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An Electromyographic Study of Lower Trapezius Muscle Activity during Exercise in Traditional and Modified Positions

Rebecca Lee Johnson
University of North Dakota

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AN ELECTROMYOGRAPHIC STUDY OF LOWER TRAPEZIUS MUSCLE
ACTIVITY DURING EXERCISE IN TRADITIONAL
AND MODIFIED POSITIONS

by

Rebecca Lee Johnson
Bachelor of Science in Physical Therapy
University of North Dakota, 1999

An Independent Study
Submitted to the Graduate Faculty
of the
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
2000
This independent study, submitted by Rebecca Lee Johnson in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

(Signature)
(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title An Electromyographic Study of Lower Trapezius Muscle Activity during Exercise in Traditional and Modified Positions

Department Physical Therapy

Degree Master of Physical Therapy

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Date 12-14-99
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ABSTRACT

Shoulder rehabilitation commonly overlooks the influence of scapular muscles in providing the stability necessary for the shoulder to function properly. When considering muscles acting on the scapulothoracic articulation, literature suggests that the lower trapezius is a key stabilizer of this articulation. Traditionally, the lower trapezius is exercised while the patient is in a prone position with the humerus abducted 145° while performing forward elevation. Unfortunately, repeated overhead activity has been proven to increase the incidence of shoulder impingement. In an effort to avoid exercising the lower trapezius in a position that would compromise the shoulder complex, a modified position of 80° of abduction while performing prone external rotation was proposed.

Purpose: The purpose of this study was to determine whether the lower trapezius was more effectively recruited in the traditional or modified exercise position. Methods: Ten subjects, both male and female, between the ages of 21 and 24 years old, were tested. Electromyographical (EMG) data was collected from each subject's right lower trapezius muscle while he/she performed exercise in the traditional position without weight, the traditional position with weight, the modified position without weight, and the modified position with weight in random order. Results: A significant difference was found in lower trapezius muscle activity when comparing exercise in the traditional position without the weight to exercise in the modified position without the weight. No significant difference was found in lower trapezius muscle activity when comparing
exercise in the traditional position without weight to exercise in the modified position with weight and the traditional position with weight. There was also no significant difference in peak muscle activity across all four exercise conditions. **Conclusion:** Exercise in the modified position with weight effectively recruits the lower trapezius and allows the patient to exercise in a position that does not compromise the shoulder complex.
CHAPTER I

INTRODUCTION

Proper function of muscles controlling the scapulothoracic articulation is vital to normal biomechanics of the shoulder.\(^1\) However, when rehabilitating the shoulder complex, this functional articulation is frequently overlooked.\(^2\) The anterior, middle, and posterior deltoid as well as the rotator cuff, consisting of the supraspinatus, infraspinatus, teres minor, and subscapularis are key muscles focused on during shoulder rehabilitation. Unfortunately, as stated above, exercises meant to improve function and stability of the scapula are often forgotten. When the scapulothoracic articulation is not addressed during shoulder rehabilitation, patients may not be achieving normal shoulder biomechanics, which may then contribute to recurrent shoulder injuries, such as impingement syndrome.

Research suggests that the lower trapezius should be emphasized when considering the muscles acting on the scapulothoracic articulation. The lower trapezius is actively recruited during upward rotation of the scapula, especially with abduction beyond 90°.\(^3\)\(^4\)\(^5\) This upward rotation of the scapula allows the glenoid fossa to be oriented, so that a stable base may be provided for articulation with the humeral head, thus allowing the full 180° of abduction.\(^1\)\(^3\)\(^4\)

Although the lower trapezius is active during humeral abduction, research states that it serves mainly as a postural muscle due to a high percentage of Type I muscle
fibers. The lower trapezius is especially active in stabilizing the scapula during the initial two thirds of abduction. Because the lower trapezius acts as both a stabilizer and a mover of the scapula, appropriate timing of scapular motion during humeral abduction is crucial for proper biomechanics of the shoulder complex in order to avoid new or recurrent shoulder injuries, such as impingement syndrome.

Problem Statement

There is little published research that clearly establishes the most effective position in which to exercise the lower trapezius muscle.

Purpose

The purpose of this study was to determine whether the lower trapezius is more effectively recruited in the traditional exercise position of forward elevation in 145° of abduction or a modified exercise position of external rotation while in 80° of abduction and 90° of elbow flexion.

Significance of Study

The results of this study were twofold. First, they would allow therapists to incorporate more effective lower trapezius exercises into shoulder rehabilitation programs, therefore, they would be able to provide more efficient and complete care. Also, if the lower trapezius was found to be significantly active in the modified position, the patient would not be required to achieve 145° of abduction during exercise of this muscle. Thus, the chance of aggravating shoulder impingement was reduced.
Research Questions

1) Is there a significant difference in recruitment of the lower trapezius between the traditional and the suggested alternative exercise positions when tested with or without resistance?

