with the elbow flexed to 90°. Position's 2 and 3 are modified from Kibler's original lateral scapular slide test^{6,18} (See Appendix D for this studies positions).

Four randomly assigned exercise trials of 10 repetitions each were performed in prone as follows: Shoulder external rotation with a 2 pound hand weight, shoulder external rotation without a 2 pound hand weight, forward shoulder elevation with a 2 pound hand weight and forward shoulder elevation without a 2 pound hand weight. Please refer to Appendix C for specific descriptions of each exercise trial. Prior to the start of each exercise trial, the subject was placed into the correct position (full elbow extension or 90° of elbow flexion) using a universal 360° goniometer. The order of exercises was randomly selected to avoid training effects.

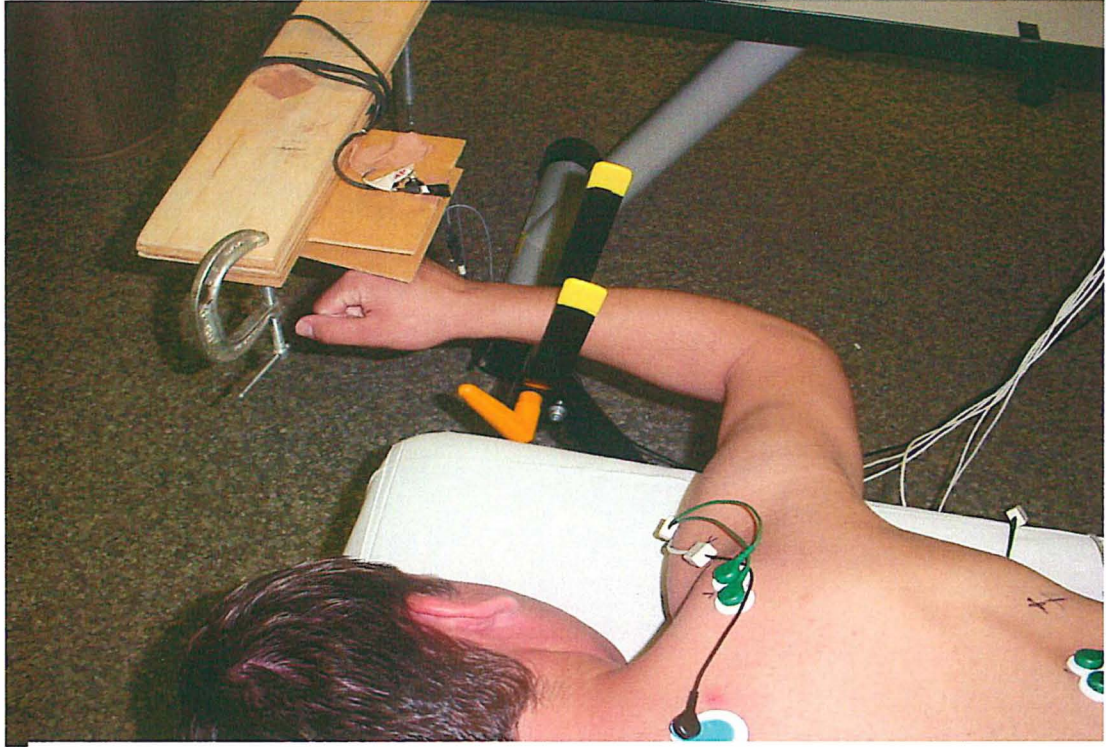


Figure 5 Exercise in the modified position performed without the 2-lb hand weight

The test exercises were performed to a metronome cadence of 30 repetitions per minute for 10 repetitions to provide consistency among trials and minimize EMG error due to movement velocity. Each repetition was counted out loud for the subject by an investigator. Each subject performed 3 to 5 practice repetitions using the metronome cadence of 30 repetitions per minute prior to performing the 10 repetitions. The subject was given 3 minutes rest between each trial. All trials were normalized to the maximal contiguous EMG activity during one second of the traditional position of forward elevation without the 2 pound weight. The traditional position of forward elevation without the weight was used for normalization because this position closely approximates the standard position for manual muscle testing of the lower trapezius. The only encouragement given to the subject was to correct improper technique.

Statistical Analysis

Data analysis of mean activity of the lower trapezius, upper trapezius, and serratus anterior was performed on the EMG activity during the experimental trials using the Statistical Package for Social Sciences (SPSS) software program (version 11.0.1, SPSS Inc., Chicago, IL). The data from the experimental trials were analyzed by selecting three consecutive cycles of exercise. For the traditional position, a cycle was defined as the period starting at zero (with the arm slightly below the plane of the table) progressing through maximum shoulder elevation and returning back to zero. For the modified position, a cycle was determined as the period starting at zero (with the arm slightly below the plane of the table) progressing through maximal external rotation and ending back at zero. After the data processing, the data for exercises in the traditional position

with weight, modified position without weight, and modified position with weight were compared to the data for traditional positions without weight using a two way repeated measures ANOVA. The alpha level for this study is (.05).

EMG Data

The raw EMG data was rectified, smoothed with a 50 ms RMS filter and normalized prior to analysis. The EMG trials were normalized to the maximal contiguous EMG activity during one second of the traditional position of forward elevation without the 2 pound weight for each subject. For all four trials of the study, the peak amplitudes occurring during the fourth, fifth and sixth repetitions were selected for analysis. The three trials were averaged and the average EMG activity of all subjects for each study condition was compiled into an average curve of EMG activity for the specific exercise (traditional position with the weight, traditional position without the weight, modified position with the weight, and modified position without the weight).

Chapter IV

Results

Subjects were tested individually and all subjects were able to complete all the exercise trials required for the data collection. The mean age of the subjects was 23 ± 0.7 years old. Four subjects were male and five were female. Characteristics of the subjects are summarized in Table 1

Table 1. Characteristics of Subjects Participating in the Research Study (n= 9)

Subjects	Age (years)	Gender (M/F)	Height (inches)	Weight (pounds)	Dominant Hand
1	23	F	66	130.5	R
2	23	F	69	195.5	R
3	23	M	71.5	178	R
4	23	F	66	115.5	R
5	23	M	78	280	R
6	25	M	71.5	205	R
7	23	M	72.5	198	L
8	23	F	66	150	R
9	24	F	69	162	R

EMG Mean Percentage of the Norm

The EMG activity for each of the test conditions was rectified, smoothed, and normalized to the highest contiguous one thousand points observed in the standard position with no weight. The mean EMG activity for three repetitions of each test condition for the groups is presented in Table 2.

