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EMG Analysis of Latissimus Dorsi, Middle Trapezius, and Erector Spinae Muscle Activity during Return to Neutral Phase of Spinal Rotation

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This Scholarly Project, submitted by Stephen Erlandson, Nathan Hasunuma, and Landon Uetz in partial fulfillments of 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.

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PERMISSION

Title	EMG Analysis of Latissimus Dorsi, Middle Trapezius, and Erector Spinae Muscle Activity During Return to Neutral Phase of Spinal Rotation
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ABSTRACT

Purpose/Hypothesis: Rotation of the spine is a common movement used to perform activities of daily living and sports performance, and contributes to a large percentage of low back injuries. Performance of spinal rotation for the rehabilitation and prevention of future back injuries should be considered, as low back pain is the second most common reason for a physician visit. Muscles that are involved in rotation of the spine have been studied, but the Latissimus Dorsi (LD) has limited research on the influence of spinal rotation. The LD muscle is one of the largest back muscles and influences many movements of the trunk and limbs, and many attachment sites including the humerus, pelvis, ribs, spine, and scapula. The purpose of this study is to understand the muscle activity of the LD, middle trapezius (MT), and erector spinae (ES) during the movement from full hip rotation to neutral in a standing (non-fixed) and quadruped (fixed) position.

Materials/Methods: Twenty-six healthy subjects (17 female) between 20-40 years of age volunteered to be a part of this study. All muscle activity being tested in this study was recorded using surface EMG electrodes while the subject performed left and right spinal rotation in standing and quadruped positions. Four spinal rotation test positions (standing rotation right/left, quadruped rotation right/left) were initiated by movement at the pelvis. A Maximal Voluntary Contraction (MVC) recorded in the prone position was used to normalize the muscle activity of the muscles being tested, and findings were analyzed for significance at α=0.05. EMG data was collected and analyzed using Noraxon MyoResearchXP software.

Results: Statistically significant differences were present in the ipsilateral and contralateral LD with upper extremities in a fixed position compared to non-fixed during the movement from full hip rotation to neutral. The mean EMG activity of the right LD was greater than the bilateral MT and ES in left return to neutral rotation with upper extremities in a fixed position, and the left LD was more active than bilateral MT and ES in right return to neutral rotation in the same fixed position. The EMG activity of the MT in all standing and quadruped return to neutral movements of spinal rotation was significantly less than the LD and ES. Lastly, in the standing position, the ES was significantly more active in both ipsilateral and contralateral return to neutral spinal rotation than bilateral LD and MT.

Discussion/Conclusion: Our findings suggest that the LD significantly contributes to the return to neutral phase of spinal rotation in the quadruped position. The MT did not have a significant influence on the return to neutral phase of spinal rotation in any position, and the ES played a greater role in standing. Results of this study correlate with ongoing studies regarding the LD's activation during the concentric phase of spinal rotation, and isometric lifting activities. Future research could include comparisons between healthy subjects and individuals who are experiencing low back pain.

Clinical Relevance: This study assessed the contribution of the LD in comparison to the MT and ES during spinal rotation. Furthermore, this study particularly analyzed the LD activation and nearby musculature during the return to neutral phase of rotation. Our findings concluded that with fixed upper extremities the contralateral LD should be considered a major contributor during the return to neutral phase of spinal rotation with fixed upper extremities. Many activities throughout the day utilize spinal rotation with fixed upper extremities in the quadruped position, such as getting out of bed or up off the floor, supporting the statement that strength and mobility assessments of the LD should become a part of comprehensive evaluations by clinicians.

CHAPTER I

INTRODUCTION

Low back pain (LBP) affects around 80% of adults at some point throughout their lifetime, and is the leading cause of job-related disability and missed workdays.[1] In 2013, low back and neck pain accounted for the third-largest health care expense of any condition in the United States at $87.6 billion, behind only diabetes and heart disease.[2] Although the economic impact of LBP is substantial, the effect on an individual's quality of life is equally detrimental. In response to a poll, 23% of patients experiencing LBP reported their symptoms as "disabling".[3] With that said, according to a survey performed by the American Physical Therapy Association in 2012, 37% of those with back pain do not seek professional treatment.[4]

Low back injuries often occur following a twisting motion such as lifting an object from the ground, reaching across the body, or swinging a baseball bat or golf club. This common mechanism of injury emphasizes the importance of the muscles that contribute to spinal rotation. As musculoskeletal experts, physical therapists can play an integral role in the prevention of LBP through education and facilitation of recovery through interventions and exercise. Despite extensive research on physical therapy interventions for LBP, there is limited knowledge on the potential for rehabilitation of the latissimus dorsi (LD). According to ongoing research, the contralateral LD plays a significant role in the initial rotation phase of spinal rotation in the quadruped position.[5-7]

Typically, rotation of the spine is defined from the head in reference to lower segments. In both the previous studies and the current study, spinal rotation was analyzed from the

segments attaching to the LD, middle trapezius (MT), and erector spinae (ES) following the initiation of pelvis movement. Therefore, non-fixed and fixed right and left rotation is determined by the pelvis rather than shoulders, and the return to neutral phase begins with maximal posterior displacement of the pelvis and ends with the pelvis returning anteriorly to a neutral position. Understanding the muscle activity during this entire spinal rotation movement may assist medical professionals in treating individuals with LBP. As a result, the field of Physical Therapy would benefit from a better understanding of the role of the LD, MT, and ES during the return to neutral phase of rotation of the spine.

Problem Statement

There is limited published research regarding the effects of the LD on spinal rotation. Trunk rotation consists of two different phases, rotation phase and return to neutral phase. According to ongoing research, the contralateral LD plays a significant role in the initial rotation phase of spinal rotation in the quadruped position.[5-7] This study analyzed the LD, MT, and ES muscle activation during the return to neutral phase to gain a better understanding of full spinal rotation.

The LD takes origin on the spinous processes of T7 to L5 vertebrae, posterior iliac crest, and sacrum through the thoracolumbar fascia (TF). The primary actions of the LD include shoulder adduction, medial rotation, and extension, insertion onto the inferior 3-4 ribs, inferior angle of the scapula, and humerus may allow the LD to contribute to spinal rotation when the UE's are fixed.[8] The MT originates on T1-T5 spinous processes and inserts onto both the clavicle and scapula. The MT primarily contributes to adduction or retraction of the scapula, but when the upper extremities are in a fixed position it may assist in spinal rotation. The ES is known to have the largest effect on ipsilateral spinal rotation due to origin on similar structures as the LD and attachments throughout the posterior trunk.[8] The ES inserts onto spinous and

transverse processes and lateral ribs ascending the spinal column which provides an ideal angle of pull for spinal rotation. Understanding the degree of LD, MT, and ES muscle activation during the return to neutral phase of spinal rotation may provide insight on alternative rehabilitation interventions for all patients.

Purpose of Study

The purpose of this study was to comprehensively analyze the muscle activity of LD, MT, and ES in the return to neutral phase of spinal rotation with and without fixation of the upper extremities. Evidence from this study is valuable in taking a deeper look at the extent of LD activity in spinal rotation, which may lead to improved interventions for patients.

Significance of Study

Many low back injuries occur during a twisting motion, which emphasizes the importance of understanding all spinal rotation contributors. Muscular imbalances found throughout the body cause excessive stress and strain on anatomical structures including the spine. Physical therapy interventions often times focus on the improvement of these imbalances. A better understanding of the role of the LD, MT, and ES during the return to neutral phase of rotation of the spine would have a positive impact on the Physical Therapy profession.

Research Questions

1.) Will ipsilateral LD muscle activation differ significantly during the movement from full hip rotation to neutral position with upper extremities non-fixed compared to fixed?
2.) Will contralateral LD muscle activation differ significantly during the movement from full hip rotation to neutral position with upper extremities non-fixed compared to fixed?
3.) Will ipsilateral LD muscle activation differ significantly from ipsilateral MT and ES during the movement from full hip rotation to neutral position with upper extremities non-fixed?

4.) Will contralateral LD muscle activation differ significantly from contralateral MT and ES during the movement from full hip rotation to neutral position with upper extremities fixed?

Null Hypothesis

1.) There is no significant difference in ipsilateral LD muscle activation during the movement from full hip rotation to neutral position with upper extremities non-fixed compared to fixed.
2.) There is no significant difference in contralateral LD muscle activation during the movement from full hip rotation to neutral position with upper extremities non-fixed compared to fixed.
3.) There is no significant difference in ipsilateral LD muscle activation from ipsilateral MT and ES during the movement from full hip rotation to neutral position with non-fixed upper extremities.
4.) There is no significant difference in contralateral LD muscle activation from contralateral MT and ES during the movement from full hip rotation to neutral position with fixed upper extremities.

Alternative Hypothesis

1.) There is a significant difference in ipsilateral LD muscle activation during the movement from full hip rotation to neutral position with upper extremities non-fixed compared to fixed.
2.) There is a significant difference in contralateral LD muscle activation during the movement from full hip rotation to neutral position with upper extremities non-fixed compared to fixed.

3.) There is a significant difference in ipsilateral LD muscle activation from ipsilateral MT and ES during the movement from full hip rotation to neutral position with non-fixed upper extremities.

4.) There is a significant difference in contralateral LD muscle activation from contralateral MT and ES during the movement from full hip rotation to neutral position with fixed upper extremities.

CHAPTER II

LITERATURE REVIEW

Rotation of the spine is one of the most frequent movements performed throughout the day, and it contributes to nearly 60% of low back injuries.[9] Rehabilitation and prevention of low back injuries require the close examination of spine anatomy and biomechanics. The spine is a mechanical structure made up of vertebrae, facets, joints, discs, ligaments, and muscles. All of these structures have a particular role in spinal kinesiology, ranging from maintaining structural stability to providing forces for movement. For example, the vertebral column is supported through its bony and ligamentous attachments, whereas muscles are able to both directly and indirectly affect the spine during movement.[10] With the multiple and broad attachment points in the lumbopelvic region and on the proximal humerus, it is apparent the LD has the largest anatomic moment arm acting on the spine.[11] Researchers found that 64% of the muscle force of LD comes from the large portion of muscle fibers located over the lumbopelvic region; in comparison to 36% of the muscle force coming from muscle fibers in the thoracic region.[12] Due to its long lever arm and numerous points of attachment, the LD muscle is capable of lumbopelvic movement with increased efficiency.

The multiple attachment sites throughout the spine for muscles and ligaments makes it difficult for health professionals to distinguish sources of spinal pathology. Physical therapists have developed strategies in order to effectively treat individuals in response to these low back conditions. Current interventions include Mechanical Diagnosis and Therapy, mobilization and manipulation, pain neuroscience education, therapeutic exercise and activity, and stabilization

programs. Directional preference exercises have shown to be superior to other conservative interventions in decreasing pain and disability in patients with chronic LBP, but there is no significant difference in patients with acute injuries.[13] In a recent systematic review it was determined that spinal manipulations had little to no effect on patients with acute LBP, but mild benefit in patients with chronic LBP.[14] Pain neuroscience education in addition to physical therapy has shown to have a moderate effect improving disability in individuals with chronic LBP in the short term, although there is currently no data showing long term improvement of pain or disability.[15] Lastly, studies have also shown that exercise and stabilization targeting the transversus abdominis, multifidus, ES, oblique abdominals, and diaphragm may reduce pain intensity and improve function.[16] There is a lack of research on the potential for rehabilitation of the LD in response to LBP

The LD is often overlooked in terms of spinal rotation and rehabilitation, yet it is one of the largest muscles of the back and has multiple attachments to the spine and pelvis. Research regarding the LD has focused mainly on the insertion on the humerus and the role it plays in upper extremity movement. Due to attachments on the scapula, ribs, spine, and pelvis, the LD is capable of influencing spinal movement.[17] Published research on LD activation during spinal rotation is limited, however, according to ongoing research the LD significantly contributes to the contralateral rotation phase of spinal rotation with fixed upper extremities.[5-7] Spinal rotation is broken down into two separate phases, rotation and return, and may be impacted whether upper extremities are non-fixed or fixed. The rotation phase begins when an individual is in an anatomical neutral position. Once maximal spinal rotation is attained, the return phase begins until the body returns to a neutral position.

