THE EFFECT OF A SUPRASCAPULAR NERVE BLOCK ON

MEAN EMG OF THE DELTOID MUSCLE

by

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A THESIS

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Dr. Andrew Karduna

Surface electromyography is used in various clinical and research settings to examine the electrical activity of muscles. The objective of our study was to understand how humeral angle and a suprascapular nerve block affected mean EMG of each head of the deltoid muscle. We recruited 7 subjects from the University of Oregon. Our results suggest that a suprascapular nerve block significantly decreased the mean EMG of the anterior head of the deltoid, but had no significant effect on the middle or posterior heads. Our results also suggest that the anterior head of the deltoid significantly decreased as angle increased and with time, but no significant difference was observed in the middle head of the deltoid. However, we did observe a significant decrease in EMG of the posterior head of the deltoid with time, but not with humeral angle change. This study may be a useful guide and resource for future studies involving nerve blocks and EMG.

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Background

Shoulder Anatomy

The shoulder complex consists of the pectoral, scapular and deltoid regions. These areas work together to provide structure and movement of the upper extremity. The bones of the shoulder region are the humerus, clavicle, scapula and sternum. They provide articulation between joints and attachments for the many muscles that allow movement of the shoulder (Moore, et al., 2013). While various muscles contribute to the movements at the shoulder joint, the muscles relevant to the research in the present study are the deltoid and supraspinatus muscles. The deltoid muscle originates at the anterior and upper surface of the lateral portion of the clavicle, and forms the rounded portion of the shoulder. It is innervated by the axillary nerve which originates from cervical nerves C5 and C6. The deltoid muscle consists of the anterior head, the posterior head and the lateral (middle) head, which all insert at the deltoid tuberosity of the humerus, creating a triangular shaped muscle. Each each set of fibers originate from different locations and contribute to various movements of the shoulder and arm. The anterior head covers the anterior and lateral portion of the clavicle and has the most effect during flexion of the shoulder. The middle deltoid originates from the acromion process and covers the lateral portion of the shoulder. Contraction of this head assists the arm in abduction, or moving upwards to the side. The posterior head originates from the posterior border of the scapular spine and covers the posterior portion of the shoulder. It has the most activation in pushing posteriorly (Moore et al., 2013).

The supraspinatus muscle also assists in abduction and external rotation of the humerus. It originates from the supraspinatus fossa and runs towards the greater

tubercle of the humerus. It is innervated by the suprascapular nerve, which runs through the suprascapular notch to innervate both the supraspinatus muscle and the infraspinatus muscle. The spinous process of the scapula separates the supraspinatus from the infraspinatus muscle. Though both the deltoid and supraspinatus muscles contribute to the elevation of the arm, the direction of force is different for each muscle. Previous research has demonstrated that the supraspinatus muscle and the deltoid muscle work simultaneously to abduct the humerus (Reed, Cathers, Halaki, & Ginn, 2013). The force from the deltoid muscle acts more superiorly on the joint while the supraspinatus muscle force acts in a more medial direction (McCully, Suprak, Kosek, & Karduna, 2007).

Electromyography

Electromyography (EMG) is used in various clinical and research settings to measure and record the electrical activity in muscles. Excitation of muscle fibers occur through a change in potential of the semi permeable membrane of the cell. Excitation occurs through motor units, which are made up of a motor neuron and the muscle fiber that it innervates and are the smallest functional units involved with muscle contractions. When an impulse is carried from the brain via spinal cord and motor nerves, electrical signals are sent to the muscle, which causes a depolarization in the membrane potential and lead to a contraction (Konrad, 2005a).

Surface EMG electrodes detect these electrical signals and measure the magnitude of impulses being sent to a specific muscle group. In voluntary contractions, force is determined by the number of motor units recruited and the frequency of their firing. The more motor units recruited and the higher their firing frequency is, the

greater the force of contraction will be (Moritani, Stegeman, Merletti, Merletti, & Parker, n.d.).