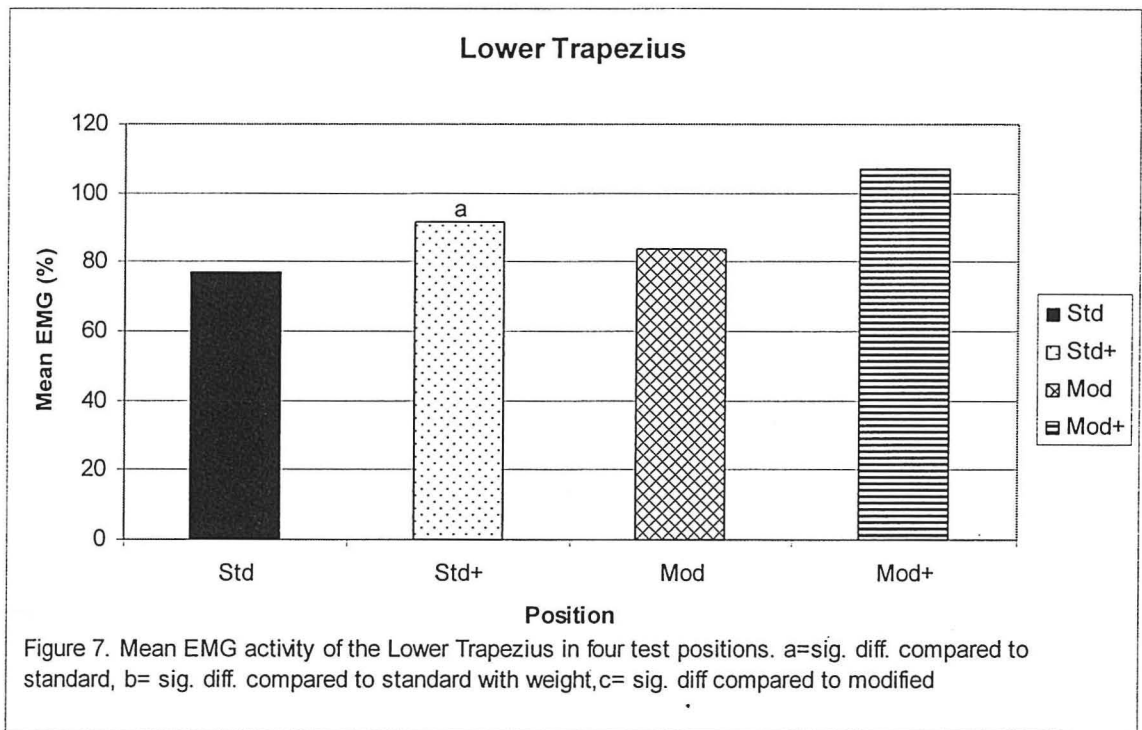
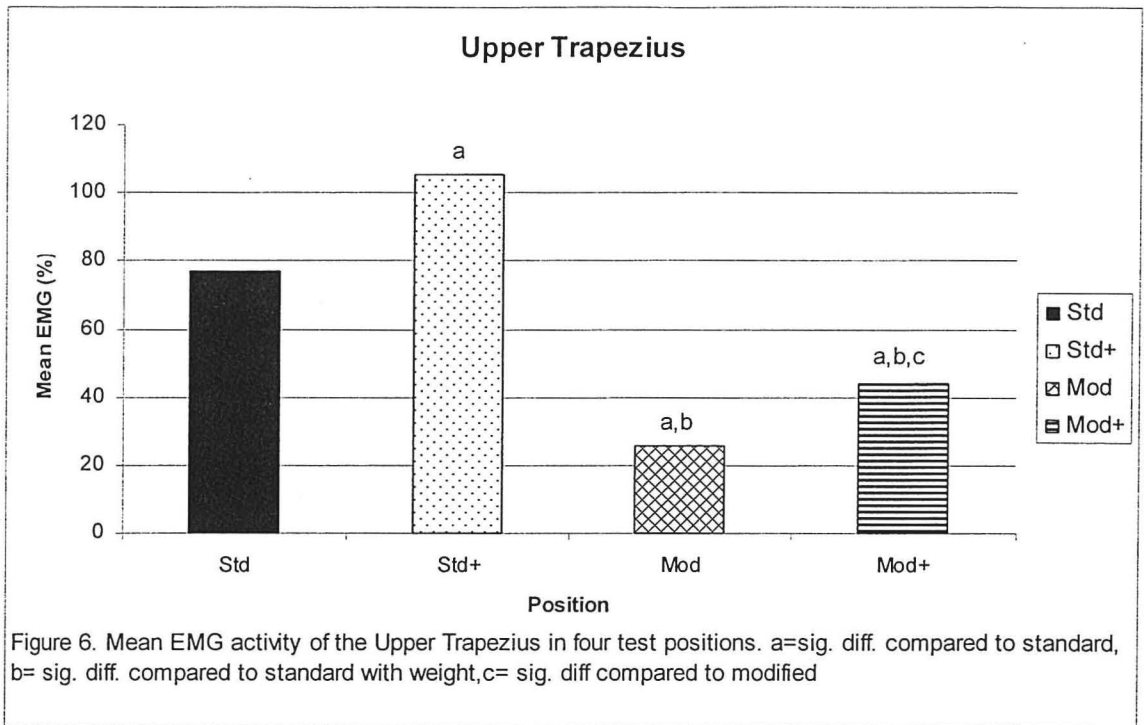
Table 2 Mean EMG Activity/Recruitment, with standard deviation, of the Upper Trapezius, Lower Trapezius, Upper Serratus, and Lower Serratus Throughout an Entire Cycle of Exercises as a Percentage of the Standard Test Position.