Spinal Anatomy

It is important to understand the spinal anatomy in order to fully recognize the LD's influence on the spine. The axial skeleton is the foundation of the body, consisting of the skull, spine, ribs, pelvis, and sternum. There are five divisions of the spinal column: 7 cervical vertebrae, 12 thoracic vertebrae, each of which has a corresponding rib, 5 lumbar vertebrae, 5 sacral vertebrae, and 4 coccygeal vertebrae. Each vertebra is abbreviated alphanumerically cranial to caudal, C1-Co4. Between each vertebra lies an intervertebral (IV) disc, which provides shock absorption and distribution of forces. These discs are not present between the occiput and C1, C1-C2, and the fused sacral and coccygeal segments.[18] The axial skeleton is connected to the appendicular skeleton by two joints on each side of the body: the sternoclavicular joints superiorly and the sacroiliac joints inferiorly.[18]

A typical vertebra is divided into different segments: the vertebral body, pedicles, lamina, and transverse and spinous processes. The vertebral body is responsible for weight bearing throughout the spinal column. When descending through the spine, the vertebral bodies become progressively larger to increase their ability to bear weight. The vertebral canal lies posterior to the vertebral body which encloses and protects the spinal cord. The posterior portion of the vertebra is comprised of the spinous and transverse processes, laminae, pedicles, and articular processes. The spinous and transverse processes serve as a site of attachment for various muscular and ligamentous structures. The lamina forms a bridge between the spinous and transverse processes, and the pedicles connect the anterior and posterior structures of the vertebra in order to distribute muscle forces.

The first of the three main divisions of the spinal column is the cervical spine. The cervical spine is composed of 7 segments that consist of a small body and carry the least amount of weight in the spine. This structure allows a greater amount of mobility resulting in less

stability than the thoracic and lumbar spine. Moving inferiorly down the cervical spine, the vertebrae begin to transition into the thoracic vertebrae with a long spinous process, large transverse processes, and narrow transverse foramen.[8] The LD does not have direct attachment onto the cervical spine, but segments of the ES directly insert onto cervical transverse processes, as well as indirectly through blending with the semispinalis capitis.[8]

Inferior to the cervical vertebrae are the thoracic vertebrae. In comparison to the cervical and lumbar vertebrae, the transverse processes are larger in size in the thoracic region (excluding C1). Thoracic vertebrae require large transverse processes to articulate with the ribs and provide support for the rib cage. These articulations take place at the costovertebral and costotransverse joints on bilateral sides. Spinous processes in this region are angled inferiorly whereas the pedicles are angled directly posterior. The lumbar region of the spine begins inferior to the 12th thoracic vertebra.[8]

The vertebral bodies are wider in the lumbar region than the cervical and thoracic which allows support of the upper trunk while limiting excessive motion. Short and thick pedicles and lamina of the lumbar vertebrae produce a stable and sturdy posterior wall of the vertebral canal. Lumbar transverse processes project laterally, and spinous processes project directly posteriorly. Facet alignment in the lumbar vertebrae allows for motion in the sagittal plane while trading excessive transverse and frontal plane motion for increased stability. The L4-5 interspace is in line with the superior portion of the iliac crest, and the 5th lumbar vertebra transitions into the fixed sacral and coccygeal portions of the spine.[8]

The sacrum and coccyx are typically fused and are composed of five and four vertebral segments respectively with the purpose of distributing weight from the vertebral column through the structures of the pelvis. The superior sacrum displays a large broad surface area that articulates with the lumbar vertebrae and contains thick pedicles extending laterally to increase

support and stability in the region. Inferior to the sacrum lies the coccyx, which provides similar function in regard to limited mobility but added spinal column stability. Several muscles and connective tissue structures attach to the sacrum and coccyx promoting additional stability.[8]

The zygapophyseal joints, intervertebral joints, and sacroiliac joints are the main joints located in the lumbopelvic region. These structures share the common function of allowing the body weight, frictional, and ground reaction forces to be dispersed throughout the entire lumbar spine.[18] In addition to these joints, the intervertebral discs assist in distribution of force and shock absorption.[8] The intervertebral discs contain a viscous center called the nucleus pulposus, which is surrounded by a protective annulus fibrosus. The dense annulus fibrosus contains the nucleus pulposus within the intervertebral disc.[8] The nucleus pulposus shifts when weight is distributed across the intervertebral disc, and adjusts to allow for better distribution of the forces acting on the body.[8]

Due to the amount of required support provided by the lumbosacral spine, increased stabilization is critical in this region. The increased stabilization is partially provided by an aponeurotic connective tissue structure called the thoracolumbar fascia (TF). The TF attaches to the ilium near the posterior superior iliac spine, the sacrum, and provides a cover to the posterior surface of the ES. This connective tissue is the main fascial structure that surrounds the ES muscles and provides additional support and stability for the lower spinal segments. It may also play a role in the stability of the sacroiliac joints through its attachment to the LD and gluteus maximus.[8] The LD takes origin from the TF, which attaches to the lumbar spinous processes, giving the LD an indirect articulation with the lumbar spinous processes.

Muscular Anatomy

The LD is the broadest muscle of the back, spanning from the pelvis to the humerus. The LD has multiple points of origin, which includes the following: superior iliac crest, spinous

process of T7-T12, TF, ribs 9-12, and the inferior angle of the scapula. The thoracodorsal nerve (nerve roots C6-C8) is responsible for innervation of the LD, which contains the following actions when the humerus is not fixed: medial rotation, extension, and adduction of the humerus. When the humerus is fixed, the LD contributes to depressing the shoulder girdle, downward rotation of the scapula, elevation of the pelvis, elevation of trunk when arms are flexed overhead (as in a climbing motion), and ipsilateral lateral flexion, contralateral rotation, and extension of the trunk.[8] It has also been found that the LD can be used as an accessory respiratory muscle when the humerus is fixed, for forced expiration during high intensity activity.[12] The most powerful actions of the LD are found when performing overhead activities such as lowering a raised arm against resistance or while elevating the lower extremities during climbing.[11]

As previously stated, the LD muscle is able to extend, medially rotate, and adduct the humerus when working unilaterally. When an object is lifted and brought in close to the body, LD muscles are activated bilaterally and work together to extend the lumbar spine.[18] During these lifting tasks, the LD acts to distribute equal forces across the lumbar spine. Lack of LD activation may lead to compensation from other back extensors, decreasing control of the object being lifted and an increasing strain on the spine. Utilization of this information during treatment plans may help prevent unnecessary stress on the lumbopelvic tissues, helping to minimize spinal pathology.[12]

Other musculature of the posterior trunk that may contribute to spinal rotation are the trapezius, ES, and the transversospinalis group to name a few. The trapezius is comprised of upper, middle, and lower fibers. The middle fibers run laterally from the origin of the T1-T5 spinous processes to the insertion on the superior crest of the spine of the scapula and the medial acromial margin. This orientation is similar to the superior portion of the LD. The MT is

active during scapular retraction, scapular stabilization exercises, and this study analyzed its contribution to spinal rotation.[8]

The ES is a large muscle that runs vertically from the pelvis to the cervical spine, and is divided into three separate muscle groups (lateral to medial): iliocostalis, longissimus, and spinalis. The origin of the ES is a broad tendon that attaches to the posterior iliac crest, sacrum, sacroiliac ligaments, sacral and inferior lumbar spinous processes, and supraspinous ligaments. The most lateral of the ES muscle groups is the Iliocostalis, which is broken up into three separate segments: lumborum, thoracic, and cervical. The lumborum segment inserts on the angle of ribs 7-12, the thoracic segment inserts on the angle of ribs 1-6 and transverse process of C7, and the cervical segment inserts on the transverse processes of C4-C6. The longissimus is the middle ES muscle group, and is also broken up into three separate segments: thoracic, cervical, and capitis. The thoracic segment inserts on the transverse process and ribs in the thoracic region, the cervical segment inserts on the transverse process in the cervical region, and the capitis segment blends with semispinalis capitis. Lastly, the most medial ES muscle group, spinalis, is broken up into three segments: thoracic, cervical, and capitis. The thoracic and cervical segments insert on the spinous processes of the middle to upper thoracic spine and the capitis portion blends with semispinalis capitis. For the purpose of this study, these three muscles will be collectively referred to as the ES.[8]

The ES works bilaterally to extend the head, neck, and trunk and has been found to be a strong stabilizer of the lumbar spine when contracted isometrically and works eccentrically to control the trunk while bending forward.[19] When the ES works unilaterally, it laterally flexes and ipsilaterally rotates the spine. A central origin and lateral insertion provides a strong lever arm allowing the ES to help with rotation of the spine.[12]

Biomechanics

Rotation of the spine is affected differently in the cervical, thoracic, lumbar, sacral, and coccyx regions. The most motion comes from the cervical segments, with a decrease in motion per segment while descending down the spinal column. Spinal rotation of this study is initiated through the pelvis, and this study mainly focused on the thoracic and lumbar components of spinal rotation. Due to the ribs posterior attachment to the thoracic vertebrae and anterior attachment on the sternum, the thoracic region is the most stable portion of the spine outside of the fused sacrum and coccyx. Although the amount of individual thoracic vertebrae rotation is limited due to these articulations, the thoracic region contains the most gross rotation of spinal regions due to a much larger number of components than the lumbar and cervical regions. Near the end of the thoracic region, vertebrae begin to change shape to resemble those of the lumbar region. For example, when comparing the 1st and 12th thoracic vertebrae, the 12th vertebrae's articular facets begin to face more in the sagittal plane to mirror lumbar vertebrae. This orientation allows more flexion and extension in the lumbar region while limiting lateral flexion and rotation. The normal range of motion for thoracic and lumbar regions are listed in Table 1.[20]

Table 1. Normal Range of Motion Values for Thoracic and Lumbar Spine

Motion	Thoracic Spine (in degrees)	Lumbar Spine (in degrees)
Flexion	40-60	20-45
Extension	20-35	20-45
Lateral Flexion	15-20	20-45
Rotation	3-18	35-50

Muscle Function

The low back is known for being highly susceptible to pain and injury. To determine where pain or dysfunction originates, it is important to understand the forces applied on different

areas of the body during a particular movement pattern. It is also important to recognize that poor motor control may lead to common pathologies. Increased knowledge regarding the roles of the LD, MT, and ES during spinal rotation may allow for advanced interventions and strengthening of muscles that may be the source of a pathology.

Muscles are able to contract concentrically, eccentrically, and isometrically. A concentric contraction involves the shortening of muscle fibers against a force, with the distal segment moving toward the proximal segment. An eccentric muscle contraction is the opposite of concentric. The muscle fibers lengthen against a force, with the distal segment moving away from the proximal segment. Elongation of the muscle takes place during eccentric contractions, which produces the greatest force in comparison to concentric and isometric. Lastly, an isometric muscle contraction occurs when the muscle force generated is equal to the force acting against it, resulting in no movement of the distal and proximal segments.

