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Electromyographic Analysis of Muscle Activity of Serratus Anterior Muscle: Pilot Study

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Electromyographic Analysis of Muscle Activity of Serratus Anterior Muscle: Pilot Study

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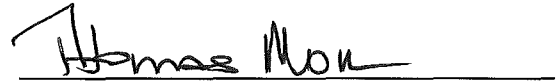
A Scholarly Project Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota

In partial fulfillment of the requirements for the degree of
Doctor of Physical Therapy

Grand Forks, North Dakota

May, 2020

This Scholarly Project, submitted by Shelby Fruechte, Shenae LaCrix, Tyler Trumble 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 Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

Handwritten signature of Thomas Mon in black ink, written over a horizontal line.

(Graduate School Advisor)

Handwritten signature of David Kelly in black ink, written over a horizontal line.

(Chairperson)

PERMISSION

Title: Electromyographic Analysis of Muscle Activity of Serratus Anterior Muscle: Pilot Study

Department: Physical Therapy

Degree: Doctor of Physical Therapy

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Date: 11/7/2019

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ABSTRACT

Introduction. The purpose of this study is to record electrical activity (electromyographic or EMG) from the serratus anterior during three different commonly applied methods to determine which method produces the most EMG activity.

Methods. Eleven male subjects voluntarily participated in the experiment. All of the subjects were healthy, active college students with no prior history of shoulder or scapular injuries. EMG was tested on right serratus anterior parallel to muscle fibers. MVC was taken in 3 different testing positions to compare EMG during a push up with a plus.

Outcomes. There were significant findings following the tests and data analysis. In all subjects, the Test 2 MVC produced the most microvolts from the serratus anterior on the EMG reading. In order to standardize the results, the EMG reading for each test position was compared with the EMG activity from the subject's push up with a plus. A percentage was determined to compare these two values. The results of this comparison demonstrated that Test 2 consistently produced greater activation of the serratus anterior than the push up plus in all subjects.

Discussion. There are no other current studies of this kind looking at the electrical activity of the serratus anterior during three commonly applied methods to test serratus anterior strength. Future studies should include both male and female participants with a larger sample size and determination of dominant arm.

CHAPTER I: INTRODUCTION

The serratus anterior muscle is a prime mover of the scapula. Weakness of the muscle can lead to abnormal shoulder motion, pain and impingement. Physical therapists routinely test the strength of the muscle by manual muscle testing which provides an objective test of the muscle's strength. However, there are different methods of testing the muscle, with no research to indicate which method provides the best test of the muscle's strength. The purpose of this study was to record electrical activity (electromyographic or EMG) from the serratus anterior during three different commonly applied methods to determine which method produces the most EMG activity. All three methods are routinely taught to physical therapy students as part of the physical therapy program at UND. In addition, we will be comparing the muscle activity recorded during the three manual muscle tests with the muscle activity that occurs during a standard push up with a plus. A standard push up with a plus has been found to maximally recruit the serratus anterior muscle. The results of this pilot study will help us determine which manual muscle test best predicts serratus anterior activity during a functional exercise routine.

CHAPTER II: METHODS

Subjects

Eleven male subjects voluntarily participated in the experiment. All of the subjects were healthy, active college students with no prior history of shoulder or scapular injuries. The subjects attended one session of testing at the Department of Physical Therapy on the University of North Dakota Campus. All of the subjects signed a consent form approved by the University of North Dakota Institutional Review Board.

Instrumentation

EMG activity was recorded using a Noraxon TeleMyo DTS telemetry unit with a sampling rate of 1 kHz. The EMG data was recorded from the serratus anterior muscle using the Noraxon Model 546 DTS EMG sensor system which transmitted the EMG data to a Noraxon Model 580 DTS receiver connected to a laptop computer which stored the collected data. The EMG data was analyzed using the Noraxon MR3 MyoMuscle software program. A video camera was synced to the EMG data collection so that we could view the push up activity.