A raw EMG recording is made up of segments with varying amplitudes that represent the level of activation (rest or contraction). When the muscle is relaxed, the EMG signal will be a relatively flat line at baseline, representing little electrical activity within the muscle. When a muscle is activated, spikes in amplitude are seen on an EMG reading, representing the electrical activity that is taking place within the muscle. Tissue thickness, temperature, moisture, and external noise can all affect the reading from an EMG. Therefore it is very important that the surface electrode is not moved during testing or between tests and that skin is cleaned thoroughly to minimize possible errors in data (Konrad, 2005).
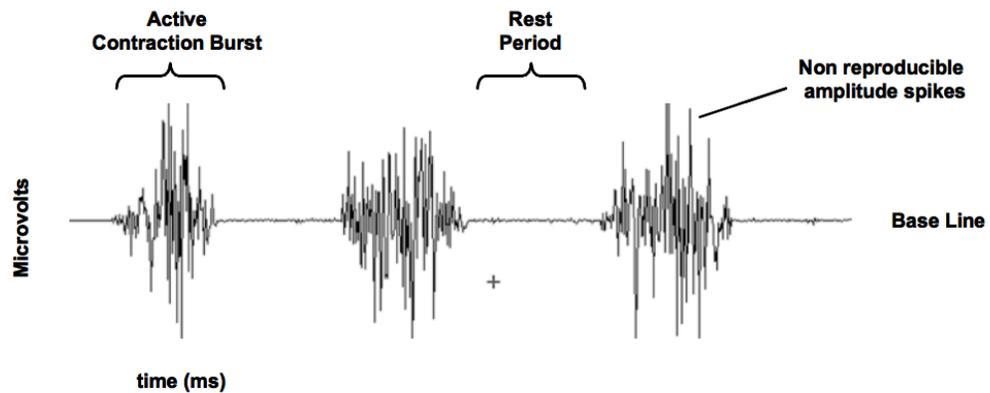
Figure 1: Example of a raw EMG recording

This example shows 3 muscle contractions with 3 rest periods between. The muscle at rest can be observed when the EMG recording is at baseline. Contraction is seen when the amplitude of microvolts increases for a short period of time (Konrad, 2005).

To compare shoulder EMG data between studies, normalization is required. The most common way to normalize EMG data is by using maximum voluntary isometric contractions (MVIC) to obtain a reference muscle activation level. Using a reference

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value allows for the conditions between the experiment and reference muscle to be constant, therefore decreasing the impact of extrinsic effects on EMG readings (Halaki & Gi, 2012). Normalizing with an MVIC is beneficial because it allows researchers to standardize between subjects within a study.

Nerve Blocks

Nerve blocks are a common therapeutic method to treat shoulder pain, specifically in patients with rotator cuff tears and rheumatoid arthritis (Shanahan et al., 2003). Nerve blocks act by reducing the membrane permeability to sodium ions, which in turn prohibits the nerve from conducting an action potential (Strichartz, 1976). As blood flow removes epinephrine and lidocaine from the area, more sodium channels become active and allows for the propagation of an action potential that results in a nerve impulse. Suprascapular nerve blocks function by reducing the excitability of the supraspinatus and infraspinatus muscles. They have been shown to result in a compensatory increase in muscle activation of the deltoid muscle, increase in humeral head translation, and increased rotation of the scapula (San Juan, Kosek, & Karduna, 2013).

Inhibition and Excitability

Inhibition of rotator cuff muscles has been observed in patients with rotator cuff injuries as well as in patients with shoulder impingement syndrome. In a study of patients with shoulder impingement syndrome, prior to receiving an injection of lidocaine and bupivacaine, patients showed much lower work, power and peak torque than after receiving the injection (Ben-Yishay, Zuckerman, Gallagher, & Cuomo,

1994). Pain may have an inhibitory effect as patients may not use specific muscles in an effort to protect the area from further damage. The three heads of the deltoid muscle have been shown to have a decrease in MVIC when accompanied with pain (Ettinger, Weiss, Shapiro, & Karduna, 2016).

Excitability of muscles may also play an important role in the present study as a study on patients with rotator cuff injuries showed the deltoid muscle exhibited hyper excitability at rest compared to control subject. Researchers hypothesized that this may be due to changes in sensory output from the shoulder in patients with injuries. A decrease in firing rate of motor units in areas of the injury may lead to a compensatory increase in other areas (Berth, Pap, Neuman, & Awiszus, 2009).