This study focuses on the eccentric, or return to neutral phase. During this phase, the contralateral LD and MT change from a concentric motion to an eccentric motion, and the ipsilateral LD and MT change from an eccentric motion into a concentric motion. The ipsilateral ES changes from a concentric motion to an eccentric motion, and the contralateral ES changes from an eccentric motion into a concentric motion. The concentric muscles during right pelvic rotation include left LD, left MT, and right ES and the eccentric muscles include right LD, right MT, and left ES. These combinations perform the opposite type of muscle contraction while returning to neutral phase. The amount of tension produced is directly related to the degree of overlap of the thick and thin filaments. In elongated muscles, little overlap occurring between the actin and myosin, making it more difficult to form cross bridges. In shortened muscles, the actin and myosin have almost overlapped completely, leaving little room for more shortening to occur. Muscles develop more tension when they are on slight stretch, and maximal tension occurs

around 100-120% of the resting sarcomere length of the muscle. Most intact human muscles usually work within the range of 70-120% of their resting length. According to the sliding filament theory, muscles in the eccentric phase will increase their maximal force potential the closer they get to neutral position. On the other hand, muscles in the concentric phase will produce their maximal force at the beginning of the return to neutral phase and will decrease the closer they get to neutral. Surface electromyography is used to monitor these muscles and to determine how active they are in each of the phases.[21]

Surface Electromyography

Surface EMG is a non-invasive technique used to measure muscle activation. A muscle elicits electrical activity in the form of an action potential, which is detected by EMG electrodes placed over the desired muscle. A muscle contraction, or action potential, is produced after a signal is sent from an alpha motor neuron to the central nervous system and back.[22,23] Action potentials are detected by electrodes on the surface of the skin, and the EMG instrument aides in amplifying the signal to give the conduction volume. An increase in motor units recruited will release a greater amount of action potentials. This will create a stronger electrical signal and increase the volume of the conducted signal on the EMG instrument. The volume of the conducted signal measures the electrical conduction of a muscle rather than the amount of force it produces. Therefore, a maximal voluntary contraction (MVC) is performed in order to compare different muscles using EMG. This will allow relationships to be made between EMG muscle activity and muscle force during submaximal movements.

Optimal electrode placement will reduce the amount of interference from surrounding muscles. Electrodes should be placed in an area with the least amount of tissue between the muscle fibers and the electrode. Additionally, the electrodes should be aligned parallel to the muscle fibers for maximum sensitivity and selectivity.[24]

Skin impedance can also be a factor of producing skewed data while using EMG. Skin impedance is the resistance of the tissue directly under the electrode to the direct current.[24] Direct current interference can result from skin moisture or oil content, hair, density of skin cells, and adipose tissue. Total impedance at the electrode site should be less than 10 kOhms to obtain the most accurate data. To help reduce impedance, the skin should be shaved, abraded with fine grit sandpaper, and cleaned with alcohol wipes. After the skin is properly prepared, electrodes can be applied for EMG analysis.

Maximal Voluntary Contraction

An MVC is the measuring of the maximal electrical signal generated by a muscle. The standards for documenting the force are set by the International Society of Electrophysiology and Kinesiology. It is recommended that the subject practice creating a MVC prior to data collection in order to obtain accurate numbers, as research has shown that there is a 20-30% decrease in MVC performance without proper training. This may be caused by the test subject demonstrating poor technique, lack of efficient movement, or providing submaximal effort. Feedback, such as visual and verbal cueing, has also been found to impact MVC results. Minimizing the potential negative effects of feedback may be required to ensure accurate data collection.[25]

The subject is required to exert maximal effort in a specific motion to collect his or her MVC. Shoulder extension in the prone position has been found to be the best test position for LD activation, producing the highest average MVC. Other test positions such as caudal shoulder depression, body lifting with shoulder depression in sitting, and trunk bending to the right in the lateral decubitus position produce a lesser average force.[26]

Traditional manual muscle testing positions were used for testing the MVC for both the MT and ES. To test the MVC of the MT, the subject is prone with the target upper extremity

abducted to 90 degrees. The researcher applies resistance proximal to the elbow, and the contralateral side of the trunk is stabilized during the muscle contraction. The MVC of the ES is performed with the subject lying in the prone position with arms at the side. The researcher stabilizes the ankles and pelvis and instructs the subject to raise his or her chest off the table by extending the spine as far as possible.[27]

Testing Position

Muscles are able to perform in both open and closed kinetic chain positions, which changes the muscle's effect on the body. Open-chain movements occur when the distal segment is non-fixed and may move freely. An example of an open-chain movement is reaching the arm above the head, where the hand is not fixed to the ground or stable object. In the open-chain position of spinal rotation, the upper extremities and spine are free to move and lower extremities are fixed to the ground. The open-chain position of this study was performed with the subject standing in an anatomical neutral position. The subject rotated one hip in a posterior direction until maximum spinal rotation is achieved (rotation). The subject then returned to neutral position (return). These are two separate phases of movement and this study analyzed the LD, MT, and ES during the return to neutral phase. The terms used for these movements are "right non-fixed rotation" and "left non-fixed rotation".

Right Non-Fixed Rotation: In standing position, the subject's feet are placed shoulder-width apart and arms crossed in front of the chest. The subject will move the right hip in a posterior direction until maximum spinal rotation is achieved (rotation). The subject's feet remain planted and shoulders stable while completing this movement. The subject then rotates the right hip anteriorly to return to neutral (return). The return phase is analyzed in this study and is named right rotation in relation to the pelvis.

Left Non-Fixed Rotation: In standing position, the subject's feet are placed shoulder-width apart and arms crossed in front of the chest. The subject will move the left hip in a posterior direction until maximum spinal rotation was achieved (rotation). The subject's feet remain planted and shoulders stable while completing this movement. The subject then rotates the left hip anteriorly to return to neutral (return). The return phase was analyzed in this study and is named left rotation in relation to the pelvis.

Closed-chain movements occur when the distal segment is fixed to the ground or a stable object. An example of a closed-chain movement is a normal squat, where the feet are fixed to the ground. In the closed-chain position of spinal rotation, the upper extremities are fixed and the trunk is free to move. The closed-chain position of this study was simulated with the subject beginning in the quadruped position with hands and knees in contact with the mat (neutral). From neutral, the subject rotated one hip in a posterior direction until obtaining maximal rotation (rotation), with both hands and contralateral knee remaining in contact with the mat. Once maximal rotation is achieved, the subject returned back to neutral (return). These are two separate phases of movement and this study analyzed the LD, MT, and ES during the return to neutral phase. The terms used for these movements are "right fixed rotation" and "left fixed rotation" depending on which direction the pelvis rotated.

Right Fixed Rotation: In the quadruped position, the subject elevates the right hip in a posterior direction until maximum spinal rotation is achieved and the thigh is close to parallel to the table. The subject then lowers the hip and returns to neutral. The return phase was analyzed in this study and is named right rotation in relation to the pelvis.

Left Fixed Rotation: In the quadruped position, the subject elevates the left hip in a posterior direction until maximum spinal rotation is achieved and the thigh is close to parallel to

the table. The subject then lowers the hip and returns to neutral. The return phase was analyzed in this study and is named left rotation in relation to the pelvis.

CHAPTER III

METHODS

Subjects

This study was approved by the University of North Dakota Institutional Review Board and Research Development and Compliance (IRB-201504-329) is found in Appendix A. Inclusion criteria consisted of subjects between the ages of 20-40, dominance of the right hand, and the ability to tolerate prone and quadruped positioning for 20 minutes each. Exclusion criteria consisted of current or previous pathology of the shoulder or spine requiring medical attention, pregnancy, and allergies to latex or isopropyl alcohol.

Twenty-six healthy subjects (17 females) volunteered to participate in the study. The subject demographics for age, height, and weight are listed in Table 2. Subjects were recruited by the placement of fliers throughout the University of North Dakota School of Medicine and Health Sciences during the months of May-June 2016 and 2017. All subjects were aware of the experimental procedure, purpose of the study, and any possible risks of the study. Subjects completed a demographic questionnaire (Appendix B) and signed a consent form (Appendix C) prior to participation in this study. A copy of the consent form was provided to the subject if they desired one.

Table 2. Subject Demographics

	Mean	Median	Standard Deviation
Age (Years)	26.20	25.5	0.631
Height (Inches)	68.43	67.25	0.497
Weight (Pounds)	159.83	156	6.71

Instrumentation

The instrumentation used for this study was wireless EMG hardware and software (Noraxon, USA, Scottsdale, AZ). The LD, MT, and ES were studied using self-adhesive, pre-surfaced EMG electrodes; silver/aluminum adult electrodes with a 3.3 cm inter-electrode distance were utilIzed for this study (Ambu/Medicotest A/S, Denmark). Data analysis for the raw EMG data was performed using Noraxon MyoResearchXP software (Noraxon, USA, Scottsdale, AZ).

Electromyography

Prior to the beginning of this study, the EMG equipment was set up and tested to ensure proper signal reception and transmission. The research testing was conducted in a private room at the University of North Dakota School of Medicine and Health Sciences. This was done to ensure the privacy and confidentiality for each participant who volunteered for the study. Prior to participation, volunteers were given a verbal explanation of the study and were allowed to ask questions or express any concerns about the procedure. All participants were asked to wear shorts to each session to allow for direct skin contact for the electrodes. Male subjects were asked to remove their shirt, and female subjects were asked to wear a tank, halter, or swimsuit top to allow for direct skin contact for the electrodes. The testing session lasted approximately 60-minutes for each participant. The researchers followed Cram's Introduction to Surface Electromyography guidelines for the preparation and placement of the electrodes.[24] The EMG procedure required electrode site preparation, placement of electrodes, and application of equipment to collect EMG data. The skin preparation consisted of removing excess hair using a razor when necessary, wiping-surface of the skin with 400-grit sandpaper, and cleaning with isopropyl alcohol pad.[24] Electrode sites were prepared in a standardized manner for all subjects.

In order to increase reliability and decrease error in the study, the same researcher applied the electrodes parallel to the LD, MT, and ES muscle fibers (Fig. 1). Electrodes were placed over the LD muscle belly 5 cm below and 3 cm lateral to the inferior angle of the scapula.[28,29] Electrodes were placed over the MT 4 cm horizontal and lateral to the spinous process of T3.[27] Lastly, electrodes were placed over the ES vertical and parallel with the L3-L4 interspace, and 4 cm lateral to the midline. A Noraxon impedance analyzer (Noraxon, USA, Scottsdale, AZ) was placed at each pair of electrodes to measure impedance, which measured less than or equal to 10 kOhm for each pair.[24] The electrodes were connected to the Telemyo 900 transmitter, and attached to the subject's skin using double sided tape. The EMG signals were transmitted to the Telemyo 900 transmitter, and the data was stored on a laptop computer to analyze (Hewlett Packard, Palo Alto, CA).

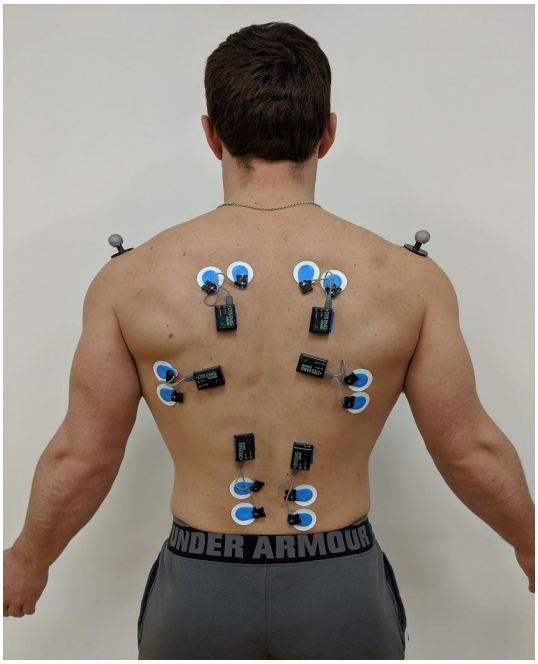


Fig. 1: Electrode Placement of LD, MT, and ES.

Reflective markers were placed bilaterally over the acromion process and the anterior superior iliac spine (ASIS) to assess spinal rotation, and testing positions were video recorded to provide a reference for data analysis. A meter stick was attached perpendicular to a wooden

box to develop a vertical point of reference to assess the amount of spinal rotation during the recordings. After placing the electrodes on the subject, a maximal voluntary contraction (MVC) was collected for each muscle.