2) Is there a significant difference in peak electromyographic (EMG) activity of the lower trapezius between the traditional and the suggested alternative exercise positions when tested with or without resistance?

Hypotheses

Null Hypothesis: There is no significant difference in recruitment of the lower trapezius between the traditional and the suggested alternative exercise positions when tested with or without resistance.

Alternative Hypothesis: There is a significant difference in recruitment of the lower trapezius between the traditional and the suggested alternative exercise positions when tested with or without resistance.

Null Hypothesis₂: There is no significant difference in peak EMG activity of the lower trapezius between the traditional and modified exercise positions when tested with or without resistance.

Alternative Hypothesis₂: There is a significant difference in peak EMG activity of the lower trapezius between the traditional and modified exercise positions when tested with or without resistance.
CHAPTER II
LITERATURE REVIEW

The shoulder complex mechanism is highly mobile. Full and pain-free mobility of the shoulder depends on smooth, coordinated efforts of all involved structures. The shoulder complex is made up of three bones: the scapula, the humerus, and the clavicle, and five joints: the acromioclavicular, glenohumeral, sternoclavicular, scapulothoracic, and subacromial joints. This complex is relatively unstable and in order for normal motion to occur it requires a stable base of support.

The scapulothoracic articulation is primarily responsible for providing the necessary dynamic stability in the shoulder mechanism. The proper function in this articulation is vital to normal biomechanics in the shoulder. The muscles included in the scapulothoracic articulation include the serratus anterior, trapezius, levator scapulae, rhomboid major, rhomboid minor, latissimus dorsi, pectoralis major, and pectoralis minor. The function of the scapulothoracic muscles is to provide mobility as well as stability for the scapula. Literature suggests that the serratus anterior and trapezius muscles are the most important muscles acting upon the scapulothoracic articulation.

Mobility at the scapulothoracic articulation is important for the normal biomechanics of the shoulder joint. The scapulothoracic muscles position the scapula to orient the glenoid fossa for appropriate humeral head placement. The glenohumeral,
scapulothoracic, sternoclavicular, and acromioclavicular joints all participate to ensure normal range of motion. This combined motion has been termed by Codman\textsuperscript{1,5,6} as scapulohumeral rhythm. During the initial 30° of humeral abduction the movement of the scapula is not well coordinated with movement of the humerus.\textsuperscript{5,6} Thus, at this point, the scapulohumeral rhythm is irregular. Coordination of scapular motion improves after the initial phase of humeral elevation. However, toward the end of humeral elevation the scapulohumeral rhythm is once again irregular; the scapula provides more motion than the humerus. Overall, for every 1° of scapular rotation 2° of humeral elevation occurs. Upward rotation of the scapula always accompanies elevation of the arm contributing to 60° of the available 180° of motion. Therefore, the two to one ratio (2:1) of glenohumeral to scapular motion is required to allow the 180° of movement available in the shoulder.\textsuperscript{6,7}

The upward rotation of the scapula, necessary for upper extremity elevation is a result of the trapezius and serratus anterior muscles acting together as a force couple.\textsuperscript{1,3,6,7} A force couple is defined as two equal forces acting in opposite directions to rotate a part about its axis of motion.\textsuperscript{1,5} The upper trapezius and upper portions of the serratus anterior comprise the upper portion of the force couple. From 0-90° of abduction, the scapula upwardly rotates approximately 30° as a result of the action of this force couple.\textsuperscript{5} The lower portion of the force couple is composed of the lower trapezius and the lower portions of the serratus anterior. The lower portion joins the upper portion of the force couple to further rotate the scapula an additional 30° during 90-180° of upper extremity elevation. The lower trapezius muscle along with the lower serratus, therefore, actively participate in upward rotation above 90°.\textsuperscript{5} Below 90°, the lower trapezius and the lower serratus act in supportive
roles as stabilizers of the scapula. Thus, the converging actions of the trapezius and serratus anterior muscles produce upward rotation of the scapula during elevation of the arm and serve as stabilizing synergists for the deltoid muscle that acts on the glenohumeral joint. During elevation, the action of the deltoid will lead to downward rotation of the scapula. The force couple of trapezius and serratus anterior prevents this downward rotation and maintains the optimum length/tension relationship for the deltoid. If there is an imbalance, weakness, or dysfunction in any portion of the force couple, scapulohumeral rhythm will be disrupted.

Scapulothoracic muscles contribute to stabilization of the scapula by offering a stable base against which the glenohumeral muscles can function properly. The actions of the scapulothoracic and the glenohumeral muscles are outlined in Table 1. As stated earlier, the lower trapezius muscle is one of the most important muscles acting upon the scapulothoracic articulation. Ballantyne et al. found the lower trapezius muscle participates minimally in glenohumeral abduction below 90°. Therefore, during the first 90° of abduction the lower trapezius acts as a stabilizer.