Introduction

The shoulder joint is a ball and socket joint, which allows for movements of the humerus, scapula, sternum and clavicle. The shoulder joint is capable of a wide range of movements, but to do so, forfeits some joint stability in the process (Moore, Dalley, & Agur, 2013). The shoulder joint is an extremely active joint that is used in many daily tasks, athletic sports and various fields of work. Therefore, shoulder discomfort and pathologies are extremely common, listed as the second most reported location of chronic pain, just behind low back pain (Luime et al., 2004). While rotator cuff injuries and shoulder discomfort are difficult to quantify, as many tears are asymptomatic, many patients over the age of 40 (Matsen et al. 2004), as well as in athletes that partake in overhead throwing sports experience shoulder injuries that cause pain and limit mobility.

Surface EMG is a method for measuring electrical activity in the shoulder. EMG is used in various clinical and research settings to examine the activity of muscles during certain movements. EMG normalization techniques allow shoulder studies to be compared with one another (Boettcher 2008). Specific normalized shoulder positions have been used in various studies with both healthy patients and patients with shoulder impingement syndrome. Results from these studies have shown discrepancies between muscle activation in patients with shoulder pain. Pain has been associated with decreased activation of muscles, and has been seen to have an inhibitory effect on affected muscles (Ettinger et al., 2016).

Lidocaine nerve blocks function by inhibiting sodium channels, thereby inhibiting action potentials from propagating along the axon (Strichartz, 1976). The

addition of epinephrine into a lidocaine nerve block has been shown to increase

duration and intensity of the block, due to epinephrine's ability to act as an acute

vasoconstrictor (Sinnott, Cogswell III, Johnson, & Strichartz, 2003). Blocking the

suprascapular nerve has been shown to result in dysfunctional mechanics of the

supraspinatus and infraspinatus muscles that has similar effects to many rotator cuff

injuries (Juan 2013). Previous research has determined that injuries of rotator cuff

muscles, such as the supraspinatus, may lead to compensation by the deltoid muscle.

This increase in deltoid activity may be due to a compensatory effect of the deltoid

muscle recruiting additional motor units to meet the original force output (McCully,

2007). Suprascapular nerve blocks are common in clinical practice for treatment of

rotator cuff injuries, adhesive capsulitis (Shanahan et al., 2003) and rheumatoid arthritis

(Fernandes, 2012). They have also been used in research settings to determine strength

of subjects as well as shoulder kinematics (Howell & Kraft, 1991).

The goal of the present study was to determine the effect of humeral elevation

and a nerve block on mean EMG activity in the deltoid muscle. It is important to

understand how nerve blocks affect the excitability of surrounding muscles because it

could determine how these studies using EMG are analyzed and understood and the

relationship between these variables has not been examined previously. We

hypothesized that during a maximal voluntary contraction in normalized positions,

EMG activity within each head of the deltoid muscle would increase after the

suprascapular nerve block was administered. We further hypothesized that as humeral

angle increased, deltoid EMG would also increase.

Methods

Subjects

Seven healthy subjects (3 female, 4 male; all right hand dominant) were tested either at the Pain Consultant's of Oregon clinic or in the Orthopedic Biomechanics Lab at the University of Oregon. Subject's self-reported their hand dominance by indicating which hand they use for daily activities. Exclusion criteria included any preexisting shoulder pain, previous injury of the shoulder and pregnancy. Prior to the experiment taking place, the procedure, purpose and potential risks were explained and written consent was obtained. Procedure and protocol were approved by the Institutional Review Board at the University of Oregon. All measurements were taken in a single, 3-hour session.

Experimental Setup

Force data were sampled at 2000 Hz with custom LabVIEW software (LabVIEW v12.0, National Instruments, Austin, Tx). The load cell was recalibrated at each angle to read 0 N. The forearm rested against the surface of the uni-axial load (Lebow Products, Troy, MI. Model 3397-50) and secured with non-elastic lifting Velcro^{TM} straps.