Maximal Voluntary Contraction

An MVC was obtained in prone with the head in a neutral position for each muscle being tested. The muscles were chosen to be evaluated in a random order for all subjects. The subjects were instructed to exert maximal force against the dynamometer (microFET2) (Hoggan Health Industries, West Jordan, UT, USA) during each MVC trial. The same researcher utilized the microFET2 for the participant during each trial to ensure consistency and increase reliability. A metronome was set at a pace of 60 beats per minute for consistent timing. Each subject had one second to move into the MVC testing position, hold the MVC for three seconds, and return to starting position in one second. Each participant was allowed to practice each MVC testing position until feeling comfortable with the testing procedure.

Three trials were performed for each MVC testing position with a 30-second rest between each trial. The subjects were instructed to give their maximal effort during each trial, and were reminded to contract slowly and fully without jerking to produce the best results. After each trial, participants were informed of their values to encourage a higher and more consistent MVC value. No additional encouragement was given to participants during the actual contraction. MicroFET2 values were recorded in each testing position for reliability, and all trials were required to be within a five-point interval. Trials would be repeated until three fell within the five-point interval for each position.

Latissimus Dorsi (Fig. 2): The subject was in the prone position with the trunk aligned with the edge of the plinth. The tested shoulder and upper extremity were placed off the plinth a dependent position. The subject was then asked to flex the elbow to 90 degrees and extend the

shoulder to be parallel with the trunk. The researcher applied resistance to the distal humerus during upper extremity adduction and extension using the MicroFET2. Stabilization was applied to the ipsilateral scapula and contralateral pelvis while the subject faced the side of the tested upper extremity.

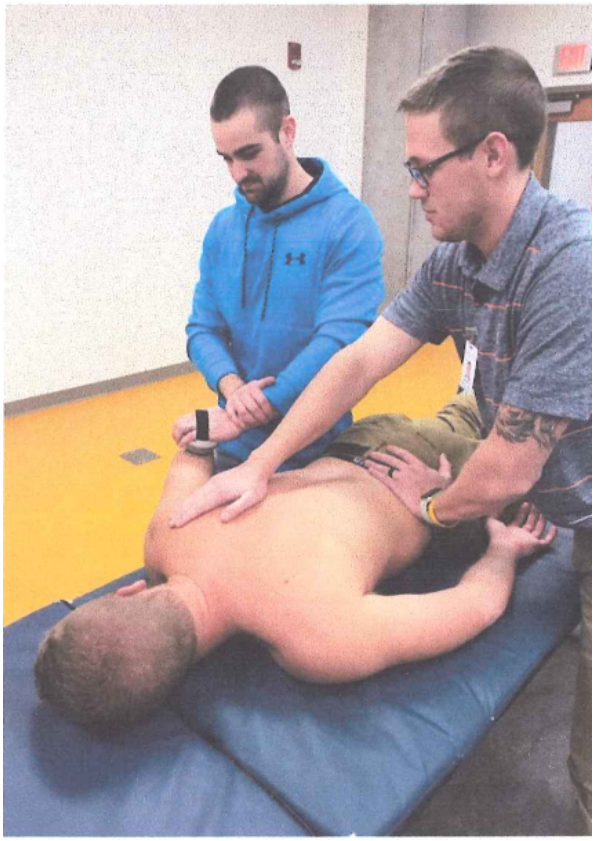


Fig. 2: MVC testing position of the LD.

Middle Trapezius (Fig. 3): The subject was lying in the prone position with the tested upper extremity placed in 90 degrees of both abduction and elbow flexion, and neutral rotation. The researcher applied resistance to the distal humerus during scapular adduction using the MicroFET2. Stabilization was applied to the contralateral scapula and bilateral pelvis while the subject faced the side of the tested upper extremity.

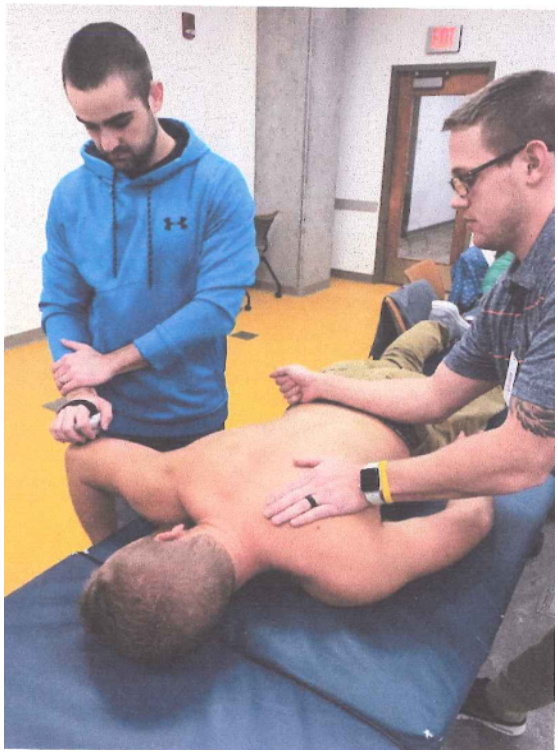


Fig. 3: MVC testing position of the MT.

Erector Spinae (Fig. 4): The subject was lying in the prone position with both upper extremities placed at the sides. The subject was instructed to lift the chest off the plinth into trunk extension through full range of motion while maintaining the head in a neutral position. Resistance was applied to bilateral scapulas in a downward motion. Stabilization was applied behind the knees and ankle by another researcher. Consistent effort was measured by assessing full range of motion prior to MVC testing, and confirming it was achieved during each trial.

Experimental Testing

Experimental testing was performed after completing all MVC trials. A sequence of testing conditions for each subject was randomly generated by a computer to eliminate selection bias. One to two minutes of rest was given to the subject both before beginning the first testing condition, and in between each subsequent testing condition. Subjects were able to practice

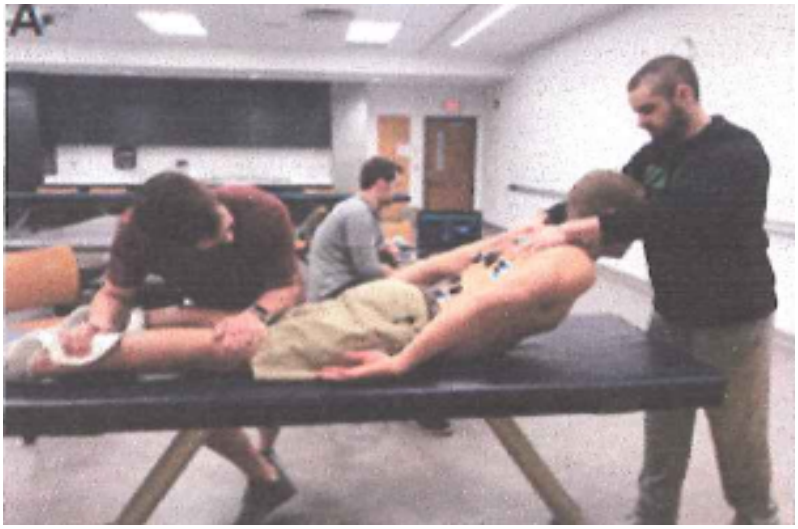


Fig. 4: MVC testing position for the ES.

each testing motion until comfortable, where a 30 second rest period was then provided before performing the first trial. Each movement was paced to a metronome set at 92 beats per minute.

Subjects were instructed to move three counts into full range of spinal rotation followed by three counts to return to neutral starting position following the beat of the metronome. A researcher verbally cued the subject during the motion to the beat of the metronome, saying, “Back, Two, Three, Forward, Two, Three.” The subject completed three trials of five repetitions for each movement with a 30 second rest period provided between each trial.

Standing non-fixed position (Fig. 5): Subjects were asked to stand with feet flat on the ground, shoulder-width apart, and arms crossed over their chest. A researcher stabilized the subject’s shoulders to avoid additional movement of the upper trunk. During left non-fixed rotation, the motion began with the left ASIS maximally displaced in the posterior direction. The subject was instructed to rotate the pelvis by moving the left ASIS in an anterior direction back to anatomical neutral. During right non-fixed rotation this was repeated on the opposite side. Motion began with the right ASIS maximally displaced in the posterior direction and the subject was instructed to rotate the pelvis by moving the right ASIS in an anterior direction back to anatomical neutral. The subject’s feet were in contact with the floor and knees were straight

throughout the motion. The video camera was placed on the side rotating back to neutral with a clear view of the reflective markers, and the lens was placed at the height of the subject's ASIS.

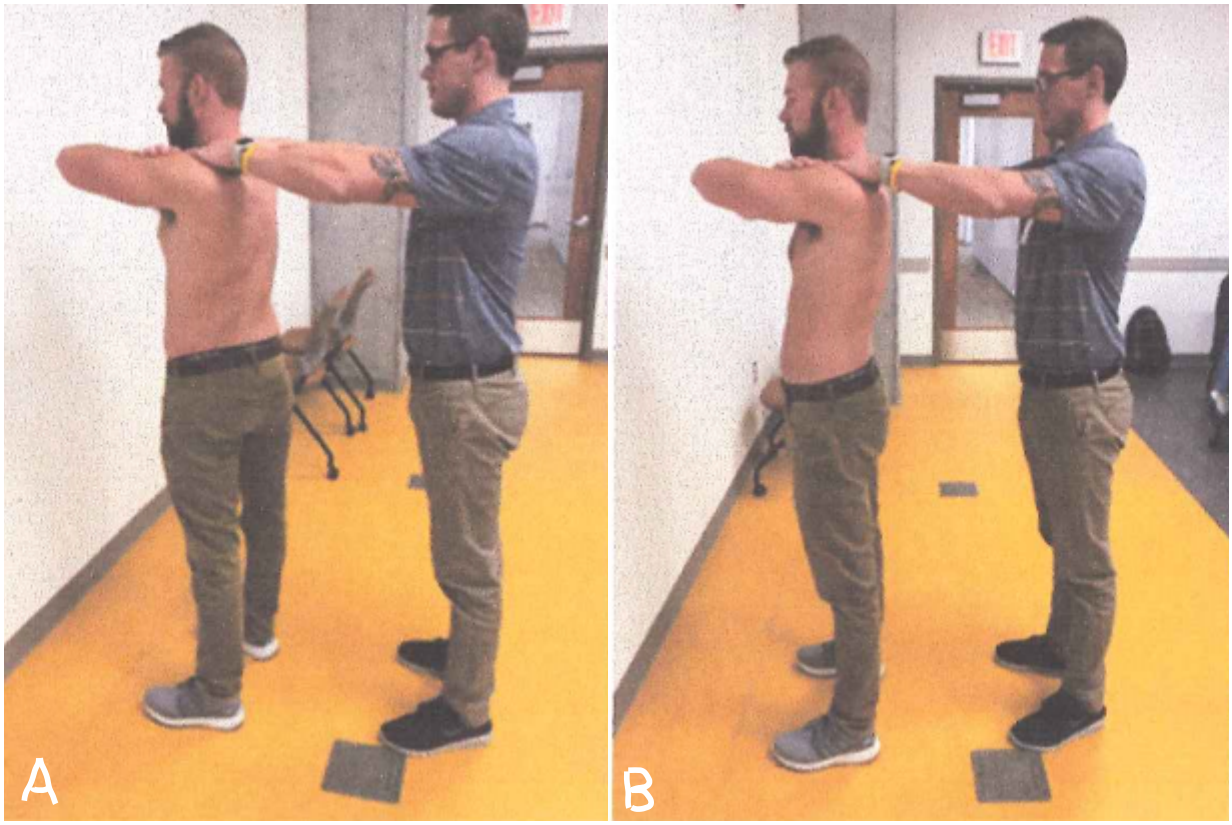


Fig. 5: Right non-fixed spinal rotation. (A) Starting position of right rotation with right ASIS maximally displaced posterior. (B) Ending position in anatomical neutral.

Quadruped fixed position (Fig. 6): Subjects were in a quadruped position with hands and knees shoulder-width apart. The six-inch wooden box was placed adjacent to the subject's knee on the tested side. A towel was placed between the box and the subject's leg for greater ease of movement. The subject was instructed to maintain contact with the box throughout movement to promote spinal rotation and prevent abduction of the thigh. During left fixed rotation, the motion began with the left hip maximally rotated in the posterior direction. The subject was instructed to rotate the hip in an anterior direction back to neutral. During right fixed rotation this was

repeated on the opposite side. Motion began with the right hip maximally rotated in the posterior direction and the subject was instructed to rotate the hip in an anterior direction back to neutral.