Procedure

The muscle tested was the right serratus anterior muscle on all subjects. Before applying the EMG electrodes, the skin was abraded and cleaned with isopropyl alcohol. The DTS sensors were attached to skin using double stick tape. The electrodes were placed on the skin, parallel to the muscle fiber orientation and followed standard, recommended placement sites.^{1,2} The serratus anterior EMG electrodes were placed

as follows: just anterior to the latissimus dorsi muscle at the level of the inferior angle of the scapula.

Before beginning the push-up activities, a maximal voluntary contraction (MVC) was elicited from the serratus anterior muscle using three different, standard manual muscle test positions. The MVC was performed to establish a normalization baseline for comparison of the individual subject's EMG activity. For the first two muscle tests the subjects were standing, for the third test the subject was supine. For each test, the subject was asked to protract the scapula and hold the contraction for five seconds against maximal resistance. EMG activity was collected over the five second period and was used as the MVC. The EMG activity recorded during the push-up was compared to the MVC and calculated as a percentage of the MVC.

For the push-up activity, each was asked to lay prone on the floor with their hands placed so that their fingers are pointing forward in the sagittal plane. The distance between the left, 1st MCP joint and right 1st MCP joint should equal the distance between the acromion tips. Each subject performed 3 pushups with a plus, holding for 5 seconds with each repetition. A three-minute rest period was given between each pushup.

Figure 1. Scapular MMT Position 1. Subject is standing. Subject flexes shoulder 120° . The subject is asked protract their shoulder and hold that position. The examiner applies resistance on forearm and arm in line with the extended arm. The subject is asked to hold against the resistance for five seconds.

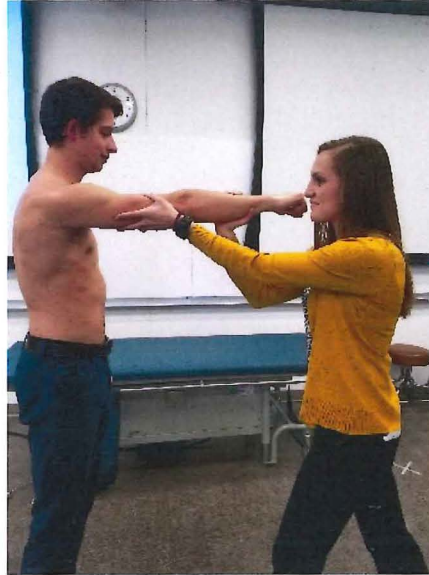


Figure 2. Scapular MMT Position 2. Subject is standing. Subject flexes shoulder 120° . The subject is asked protract their shoulder and hold that position. The examiner applies resistance on the dorsal surface of the arm in a downward direction. The subject is asked to hold against the resistance for five seconds.

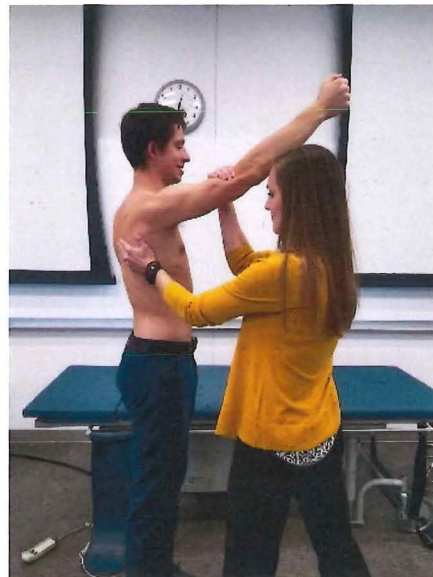


Figure 3. Scapular MMT Position 3. Subject is supine on a plinth. The subject is asked protract their shoulder upward towards the ceiling and hold that position. The examiner applies resistance by grasping the wrist and elbow and pushes in a downward direction. The subject is asked to hold against the resistance for five seconds.