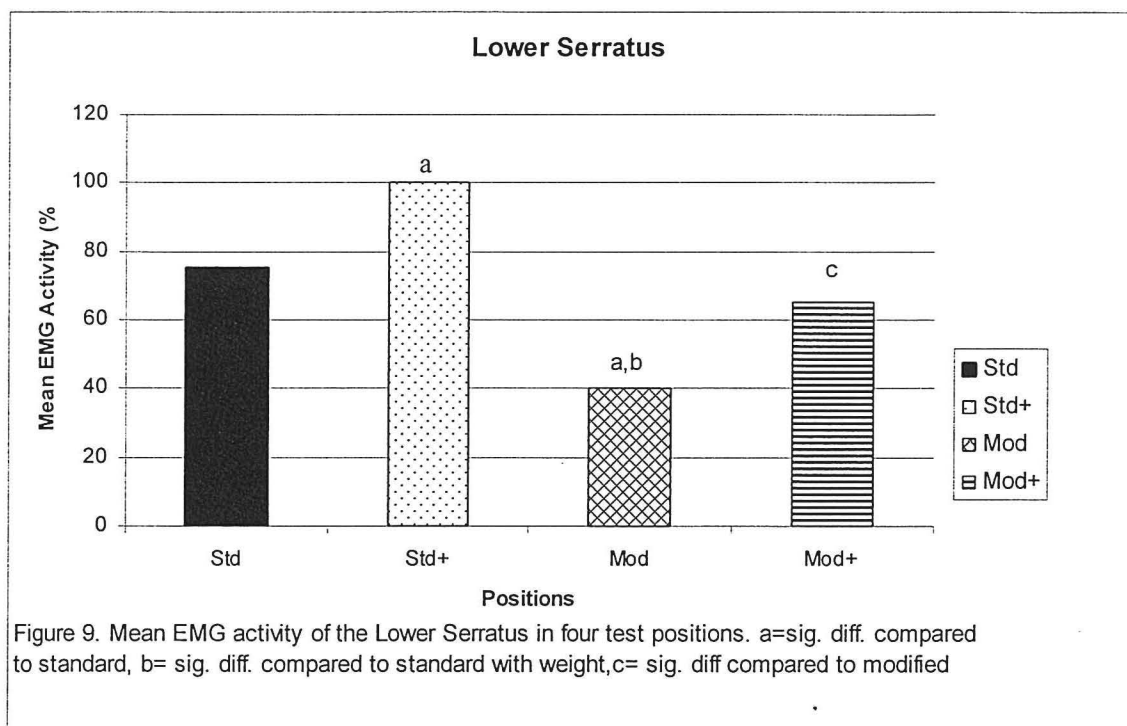
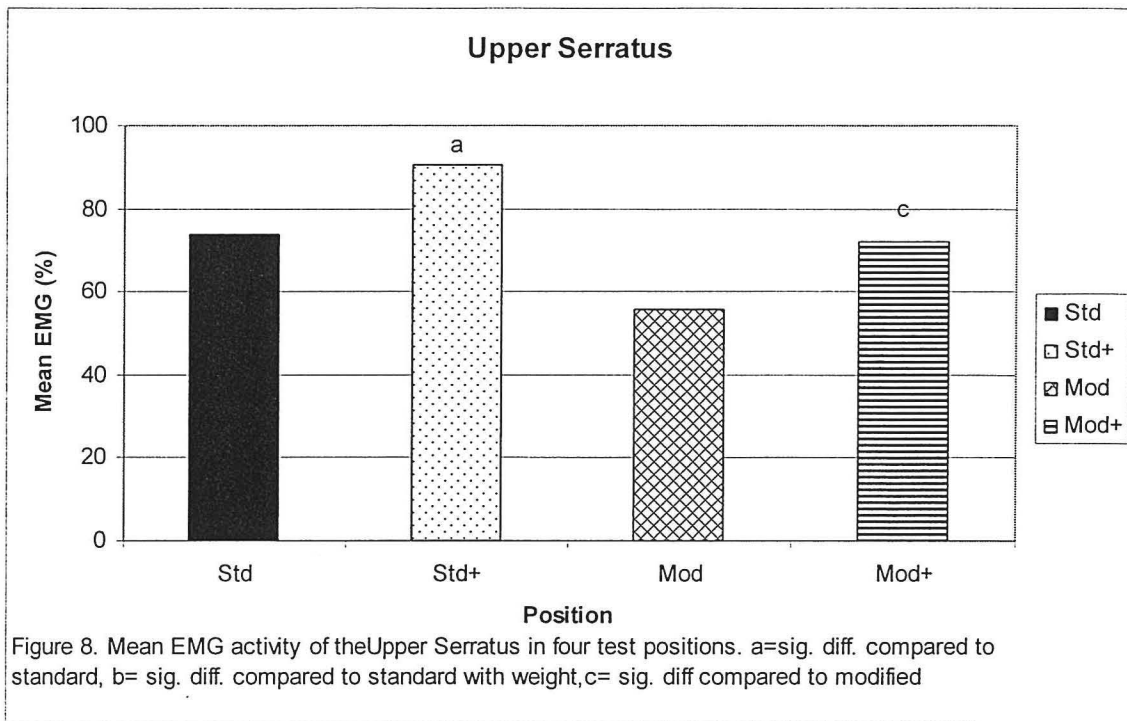
Muscle	Std no Weight (% of norm)	Std with Weight (% of norm)	Modified no Weight (% of norm)	Modified with Weight (% of norm)
Upper Trapezius	77.1±7.3	105.8±25.4	25.9±6.9	44.3±19.9
Lower Trapezius	76.9±3.7	91.4±11.5	83.8±26.2	108.0±39.6
Upper Serratus	74.0±5.4	90.6±17.8	55.8±20.1	72.2±19.9
Lower Serratus	75.0±5.3	100.1±20.4	40.2±19.0	65.0±26.2

A significant interaction was observed between the muscle and position using a two way repeated measure ANOVA ($F(9,120)=7.36$, $p<0.05$; partial $\eta^2 = 0.356$, power = 1.00). When assessing the main effects of muscle and position, a significant main effect of muscle ($F(3,120)=13.497$, $p<0.05$; partial $\eta^2=0.252$, power = 1.00) and position ($F(3,120) = 36.532$, $p<0.05$; partial $\eta^2=0.477$, power =1.00) were observed. A pair wise comparison t-test was used for post hoc analysis for the interaction between muscle and position. A Bonferroni correction was made to the alpha level to minimize

error while associated with the pair wise comparison t-test for post hoc analysis ($p < 0.01$).¹⁴

Not surprisingly, more EMG activity was found in the four muscles for positions using weight compared to the no weight position regardless of the testing position implemented (See Figures 6-9). The EMG activity in the modified position was decreased in the upper trapezius and lower serratus when compared to the standard position (Figures 6 and 9). This was true regardless of the presence of the two pound weight. Notably, there was no significant difference in EMG activity of the lower trapezius and the upper serratus when comparing the modified and standard positions, regardless of the presence of the two pound weight (Figures 7 and 8).





The lateral scapular shift test was performed to determine the position of the scapula in the anatomical position as well as the standard and alternate position for each subject in this study. The lateral scapular shift data are presented in Table 3. The mean distance from the spinous process of the third thoracic vertebra to the vertebral border of the scapula for all subjects in the anatomical position (position 1) was 141 ± 12 mm. As the subjects elevated the extremity into the muscle testing positions, the scapula moved laterally. The mean lateral position from the spinous process of the third thoracic vertebra to the vertebral border of the scapula was 193 ± 21 mm and 183 ± 18 mm for the standard (position 2) and alternate (position 3) respectively.

Table 3. Lateral Scapular Shift for each subject in the anatomical, standard, and modified positions (Positions 1, 2, & 3 respectively).

Subjects	Position 1 (mm)	Position 2 (mm)	Position 3 (mm)
1	130	180	190
2	140	185	195
3	140	185	180
4	122	171	175
5	150	219	223
6	161	215	175
7	151	206	163
8	134	162	185
9	137	217	164

Chapter IV

Discussion

The lower trapezius is a key muscle in the functioning of the scapulo-humeral complex. As a key muscle in scapular function, the lower trapezius has been the focus of many studies. However, focusing on one muscle of the complex may obscure the interaction and functional results of the movement. The current study was performed to evaluate the key muscles involved in the scapulo-humeral complex during movement in a modified testing position. This modified position is hoped to minimize the impingement seen with the standard position, which often leads to dysfunction. The modified position of 80 degrees of shoulder abduction and 90 degrees elbow flexion, while externally rotated was compared to the standard test position for the lower trapezius.

The activity of the lower trapezius during the standard and modified testing positions was found to be similar. The addition of a 2 lb. hand weight, regardless of the testing position, resulted in increased EMG activity. In addition, the modified position demonstrated decreased EMG activity of the upper trapezius and lower serratus anterior muscles, when compared to the standard position (Figures 6 and 9). Interestingly, EMG activity of the lower trapezius and upper serratus muscles was not affected by changing from the standard and modified positions. The EMG observations between test positions in the muscles occurred regardless of the presence of the 2 lb. weight.