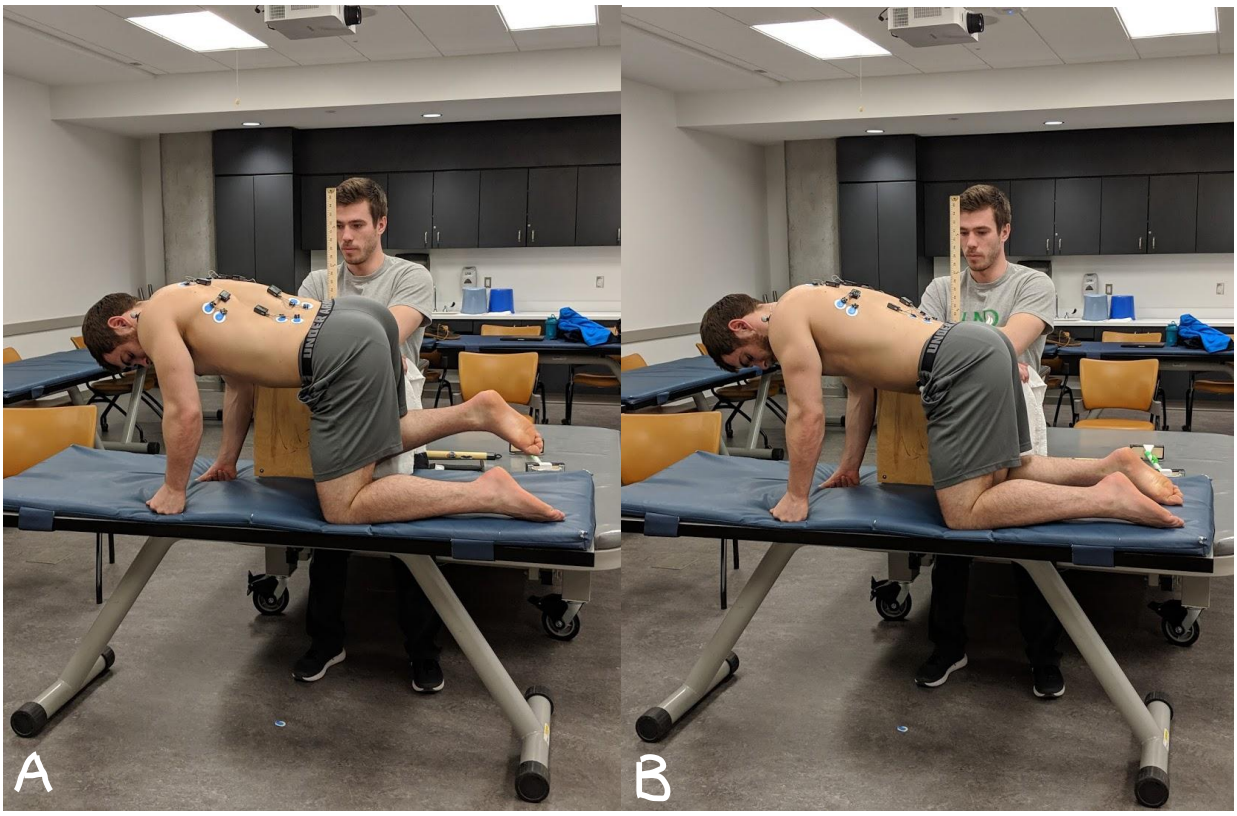


Fig. 6: (A) Lateral view of starting position of fixed right rotation with right hip maximally elevated in the posterior direction. (B) Ending position after subject returned to neutral in quadruped.

Data was collected and stored during each MVC and three trials of each testing position in separate files. Once all data collection was completed, the electrodes and reflector markers were removed from the subject and skin was cleaned using isopropyl alcohol.

Data Analysis

Data analysis utilized the MyoResearch XP software. The collected EMG data was transported, rectified, and normalized to the MVC for each muscle by the Noraxon MyoReseachXP software (NoraxonUSA, inc., Scottsdale, AZ). The EMG data was recorded in

5-count intervals during every muscle contraction for the MVC's. The EMG data was recorded in 3-count intervals during testing positions while returning to neutral. Data from seconds 2-4 was used for data analysis to find the precise data representation within the 5-count interval. When the values were obtained, EMG signals were normalized to the MVC, smoothed, and rectified. All data was then transferred to the Statistical Package for Social Sciences (SPSS) for Windows, Ver. 24. (IBM, Armonk, New York, USA) for analysis. A repeated measures ANOVA with Bonferroni analysis was performed to compare planned pairwise comparisons of the right and left LD in a non-fixed and fixed position. A univariate repeated measures ANOVA and Scheffe post hoc analysis was also completed (α=0.05) to determine whether there was a significant difference in EMG activity of the LD, MT, and ES in a non-fixed and fixed position. These tests were completed to analyze each of the research questions.

CHAPTER IV

RESULTS

The first and second research questions aimed to identify differences in ipsilateral and contralateral LD muscle activation under differing conditions of fixation (Table 3). A significant difference in EMG activity was found in the right and left LD when the conditions of non-fixed and fixed upper extremities were compared during ipsilateral movement of full hip rotation back to the neutral position ($p<0.001$). Similarly, a significant difference in EMG activity was found in the right and left LD when the conditions of non-fixed and fixed upper extremities were compared during contralateral movement of full hip rotation to neutral position ($p<0.001$). Overall, the right and left LD were most active during both contralateral non-fixed and fixed rotation, and higher right and left LD mean (%MVC) values were present with the upper extremities fixed.

The third question compared the EMG activity of the LD, MT, and ES under the condition of non-fixed upper extremities. In Table 4, a significant difference in EMG activity was identified between the right LD and ES and left LD and ES during ipsilateral movement of full hip rotation back to the neutral position with non-fixed upper extremities ($p<0.001$). Although significant differences in EMG activity were found between the right and left MT and ES during ipsilateral and contralateral return to neutral hip rotation, there was no significant difference in EMG activity between the LD and MT in any non-fixed motion. Throughout all non-fixed conditions, the EMG activity of the ES was significantly greater than both the LD and MT.

Table 3: Repeated Measures ANOVA: Difference of LD EMG activity during movement from full hip rotation to neutral position with upper extremities non-fixed and fixed

Condition	N	Mean (%MVC)	SD	Df (degrees of freedom)	F	Eta^2	p	Power	Sig dif. Between conditions
Right Latissimus Dorsi									
1) Non-Fixed Right	26	3.892	1.881	1	41.068	.622	<.001	1	1 & 3 1 & 4
2) Non-Fixed Left	26	5.125	3.209						2 & 3 2 & 4
3) Fixed Right	26	12.256	8.516						3 & 1 3 & 2 3 & 4
4) Fixed Left	26	17.752	9.399						4 & 1 4 & 2 4 & 3
Left Latissimus Dorsi									
1) Non-Fixed Right	26	5.073	3.034	1	43.222	.634	<.001	1	1 & 3 1 & 4
2) Non-Fixed Left	26	4.100	2.380						2 & 3 2 & 4
3) Fixed Right	26	17.370	9.350						3 & 1 3 & 2 3 & 4
4) Fixed Left	26	9.873	5.161						2 & 1 2 & 3 2 & 4

*Bonferroni analysis

Table 4: Univariate Repeated measures ANOVA: Difference of LD muscle activation from MT and ES during the movement from full hip rotation to neutral position with upper extremities non-fixed

Direction of Rotation	Muscle	N	Mean (%MVC)	SD	F	p	power	Sig dif. between conditions
Right	1. R LD	26	3.892	1.882	77.182	<.001	1.0	1 & 3 2 & 3
	2. R MT	26	2.711	2.278				
	3. R ES	26	15.650	6.778				
Left	1. R LD	26	5.125	3.209	30.167	<.001	1.0	1 & 3 2 & 3
	2. R MT	26	4.059	3.749				
	3. R ES	26	11.878	5.227				
Right	1. L LD	26	5.073	3.034	21.467	<.001	1.0	1 & 3 2 & 3
	2. L MT	26	3.927	3.671				
	3. L ES	26	10.901	6.093				
Left	1. L LD	26	4.100	2.380	69.897	<.001	1.0	1 & 3 2 & 3
	2. L MT	26	2.332	1.269				
	3. L ES	26	16.074	7.844				

*Scheffe post hoc analysis
**The degrees of freedom for all cases is 2.

The fourth research question compared the EMG activity of the LD, MT, and ES with fixed upper extremities. In Table 5, a significant difference in EMG activity was identified between the right LD and both the right MT and ES during the contralateral movement of full hip rotation back to the neutral position with fixed upper extremities ($p<0.001$) . Additionally, there was a significant difference in EMG activity between the left LD and both left MT and ES during the contralateral movement of full hip rotatoin back to neutral with fixed upper extremities ($p<0.001$). Right and left LD and ES EMG activity during the motion of ipsilateral full hip rotation to neutral with fixed upper extremities was much greater than the MT. Furthermore, EMG activity of the LD was significantly greater than both the ES and MT during contralateral movement of full hip rotation to neutral position with fixed upper extremities.

Table 5: Univariate Repeated measures ANOVA: Difference of LD muscle activation from MT and ES during the movement from full hip rotation to neutral position with upper extremities fixed

Direction	Muscle	N	Mean (%MVC)	SD	F	p	power	Sig dif. Between conditions
Right	1.R LD	26	12.256	8.516	13.974	<.001	.998	1 & 2 2 & 3
	2. R MT	26	4.876	1.924				
	3. R ES	26	12.330	6.570				
Left	1. R LD	26	17.752	9.398	26.784	<.001	1.0	1 & 2 1 & 3
	2. R MT	26	5.474	3.385				
	3. R ES	26	10.017	5.255				
Right	1. L LD	26	17.370	9.350	20.960	<.001	1.0	1 & 2 1 & 3
	2. L MT	26	7.103	6.326				
	3. L ES	26	9.374	5.029				
Left	1. L LD	26	9.873	5.161	14.428	<.001	.998	1 & 2 1 & 3 2 & 3
	2. L MT	26	5.289	3.360				
	3. L ES	26	14.403	9.643				

*Scheffe post hoc analysis
**The degrees of freedom for all cases is 2

CHAPTER V

DISCUSSION and CONCLUSION

Discussion

This study showed that significant differences existed in the EMG activity of the LD in comparison to the MT and ES during the return to neutral phase of spinal rotation. Spinal rotation is broken up into two separate phases, the rotation phase and the return to neutral phase. During the movement of spinal rotation to the right, the left LD fires concentrically. During the return to neutral phase, the left LD shifts to an eccentric contraction. Studies during both phases of rotation are needed to understand the muscle involvement throughout the complete movement of spinal rotation, with and without different conditions of upper extremity fixation that simulate real life activities. Results of this study correlate with the findings of the ongoing study that analyzes LD activation in the concentric phase of spinal rotation.[5-7] This study is also in agreement with a study conducted by Kumar et al[25] that found the LD played a significant role in spinal rotation during isometric lifting activities.

A statistically significant difference in ipsilateral LD EMG activation during the movement from full hip rotation to neutral with upper extremities in a fixed position was found compared to the non-fixed position, supporting hypothesis one. Similarly, there was a statistically significant difference in contralateral LD EMG activation during the same movement with upper extremities in a fixed position compared to the non-fixed position, supporting hypothesis two. When comparing the LD to the MT and ES during the movement from full hip rotation to neutral,

significant differences existed based on whether upper extremities were in the non-fixed or fixed position, supporting hypotheses three and four.