Surface EMG electrodes were placed on the anterior deltoid, middle deltoid and posterior deltoid of the dominant arm. Prior to electrodes being placed, the subjects arm was cleaned with rubbing alcohol wipes. The anterior deltoid electrode was placed 4 cm below the clavicle on the anterior portion of the arm. The middle electrode was placed 2 cm below the acromion process and the posterior electrode was placed 2cm below the

lateral border of the scapular spine. A ground electrode was placed on the right lateral malleolus to minimize feedback during data collection. Deltoid EMG was collected using the Myopac Jr Unit (Run Technologies, Mission Viejo, CA) and sampled at 2000 Hz.

Maximal Voluntary Contractions

Prior to testing, subjects performed two, 5-second maximal voluntary contractions (MVC) in 3 different positions. First, to measure the MVC for the anterior head of the deltoid, the subject flexed their shoulder 90° in the sagittal plane and provided an upward force while a researcher resisted the motion. The MVC for the middle deltoid was obtained by the subject abducting their shoulder 90° in the coronal plane while providing an upward force while a researcher resisted the motion. The posterior deltoid was tested by the subject placing their forearm parallel to the floor with a 90° bend in their elbow and then applying a backward force while the researcher resisted the motion.

Following the MVC tests, subjects then completed MVCs for 30°, 60° and 90° in the scapular plane by pushing against a load cell. The subject placed their arm in a "thumbs up" position with their radius placed against the load cell and elbow fully extended. The order of testing for each angle was randomized for each subject and the height of the load cell was adjusted and zeroed before each new angle. Two, 5-second MVCs were taken in these positions and a one-minute rest period was given between each contraction.

Figure 2: Testing position for maximal voluntary contractions

Angles were randomized and adjusted between each new trial. The arm is in a "thumbs up" position with the radius pressed against the load cell.

Suprascapular Nerve Block

A suprascapular nerve block was performed by a board-certified anesthesiologist. The subject was seated for the procedure with the head flexed slightly to the contralateral side. Ultrasound imaging was used to visualize the scapular notch where the suprascapular nerve travels. The ultrasound gel served as a conductive medium and surface preparation. A 3.5 inch 23 ga quince needle was advanced toward the scapular notch in a medial to lateral direction using an in-plane technique. The

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advancing needle was observed on the ultrasound until it reached the scapula notch. At this point the lidocaine and epinephrine (1.5%, 1:200,000, 5 ml) was injected. The needle was removed and the subject was allowed to remain seated for 5 minutes.

Maximal voluntary contraction measurements were taken 5 minutes, 10 minutes and then every 2 minutes' post nerve block until the subject demonstrated a drop of 50% in external rotation force, which ensured that the block was successful. The initial procedure to obtain MVC values was then repeated with the subject's suprascapular nerve blocked. An MVC for external rotation was taken again at the end of testing to ensure that the suprascapular nerve was still effectively blocked. Subject's were able to leave testing once they recovered over 50% of their external rotation force.

Statistical Analysis

Independent variables were time (pre block and post block) and angle of the humerus (30°, 60°, 90°). The dependent variables in this study were mean EMG of the three heads of the deltoid muscle (anterior, middle, posterior) and normalization positions. SPSS version 22.0 (IBM Chicago, IL) was used for all statistical tests. Raw EMG data were smoothed by calculating the Root Mean Square (RMS) of the data. A paired t-test was run for each head of the deltoid in the normalized position, before and after the block was administered. A two-way repeated measures analysis of variance (ANOVA) was run with condition (pre block, post block) and humeral angle (30°, 60°, 90°) for each head of the deltoid (anterior, middle, posterior). Alpha level was set at 0.05 for all tests.