Scapulothoracic muscles are not required to contract powerfully or forcefully in short periods of time, rather their role is primarily to serve a postural function. Postural muscles, muscles that help maintain upright posture, contain larger portions of Type I fibers and function more during endurance activities. This fiber type is predominately aerobic in its metabolic capacity and has a relatively slow speed of contraction. Thus, Type I fibers are fatigue-resistant and well suited for prolonged activities. Autopsy studies

<table>
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<th>Muscle</th>
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<th>Humerus</th>
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<tbody>
<tr>
<td></td>
<td>Flexion</td>
<td>Extension</td>
<td>IR</td>
</tr>
<tr>
<td>Trapezius</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Upper</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Middle</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
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<tr>
<td>Lower</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Serratus Anterior</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Levator Scapula</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Rhomboids</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Latissimus Dorsi</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
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<tr>
<td>Pectoralis Major</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
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<tr>
<td>Pectoralis Minor</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
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<tr>
<td>Deltoid</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
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<tr>
<td>Anterior</td>
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<tr>
<td>Lower</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>X X X X</td>
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<td>X</td>
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<tr>
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<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Teres Minor</td>
<td>X X X X</td>
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<td>X</td>
</tr>
<tr>
<td>Teres Major</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
</tr>
<tr>
<td>Coracobrachialis</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X</td>
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</table>

*IR indicates internal rotation; ER, external rotation; DR, downward rotation; and UR, upward rotation
have shown that the lower trapezius muscle contains eighty percent Type I fibers. This evidence supports the lower trapezius' function as a postural muscle. Further verification of the postural function of the lower trapezius was provided in a study by Inman that exhibited muscle activity in the lower trapezius even while the arm was at rest.

Shoulder pain and disability are common orthopedic problems seen by physical therapists. Weakness of the scapulothoracic muscles leads to abnormal positioning of the scapula. This abnormal positioning disrupts the scapulohumeral rhythm which leads to impingement syndrome when humeral elevation is not synchronized with scapular elevation and upward rotation. Impingement occurs as the rotator cuff and other subacromial structures become encroached between the greater tuberosity and the coracacromial arch. Overhead activity can cause friction, impingement, and increased wear on the rotator cuff tendons and has been implicated as a contributing factor in impingement syndrome.

Deficits in range of motion also may exist in patients with shoulder impingement. These deficits are due to tightness in the posterior portion of the glenohumeral joint capsule. Shoulder pain from impingement further inhibits scapular muscles, which ultimately leads to further impingement (Figure 1). The key to breaking this cycle of pathology is to strengthen the scapulothoracic musculature.

Even though both mobility and stability of the scapulothoracic articulation are vital to normal biomechanics at the shoulder, the significance of the scapular rotators is frequently overlooked in rehabilitation. Several protocols have been published outlining the rehabilitation of the injured shoulder. Most protocols focus on strengthening the rotator cuff muscles with little emphasis on scapulothoracic musculature. In addition, most of the
Figure 1. Factors Involved in Shoulder Impingement

- Scapulothoracic Muscle Weakness
- Disruption of Scapulohumeral Rhythm
- Functional Scapulothoracic Instability
- Narrowing of Subacromial Space
- Pain
- Subacromial Impingement Syndrome
information available on exercising specific shoulder complex musculature is based on anatomic knowledge rather than quantifiable data such as electromyography (EMG). This is particularly true when it comes to the scapulothoracic muscles.

Stability of the scapulothoracic joint cannot be achieved by one muscle alone. Proper function of all scapulothoracic muscles is a necessary focus in rehabilitation. However, there is much debate in literature as to which exercises most effectively recruit the lower trapezius.\textsuperscript{4,6,9} EMG activity in the lower trapezius has been proven highly variable.\textsuperscript{9} Bagg and Forrest\textsuperscript{6} found the lower trapezius to elicit the most activity when exercising from 90°-120° of scaption; whereas, Moseley et al.\textsuperscript{6} found the lower trapezius to demonstrate its peak muscle activity from 90° to 150° of abduction. Finally, Ballantyne et al.\textsuperscript{4} found the lower trapezius to elicit the most EMG activity during prone lateral rotation and the least amount of activity in the empty can position (elevation of the arm in the scapular plane with maximal internal rotation). This debate laid the groundwork for a study, which attempted to determine a position that strengthened the lower trapezius without placing the shoulder in the overhead position.

Clinically, exercises for the lower trapezius are based on manual muscle testing. The position of testing is prone with arms overhead to approximately 145° of abduction with the forearm in midposition and the thumb pointing toward the ceiling.\textsuperscript{11} The muscle is then exercised in this position by performing forward elevation. Although muscle activity is elicited in the lower trapezius when exercising in this position, it is not ideal for patients with shoulder pathology. Not only do patients with shoulder impingement display deficits in
range of motion making this angle of abduction difficult to reach, the degree of abduction should be limited to fewer than $90^\circ$ to avoid impingement.