The ipsilateral LD was significantly more active during the movement from full hip rotation to neutral with upper extremities in a fixed position compared to non-fixed. In addition, the findings indicated that during the same movement, the contralateral LD was significantly more active with the upper extremities in the fixed position compared to the non-fixed position. Overall, the right and left LD were most active during both contralateral non-fixed and fixed rotation, and higher right and left LD mean (%MVC) values were present with the upper extremities fixed. When the upper extremities are in a fixed position, the humerus is not allowed to move and is stable. If movement is initiated through the pelvis in this closed-chain scenario, contraction of musculature that inserts onto the humerus will have a reverse effect and influence movement at the origin. The LD takes origin on the T7-T12 spinous processes, so contraction with the humerus fixed theoretically promotes contralateral spinal rotation of the vertebral segments. Although the ES is significantly more active than the LD in standing, the quadruped position analyzed in this study fixed the humerus which favored the LD as a contralateral spinal rotator.

When evaluating the LD, MT and ES during the movement from full hip rotation to neutral with upper extremities in a non-fixed position, both the right and left ES were significantly more active than the right and left LD and MT in both right and left rotation. During non-fixed right and left rotation, there were significant differences found between the LD and ES, and MT and ES on both sides. No significant differences were identified between the LD and MT with upper extremities in a non-fixed position. Due to the LD and MT's origin on the spinous processes it was expected they would have similar effects on spinal rotation, although to a different degree. The greater mean EMG activity of the ES in standing suggests that the LD and

MT are not positioned favorably to contribute to spinal rotation under this condition. This position may allow the test subject to extend his or her back which could increase the activity in ES.

When evaluating the LD, MT and ES during the movement from full hip rotation to neutral with upper extremities in a fixed position, the LD demonstrated the most EMG activity in both right and left directions. With upper extremities fixed during right rotation, this study found significant differences between the right and left LD and MT, right MT and right ES, and left LD and left ES. With upper extremities fixed during left rotation, significant differences were identified between the right and left LD and MT, the right and left LD and ES, and the left MT and left ES. These results indicate that the LD has a major role in the return to neutral phase of spinal rotation when the upper extremities are fixed. In this fixed position, the mean EMG activity of the right LD was greater than bilateral MT and ES in left return to neutral rotation, and the left LD was more active than bilateral MT and ES in right return to neutral rotation. These findings in the quadruped position may also be relevant during functional activities that require upper extremity fixation. Daily activities include walking with heavy groceries, picking up a child off the ground, and shoveling large amounts of snow.

This study included several limitations. First, the study was limited to 26 participants who were similar in terms of demographics. Participants ranged from the age of 20-31 and were healthy, active physical therapy students rather than individuals from the general public. Second, differences may have existed in muscular development and coordination because the study did not require body composition or coordination testing. Other variables that may have affected results include discrepancies in both stabilizing forces and dynamometer pressure when counteracting the participant's maximal force, and discomfort at the dynamometer placement site. Lastly, human error between researchers may have altered results when manually setting intervals of EMG data for analysis.

Future research could include individuals of different fitness levels, compare gender differences, and increase the sample size. These variations would increase the study's significance and allow comparisons to be made with the general population. Eventually, comparing EMG activity of the LD, MT and ES in individuals experiencing LBP with healthy subjects could expand the knowledge on spinal pathologies. Based on these results, exploring the options of utilizing the LD in rehabilitation exercises as physical therapists may provide insight for other health professionals in treating LBP.

Conclusion

In conclusion, the LD was found to be more active in the contralateral return to neutral phase of spinal rotation in the quadruped position than bilateral MT and ES. The EMG activity of the MT in all standing and quadruped return to neutral movements of spinal rotation was significantly less than bilateral LD and ES. In the standing position, the ES was significantly more active in both ipsilateral and contralateral return to neutral spinal rotation than bilateral LD and MT.

This study highlights the contributions of the LD in the return to neutral phase of spinal rotation. Previous studies have indicated that the LD influences the initial phase of spinal rotation in the quadruped position, and future studies will compare and contrast both phases of spinal rotation. This study is part of ongoing research concerning differences in LD activation in individuals with and without LBP. Many activities throughout the day require movement with the upper extremities in a fixed position such as carrying heavy groceries or pushing up out of bed. Additionally, many LBP interventions include quadruped exercises. Due to significant muscle activity throughout these everyday activities, the LD should be included in comprehensive evaluations by medical professionals.

Appendix A

University of North Dakota Human Subjects Review Form
January 2015 Version

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

Please provide the information requested below. Handwritten forms are not accepted – responses must be typed on the form.

Principal Investigator: Susan H N Jeno, PT, PhD

Telephone: 777-3662 E-mail Address: sue.jeno@med.und.edu

Complete Mailing Address: 501 North Columbia Road Stop 9037 Grand Forks, ND 58202-9037

School/College: SMHS Department: PT

Student Advisor (if applicable):

Telephone: E-mail Address:

Address or Box #:

School/College: Department:

****** All IRB applications must include a Key Personnel Listing.***

Project Title: EMG Analysis of Latissimus Dorsi, Erector Spinae and Middle Trapezius Muscle Activity During Trunk Rotation

Proposed Project Dates: Beginning Date: April 15, 2015 Completion Date: April 15, 2016 (Including data analysis)

Funding agencies supporting this research: N/A

Did the contract with the funding entity go through UND Grants and Contracts Administration? ☐ YES or ☐ NO
Attach a copy of the contract. Do not include any budgetary information. The IRB will not be able to review the study without a copy of the contract with the funding agency.

☐ YES or ☒ NO Does any researcher associated with this project have an economic interest in the research, or act as an officer or a director of any outside entity whose financial interests would reasonably appear to be affected by the research? If yes, submit on a separate piece of paper an additional explanation of the financial interest. The Principal Investigator and any researcher associated with this project should have a Financial Interests Disclosure Document on file with their department.

☐ YES or ☒ NO Will any research participants be obtained from another organization outside the University of North Dakota (e.g., hospitals, schools, public agencies, American Indian tribes/reservations)?

☐ YES or ☒ NO Will any data be collected at or obtained from another organization outside the University of North Dakota?

If yes to either of the previous two questions, list all organizations:

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

Does any external site where the research will be conducted have its own IRB? ☐ YES ☐ NO ☐ N/A

If yes, does the external site plan to rely on UND's IRB for approval of this study? ☐ YES ☐ NO ☐ N/A
(If yes, contact the UND IRB at 701 777-4279 for additional requirements)

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

_____ Date submitted: _____ Status: ☐ Approved ☐ Pending

_____ Date submitted: _____ Status: ☐ Approved ☐ Pending

(include the name and address of the IRB, contact person at the IRB, and a phone number for that person)

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

☒ YES or ☐ NO	New Project	☐ YES or ☒ NO	Dissertation/Thesis/Independent Study
☐ YES or ☒ NO	Continuation/Renewal	☐ YES or ☒ NO	Student Research Project
☐ YES or ☒ NO	Is this a Protocol Change for previously approved project? If yes, submit a signed Protocol Change Form, along with a signed copy of this form with the changes bolded or highlighted.		
☐ YES or ☒ NO	Does your project involve abstracting medical record information? If yes, complete the HIPAA Compliance Application and submit it with this form.		
☐ YES or ☒ NO	Does your project include Genetic Research?		

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

- ☐ Children (< 18 years)
- ☐ Prisoners
- ☐ Cognitively impaired persons or persons unable to consent
- ☐ Other _____
- ☒ UND Students
- ☐ Pregnant Women/Fetuses

Please use appropriate checklist when children, prisoners, pregnant women, or people who are unable to consent will be involved in the research.

This study will involve: Check all that apply.

- ☐ Deception (Attach Waiver or Alteration of Informed Consent Requirements)
- ☐ Radiation
- ☐ New Drugs (IND) IND # _____ Attach Approval
- ☐ Investigational Device Exemption (IDE) # _____ Attach Approval
- ☐ Non-approved Use of Drug(s)
- ☒ None of the above will be involved in this study
- ☐ Stem Cells
- ☐ Discarded Tissue
- ☐ Fetal Tissue
- ☐ Human Blood or Fluids
- ☐ Other _____

I. Project Overview

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

To date, the research concerning the activation of the latissimus dorsi muscle focuses on its contribution to upper extremity movement. With attachments on spinous processes, the latissimus dorsi as well as the middle trapezius has the potential to impact spinal rotation. Without proper identification of these muscles' contribution to spinal rotation, proper rehabilitation of a patient with upper extremity or spinal pathology would be impossible. This pilot project is intended to analyze the activation of the latissimus dorsi, middle trapezius and for comparison, the erector spinae muscles during spinal rotation to identify the muscles' contribution to this biomechanical movement.

II. Protocol Description

Please provide a thorough description of the procedures to be used by addressing the instructions under each of the following categories.

1. Subject Selection.

a) Describe recruitment procedures (i.e., how subjects will be recruited, who will recruit them, where and when they will be recruited and for how long) and include copies of any advertisements, fliers, etc., that will be used to recruit subjects.
Investigators will voluntarily recruit subjects through fliers posted throughout the SMHS during the months of April-June 2015. No incentives will be provided to participants in this study. See attached flier. (See attached)

b) Describe your subject selection procedures and criteria, paying special attention to the rationale for including subjects from any of the categories listed in the "Subject Classification" section above.
Subjects will be between the ages of 20-40, have no history of shoulder or spine pathology. They will also be able to lay in a prone position for a maximum of 20 minutes and maintain a 4-point quadruped position for approximately 15 minutes during the testing procedure. Subjects from the SMHS will be recruited as a sample of convenience.

c) Describe your exclusionary criteria and provide a rationale for excluding subject categories.
Exculsion criteria include pathology to the shoulder or spine that required medical attention, if the subject is pregnant, or has allergies to latex or isopropyl alcohol. Any of these criteria would pose a risk for the subject to participate in the research study.
Exclusion criteria for this study include: 1) history of shoulder or spine pathology - differences in electrical activity and functional movements associated with pathology could alter the patterns demonstrated during the testing procedure and subjects will be asked to perform an isometric contraction of the shoulder extensors, scapular retractors and trunk extensors which may exacerbate previous pathologies; 2) age of subjects less than 20 years or greater than 40 years. Differences in muscle physiology in younger and older individuals could enhance variability between subjects; 3) sensitivity to isopropyl alcohol or latex - electrodes used during the procedure may contain trace amounts of latex; skin is cleaned with isopropyl alcohol; in an effort to avoid adverse reactions, individuals with these sensitivities will be excluded from participation in this study.

d) Describe the estimated number of subjects that will participate and the rationale for using that number of subjects.
It is anticipated that a maximum of 50 healthy UND students will be recruited for this study to reduce the risk of research error associated with smaller sample sizes.

e) Specify the potential for valid results. If you have used a power analysis to determine the number of subjects, describe your method.
Valid results are anticipated with a sample size of up to 50 subjects and randomization of the order of the testing position during the data collection protocol to minimize the error associated with training effects or fatigue.

2. Description of Methodology.

a) Describe the procedures used to obtain informed consent.
Informed consent will be obtained from each subject through the information and consent form (see attached form). All individuals participating in this study will be capable of independent decision making and will sign a consent form stating their understanding and willingness to participate in this study. A copy of the consent form will be provided for each subject.

b) Describe where the research will be conducted. Document the resources and facilities to be used to carry out the proposed research. Please note staffing, funding, and space available to conduct this research.
All data collection will occur within a private room in the UND Department of Physical Therapy within the SMHS. EMG equipment owned by the Department will be utilized for all data collection.

c) Indicate who will carry out the research procedures.
Research will be carried out by Dr. Sue Jeno and Year 2 Graduate Physical Therapy Students.

d) Briefly describe the procedures and techniques to be used and the amount of time that is required by the subjects to complete them.