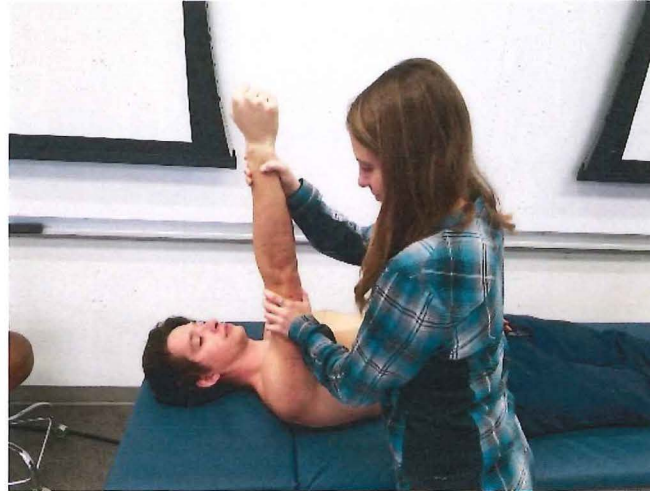


Figure 4. For the push-up activity, each was asked to lay prone on the floor with their hands placed so that their fingers are pointing forward in the sagittal plane. The distance between the left, 1st MCP joint and right 1st MCP joint should equal the distance between the acromion tips. Each subject performed 3 pushups with a plus, holding for 5 seconds with each repetition. A three-minute rest period was given between each pushup.



Data Analysis

The EMG signals were full wave rectified and smoothed using RMS averaging with a 50 millisecond window. The EMG data from the serratus MVCs was compared to the EMG data collected during the push-up trial. To calculate the MVC for the serratus anterior, a three second period of the five second contraction was marked in the software. The software then calculated the highest one second period of contiguous EMG activity found during that three second time period. That EMG activity was saved as the MVC value for each of the three muscle test positions.

For the normalization, a three second time period during the plus phase of the push-up with a plus was marked and analyzed. The MyoMuscle software was set to identify the highest one second period of contiguous EMG activity found during the three second time period and compare that level of EMG with the level of EMG that occurred during the MVC tests. The EMG activity occurring during each push-up trial was compared to the activity occurring during the serratus anterior MVC tests:

$$\text{Percent of MVC} = \frac{\text{EMG Activity During Pushup}}{\text{EMG Activity During MVC}}$$

The resulting percent of EMG was used for all the subsequent data comparisons.

CHAPTER III: OUTCOMES

There were significant findings following the tests and data analysis. In all subjects, Test 2 MVC produced the most microvolts from the serratus anterior on the EMG reading. In order to standardize the results, the EMG reading for each test position was compared with the EMG activity from the subject's push up with a plus. A percentage was determined to compare these two values. The results of this comparison demonstrated that Test 2 consistently produced greater activation of the serratus anterior than the push up plus in all subjects. The below equation and tables demonstrate the results.

$$\text{Percent of MVC} = \frac{\text{EMG Activity During Pushup}}{\text{EMG Activity During MVC}}$$

Table 1. Push Up EMG as a Percent of MVC for Each Test Condition

Subject	Test 1 %	Test 2 %	Test 3%
1	95.3	85.3	147
2	74.7	38.1	99.7
3	80.4	26.9	109
4	70.6	48.4	59.8
5	68.8	43.6	76.9
6	45.3	26.2	41.1
7	86.6	41.3	108
8	75.5	61.9	99.7
9	156	47.7	107
10	48.5	28.4	155
11	42.8	27.1	92.1
Average	76.77	43.17	99.57

Figure 5. Push Up EMG as a Percent of Test Condition.