The standard position, which involves abducting the upper extremity to 145 degrees, puts the patient in a vulnerable position for impingement leading to further shoulder dysfunction. Because of this, using the modified position might be appropriate for equal recruitment of the lower trapezius and upper serratus anterior. On the other hand, our study showed a decrease in upper trapezius and lower serratus anterior EMG activity in the modified position. This suggests that the modified testing position may be appropriate for recruiting the lower trapezius, while other positions should be utilized for optimal recruitment of the remaining shoulder complex musculature. The maximum mean amount of EMG activity in the serratus anterior has been reported to occur with resistance to upward rotation of the scapula with the shoulder flexed to 125 degrees (91%MVIC) or abducted to 125 degrees in the plane of the scapula (89% MVIC) with the subject in the sitting position.⁴ Maximal mean EMG activity in the upper trapezius has been reported to occur when resistance is given to shoulder abduction at 90 degrees with simultaneous resistance to the head after the neck is first side bent to the same side, rotated to the opposite side, and then extended (92% MVIC).⁴ This previously performed study implies that the maximal strengthening position for the upper trapezius and serratus anterior is unlike the modified position investigated in our study. This demonstrates the need for exercise and testing positions for the scapular stabilizers, which are separate from the modified position proposed in this study, to optimally recruit the upper trapezius and serratus anterior.

One of the main problems facing physical therapists in the clinic has to do with manual muscle testing and resistance training for the scapular musculature. This is due to the possibility of impingement in the subacromial bursa. If the relationship between

scapular motion and shoulder impingement syndrome can be determined, it is possible that new methods for modifying motion patterns may be developed. These developments, when they occur might relieve patient's symptoms and potentially prevent the progression of rotator cuff disease. A study performed by Karduna and Kerner reported that subacromial clearance decreases as upward rotation of the scapula increases, contrary to the researcher's expectations.¹⁶ This suggests that decreased or controlled upward rotation of the scapula may serve to open the subacromial space, particularly in clients with impingement syndrome, further demonstrating the need for a modified position.

The lateral scapular slide test (LSST) was also performed to determine the position of the scapula in the anatomical, standard, and modified positions for each subject in the study. The mean lateral position from the spinous process of the third thoracic vertebra to the vertebral border of the scapula was 193 ± 21 mm and 183 ± 18 mm for the standard (position 2) and alternate (position 3) test conditions respectively. Lateral Scapular Slide Test shows that the scapular positioning is affected only by its muscular attachments, as it has no bony or ligamentous attachments that secure it directly to the axial skeleton.⁶ The altered scapular kinematics and positioning can lead to alterations of shoulder movements and eventually shoulder pathologies.⁶

In the current study, there was no difference in scapular distance from the vertebra of the tested shoulder across all test positions. Notably, results from a recent study indicate poor reliability of measurements obtained using the LSST.¹⁵ Therefore, the implications of scapular mobility occurring in the alternative and standard test positions may require further study.

Finally, the scapulothoracic musculature has been overlooked in the past when dealing with common shoulder injuries. The surrounding musculature of the scapula provides most of the stability. The stabilizing musculature includes the levator scapulae, rhomboids (major and minor), pectoralis (major and minor), serratus anterior, and trapezius (upper, middle, and lower).^{9,12} Most of the focus for shoulder programs has been on the rotator cuff muscles including supraspinatus, infraspinatus, teres minor, and subscapularis. Because of this practice of setting aside the lower half of the shoulder complex, the patient's aren't receiving total treatment, which can lead to further impairment. Notably, fatigue of the external rotators of the shoulder can temporarily alter scapular kinematics.¹⁷ The altered kinematics have been implicated in subacromial impingement and shoulder impairment.¹⁷ All muscles pertaining to the shoulder complex must be assessed and treated. This will allow for optimal functioning while decreasing the chance of impingement. At this time the common testing position for the lower trapezius is 145 degrees of abduction. Overhead movements of the upper extremities increase the chance of impingement due to a decrease in the subacromial space.⁷

Impingement has been linked to inflammation in the suprahumeral space, inhibition of rotator cuff muscles, damaged rotator cuff tendons, and altered kinematics which could cause a decrease in the subacromial space resulting in diminished movement.⁷ Other possible causes of impingement include excessive anterior or superior translations of the humeral head on the glenoid fossa, inadequate lateral rotation of the humerus, and a decrease in normal scapular upward rotation and posterior tipping on the thorax, all occurring with humeral elevation.⁷

The lack of a complete exercise program for the shoulder complex and a testing procedure that place's the patient in a compromised position are the two main downfalls in the clinic at this time. Because of these issues patients continue to have inadequate strength in the scapular complex leading to dysfunction, and possibly impingement. This study demonstrates that the lower trapezius has equal or greater EMG activity in the modified position which will place the patient in a less vulnerable position for impingement, yet optimal lower trap recruitment. On the other hand this study reports a decrease in mean EMG activity for the upper trapezius, and serratus anterior which suggests that the modified position may not be the best position for strengthening these muscles.

Conclusion

The current study is an expansion of a previous study which investigated the activity of the lower trapezius in the traditional and modified test positions. The results for the lower trapezius were similar in the current study. Along with repeating the analysis with the lower trapezius, the current study included the upper trapezius, and serratus anterior EMG activity in the standard, and modified positions. The EMG activity for the upper trapezius and serratus anterior decreased in the modified position when compared to the standard position (Figure 6 and 9). Interestingly, this decrease was also present with the addition of the 2 lb. weight in both positions. In the lower trapezius and the upper serratus anterior there was no significant difference between the modified and standard positions regardless of the presence of the 2 lb. weight (Figures 7 and 8).

Limitations of this study include the limited number and range of subject characteristics. All subjects were recruited from a sample of convenience and were young, healthy individuals. Differences in testing table height and the height of the EMG switch were adjusted to best fit each subject. However, the variation in subject size made it difficult to reliably adjust the range of motion for each subject so that it was exactly the same or standardized. Therefore, future studies may want to include a broader variety of subjects including those with shoulder pathology. In addition, the benefits of training in the modified testing position have not been investigated. Various occupations and athletes may benefit from training in the modified position rather than the standard position. However, training in the modified position should be assessed to determine whether strength gains are similar in both modified and standard positions.

Appendix A

Information and Consent Form

Title: An Electromyographic and Motion Analysis Study of Upper and Lower Trapezius, and Serratus Anterior Muscle Activity During Traditional and Modified Muscle Testing Positions.

You are being invited to participate in a study conducted by Jace Everett, Mike Fowler, Jason Haak, Robby Luck, Dr. David Relling, and Dr. Sue Jenö. The purpose of this study is two fold. The first is to determine whether the lower and upper trapezius and serratus anterior muscles are more active in the traditional overhead testing position or in a second position with the arm 80° away from the side of the body. The second purpose is to assess the movement of the shoulder blade, spine and arm during the two positions. The results of this study will assist physical therapists in choosing the best position for testing and exercising these muscles during a shoulder rehabilitation program. Only healthy subjects with no history of shoulder problems will be asked to participate in this study.