Electromyographic (EMG) activity of the muscles will be monitored during standing trunk rotation and trunk rotation in a 4-point quadruped position with the use of pre-gelled, self-adhesive electrodes placed over motor points of the relavent muscles in the back. Muscles to be monitored include the latissimus dorsi, middle trapezius, erector spinae muscles on both sides of the body. Precise electrode placement will be determined by standard electrode placement charts and previously published research. Female subjects will be asked to wear shorts and bathing suit top and male subjects will be asked to wear shorts to facilitate access to the muscles and protect modesty. Prior to electrode placement, the skin will be prepared in standardized fashion and skin impedance will be measured to ensure adequate electrical conduction at each site. Preparation of the skin includes removing excess hair in the area where the electrodes will be positioned will an electric razor, the skin slightly abraded with sandpaper and then cleaned with alcohol wipes. A goniometer attachment will be placed along the lumbar spinous processes to record trunk rotation. The electrodes and goniometer will be connected to a transmitter which will be placed in a belt around the subject's waist. The EMG signals will be transmitted to a receiver and then to a computer. Raw EMG data will be obtained for analysis.

Once the electrodes are in place, each subject will perform a maximal voluntary contraction (MVC) of each of the muscles on both sides of the body for muscle activity comparison. A hand-held device will be utilized to record the amount of force generated by each contraction in addition to the EMG data. Each exercise will be performed 3 times, held for 5 seconds with 30-60 sec rest between trials. The MVC testing position for all muscles is a prone position; latissimus dorsi (LD) - resistance to arm extension from a neutral position will be used to record the MVC; middle trapezius (MT) - the arm will be abducted to 90 degrees with the elbow bent to 90 degrees and scapular retraction will be resisted at the proximal humerus; erector spinae (ES) muscles - trunk extension with the arms at sides with resistance provided across the upper back. Subjects will be allowed to practice the testing and rotation activities prior to data collection to ensure understanding of the motions and appropriate speed of motion. Following the collection of the MVC data, you will be asked to perform a series of trunk rotations both to the right and to the left from a standing position with arms at your side, and holding a bar against a wall in 3 different positions of arm forward elevation (45 deg, 90 deg, 120 deg) and from a position on your hands and knees. The motions will be performed with the order randomized to avoid research bias or error. Each rotation will be timed with a metronome for a 3 count motion to obtain full rotation and a 3 count motion to return to a neutral position. Subjects will be asked to perform 5 continuous repetitions of each rotation paced by a metronome for each trial. A rest of 30-60 seconds will be provided between each trial. The rotational motions will be digitally video recorded for use in analyzing the EMG data.

e) Describe audio/visual procedures and proper disposal of tapes.
Video recording is directly linked to the computer and EMG data for analysis. No actual audio recordings are made of the subjects. Video recordings will be utilized in the data analysis process, saved and stored in similar fashion as the EMG data and destroyed simultaneously. No separate tapes are created in this process.

f) Describe the qualifications of the individuals conducting all procedures used in the study.
The primary investigator for this study is a faculty member in the Department of Physical Therapy who will be assisted by Year 2 Gradute Physical Therapy students all of whom are trained in the use of EMG equipment.

g) Describe compensation procedures (payment or class credit for the subjects, etc.).
There will be no compensation given to subjects involved in this study.

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

3. Risk Identification.

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

The potential physical risks associated with this study are minimal. The EMG electrode placement and analysis is a non-invasive procedure utilized in clinical practice. During the performance of the MVC contractions and trunk rotation activities, there is a slight chance the subject may lose balance or experience shoulder or back pain. This potential risk will be minimized by the presence of a spotter during the activity. Minor skin irritation from the skin preparation and EMG electrodes is possible. Subjects may experience slight fatigue or muscle soreness following participation in this study but it is anticipated that this would not be any worse than that experienced during minimal physical exercise. All subjects will be healthy with no history of shoulder or spine pathology so these risks are minimized by inclusion/exclusion criteria.

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

Subject's names will not be used in any reports of the results of this study. Each participant will be assigned an identification number, known only by the investigators, which will be the only association between consent forms and data collected by EMG. Any information that is obtained in connection with this study and that can be identified with the subject will remain confidential and will be disclosed only with permission from the subject. At the completion of the study, the research data and the consent forms will be stored in separate locked locations in the Department of Physical Therapy for 3 years at which point the forms will be shredded and electronic data deleted. Data will be reported in aggregate form only to protect the confidentiality of all subjects.

c) Provide a description of the data monitoring plan for all research that involves greater than minimal risk.

d) If the PI will be the lead-investigator for a multi-center study, or if the PI's organization will be the lead site in a multi-center study, include information about the management of information obtained in multi-site research that might be relevant to the protection of research participants, such as unanticipated problems involving risks to participants or others, interim results, or protocol modifications.

4. Subject Protection.

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

Selection of the subject pool utilizing the exclusion criteria will minimize the risks associated with this study. Limiting the trunk rotation to what the subject can complete comfortably will also limit potential risks of back pain associated with trunk rotation. Muscle soreness will be minimized by limiting the number of repetitions in each position. The possibility of skin irritation will be minimized by proper skin preparation and subject screening prior to participation. To protect confidentiality and modesty, all data collection will occur in a private room. 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. All subjects will be allowed to terminate their participation in this study at any time without prejudice.

b) Describe procedures you will implement to protect confidentiality and privacy of participants (such as coding subject data, removing identifying information, reporting data in aggregate form, not violating a participants space, not intruding where one is not welcome or trusted, not observing or recording what people expect not to be public, etc.). If participants who are likely to be vulnerable to coercion and undue influence are to be included in the research, define provisions to protect the privacy and interests of these participants and additional safeguards implemented to protect the rights and welfare of these participants.

Subject and result information will not be linked to the consent form in order to protect the confidentiality of the subjects. Names will not be associated with data collection forms. Subjects will be assigned a confidential, unique number which will be used for identification purposes. To protect confidentiality and modesty, all data collection will occur in a private room.

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

Prior to participation in this study, each subject will read and sign a consent form. Participants in this study will all be capable of independent decision making and will sign a consent form stating their understanding and willingness to participate in this study. Participants will be encouraged to ask any questions regarding the consent form to ensure their understanding of the document. Each participant will be given a copy of the signed consent form for their records.

d) Describe the protocol regarding record retention. Please indicate that research data from this study and consent forms will both be retained in separate locked locations for a minimum of three years following the completion of the study.
Describe: 1) the storage location of the research data (separate from consent forms and subject personal data)
2) who will have access to the data
3) how the data will be destroyed
4) the storage location of consent forms and personal data (separate from research data)
5) how the consent forms will be destroyed

Participant consent forms and data collection sheets/computerized files will be stored separately and secured in separate locked locations in the Department of Physical Therapy. Only the investigators will have access to this information. After a period of 3 years from the completion of the study, the consent forms and data collection sheets will be shredded for final disposition and computerized data will be deleted from all disks/drives.

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

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. If subjects consent to participate they will be allowed to terminate their participation in this study at any time without prejudice or jeopardizing any future relationships with the UND Department of Physical Therapy. All investigators are CPR trained. Medical treatment will be provided to each subject as needed, including first aid, CPR, and follow-up care as that provided to a member of the general public in a similar circumstance.

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

In the event an adverse event occurs during participation in this study, the subject will be prompted to seek immediate medical attention. All incurred medical expenses will be the repsonsibility of the subject or the subject's third-party payer.

III. Benefits of the Study

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

Possible benefits of this study include but are not limited to: 1) gaining a better understanding of the muscle activity in the back muscles with trunk rotation and 2) increasing the current level of knowledge of muscle activity and motion patterns of these muscles during this activity; 3) further research may be stimulated; and 4) improved understanding of the kinematics of trunk rotation to aid in the teaching of this activity to students enrolled in the professional physical therapy curriculum. There will be neither cost associated with nor any compensation to any subject who participates in this study.

IV. Consent Form

Clearly describe the consent process below and be sure to include the following information in your description (Note: Simply stating 'see attached consent form' is not sufficient. The items listed below must be addressed on this form.):

1) The person who will conduct the consent interview
2) The person who will provide consent or permission
3) Any waiting period between informing the prospective participant and obtaining consent
4) Steps taken to minimize the possibility of coercion or undue influence
5) The language to be used by those obtaining consent
6) The language understood by the prospective participant or the legally authorized representative
7) The information to be communicated to the prospective participant or the legally authorized representative

1. The person who will conduct the consent interview will be the primary investigator or a second year PT graduate student. Consent interview will be done in a private location within the PT Department in the SMHS.
2. The person who will provide consent or permission will be the subject in the study. Only those subjects who understand written and verbal explanation of the test protocol in English and who are able to provide consent will be subjects in this study.
3. There will be no waiting period between informing the participant and obtaining consent.
4. All subjects will gain access to the study through voluntarily contacting the researcher for an opportunity to participate. During the consenting process, it will be explained to the potential subjects that the process is entirely voluntary and that they are free to withdraw at any point in the process. Withdrawal from the study will not alter their relationship with the Department of Physical Therapy in any way.
5. English will be the language used to obtain consent. Medical jargon will not be utilized to ensure subject understanding of the research protocol.
6. English will be the language understood by the participant.
7. All risks and benefits, test procedures, and consent document will be explained to each prospective subject.

See Attached form.

A copy of the consent form must be attached to this proposal. If no consent form is to be used, document the procedures to be used to protect human subjects, and complete the Application for Waiver or Alteration of Informed Consent Requirements. Refer to form IC 701-A, Informed Consent Checklist, and make sure that all the required elements are included. **Please note:** All records attained must be retained for a period of time sufficient to meet federal, state, and local regulations; sponsor requirements; and organizational policies. The consent form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. **The consent form should be written at no higher than an 8th grade reading level**, and it is recommended that it be written in the third person (please see the example on the RD&C website). A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp.

Necessary attachments:

- ☐ Signed Student Consent to Release of Educational Record Form (students and medical residents only);
- ☐ Investigator Letter of Assurance of Compliance; (all researchers)
- ☐ Consent form, or Waiver or Alteration of Informed Consent Requirements (Form IC 702-B)
- ☐ Key Personnel Listing
- ☐ Surveys, interview questions, etc. (if applicable);
- ☐ Printed web screens (if survey is over the Internet); and
- ☐ Advertisements (flyer, social media postings, email/letters, etc.).

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

Signatures:

(Principal Investigator)	Date:
(Student Advisor)	Date:

All students and medical residents must list a faculty member as a student advisor on the first page of the application and must have that person sign the application.

Requirements for submitting proposals:
Additional information can be found on the IRB website at: http://und.edu/research/resources/human-subjects/index.cfm

Original, signed proposals and all attachments, along with the necessary number of copies (see below), should be submitted to: Institutional Review Board, 264 Centennial Drive Stop 7134, Grand Forks, ND 58202-7134, or brought to Room 106, Twamley Hall.

Required Number of Copies:

- Expedited Review: Submit the signed original and 1 copy of the entire proposal.
- Full Board Review: Submit the signed original and 22 copies of the entire proposal by the deadline listed on the IRB website: http://und.edu/research/resources/human-subjects/meeting-schedule.cfm
- Clinical Medical Subcommittee and Full Board Review: Submit the signed original and 24 copies of the entire proposal by the deadline listed on the IRB website: http://und.edu/research/resources/human-subjects/meeting-schedule.cfm

Prior to receiving IRB approval, researchers must complete the required IRB human subjects' education. Please go to: http://und.edu/research/resources/human-subjects/human-subject-education.cfm

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

In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 5 copies if the proposal is clinical-medical. If the proposed work is being conducted for a pharmaceutical company, 5 copies of the company's protocol must be provided.

Appendix B

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

I Susan H. N. Jeno
(Name of Investigator)

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

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

1. Should I wish to make changes in the approved protocol for this project, I will submit them for review PRIOR to initiating the changes. (A proposal may be changed without prior IRB approval where necessary to eliminate apparent immediate hazards to the subjects or others. However, the IRB must be notified in writing within 72 hours of any change, and IRB review is required at the next regularly scheduled meeting of the full IRB.)

2. If any problems involving human subjects occur, I will immediately notify the Chair of the IRB, or the IRB Coordinator.