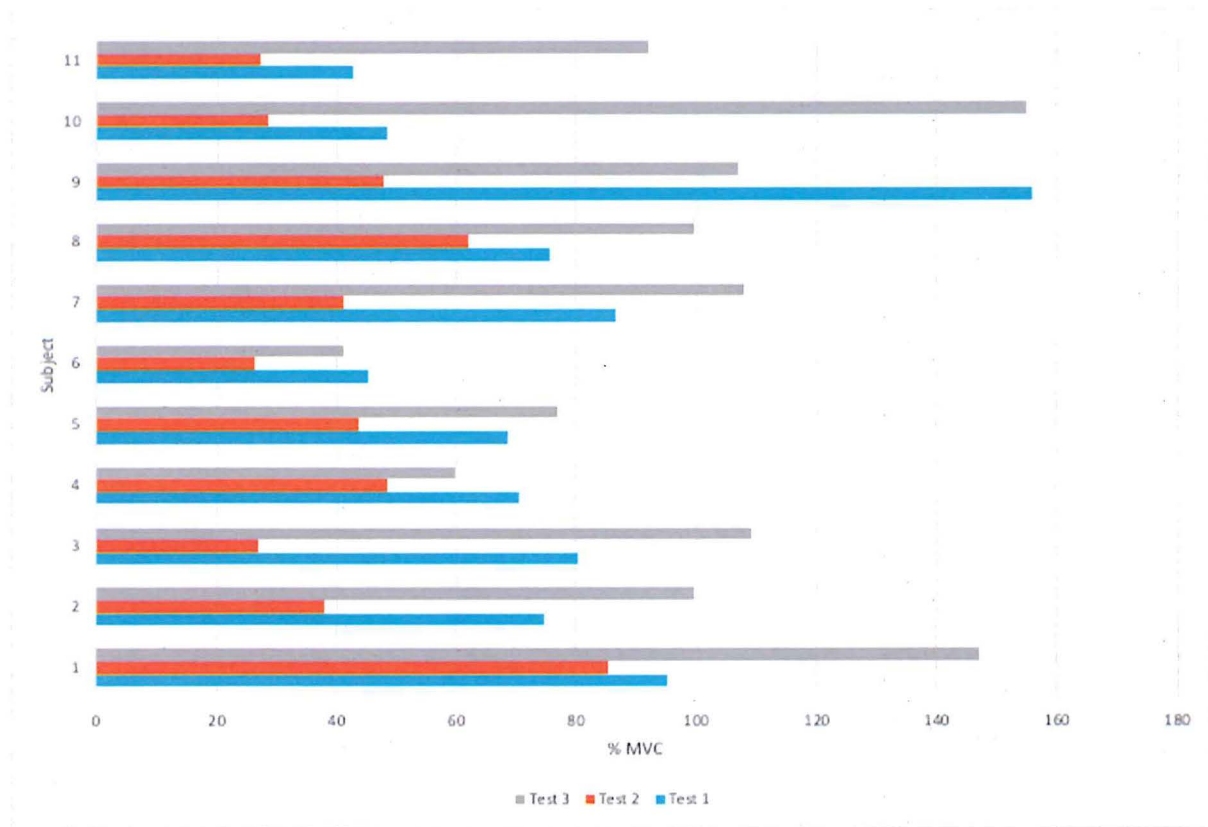


Table 2. Mean EMG Activity (μ Volts) for Each Test Condition.

Subject	Test 1	Test 2	Test 3
1	89.4	92	93.4
2	91.6	95.7	91.3
3	85.5	79.8	92.2
4	85.8	89.6	96.3
5	91.3	85.8	92.5
6	78.2	94.9	91.5
7	93	94.6	93.7
8	91.9	95	94.8
9	90.5	88.1	91.1
10	88.6	87.7	87
11	93	92.5	91.9
Average	88.98	90.52	92.34

Table 3. Maximal EMG Activity (μ Volts) for Each Test Condition.

Subject	Test 1	Test 2	Test 3
1	119	133	77
2	476	933	357
3	207	618	153
4	888	1297	1049
5	806	1272	721
6	368	636	405
7	174	365	139
8	394	484	300
9	71	233	104
10	547	932	171
11	447	706	207

CHAPTER IV: DISCUSSION

To our knowledge, there are no other research studies that have been completed comparing these three different manual muscle tests for serratus anterior activation. This study will help therapists choose the correct manual muscle test to perform on their patients to get the most accurate prediction of serratus anterior strength.