Research needs to be done to provide a position that safely recruits the lower trapezius. This study proposed a modified prone exercise position of external rotation while in $80^\circ$ of abduction and $90^\circ$ of elbow flexion in order to examine whether or not this position will effectively recruit the lower trapezius.
CHAPTER III

METHODOLOGY

Subjects

Ten normal, healthy students from the Department of Physical Therapy were voluntarily recruited to participate in this study. The mean age of the subjects was 22.3 years old. Seven subjects were female and three were male. Characteristics of the subjects are summarized in Table 2. Individuals with a previous history of right shoulder pathology requiring medical attention were excluded from the study. This was determined by a patient questionnaire that was filled out prior to testing (Appendix B). Each subject signed a letter of informed consent prior to the testing procedure (Appendix C). A letter giving permission to use pictures of setup and positioning was also signed by the appropriate subject (Appendix D). This study was approved by the Institutional Review Board of the University of North Dakota (Project # IRB-9904-200; Appendix E).

Table 2. Characteristics of Subjects (n = 10)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (years)</th>
<th>Gender (M/F)</th>
<th>Height (inches)</th>
<th>Weight (pounds)</th>
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<td>1</td>
<td>21</td>
<td>F</td>
<td>69</td>
<td>150</td>
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<td>10</td>
<td>21</td>
<td>F</td>
<td>63</td>
<td>136</td>
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</table>
Instrumentation

The EMG data was collected using a Naraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254). Information was collected, transmitted, and converted to a digitized form by an analog to a digital interface board installed in the computer. The digitized EMG signals were analyzed using the MyoResearch '97 software package. EMG data was collected during four exercise trials of ten repetitions each.

Procedure

As shown in Figure 2, two hi-lo plinths, a homemade trapeze system, and a handswitch were set up and positioned before the subjects entered the room. A handswitch was attached to one plinth with a 2 X 4 and a metal clamp. The plinth was then adjusted during each exercise trial, to allow the subject to strike the handswitch at his/her extreme range of elevation or external rotation. The subject was instructed to lay prone on a second plinth and remained in this position throughout the exercise trials.

After giving consent, each subject’s age, gender, height, and weight was recorded on a patient questionnaire (Appendix B). Sensitivity to isopropyl alcohol was also recorded on the patient questionnaire. Each subject was then given a short training session (Appendix F) to learn the proper procedure and technique to be used during the exercise trials. The subject’s right upper extremity was used for data collection.

In order to prepare the subject for data collection, he/she was instructed to lay prone. Being sure to maintain each subject’s modesty, the mid-back area was exposed. The motor point, defined as the mid-point of a line drawn from the seventh thoracic vertebrae to the inferior angle of the scapula, was located and marked with a felt tip pen.
Figure 2. Setup of study, including two hi-lo plinths, a homemade trapeze system, and a handswitch.
The skin over the motor point of each subject was prepared by cleansing the area with alcohol before attachment of the EMG surface electrodes. Two pre-gelled, self-adhesive electrodes (Multi Bio-Sensory, El Paso, TX, 79913) were then applied to the skin at a point corresponding to the motor point of the lower trapezius muscle of the right upper extremity (Figure 4). The distance between surface electrodes was minimized in an attempt to decrease interference from surrounding muscles, thus, increasing the accuracy of specific muscular activity in the lower trapezius. A ground electrode was placed over the spinous process of the second lumbar vertebrae (Figure 5).

Four exercise trials of ten repetitions each were performed. They were as follows: external rotation with a two-pound handweight, external rotation without a two-pound handweight, forward elevation with a two-pound handweight, and forward elevation without a two-pound handweight. Please refer to Appendix F for specific descriptions of each exercise trial. Prior to beginning each exercise, the investigator assisted the subject into the correct starting position. The desired degree of abduction was obtained using a 360° universal goniometer. The order that the exercises were to be performed was determined by random selection.

Each subject practiced the exercises at a metronome cadence of 60 repetitions per minute for three to five repetitions in order to increase consistency in the timing of the exercises within each subject. Beginning on a cue from the investigator, the subject then performed ten repetitions of each exercise trial with two minutes of rest between each trial. The investigator counted each repetition out loud for the subject. No other encouragement was offered unless a technique was being performed incorrectly.
Figure 3. The motor point of the lower trapezius was defined as the mid-point of a line drawn from the seventh thoracic vertebrae to the inferior angle of the scapula.
Figure 4. Electrode placement over the motor point of the lower trapezius.
Figure 5. Electrode placement, with lead wires attached, over the motor point of the lower trapezius and the second lumbar vertebrae. The electrode over the second lumbar vertebrae served as a ground electrode.
If a technique was being performed incorrectly, the exercise was stopped, the correct technique was explained to the subject, and the exercise was begun again.

During exercise in the traditional position, the subject was prone with his/her humerus abducted 145° and thumb pointed toward the ceiling (Figure 6). One trial of forward elevation was performed with a two-pound handweight, and a second trial was performed without a two-pound handweight.