For this study you will first be asked to lie on your stomach and to hold your right arm in the overhead position. The tester will then push down on your arm to determine the strength of the muscles. Following this, you will be asked to perform 4 separate exercises while lying on your stomach with your arm in the 2 different exercise positions. You will be asked to perform 2 exercises in each of the positions, one with a 2-pound weight and one without any weight. Ten repetitions will be done with each of the 4 exercises, totaling 40 repetitions. During the experiment, we will be recording the amount of muscle activity in the muscles described earlier. This study will take approximately 1 hour of your time. You will be asked to come to the Physical Therapy Department at the University of North Dakota at an assigned time.

The investigators in this study feel that the risk of injury or discomfort is minimal; the risk of injury is not any greater than would be anticipated with light exercise. In order for us to record muscle activity we will be placing small, self-stick electrodes on the right middle and right upper part of your back, as well as on your right side between your arm pit and bottom of your rib cage. Before placing the electrodes, the skin over each placement site will be cleaned with alcohol and excess hair will be shaved (if necessary) with an electric clipper. We will also attach reflective markers at various points along your spine, shoulder blade and arm. You will then be correctly positioned for testing. At this time you will be asked to perform the exercise with your right arm in the 2 different positions, with and without the 2-pound weight. The electrodes and reflective markers only record information from your muscles. They do not affect the skin, so no uncomfortable feelings should occur from the electrodes. The skin under the areas where the electrodes are placed may possibly be red after the removal due to the self-stick adhesive. No costs to you are expected.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study that can be connected with you will remain private and will be revealed only with your permission. The video taped data will be

University of North Dakota
Institutional Review Board
Approved on MAY 13 2005
Expires on MAY 12 2006

analyzed by a computer and the markers placed on your body may be used to construct a "stick man" like figure. Your real, photographic image will not be used in reporting of the findings of this study. A number known only to the investigators will identify the data. The consent forms will be stored separate from the data collected using separate, locked file cabinets in the Physical Therapy Department at the University of North Dakota. The data and consent forms will be retained for a period of 3 years from the date of completion of the study. After this time, the information will be shredded. The computer files and video tapes are kept in a separate locked cabinet in the Physical Therapy Department at the University of North Dakota for a period of 3 years. After that time, all electronic media will be erased.

The experiment may be stopped at any time by yourself or the investigators if any discomfort, pain, fatigue or other symptoms that may be harmful to your health are identified. Your decision whether or not to participate will not damage your future relationship with the Physical Therapy Department or the University of North Dakota.

The investigators involved are available to answer any question you have about this study. In addition, you are encouraged to ask any questions about this study you may have in the future, including any interest in being informed of the study's findings. If you have questions about the research please call Dr. David Relling at (701) 777-4091 or Mike Fowler at (701) 777-9794. If you have any other questions or concerns, please call the Office of Research and Program Development at (701) 777-4279. A copy of the consent form is available to all participants in the study.

In the unlikely event that this research activity results in injury, medical treatment will be available, including first aid, emergency treatment and follow-up care as it is to the general public in similar circumstances. You and your third party payer, if any, must provide payment for any such treatment.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION; I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by on of the investigators. I have received a copy of this informed consent for my records.

Participant's Signature

Date

University of North Dakota
Institutional Review Board
Approved on MAY 13 2006
Expires on MAY 12 2006

Appendix B

University of North Dakota Human Subjects Review Form

All research with human participants conducted by faculty, staff, and students associated with the University of North Dakota, must be reviewed and approved as prescribed by the University's policies and procedures governing the use of human subjects. It is the intent of the University of North Dakota (UND), through the Institutional Review Board (IRB) and Research Development and Compliance (RD&C), to assist investigators engaged in human subject research to conduct their research along ethical guidelines reflecting professional as well as community standards. The University has an obligation to ensure that all research involving human subjects meets regulations established by the United States Code of Federal Regulations (CFR). When completing the Human Subjects Review Form, use the "IRB Checklist" for additional guidance.

Please provide the information requested below:

Principal Investigator: Dr. David Relling, Dr. Sue Jenö, Jace Everett, Mike Fowler, Jason Haak, and Robby Luck
Telephone: (701) 777-2831 E-mail drelling@medicine.nodak.edu
Complete Mailing Address: University of North Dakota, P.O. Box 9037, Grand Forks, ND 58202
School/College: School of Medicine and Health Sciences Department: Physical Therapy

Student Adviser (if applicable): Dr. David Relling
Telephone: (701) 777-4091 E-mail drelling@medicine.nodak.edu
Complete Mailing Address: University of North Dakota, P.O. Box 9037, Grand Forks, ND 58202
School/College: School of Medicine and Health Sciences Department: Physical Therapy

Project Title: An Electromyographic and Motion Analysis Study of Upper/Lower Trapezius, and Serratus Anterior Muscle Activity During Traditional and Modified Muscle Testing Positions

Proposed Project Dates: Beginning Date: May 23, 2005 Completion Date: May 23, 2006
 (Including Data Analysis)

Funding agencies supporting this research: None

(A copy of the funding proposal for each agency identified above MUST be attached to this proposal when submitted.)

Does the Principal Investigator or any researcher associated with this project have a financial interest in the results of this project? If yes, provide an additional explanation of the financial interest (other than receipt of a grant) on a separate piece of paper.

YES or X NO

If your project has been or will be submitted to other IRBs, list those Boards below, along with the status of each proposal.

_____ Date submitted: _____ Status: ___ Approved ___ Pending
 _____ Date submitted: _____ Status: ___ Approved ___ Pending

Type of Project: Please check "Yes" or "No" for each of the following.

X YES or _____ NO New Project _____ YES or X NO Dissertation/Thesis
 _____ YES or X NO Continuation/Renewal X YES or _____ NO Student Research Project

- YES or NO Is this a Protocol Change for previously approved project? If yes, submit a signed copy of form with the changes bolded or highlighted.
- YES or NO Does your project involve medical record information? If yes, complete the HIPAA Consent Application and submit it with this form.
- YES or NO Does your project include Genetic Research? If yes, refer to Chapter 3 of the Researcher Handbook for additional guidelines regarding your topic.
- YES or NO Does your project include Internet Research? If yes, refer to Chapter 3 of the Researcher Handbook for additional guidelines regarding your topic.
- YES or NO Will subjects or data be provided by Altru Health Systems? If yes, submit two copies of proposal. A copy of the proposal will be provided to Altru.
- YES or NO Will research subjects be recruited at another organization (e.g., hospitals, schools, YMC) assistance with the data collection be obtained from another organization?

If yes, list all institutions:

Letters from each organization must accompany this proposal. Each letter must illustrate that the organization understands their involvement in the study and agrees to participate in the study. Letters must include the name and title of the individual signing the letter and, if possible, should be printed on letterhead.

Subject Classification: This study will involve subjects who are in the following special populations: Check all that apply.