It is commonly thought that the serratus anterior is maximally activated in a fully protracted position. However, research has shown that movements that create upward rotation of the scapula such as shoulder elevation were found to produce more EMG activity than straight scapular protraction.³ Specifically, shoulder elevation from 120° to 150° produced maximum EMG activity in the serratus anterior.⁴ This may be why Test 2 consistently demonstrated the highest overall EMG activity as the test position required shoulder elevation at 120°. Furthermore, this may be why Test 2 demonstrated greater EMG activity than the push up plus indicating it might be the best test position to determine maximum serratus anterior muscle strength.

Many studies have been completed looking at the push-up with a plus to predict serratus anterior strength. These studies tend to compare different hand position widths and difference in surface stability then look at EMG activation of the serratus anterior and other shoulder stabilizers. Researchers found that the push-up with a plus should be completed with the hands at shoulder width apart to get the most serratus anterior activation. In addition, the serratus anterior has increased activation during a push-up plus if the shoulder is in slight external rotation and the palms of the hands are on an unstable surface.

It is important to note that excess upper trapezius muscle activity may compensate for a weak serratus anterior. This can lead to shoulder impingement and reduced dynamic stability of the scapula. While strengthening the scapular stabilizers it is more effective to perform activities on an unstable platform.

Limitations

The sample size was limited to 11 participants who were all males due to ease of electrode placement. The subjects of this project were all healthy, college aged individuals, which does not provide adequate representation of the general population. It would be interesting to investigate individuals of all age groups, abilities and those who may have experienced previous shoulder injuries. Additionally, the dominant arm of the subjects was not determined. This may be important if the subject has better control and motor recruitment of the scapular musculature including the serratus anterior. Measuring EMG activity of both the left and right serratus anterior would have also provided results for comparing recruitment of dominant versus non dominant arm. Future studies should include a larger sample size with both male and female participants and determination of dominant arm.

Regarding this study's procedure, we used three of the most common methods for measuring serratus anterior strength. There may be other methods for assessing serratus anterior strength that were not included in the study.

CHAPTER V: CONCLUSION

The purpose of this study was to record EMG activity from the serratus anterior during three different commonly applied methods to determine which method produces the most EMG activity. All three methods are routinely taught to physical therapy students as part of the physical therapy program at UND. This study compared the MVC of each manual muscle test to the EMG during a push up with a plus. Overall, manual muscle testing position number two produced the highest overall gross MVC of the test positions, and when standardized, demonstrated the greatest difference in EMG activity between the test position and the push up with a plus. The results of this pilot study will help us determine which manual muscle test best predicts serratus anterior activity during a clinical evaluation.

Test 2 MVC produced the most microvolts from the serratus anterior on the EMG reading. In order to standardize the results, the EMG reading for each test position was compared with the EMG activity from the subject's push up with a plus. A percentage was determined to compare these two values. The results of this comparison demonstrated that Test 2 consistently produced greater activation of the serratus anterior than the push up plus in all subject. This is significant that test 2 had the most EMG activity in all subjects.

For future research a variety of populations, male and female, and larger sample size would be beneficial to see if test 2 is the best predictor for serratus anterior manual muscle testing for all populations. Measuring EMG activity of both the left and right serratus anterior would have also provided results for comparing recruitment of

dominant versus non dominant arm. Future studies should include a larger sample size with both male and female participants and determination of dominant arm.

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By: Shelby Fruechte, Shenae LaCroix, Tyler Trumble

Abstract

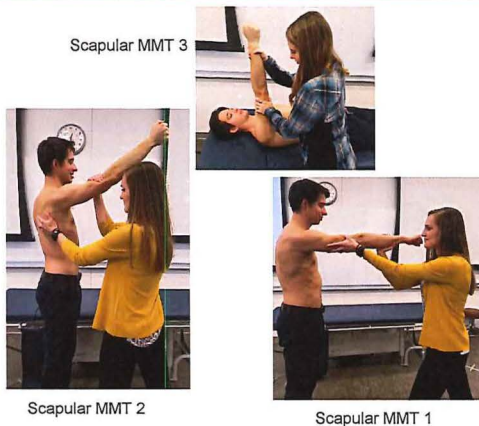
Introduction. The purpose of this study was to compare the electromyographic (EMG) from the Serratus Anterior muscle during three different manual muscle tests (MMT) to determine which test produced the most EMG activity. **Methods.** Eleven male subjects voluntarily participated in the experiment. EMG was collected from the right serratus anterior muscle during a maximal voluntary contraction (MVC) and a pushup. **Outcomes.** In all subjects, the MMT 2 produced the most EMG activity from the Serratus Anterior. The pushup exercise produced the least percentage of the MMT 2 MVC. **Discussion.** MMT 2 produced the greatest amount of EMG activity and should be used to test for maximal muscle activity in the Serratus Anterior muscle. Future studies should include both male and female participants with a larger sample size and determination of dominant arm.