During exercise in the modified position, the subject was prone with his/her humerus abducted 80°, while resting in a sling, and elbow flexed to 90° with the palm facing the floor (Figure 7). External rotation was performed with a two-pound handweight, and a second trial was performed without a two-pound handweight.

For each subject, the EMG signals were transmitted to the receiver unit and then into a computer for display and recording of the data. The EMG information for each subject was recorded and stored on the computer hard drive for future analysis. The EMG equipment and electrodes were removed from each subject at the conclusion of the experiment, and the skin was cleansed with alcohol where electrodes had been attached. Each subject was advised that minimal redness around the electrode sites was normal for a couple of days following the testing, however, if this persisted or a rash developed, he/she should return for possible medical follow-up. Each subject was thanked for his/her participation and encouraged to call with any questions or concerns.

Data Analysis

Statistical analysis of the mean activity of the monitored muscle was performed on the EMG activity during the experimental trials using the Statistical Package for Social Sciences (SPSS) software program. Data from the experimental trials was
Figure 6. Exercise in the traditional overhead position while using the two-pound handweight.
Figure 7. Exercise in the modified position performed without the two-pound handweight.
analyzed by selecting three consecutive cycles of the exercise. In the traditional position, one cycle was defined as the period starting at zero (with the arm slightly below the plane of the table) progressing through maximal shoulder elevation and ending back at zero. In the modified position, one cycle was defined as the period starting at zero (with the forearm slightly below the plane of the table) progressing through maximal external rotation and ending back at zero. During each exercise, a handswitch was activated by the subject at maximal elevation and maximal external rotation respectively (Figures 6 & 7). The handswitch activation marked the amount of lower trapezius muscle activity at the extreme of external rotation or forward elevation and was used during analysis of data to determine the subject’s place in the motion.

To determine the mean EMG activity during exercise, an average of the 100 highest peak amplitudes during the selected three cycles were calculated by computer. These calculations were completed for all four trials of each subject. The average EMG activity of all subjects were then 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, or modified position without the weight). The resulting four curves were defined as the "normative" curve for each specific exercise.

According to Yang and Winter, intersubject variability was significantly less when using the peak ensemble or mean ensemble of walking trials in gait analysis rather than during 50% maximal voluntary contraction or the EMG per unit moment. For this reason the normative curve of the exercise trial in the traditional position without the two-pound handweight was considered the baseline EMG activity for the lower trapezius.
The normative curves of the EMG activity with and without the weight in the remaining positions were then compared to the baseline activity.

The independent variables of this study include each specific exercise trial, and the dependent variable is the muscle activity recorded. A repeated measures analysis of variance (ANOVA) statistical test was used to determine significant differences between each trial using the SPSS software program. Post hoc Scheffe's test was performed to determine significance between trials. Statistics were considered to be statistically significant at $\alpha = .05$ level.
CHAPTER IV

RESULTS

The results of this study were determined from the collected EMG data from the subjects (n=10) and calculated means and standard deviations. The data for exercise in the traditional position with the weight, modified position without the weight, and modified position with the weight were then compared to the data for exercise in the traditional position without the weight by the use of a repeated-measures ANOVA. No subjects were excluded from this study. Subjects were tested one time, and all subjects were able to complete all of the exercise trials.

Entire Cycle

Comparisons of muscle activity for the lower trapezius in each exercise condition were performed, as shown in figures 8-11. The data points 0-100 represented one entire cycle of motion. For increased ease when reading the figures, the traditional position without weight was referred to as Trap 1, the traditional position with weight was referred to as Trap 2, the modified position without the weight was referred to as Trap 3, and the modified position with the weight was referred to as Trap 4.

The means and standard deviations for each subject during exercise throughout the entire range of motion are shown in Table 3. A repeated measures ANOVA indicated a significant difference between exercise trials (F(9,27) = 11.21, p<.05). Post hoc testing analysis revealed that lower trapezius muscle activity in the traditional position without
Figure 8. Comparison of lower trapezius muscle activity between the traditional and modified exercise positions both with and without the weight.
Figure 9. Comparison of lower trapezius muscle activity between the traditional position without the weight and the modified position with the weight.
Figure 10. Comparison of lower trapezius muscle activity between the traditional position without the weight and the modified position without the weight.
Figure 11. Comparison of lower trapezius muscle activity between the traditional position without the weight and the traditional position with the weight.
Table 3. Lower trapezius muscle activity from points 0-100, which are defined as the points representing an entire cycle of exercise.