Results

Normalization Positions

A paired t test was run for each head of the deltoid to compare the mean EMG within the muscle before the nerve block was administered to after the nerve block. A significant decrease in EMG activity was observed in the anterior head of the deltoid ($p=0.001$). However, there was no significant effect in middle deltoid ($p>0.05$) or in the posterior deltoid ($p>0.05$). Figure 4 represents the average EMG for each head of the deltoid before and after a nerve block was administered. All three muscle heads showed a decrease in EMG activity post nerve block, but only the anterior head showed a significant decrease.
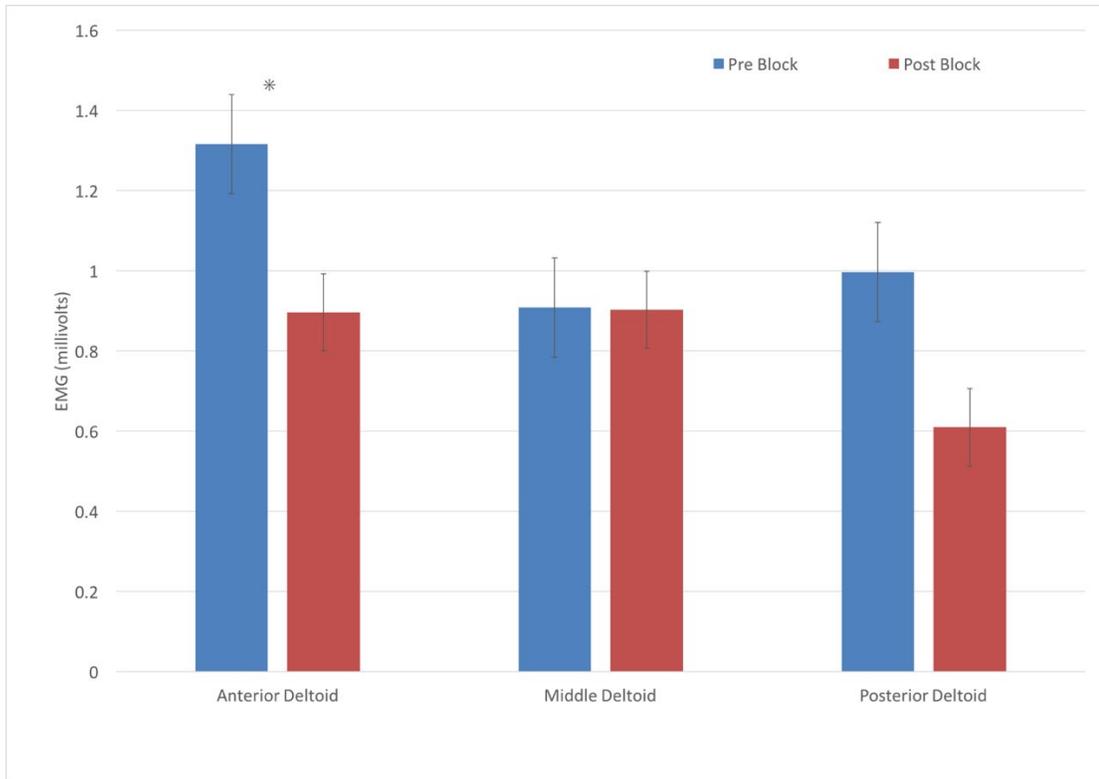
Figure 3: Average EMG in the anterior, middle and posterior deltoids before and after nerve block was administered. Asterisk indicates significance.

Angle and Time

A main effect was seen in the anterior head of the deltoid muscle for both angle (p=0.045) and time (p=0.019). There was no interaction effect seen between time and angle for the anterior deltoid. There was no main effect seen for either time (p>0.05) or angle (p>0.05) in the middle deltoid. A main effect was seen in the posterior head for time (p=0.007) but not for angle (p>0.05). No interaction effect was seen in the posterior deltoid for angle and time. Follow up T-tests were performed with a Bonferroni adjustment for multiple comparisons. A significant difference was seen between 30° and 90° for the posterior deltoid. Figure 5 represents the mean EMG for