- Minors (< 18 years)
- UND Students
- Prisoners
- Pregnant Women/Fetuses
- Persons with impaired ability to understand their involvement and/or consequences of participation in this research
- Other: _____

For information about protections for each of the special populations, refer to Chapter 5 of the Researcher Handbook.

This study will involve: Check all that apply.

- Deception
- Radiation
- New Drugs (IND)
- Non-approved Use of Drug(s)
- Recombinant DNA
- None of the above will be involved in this study
- Stem Cells
- Discarded Tissue
- Fetal Tissue
- Human Blood or Fluids
- Other

I. Project Overview

Provide a brief explanation (limit to 200 words or less) of the rationale and purpose of the study, introduction of any sponsor(s) of the study, and justification for use of human subjects and/or special populations (e.g., vulnerable populations such as minors, prisoners, pregnant women/fetuses).

There is limited research involving the most effective shoulder joint position in which to evaluate and exercise the upper trapezius, lower trapezius, and serratus anterior shoulder muscles with EMG and Motion Analysis.

The purpose of this study is to look at the scapular kinematics and muscle activity of the shoulder joint force couple as well as to further establish whether the upper trapezius, lower trapezius, and serratus anterior are more effectively recruited during the traditional exercise position of forward shoulder elevation in 145° of shoulder abduction versus a modified position of shoulder external rotation while in 80° of shoulder abduction and 90° of elbow flexion. The current testing position for the lower trapezius at 145° of shoulder abduction has been hypothesized to cause shoulder impingement and pain. Pain will often limit muscle contraction and therefore the standard testing position of the lower trapezius may result in a decreased force output. This study is proposed to assess an alternate test position which would avoid the impingement position. The muscle activity of 60 recruited subjects will be collected via electromyographic (EMG) procedures using non-stimulating, surface electrodes. Motion analysis video equipment will be utilized simultaneously to determine the role of scapular positioning and control in the two test positions.

Healthy adult subjects (18-45 years of age) without reported shoulder dysfunction will be used in this research project. Human subjects are needed for this research study in order to measure muscle activity of the upper trapezius, lower trapezius, and serratus anterior in two different test positions.

II. Protocol Description

Provide a succinct description of the procedures to be used by addressing the instructions under each of the following categories. Individuals conducting clinical research should refer to the “Guidelines For Clinical-Research Proposals” in Appendix A of the Researcher Handbook.

1. Subject Selection.

- a) Describe recruitment procedures (i.e., how subjects will be recruited, who will recruit them, where and when they will be recruited and for how long) and include copies of any advertisements, fliers, etc., that will be used to recruit subjects. If incentive payments will be made to anyone for enrolling participants, describe the incentive package.**

It is anticipated that we will recruit a total of 60 male and female subjects between the ages of 18-45 years of age. The subjects for this study will be recruited from the University of North Dakota student population by the principle investigators through the use of flyers explaining the study at various campus locations (see attached flyer).

- b) Describe your subject selection procedures and criteria, paying special attention to the rationale for including subjects from any of the categories listed in the “Subject Classification” section above.**

Subjects will be chosen based upon their availability, age, and health status.

- c) Describe your exclusionary criteria and provide a rationale for excluding subject categories.**

Only subjects with no history of right shoulder pathology will be used in this study because only healthy subjects will be tested to obtain optimal data. Shoulder pathology for this study will be defined as any condition that required physician intervention. Subjects who are allergic to latex and alcohol will also be excluded from this study.

- d) **Describe the estimated number of subjects that will participate and the rationale for using that number of subjects.**

It is anticipated that we will recruit 60 male and female subjects between 18-45 years of age. The number of subjects will be used to add power and validity to the statistical analysis of this study.

- e) **Specify the potential for valid results. If a power analysis was used to determine the number of subjects, describe your method.**

With 60 subjects and a standardized protocol for electrode placement and data collection, the risk of errors is reduced and the potential for valid results will be high. Also contributing to validity and reduction of training effects is the randomization of the testing exercises.

2. Description of Methodology.

- a) **Describe the procedures used to obtain informed consent.**

Informed consent will be obtained from all subjects by asking each subject to complete an informed consent form (see attached form). All individuals participating in this study will be capable of individual decision making and will be required to sign a consent form stating their understanding and consent to participate in this study. A copy of the consent form will be provided to each individual participant.

- b) **Describe where the research will be conducted. Document the resources and facilities to be used to carry out the proposed research. Please note staffing, funding, and space available to conduct this research.**

The research will be conducted in the Physical Therapy Department at the University of North Dakota. The UND PT department has EMG and motion analysis equipment and analyzing software. There are two faculty members in the department who are familiar with the equipment and its use. One or more of these individuals will be present during all data collection sessions.

- c) **Indicate who will carry out the research procedures.**

The research will be conducted by David Relling, PT, PhD, Sue Jenö PT, PhD, and four graduate students: Jace Everett, Mike Fowler, Jason Haak, and Robby Luck

- d) **Briefly describe the procedures and techniques to be used, and the amount of time that will be required of the subjects to complete them.**

EMG data will be collected during 4 exercise trials of 10 repetitions each on the right shoulder. Each subject will be given a shoulder training session to learn the proper procedures and techniques to be used during the trials. During the training session each subject will learn how to perform each exercise properly without losing form as well as maintaining the proper cadence. The subject will lie prone on a hi-lo plinth with a hand switch attached to a second hi-low plinth with a 2X4 clamp. To prepare for data collection, the subject's mid-back will be exposed being sure to maintain the subject's modesty. Adhesive electrodes will be placed on the lower trapezius motor point that will be defined as the mid-point of a line drawn from the 7th thoracic vertebrae to the inferior angle of the scapula, upper trapezius motor point that will be defined as over the muscle belly 1/2 the distance from the acromion to C7, and the serratus anterior motor point that is defined as 2 cm below the inferior tip of the scapula in the axillary area at the anterior border of the latissimus dorsi muscle. The ground electrode for the EMG will be placed on the spinous process of the third thoracic vertebra. All EMG sites will be marked with a felt tip pen. Prior to placing the electrodes the area

will be cleaned with isopropyl alcohol and any excess hair will be shaved using an electric razor if necessary.

The subjects will perform a voluntary maximal isometric contraction of the lower trapezius, upper trapezius and serratus anterior in the traditional positions prior to beginning the exercise. This information will be used for normalization of the EMG data. Four exercise trials of 10 repetitions each will be performed in prone as follows: Shoulder external rotation with a 2 pound hand weight, shoulder external rotation without a 2 pound hand weight, forward shoulder elevation with a 2 pound hand weight and forward shoulder elevation without a 2 pound hand weight. The shoulder external rotation position will occur at 80° of shoulder abduction with the elbow flexed to 90°, and palm facing the floor. The forward shoulder elevation position will occur at 145° of shoulder abduction with thumb pointed toward the ceiling. The order of exercise will be randomly selected to avoid training effects. These exercises will be performed at a metronome cadence of 30 repetitions per minute for 10 repetitions to increase consistency in timing. The subject will be given 3 minutes rest between each trial. All trials will be compared to the traditional position of forward elevation without the 2 pound weight because this is the standard position for manual muscle testing of the lower trapezius.