<table>
<thead>
<tr>
<th></th>
<th>Traditional Position without Weight</th>
<th>Modified Position without Weight</th>
<th>Traditional Position with Weight</th>
<th>Modified Positions with Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>73.32</td>
<td>44.68</td>
<td>94.33</td>
<td>51.12</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>38.06</td>
<td>26.83</td>
<td>53.91</td>
<td>29.33</td>
</tr>
</tbody>
</table>
the weight was significantly greater than EMG activity of the lower trapezius in the modified position without the weight ($p = .048$). No significant difference was found when comparing the amount of lower trapezius muscle activity during exercise in the traditional position without the weight to the amount of activity during exercise in the traditional position with the weight ($F(9,27) = 11.21$, $p = .209$) or the modified position with the weight ($F(9,27) = 11.21$, $p = .170$).

Peak Muscle Activity

Peak lower trapezius muscle activity during each exercise trial was identified for additional comparison (figures 12 and 13). Out of 100 possible points during one cycle of motion, points 36-62 represented peak muscle activity.

The means and standard deviations for the sample of subjects during peak muscle activity are shown in Table 4. No significant difference was found when comparing peak lower trapezius muscle activity during exercise in the traditional position without the weight to muscle activity during exercise in the traditional position with the weight ($F(9,27) = 1.59$, $p = .583$), the modified position without the weight ($F(9,27) = 1.59$, $p = .932$), or the modified position with the weight ($F(9,27) = 1.59$, $p = .92$).
Figure 12. Definitions of boundaries of peak lower trapezius muscle activity.
Figure 13. Comparison of lower trapezius muscle activity between the traditional and modified exercise positions both with and without the weight.
Table 4. Lower trapezius muscle activity from points 36-62, which are defined as the points representing peak muscle activity.

<table>
<thead>
<tr>
<th></th>
<th>Traditional Position without Weight</th>
<th>Modified Position without Weight</th>
<th>Traditional Position with Weight</th>
<th>Modified Position with Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>136.49</td>
<td>153.48</td>
<td>100.25</td>
<td>118.57</td>
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<tr>
<td>Standard Deviation</td>
<td>61.56</td>
<td>79.89</td>
<td>57.62</td>
<td>67.07</td>
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</tbody>
</table>
CHAPTER V
DISCUSSION

Entire Cycle

A repeated measures ANOVA indicated a significant difference between exercise trials. Post hoc analysis (Scheffe’s test) revealed EMG activity of the lower trapezius was found to be significantly higher in the traditional position without the weight than in the modified position without the weight; therefore, the results supported the first hypothesis. These results were not surprising since when exercising in the traditional position the lower trapezius was lengthened more than in the modified position. Muscles that are in an elongated position can generate more force than muscles in a shortened position due to the actin-myosin filament overlap and the greater number of actin-myosin cross bridges. Hence, the traditional exercise position was expected to exhibit more EMG activity than the modified exercise position. Yet this was found to be true only without the weight. Results showed no significant difference in EMG activity when exercising in the traditional position without weight as compared to exercising in the modified position with weight. This supports the idea that the modified position effectively recruits the lower trapezius allowing for exercise in a less compromising position. Adding resistance to exercising in the modified position recruits more muscle fibers and achieves an equally effective contraction.
When establishing a rehabilitation protocol, the best exercise for the patient depends on what goal the clinician is trying to accomplish. The optimal exercise is one that comes the closest to mimicking the functional activity which you are trying to achieve. By exercising in the optimal position, the lower trapezius is able to adapt through increased circulation and better oxygen utilization to the task at hand. Since the lower trapezius is considered a postural muscle it would be beneficial to exercise the muscle in the position specific to its role as a stabilizer. Literature states that below 90° of abduction the lower trapezius is functioning as a stabilizer. Therefore, if the functional goal is to train the lower trapezius as a stabilizer, exercising in the modified position with weight would be the optimal position. In addition, in an injured shoulder, abduction exercise should be limited to 90° to avoid further shoulder pathology. The modified position limits the range to 80° of abduction. The lower trapezius was not only shown to be recruited in this limited range but exercising in this position also reduces the possibility of further impingement.

In addition to effectively recruiting the lower trapezius, the modified position recruits several muscles simultaneously. These muscles include the teres minor and infraspinatus, which act to externally rotate the humerus, as well as the muscles acting to stabilize the scapula during external rotation: rhomboid major, rhomboid minor, upper trapezius, middle trapezius, and lower trapezius. Isolated strengthening of any one of the scapulothoracic muscles will create a muscle imbalance. Stability of the scapulothoracic joint also cannot be achieved by one muscle alone. Placing an equal emphasis on strengthening multiple scapular stabilizers will provide for proper function of the scapulothoracic articulation. By simultaneously recruiting several muscles, a more
A concise rehabilitation protocol emphasizing stability could be devised that will decrease muscle fatigue and increase patient compliance.

Finally, no significant difference in EMG activity was found when exercising in the traditional position with the weight as compared to exercising in the traditional position without the weight. These results show that recruitment of the lower trapezius in the traditional position is not significantly affected by an increase in resistance. Although more muscle fibers are recruited with the added resistance, there is no benefit to exercising in the traditional position with a weight, which increases the chances of impingement. Although the overhead position, regardless of resistance, increases the chances of impingement, it cannot be avoided in some patient populations, such as occupations and athletics requiring overhead activity. Rehabilitation needs to focus on exercising safely in the overhead position. The importance of this study’s findings show that the lower trapezius can be effectively exercised in the modified position and advance to the traditional position without a weight in those patient populations where overhead activity cannot be avoided.