each head of the deltoid at 30°, 60° and 90° both before and after the nerve block was administered.
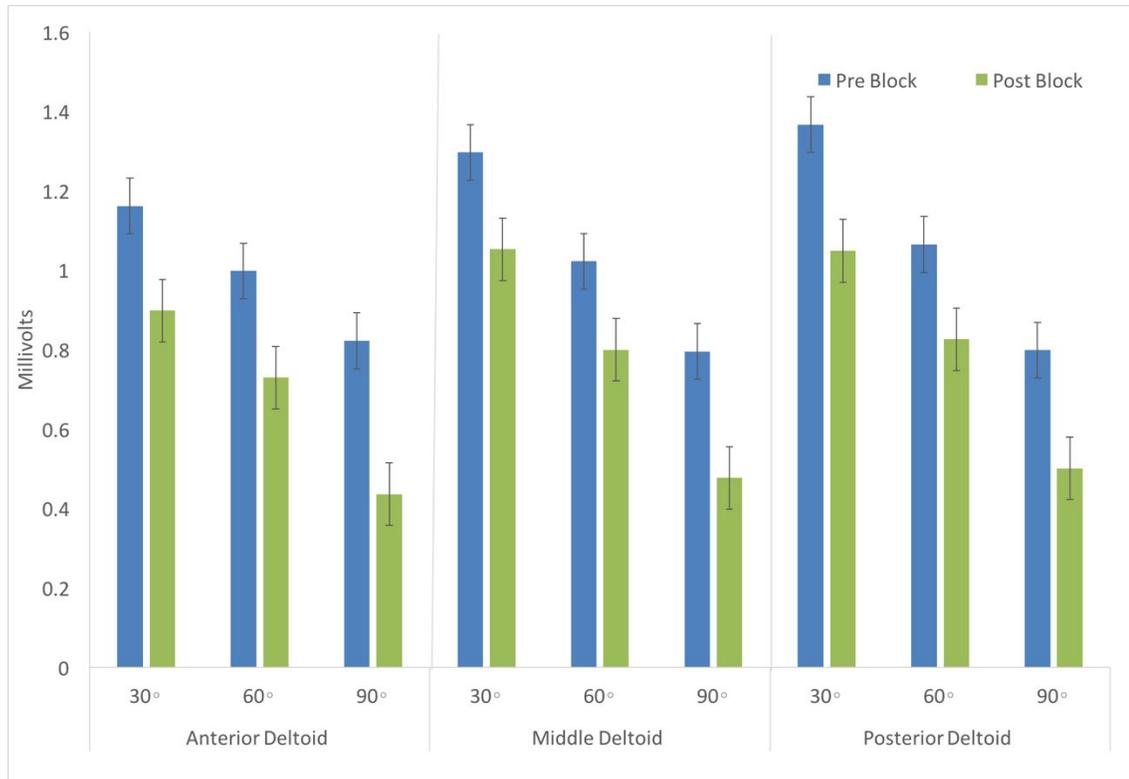
Figure 4: Mean EMG of Anterior, Middle and Posterior Deltoid Pre and Post Block at 30°, 60° and 90 °

Discussion

The purpose of the present study was to examine how a suprascapular nerve block and a change in humeral angle affected the mean EMG of the deltoid muscle at its three heads (anterior, middle and posterior). It was hypothesized that an increase in deltoid excitability would be seen following the injection into the suprascapular nerve. It was also hypothesized that as angle increased from 30° to 90°, deltoid excitability would also increase.

Our results suggest that there was a significant decrease in EMG activity from the anterior head after the nerve block was administered in the normalization position. However, no significant change was observed in either the middle or posterior heads of the deltoid in the normalization positions. A significant decrease in EMG was also observed in the anterior deltoid for both time and angle. No significant difference was observed in the middle deltoid for either time or angle. However, a main effect was seen for time in the posterior deltoid, but not for angle.

Previous studies involving the deltoid and suprascapular nerve blocks have demonstrated that they may disrupt normal kinematics of the scapula such as humeral head elevation, scapular rotation and an increase in deltoid activity (McCully, Suprak, Kosek, & Karduna, 2006). These changes in kinematics can cause subjects to change their strategy for completing the same motion compared to the pre block control. This may cause different forces to be placed on different muscles before and after blocks are administered. Other studies done on patients with shoulder impingement syndrome have demonstrated decreased EMG activity when compared to normal subjects (Ashok S. Reddy MD, Karen J. Mohr PT, SCS, Marilyn M. Pink PhD, PT, 2000).

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For results to be statistically significant, the p-value from a t test must be less than the alpha level of 0.05. For the p-values to represent a significant difference in the data, the difference between the averages of the two groups should be large and have the same direction of change. Small standard deviations and large subject sample sizes also help contribute to a low p-value when calculating a t-value. Calculating power determines the real effect that a test has on a population. Power usually increases as sample size increases. Therefore, having a large sample size, small standard deviation, and large mean difference can greatly affect the statistical outcome of a test. However, our sample size was small due to issues with an effective nerve block. Therefore, the power for our experiment is very low which led to issues when running statistical tests and may contribute to our results. Increasing the power of the study would help to minimize this issue and could lead to more conclusive results.