3. I will cooperate with the UND IRB by submitting Research Project Review and Progress Reports in a timely manner.

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

Investigator Signature

Date

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

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD[1]

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The title of the study to which this release pertains is EMG analysis of Latissimus Dorsi, Erector Spinae and Middle Trapezius Muscle Activity During Trunk Rotation.

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

ID # _____ Printed Name _____

Date _____ Signature of Student Researcher _____

[1]Consent required by 20 U.S.C. 1232g.

ID #_____

Patient Questionnaire

Name_____

Date of Birth_____ Height_____ Weight_____

Dominant Arm_____

Sensitivity to: Latex Y N Isopropyl Alcohol skin sensitivity Y N

If yes, please explain_____

_____

Do you have any history of shoulder pain/pathology? Y N

If yes, please explain_____

_____

Do you have any history of back or spinal disc/pathology? Y N

If yes, please explain_____

_____

Are you pregnant? Y N

Do you have any condition for which lying on your stomach would be a problem? Y N

If yes, please explain_____

_____

All the information provided in this questionnaire has been answered accurately and to the best of my knowledge.

_____

Signature of participant Date

Appendix C

THE UNIVERSITY OF NORTH DAKOTA
CONSENT TO PARTICIPATE IN RESEARCH

TITLE:	*Electromyographic Analysis of Latissimus Dorsi, Erector Spinae and Middle Trapezius Muscle Activity During Trunk Rotation*
PROJECT DIRECTOR:	*Susan H N Jeno, PT, PhD*
PHONE#	*701 777-3662*
DEPARTMENT:	*Physical Therapy*

STATEMENT OF RESEARCH

A person who is to participate in the research must give his or her informed consent to such participation. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only subjects who choose to take part. Please take your time in making your decision as to whether to participate. If you have questions at any time, please ask.

WHAT IS THE PURPOSE OF THIS STUDY?

You are invited to be in a research study about muscle activity during trunk rotation because you are a student in the UND School of Medicine and Health Sciences.

The purpose of this study is to determine the level of muscle activity of several back muscles including latissimus dorsi, middle trapezius, and erector spinae muscles with trunk rotation with and without fixation of the upper extremities. The conclusions drawn from this study will allow practicing clinicians to better develop the exercise programs provided to their clients with back or upper extremity pathology.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 100 people will take part in this study at the University of North Dakota

HOW LONG WILL I BE IN THIS STUDY?

Your participation in the study will last approximately 75 minutes. You will need to visit the Department of Physical Therapy 1 time to participate in this study.

WHAT WILL HAPPEN DURING THIS STUDY?

After you agree to participate in this study, you will be asked to complete a questionnaire pertaining to information about you. You are free to skip any question that you would prefer not to answer. This study will involve the collection of electrical activity of some of the muscles in your back while you perform trunk rotation activities while standing upright and while on your hands and knees. In order to access the muscles on your back and for comfort during the test

Approval Date: AUG 16 2019
Expiration Date: AUG 14 2020
University of North Dakota IRB

Date: __ __ __ __
Subject Initials: _ _ _

procedures, female subjects will be asked to wear shorts and a swimsuit top or sports bra to expose the appropriate areas of your back for placement of the electrodes. For male subjects, you will be asked to wear shorts and remove your shirt to expose your back. You will be asked to lie on your stomach on a padded table and marks will be placed on your skin where the electrodes will be placed over the muscles on both sides of your back (see attached diagram). Pre-gelled, self-adhesive electrodes placed over the muscles will collect the electrical signal the muscles produce when they contract. In order to obtain the best signal from the muscles, the skin where the electrodes will be placed will be prepared in standard fashion which includes clipping any excess hair with an electric razor, lightly rubbing the skin with fine grit sandpaper followed by cleaning the area with rubbing alcohol wipes. This process is intended to reduce the resistance of the skin to allow of better signal collection by the electrodes. Wireless transmitters will be attached to the electrodes. Elech:ical signals are sent from the transmitter to a computer for recording and analysis.

Once the electrodes are in place, you will be asked lie on your stomach and to perform a maximal voluntary contraction (MVC)- a full effort contraction - of each of the muscles which will be used for comparison of muscle activity. A hand-held device will be used to record the amount of force created by each contraction. For each MVC, you will be asked to push against a fixed device as hard as you can for 5 seconds. This will be repeated 3 times for each muscle with 30-60 seconds rest between trials. You will be allowed to practice the testing procedure before data collection.

Following the collection of the MVC data, you will be asked to perform a series of trunk rotations both to the right and to the left from a standing position with arms at your side, and holding a bar against a wall in 3 different positions and from a position on your hands and knees. Each rotation will be timed with a metronome for a 3 count motion to obtain full rotation and a 3 count motion to return to a resting position. You will be allowed to practice to be sure the timing of the motions is clear. The rotation measurements will be randomized through a computer randomization program. You will perform 5 repetitions of each rotation timed by a metronome for each trial. You will be given 30-60 seconds rest between each trial. The rotational motions will be recorded on the computer for use in analyzing the data.

WHAT ARE THE RISKS OF THE STUDY?

Although there is some degree of risk involved in physical activity testing, the researchers believe the risk of injury and discomfort is minimal; however, minor muscle soreness may occur following repeated activity. The use of a spotter will minimize any risk from loss of balance during the activity. Reddening of the skin in the areas where the electrodes are placed is possible due to the adhesive material. The EMG equipment will only monitor muscle activity and the equipment will not cause discomfort. If at any time you experience pain, discomfort, fatigue, or any other uncomfortable symptoms, you may stop your participation in this study.

Subject Initials: _ _ Date _

WHAT ARE THE BENEFITS OF TIITS STUDY?

You may not benefit personally from being in this study. However, we hope that, in the future, other people might benefit from this study and these benefits include but are not limited to 1) gaining a better understanding of the muscle activity in the back muscles with trunk rotation and 2) increasing the current level of knowledge of muscle activity and motion patterns of these muscles during this activity. This will begin to provide more information on how to design treatment programs that include these muscles.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not have any costs for being in this research study.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study.

WHO IS FUNDING THE STUDY?

The University of North Dakota and the research team are receiving no payments from other agencies, organizations, or companies to conduct this research study.

CONFIDENTIALITY

The records of this study will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Your study record may be reviewed by Government agencies, the UND Research Development and Compliance office, and the University of North Dakota Institutional Review Board.

Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained as each subject will be given a randomly selected identification number at the beginning of the study, which will be known by the researchers only. All information involving the research study, digital and hard copy, along with a hard copy of the statistically analyzed data, will be secured in a locked cabinet inside the Department of Physical Therapy at the University of North Dakota. Unless the data is required for future studies, the information will be destroyed via shredding three years after the study has been completed.

If we write a report or aiticle about this study, we will describe the study results in a summarized manner so that you cannot be identified.

EMG data and digital recordings of the motions performed as part of this research study will be coded in the same manner as the information form. Your name will not be associated with the digital file. All digital information will be stored separately form the consent forms in a secure location in the Department of Physical Therapy. After a period of 3 years from the completion of the study, the digital data will be deleted from all disks/drives. You are free to look at the digital recordings of your muscle activity at the conclusion of the data collection period.

Date
Subject Initials:

COMPENSATION FOR INJURY

In the event that this research activity results in an injury, treatment will be available including first aid, emergency treatment and follow-up care as needed. Payment for any such treatment is to be provided by you (you will be billed) or your third-party payer, if any (such as health insurance, Medicare, etc.) No funds have been set aside to compensate you in the event of injury. Also, the study staff cannot be responsible if you knowingly and willingly disregard the directions they give you.

IS THIS STUDY VOLUNTARY?

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota.

The investigators or you may stop the experiment at any time if you are experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to your health. If you agree to participate , you will be allowed to stop your participation in this study at any time without prejudice or jeopardizing any future relationships with the UND Department of Physical Therapy.

CONTACTS AND QUESTIONS?

The researcher conducting this study is Susan H. N. Jeno, PT, PhD. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Susan Jeno at 701 777-2831 during the day.

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at **(701) 777-4279.**

- You may also call this number about any problems, complaints, or concerns you have about this research study.
- You may also call this number if you cannot reach research staff, or you wish to talk with someone who is independent of the research team.
- General information about being a research subject can be found by clicking "Information for Research Participants" on the web site: http://und.edu/research/resources/human-sub jec ts/research -participants .cfm

I give consent to be videotaped during this study.

Please initial: **Yes** **No**

Approval Date: - - AUG 15 2019 __- -
Expiration Date: ___ AUG 14 fffl _____
University of North Dakota IRB

Date_ - -
Subject Initials: _ _

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name: _____

_____ _____

Signature of Subject Date

I have discussed the above points with the subject or, where appropriate, with the subject's legally authorized representative.

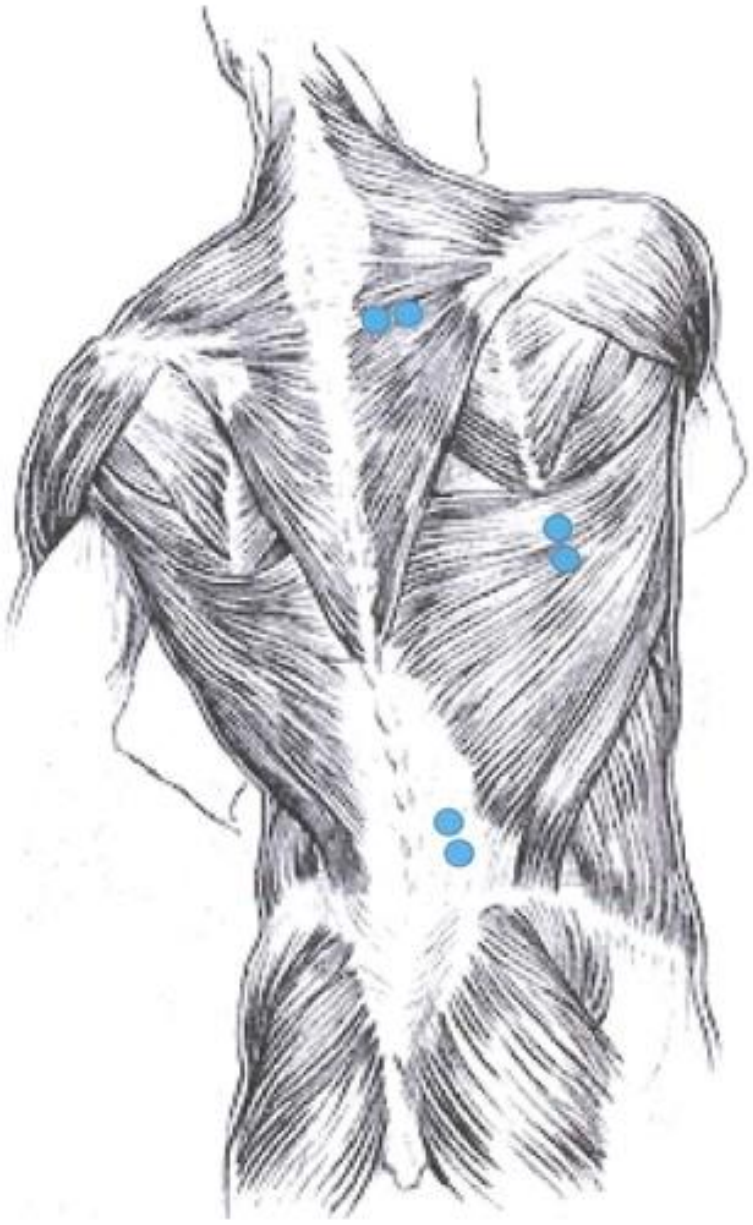
_____ _____

Signature of Person Who Obtained Consent Date

Approval Date: AUG 15 2019
Expiration Date: AUG 14 2020
University of North Dakota IRB

Date: _____
Subject Initials: _____

Location of electrodes on your back. Electrodes are placed on both sides of the back (small circles).



Approval Date: AUG 15 2019
Expiration Date: AUG 14 2020
University of North Dakota IRB

Date_
Subject Initials-:

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