Peak Muscle Activity

No significant difference in peak EMG activity was found when comparing any of the exercise trials; therefore, the results failed to support the second null hypothesis. These findings indicated that the peak activity of the muscle is occurring at the end ranges of forward elevation and external rotation and that there is no statistical difference between the peaks of the two positions regardless of weight. To maximize rehabilitation efforts the goal should be to work in the end ranges. Since the maximal muscle activity is
being elicited in the terminal ranges, fewer repetitions will need to be performed to obtain the same results; this will decrease fatigue and improve patient compliance.

Future Research

The results of this pilot study show not only promise but also a need for expansion in future studies. No studies were found in literature that specifically examined the lower trapezius muscle activity in exercise. Currently, research examining lower trapezius muscle activity in several exercise positions is being conducted, however this research is only in the pilot stages and not yet published (T. Ellenbecker [tellenbecker/007306866@mcimail.com], e-mail, February 18 Thursday, 1999).

This study incorporated the voluntary effort of only ten subjects from the Department of Physical Therapy, so any slight deviation in any single subject’s performance would have profoundly affected the results. Therefore, it is recommended that several more subjects participate in order to increase the sample size. In addition, data expansion into patient populations of various ages, occupations, hobbies, and physical abilities is suggested.

Another recommendation made for future studies includes locating the motor point through electrical stimulation as opposed to the method used in this study. This would ensure the exact location of greatest muscle activity, which would allow for a better representation of muscle recruitment. Also, future studies should consider discontinuing the use of the sling. More muscle activity would be expected in the lower trapezius if the subject were verbally cued to actively retract and stabilize his/her scapula.

Finally, since the table heights and locations had to be changed frequently during testing, consistency between trials would be improved by measuring and marking the
exact height and location of the plinth used in this study. In addition, data analysis would be made easier if two switches are used to mark the exact beginning as well as the end of the range, which defines the cycle of muscle activity.

Clinical Implications/ Conclusions

The results of this study showed that the modified position with the weight effectively recruited the lower trapezius. Even though the greatest amount of EMG activity was found in the traditional position, it is not ideal for patients with shoulder pathology. Overhead activity can cause friction, impingement, and increased wear on the rotator cuff tendons. In addition, patients with shoulder impingement display deficits in range of motion, making the traditional position difficult and painful to obtain. The modified position with weight benefits patients with shoulder pathology and limited shoulder ranges by allowing them to participate in a strengthening program without causing further impingement. The modified position also mimics the functional activity of the lower trapezius as a stabilizer in the shoulder; therefore, in order to strengthen the lower trapezius as a stabilizer the optimal position would be the modified position. Finally, the modified position recruits several muscles simultaneously allowing for a more concise rehabilitation protocol that will decrease muscle fatigue and increase patient compliance.
APPENDIX A
Patient Questionnaire

Name: _______________________________________________________

Age: _______  Height: _______________  Weight: _______

Dominant Arm: _______  Isopropyl (Rubbing) Alcohol skin sensitivity?  Y/N

Do you have any history of shoulder problems for which you sought medical attention (i.e. instability, impingement, rotator cuff tear)?  Y/N

If yes, please explain:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Do you have any history of shoulder pain during or after daily activities or exercise?  Y/N

If yes, please explain: ________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

ALL INFORMATION PROVIDED IN THIS QUESTIONNAIRE HAS BEEN ANSWERED ACCURATELY TO THE BEST OF MY KNOWLEDGE.

__________________________________________  _____________
Signature of participant                     Date
INFORMATION AND CONSENT FORM


You are being invited to participate in a study conducted by Erika Engelstad and Rebecca Johnson, physical therapy students at the University of North Dakota. The purpose of this study is to determine in which position the lower trapezius muscle is more actively recruited during manual muscle testing and exercise. The conclusions drawn from this study will allow you as a physical therapy student as well as other therapists to incorporate more effective lower trapezius exercises into a shoulder rehabilitation program, which will help to provide more efficient and complete care. Only normal, healthy subjects who have no history of shoulder problems will be asked to participate in this study.

You will be asked to perform manual muscle testing and a series of shoulder exercises with up to a two-pound weight. This study will take approximately one hour of your time. You will be asked to report to the Physical Therapy Department at the University of North Dakota at an assigned time. During the experiment, we will be recording the amount of muscle activity you have in your lower trapezius muscle while you perform manual muscle testing and resistive exercises. We also will be videotaping your performance in muscle testing and exercises.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing adhesive electrodes on your upper back. The recording electrodes are attached to the surface of the skin with an adhesive material. You will then be positioned for manual muscle testing and you will be asked to perform the test and several different exercises with your right upper extremity. We will also attach reflective markers to your right upper extremity and trunk with adhesive material. The markers will be photographed while we collect muscle activity and film your movements. The EMG and video analysis devices only record information from your muscles and joints, they do not stimulate the skin so adverse sensation should not be felt from these devices. Reddening of the skin in the areas where the electrodes are placed is possible due to the adhesion. The amount of muscle testing and exercise you will be asked to perform will be minimal. No costs to you are anticipated.