Motion analysis will be used to analyze the kinematic variables associated with the traditional and modified testing positions. Reflective markers will be attached using double sided tape. Markers will be placed on the radial styloid, the olecranon process, anterior lateral tip of the acromion process, inferior angle of the scapula, superior angle of scapula, and the spinous process's of C7, T5 and T12. Video cameras will be placed on the side and in front of the subject's upper trunk specifically looking at scapular kinematics and shoulder movement during the two test positions.

The EMG signals will be transmitted to the receiver unit and into a computer for display and analysis. Motion analysis will be captured on video tape and the video image may be converted to a stickman like figure, from which the motion at the shoulder and scapula can be determined. At the conclusion of data collection, the electrodes will be removed and the skin will be cleaned with alcohol. This will end the subject's participation in the study. The study will require no longer than 1 hour of each of the subject's time.

After all data is collected we will use descriptive and analytical statistics looking at all data for scapular kinematics and EMG muscle activity of the upper trapezius, lower trapezius, and serratus anterior during all testing situations.

e) Describe audio/visual procedures and proper disposal of tapes.

Digital photographs and videotaping will be taken for illustration purposes only. Consent will be received for use of these pictures and videos prior to the procedure.

All electronic data (computer files/video tapes) will be stored in a separate, locked file cabinet in the Department of Physical Therapy for a period of three years, at which time the data will be erased.

f) Describe the qualifications of the individuals conducting all procedures used in the study.

All the individuals who are conducting the procedures for this study are currently faculty or Graduate Doctorate Physical Therapy Students at the University of North Dakota, who have completed an instrumentation course in Electromyography and Motion Analysis.

g) Describe compensation procedures (payment or class credit for the subjects, etc.).

Subjects will receive no payment or class credit for participation in this study.

Necessary Attachments: Copies of all instruments (such as survey/interview questions, data collection forms completed by subjects, etc.) must be attached to this proposal.

3. Risk Identification.

- a) **Clearly describe the anticipated risks to the subjects/others including any physical, emotional, and financial risks that might result from this study.**

The risks involved in this study are minimal. The EMG and Motion Analysis testing equipment monitor skeletal muscle electrical activity and joint motion respectively. Neither of the devices stimulates or alters the subject's motion. Therefore no discomfort to the subjects is expected.

The process used with EMG in this study may impose a potential for a minimal risk of injury to the subjects muscles, however the risk of injury is not any greater than would be anticipated with light exercise. The testing for this study will occur in a controlled environment with all testing being performed in a private room, and due to the fact that only healthy subjects will be participating in this study, the risk of injury is low. There is minimal risk for the subjects to experience discomfort, pain, fatigue or other symptoms associated with light exercise including but not limited to: increased heart rate, sweating or dizziness. Because of exposure of the back, there is a slight risk to the modesty of the subject during electrode placement; however modesty will be controlled with the use of sheets and having female subjects wear halter tops. There may be a risk of slight redness of the skin following removal of the electrodes; however the redness should only be temporary.

In the event that this research activity results in a physical injury, medical treatment will be readily available, including first aid, emergency treatment and follow-up care as it is to any member of the general public in similar circumstances. Payment for any treatment must be provided by the subject or the subject's third party payer, if applicable.

- b) **Indicate whether there will be a way to link subject responses and/or data sheets to consent forms, and if so, what the justification is for having that link.**

No subject's names will be used in any reports of this study. Any information that is obtained in this study and can be identified with any subjects will remain confidential and will only be disclosed with permission from the subject. The research data and subjects consent forms will be connected by a single number, which will only be known by the investigators conducting this study. The identifying number is required to assure EMG and motion analysis data is coordinated and processed from the appropriate subject. At the completion of this research project all research data and subject consent forms will be stored in separate, locked locations in the Physical Therapy Department for a minimum of 3 years, at which time they will be shredded. All data will be reported in aggregate form only.

4. Subject Protection.

- a) **Describe precautions you will take to minimize potential risks to the subjects (e.g., sterile conditions, informing subjects that some individuals may have strong emotional reactions to the procedures, debriefing, etc.).**

All participants will have close supervision throughout the testing procedure to decrease the potential of harm. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue or any other symptoms that may be hazardous to the subject's health. To avoid risk to subject's modesty, each subject will be placed in a private room during placement of electrodes. All electrodes will be disposable and given to each subject for

their personal use only. The electrodes are used only for recording, thus there is no potential risk of injury from the electrodes specifically.

- b) Describe procedures you will implement to protect confidentiality (such as coding subject data, removing identifying information, reporting data in aggregate form, etc.).**

No subject names will be used in any results of this study. Any information that is obtained in this study and can identify any subjects will remain confidential and will only be disclosed with permission from the subject. The research data and subjects consent forms will be connected by a single number, which will only be known by the investigators conducting this study.

- c) Indicate that the subject will be provided with a copy of the consent form and how this will be done.**

All subjects will be given a separate copy of the consent form for their own records at the beginning of this study.

- d) Describe the protocol regarding record retention. Indicate that research data from this study and consent forms will both be retained in separate locked locations for a minimum of three years following the completion of the study.**

Describe: 1) the storage location of the research data (separate from consent forms and subject personal data)

2) who will have access to the data

3) how the data will be destroyed

4) the storage location of consent forms and personal data (separate from research data)

5) how the consent forms will be destroyed

Signed consent forms and data collected from this study will be kept in a separate locked filing cabinet in the Physical Therapy Department for a minimum of 3 years. After all forms and data are no longer needed they will be shredded.

All electronic data (computer files/video tapes) will be stored in the Department of Physical Therapy for a period of three years, at which time the data will be erased.

- e) Describe procedures to deal with adverse reactions (referrals to helping agencies, procedures for dealing with trauma, etc.).**

The investigators or subjects may stop the experiment at any time if the subject is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his or her health. The decision whether or not to participate will not prejudice the individual's future relationship with the Department of Physical Therapy or the School of Medicine at the University of North Dakota. If subjects decide to participate, they are free to discontinue participation at any time without prejudice.

- f) Include an explanation of medical treatment available if injury or adverse reaction occurs and responsibility for costs involved.**

In the unlikely event that this research activity results in injury, medical treatment will be available, including first aid, emergency treatment and follow-up care as it is to the general public in similar circumstances. The person and their third party payer must provide payment for any such treatment.

III. Benefits of the Study

Clearly describe the benefits to the subject and to society resulting from this study (such as learning experiences, services received, etc.). Please note: payment is not a benefit and should be listed in the Protocol Description section under Methodology.

The data collected throughout this research study will be analyzed to determine if there is any difference in muscle activity of the lower trapezius, upper trapezius, and serratus anterior in the traditional manual muscle testing position and an alternate position. With the data this study will provide, we anticipate finding a lower trapezius, upper trapezius, or serratus anterior strengthening and/or testing position that will allow the same amount of muscle activity as the traditional testing position, but without risk of shoulder impingement. The benefit to the participant will be the experience of being involved in a scientific study, and knowing that they will be contributing to the body of knowledge of exercise physiology and physical therapy.