Methods

Subjects: 11 male subjects >18 years of age with no previous shoulder injuries. **Procedure:** EMG was collected from the right Serratus Anterior muscle. MVC was collected in 3 different MMT positions to compare EMG activity during the three tests and during a push up with a plus. For each testing position, the subject was asked to protract the scapula and hold for 5 seconds against maximum resistance. Each subject performed 3 pushups with a plus with a 5 second hold.

Outcomes

In all subjects, the MMT produced the most EMG (microvolts) from the Serratus Anterior. In order to standardize the results, the EMG activity for each test position was compared with the EMG activity from the subject's push up with a plus. The EMG activity during the pushup was expressed as a percentage of each test's MVC. In all subjects the EMG activity during the pushup produced the least percentage of the MMT 2 MVC. This indicates that MMT 2 had the highest percentage of MVC relative to MMT 1 and MMT 3.



Discussion/Limitations

To our knowledge, there are no research studies that have compared the three different manual muscle tests for testing the strength of the Serratus Anterior muscle. It is commonly thought that the Serratus Anterior is maximally activated in a fully protracted position. However, this study demonstrated that manual muscle testing with shoulder elevation to 120° elicited more EMG activity than straight scapular protraction. Limitations of this study include the small sample size and only male participants. The subjects of this project were all healthy, college aged individuals, which does not provide adequate representation of the general population. Future studies should aim to look at a larger sample size with both male and female participants. The results of this study will help therapists choose the best manual muscle test to perform on their patients to get the most accurate prediction of serratus anterior strength.

Data

Table 1. Push up EMG as a Percent of Test Condition.

Subject	Test 1 %	Test 2 %	Test 3 %
1	95.3	85.3	147
2	74.7	38.1	99.7
3	80.4	26.9	109
4	70.6	48.4	59.8
5	68.8	43.6	76.9
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Figure 1. Push up EMG as a Percent of Test Condition.

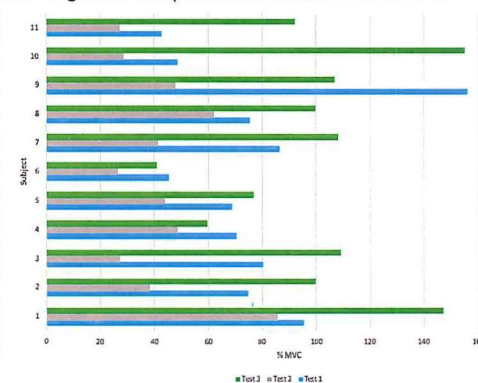


Table 2. μvolts for each Test Position.

Test 1	Test 2	Test 3
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476	933	357
207	618	153
888	1297	1049
806	1272	721
368	636	405
174	365	139
394	484	300
71	233	104
547	932	171
447	706	207

Conclusions

The purpose of this study was to compare EMG from the Serratus Anterior muscle during three different manual muscle tests. All three methods are routinely taught to physical therapy students as part of the physical therapy program at UND. Overall, manual MMT 2 produced the highest level of EMG activity and the greatest MVC of the three test positions. The pushup exercise consistently produced the least percentage of MVC for MMT 2, indicating that MMT 2 had the greatest MVC of all the tests. The results of this pilot study will help physical therapists determine which manual muscle test best predicts Serratus Anterior strength during a clinical examination.