T tests are used to determine if the data is statically relevant, but they do not explain if the data supports practical significance. Therefore, we must also examine the effect size. Effect size is used to estimate the ratio of the mean difference over the standard deviation. Calculating the effect size produces a number that can be used to determine the size of the effect between groups. An effect size that is smaller than 0.2 represents small differences within the groups, 0.2- 0.5 represents a moderate amount of difference, and an effect size that is 0.8 or larger represents large differences between groups (Vincent & Weir, 2012).

We calculated the effect size for each head of the deltoid with both time and angle. The effect size for the anterior head of the deltoid and angle ($\eta^2 partial = 0.404$) and time ($\eta^2 partial = 0.627$) are both moderately sized effect sizes. The effect

size for the middle deltoid and angle ($\eta^2 partial = 0.082$) is small but is moderately

sized for time ($\eta^2 = 0.367$). Finally, the effect size for the posterior deltoid and angle

is moderate-large size ($\eta^2 = 0.726$) and time ($\eta^2 = 0.006$) is small. This data suggests

that differences may be present in both the middle deltoid for time and the posterior

deltoid for angle if the sample size for our study was increased.

Type I and type II errors are important to take into account with statistical

analyses. Type I errors are also called "false positive" errors, where a test gives a

positive outcome when no significance actually occurred. A type II error, or false

negative finding, occurs when a test outcome suggests that no effect was observed,

when there may actually be a difference that exists. Based on my sample size of 7, and a

the moderate-large effect sizes seen in the middle and posterior deltoid, that a type II

error may have occurred.

Limitations

A limitation for our study was that our sample size for the study was relatively

small which led to an issue of power during statistical analysis. The first few subjects'

that we tested experienced incomplete blocks, where the lidocaine had worn off before

the test was completed, so we were unable to use their data in our research. Therefore,

we only had usable data from seven subjects total. While some significant changes were

observed, further research with a larger subject pool should be done to further examine

the effect that a suprascapular nerve block has on the EMG of the deltoid muscle.

Another limitation to our study could be physical and mental fatigue. The testing

procedure took 3 hours per subject and required each subject to exert their maximal

voluntary contractions many times over. This could lead to subject's experiencing

muscular fatigue as they are completing MVC's as well as mental fatigue as the time of the study increased. Our data suggest that peak EMG activity in the middle deltoid was not statically significant for time or angle, but the effect size for angle, representing that it may be an important effect if we were to increase the power. Similarly, the posterior head of the deltoid had a large effect size for angle, which may suggest that a difference could be seen by increasing the subject pool size.

Future Studies

The results from our study suggest that further research is necessary to understand what the interactions between EMG and a nerve block may be. However, our study may be useful as a guide for future studies that involve suprascapular nerve blocks and measurements of muscle activation within the deltoid muscle. If further studies do suggest that deltoid muscle activity can be affected by a suprascapular nerve, consideration of this variable must be taken into account when analyzing data. Potential future studies could focus on the suprascapular nerve, or look at other areas of the body and how nerve blocks influence muscle activation in synergistic muscles. Larger sample sizes and the use of norepinephrine with lidocaine are recommended for future nerve block studies.

Research on the shoulder joint can have many positive implications for the health field. Shoulder discomfort is not only very prevalent, but can also be debilitating. Shoulder pain is associated with a high patient burden (Meislin, Sperling, & Stitik, 2005), both due to cost of treatment and possible changes in employment and lifestyle. Therefore, research in this field is important and could lead to more knowledge about pathologies and possibly better treatment methods in the future.

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Conclusions

Our findings suggest that the electrical activity of the anterior deltoid significantly decreases in normalization positions, while the middle and posterior deltoid do not show significant differences before and after nerve blocks. Similarly, the anterior deltoid also shows a significant decrease in EMG activity for time and angle. No significant differences were observed in the middle deltoid for time or angle. Finally, the posterior deltoid showed a significant decrease for time, but no change was seen for angle. Our data suggests that suprascapular nerve blocks could have an affect on the electrical activity within the deltoid muscle, specifically at the anterior head of the muscle. Future studies should include larger sample sizes to gain more knowledge and information on the effect that nerve blocks may have on EMG.

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