IV. Consent Form

A copy of the consent form must be attached to this proposal. If no consent form is to be used, document the procedures to be used to protect human subjects. Refer to the RD&C website for further information regarding consent form regulations.

Please note: Regulations require that all consent forms, and all pages of the consent forms, be kept for a minimum of 3 years after the completion of the study, even if the subject does not continue participation. The consent form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. It is recommended that the consent form be written in the third person (please see the examples on the RD&C website), and at no higher than an 8th grade reading level. A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp, and only copies of the consent form with the stamp may be used in the research. The consent form must include the following elements:

- a) An introduction of the principal investigator
- b) An explanation of the purposes of the research
- c) The expected duration of subject participation
- d) A brief summary of the project procedures
- e) A description of the benefits to the subject/others anticipated from this study
- f) A paragraph describing any reasonably foreseeable risks or discomforts to the subject
- g) Disclosure of any alternative procedures/treatments that are advantageous to the subject
- h) An explanation of compensation/medical treatment available if injury occurs.
- i) A description of how confidentiality of subjects and data will be maintained. Indicate that the data and consent forms will be stored separately for at least three years following the completion of the study. Indicate where, in general, the data and consent documents will be stored and who will have access. The following statement must be included on the consent forms and informational letters: "Only the researcher, the adviser, [if applicable] and people who audit IRB procedures will have access to the data." Please make appropriate additions to the persons that may have access to your research data. Indicate how the data will be disposed of. Be sure to list any mandatory reporting requirements that may require breaking confidentiality.
- j) The names, telephone numbers and addresses of two individuals to contact for information (generally the student and student adviser). This information should be included in the following statement: "If you have questions about the research, please call (insert Principal Investigator's name) at (insert phone number of Principal Investigator) or (insert Adviser's name) at (insert Adviser's phone number). If you have any other questions or concerns, please call Research Development and Compliance at 777-4279."

- k) If applicable, an explanation of who to contact in the event of a research-related injury to the subject.
- l) If applicable, an explanation of financial interest must be included.
- m) Regarding participation in the study:
 - 1) An indication that participation is voluntary and that no penalties or loss of benefits will result from refusal to participate.
 - 2) An indication that the subject may discontinue participation at any time without penalty, with an explanation of how they can discontinue participation.
 - 3) An explanation of circumstances which may result in the termination of a subject's participation in the study.
 - 4) A description of any anticipated costs to the subject.
 - 5) A statement indicating whether the subject will be informed of the findings of the study.
 - 6) A statement indicating that the subject will receive a copy of the consent form.

By signing below, you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate, and that the project will be completed as indicated.

Signatures:

(Principal Investigator)

Date:

(Student Adviser)

Date:

Requirements for submitting proposals:

Additional information can be found on the IRB web site at www.und.nodak.edu/dept/orpd/regucomm/IRB/index.html.

Original Proposals and all attachments should be submitted to Research Development and Compliance, P.O. Box 7134, Grand Forks, ND 58202-7134, or brought to Room 105, Twamley Hall.

Prior to receiving IRB approval, researchers must complete the required IRB human subjects education. Please go to <http://www.und.nodak.edu/dept/orpd/regucomm/IRB/IRBEducation.htm> for more information.

The criteria for determining what category your proposal will be reviewed under is listed on page 3 of the IRB Checklist. Your reviewer will assign a review category to your proposal. Should your protocol require full Board review, you will need to provide additional copies. Further information regarding required copies and IRB review categories can be found on the RD&C website, or you may call the RD&C office at 701 777-4279.

In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical-medical. If the proposed work is being conducted for a pharmaceutical company, 7 copies of the company's protocol must be provided.

Please Note: Student Researchers must complete the "Student Consent to Release of Educational Record".

Revised 6/7/04

**INVESTIGATOR LETTER OF ASSURANCE OF COMPLIANCE
WITH ALL APPLICABLE FEDERAL REGULATIONS FOR THE
PROTECTION OF THE RIGHTS OF HUMAN SUBJECTS**

I _____
(Name of Investigator)

agree that, in conducting research under the approval of the University of North Dakota Institutional Review Board, I will fully comply and assume responsibility for the enforcement of compliance with all applicable federal regulations and University policies for the protection of the rights of human subjects engaged in research. Specific regulations include the Federal Common Rule for Protection of the Rights of Human Subjects 45 CFR 46. I will also assure compliance to the ethical principles set forth in the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research document, The Belmont Report.

I understand the University's policies concerning research involving human subjects and agree to the following:

1. Should I wish to make changes in the approved protocol for this project, I will submit them for review PRIOR to initiating the changes.
2. If any problems involving human subjects occur, I will immediately notify the Chair of the IRB, or the IRB Coordinator.
3. I will cooperate with the UND IRB by submitting Research Project Review and Progress Reports in a timely manner.

I understand the failure to do so may result in the suspension or termination of proposed research and possible reporting to federal agencies.

Investigator Signature

Date

STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD¹

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit.

The study to which this release pertains is _____

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

NAID #

Printed Name

Date

Signature of Student Researcher

¹Consent required by 20 U.S.C. 1232g.

Appendix C

TRAINING TEMPLATE

You will be asked to complete a series of four exercises with your arm in different positions. All exercises will be completed while lying on your stomach. While in each position you will perform ten repetitions of an exercise once without a two-pound weight and once with a two-pound weight. You will be given three minutes rest in between each set of ten repetitions. You will randomly select the order of the exercises and be instructed on the exercises in the order that you have selected them.

Traditional Position without the Weight

Your arm will be placed in 145 of abduction parallel to the plane of the table. Your elbow will be straight with your arm rotated out so your thumb is pointed towards the ceiling. You will then complete ten repetitions of forward elevation without a two-pound hand weight to a cadence determined by a metronome. Each repetition will begin with your arm slightly below the table and proceed through maximum elevation where a hand switch will be placed and activated with each repetition. A repetition will be considered complete when your arm is returned to the beginning position of slightly below the level of the table.

Traditional Position with the Weight

This exercise will be performed in the same position as the traditional position without weight except that you will be holding a two-pound hand weight.

Modified Position without the Weight

Your arm will be placed in 80 degrees of abduction in a plane parallel to the table. Your elbow will be flexed to 90 degrees and your palm will be facing the floor. You will then complete ten repetitions of external rotation without a two-pound hand weight while stabilizing your arm in 80 degrees of abduction. A metronome will determine the cadence of the exercises. The starting position will be with your arm in slight internal rotation and you will proceed with external rotation until you reach and activate a hand switch placed at your maximum external rotation. A repetition will be considered complete when your arm is returned to the starting position.

Modified Position with the Weight

This exercise will be performed in the same position as the modified position without weight except that you will be holding a two-pound hand weight.

Appendix D



Figure 10. Position 1 of lateral scapular slide test performed with both of the subjects arms relaxed at their side



Figure 11. Position 2 of the lateral scapular slide test was performed with the subject's right shoulder in 145° of shoulder abduction.



Figure 12. Position 3 of the lateral scapular slide test was performed with the subject's right shoulder in 90° of abduction with the elbow flexed to 90°.

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