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 and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only to the investigators. In order to synchronize EMG activity, all subjects will be videotaped and confidentiality will be maintained. The investigators or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to
his/her health. The data and records collected in this study will be kept under file in the UND Physical Therapy Department for three years following the completion of the study and will be disposed of according to the department's policy after that time. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigators involved are available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future, including any interest in being informed of the study's findings. Questions may be asked by calling Susan Jeno at (701) 777-2831, Erika Engelstad (701) 772-2458, or Rebecca Johnson (701) 777-9520. A copy of this consent form is available to all participants in the study.

In the event that this research activity (which will be conducted at the UND Physical Therapy Department) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payment, if any.

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 Erika Engelstad and Rebecca Johnson.

Participant’s Signature Date

Witness (not the scientist) Date
APPENDIX C
Consent for Taking and Publication of Photographs

Name: Christel Parvey

Location: University of North Dakota School of Medicine and Health Science

Date: May 26, 1999

In connection with Erika Engelstad and Rebecca Johnson’s independent study project entitled, An Electromyographic Study of Lower Trapezius Muscle Activity During Exercise in Traditional and Modified Positions, I consent that photographs may be taken of me and may be published under the following conditions:

1) The photographs shall be used if the researchers, Erika Engelstad and Rebecca Johnson deems that medical research, education, or science will be benefited by their use. Such photographs may be published and republished, either separately or in connection with each other, in professional journals or medical books; provided that it is specifically understood that in any such publication or use I shall not be identified by name.

2) The aforementioned photographs may be modified or retouched in any way that the researchers, Erika Engelstad and Rebecca Johnson may consider desirable.

Signed Christel Parvey

Witness
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: April 1, 1999      PROJECT NUMBER: IRB-9904-200
Sue Jeno, Erika Engelsstad,
NAME: Rebecca Johnson      DEPARTMENT/COLLEGE: Physical Therapy

PROJECT TITLE: An Electromyographic and Motion Analysis Study of Lower Trapezius Muscle
Activity During Manual Muscle Testing and Resistive Exercise

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on April 5, 1999 and the following action was taken:

☐ Project approved. EXPEDITED REVIEW No. 4, 6
☐ Next scheduled review is on April 2000
☐ Project approved. EXEMPT CATEGORY No. __________ No periodic review scheduled unless so stated in the Remarks Section.
☐ Project approved PENDING receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. This study may NOT be started until final IRB approval has been received. (See Remarks Section for further information.)
☐ Project approval deferred. This study may not be started until final IRB approval has been received. (See Remarks Section for further information.)
☐ Project denied. (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature.

cc: S. Jeno, Adviser
    Dean, Medical School

Signature of Designated IRB Member
UND's Institutional Review Board

Date

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.
You will be performing a series of four exercises in two different positions. In each position an exercise will be performed once with a two-pound handweight and once without a two-pound handweight. All exercises will be performed while lying on your stomach with two minutes of rest between each exercise. You will be instructed in the exercises in the order that you select them.

**Traditional Position without the Weight**

Your arm will be in 145° of abduction parallel to the plane of the table. Your elbow will be extended and your arm will be externally rotated so that your thumb is pointed toward the ceiling. You will then perform ten repetitions of forward elevation without a two-pound handweight beginning slightly below the plane of the table and continuing until the handswitch is activated, which will be positioned at your maximum level of forward elevation. One repetition will be completed when you return your arm to the starting position. The speed of your repetitions will be determined by a metronome.

**Traditional Position with the Weight**

This will be performed the same as in the traditional position without the weight with the exception that you will be holding a two-pound handweight.

**Modified Position without the Weight**

Your arm will be in 80° of abduction and held in a suspended sling in order for the arm to rest parallel to the plane of the table. Your elbow will be flexed to 90° with your palm facing the floor. You will perform ten repetitions of external rotation without a two-pound handweight while allowing your arm to roll in the sling. Your starting point will be with your arm slightly below the plane of the table and you will continue until the
handswitch is activated at your predetermined maximal external rotation. One repetition will be completed after you return to the starting position. The speed of your repetitions will be determined by a metronome.

Modified Position with the Weight

This will be performed the same as in the modified position without the weight with the exception that you will be using a two-pound handweight.
REFERENCES CITED
REFERENCES CITED


10. Snyder AC. *Exercise, Nutrition, and Health.* Carmel, IN: Cooper Publishing Group, LLC;1998:149.


