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EMG Analysis of Latissimus Dorsi, Middle Trapezius, and Erector Spinae Muscle Activity During Spinal Rotation: A Pilot Study

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This Scholarly Project, submitted by Alyssa Wagner, Zachary Huot, Brandon Forister, and Tyler Snellings in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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ABSTRACT

Purpose/Hypothesis: Rotation of the spine is a common movement used to complete daily activities and participate in sports. As a contributing factor to back injuries, the performance of spinal rotation is an important consideration for the rehabilitation of current and prevention of future back injuries. Muscles involved in spinal rotation have been researched, though limited findings exist for one of the largest back muscles, the Latissimus Dorsi (LD). The LD muscle contributes to many movements of the trunk and limbs given its multiple attachment sites including the pelvis, ribs, scapula, and humerus. Influence of the LD on spinal rotation has not been thoroughly researched yet, but results will play a role in the patient's plan of care when treating back pain. The purpose of this study was to increase understanding of muscle activity during spinal rotation and compare muscle activity in fixed and non-fixed positions.

Materials/Methods: Muscle activity was recorded using EMG surface electrodes while subjects performed left and right rotation in both standing and quadruped positions. Ten spinal rotation test positions (standing non-fixed rotation right/left, quadruped rotation right/left, and standing rotation right and left with arms fixed on the wall at 45°, 90° and 120° of shoulder flexion) were initiated by movement of the pelvis. Using Maximal Voluntary Contraction (MVC) to normalize muscle activity, findings were analyzed for significance at α=.05.

Results: When significant differences were found, the perspective muscle showed increased muscle firing compared to other muscles listed. Significance was found in the right LD between non-fixed right and left rotation and fixed right rotation. During non-fixed right and left rotation as well as fixed right rotation, the right MT showed significance. Left MT showed significant differences were shown when comparing non-fixed right rotation to fixed right and left rotation. The MT was also significant with non-fixed left rotation compared with fixed right and left rotation. Significance was found in the right ES when comparing right rotation at 45° to left

rotation at 45° and 90°, as well as right and left rotation at 120°. Significance was shown with right ES when comparing right rotation at 90° to right and left rotation at 120°. As for the left ES, results were significant when comparing left rotation at 45° to left rotation at 90° and 120°.

Discussion/Conclusion: The findings suggest the LD contributes significantly to fixed position contralateral spinal rotation when compared to MT and ES. In fixed positioning, the LD may be mechanically advantaged with a positive length tension relationship to contribute to spinal rotation as established with the trends correlating with increased LD muscle activity during 90 and 120 degree fixed spinal rotation. Whereas in non-fixed positioning, the LD may be at a disadvantaged due to length tension relationship and or the lack of stability from the upper extremities. to contribute to spinal rotation compared to ES.

Clinical Relevance: This pilot study looks at the effects of the LD, MT, and ES during spinal rotation. This study is a part of ongoing research to assess the rotational movement strategies in individuals without low back pain. During daily activities, many movements require spinal rotation movements such as putting dishes away in cupboards, taking out laundry, reaching for groceries at the store, and looking behind us when driving to check for upcoming traffic. Our findings suggest clinicians should consider the LD as a possible contributor to spinal rotation. Treatment of patients with back pain should involve thorough examination and specific interventions addressing LD strength and mobility.

CHAPTER I

INTRODUCTION

Spinal rotation, though being a very common motion of the body, is poorly understood. Spinal rotation is argued to be an essential feature for an efficient two-step gait pattern.[1] Studies show that two-thirds of people in the United States will experience low back pain at least once in their life, which is the second most common reason for scheduling a physician visit.[2] In 2010, the healthcare system estimated to have $34 billion in direct medical costs spent on low back pain alone.[3] Not only does low back pain have a significant impact on the economy, but on an individual's quality of life and functional level as well. When polling patient's, 23% of those polled used the term "disabling" to classify their level of back pain.[4] It is estimated that among the working population (age 20-64), more than 26 million Americans have frequent low back pain, whereas among Americans aged 65 and older, almost 60 million have frequent low back pain.[4] Lifting in the occupational setting is found to be one of the major risk factors of low back pain. As many as 30% of workers lift in a manner that is harmful to their back. Spinal rotation often coincides with lifting, and is associated with 60% of low back injuries.[5] When a low back injury occurs, physical therapists find themselves being the first stop on a physician's referral note.[2]

Currently, physical therapists use exercises targeting transversus abdominis, internal and external oblique abdominals, erector spinae (ES), quadratus lumborum, pelvic floor muscles, multifidus, and the diaphragm to help improve low back pain.[6] These muscles have all been shown to help in the improvement of low back pain, but there is a possibility that rehabilitation of the LD could also improve low back pain, as well as help with proper stabilization. When low back stability is an issue, therapists need to consider targeting LD as well as the other aforementioned muscles when patients with low back pain come into the clinic.

Problem Statement

Research regarding the LD is primarily focused on upper extremity movements with limited research on the LD's influence during spinal rotation.[7] Currently the primary actions of the LD are recognized as shoulder adduction, medial rotation and shoulder extension. With the attachment on the spinous processes of T7 to L5 vertebrae, it is expected that the LD has an influence on spinal rotation.[7]

The ES muscle group is commonly recognized as the primary agonist of spinal rotation due to its origins of posterior iliac crest and sacrum as well as the sacral and inferior lumbar spinous processes. It's insertion to the medial, intermediate, and lateral column attaching to the corresponding lateral ribs and transverse processes makes an angle of pull that is ideal for spinal rotation. Latissimus dorsi and middle trapezius (MT) originate on the spinous processes of the vertebrae.[7] These attachments potentially allow the LD and MT to contribute to spinal rotation opposite ES. Therefore, understanding the magnitude of LD muscle activity during spinal rotation may impact the types of rehabilitative interventions for patients with spinal pathology and back pain.

Purpose of Study

The purpose of this study was to analyze muscle activity of back muscles (LD, MT and ES.) while subjects perform spinal rotation in positions with and without fixation of the upper extremities. Evidence from this study was valuable in defining the extent of LD activity in spinal rotation, which may lead to improved interventions for clients with low back pain.

Significance of Study

A greater understanding of the contribution LD makes in spinal rotation would highly benefit the field of physical therapy. Standard interventions for back pain address muscular imbalances, which contribute to excessive stress and strain on tissues and structures of the spine. The findings of this study will help physical therapists better understand the contributions of LD, MT, and ES to spinal rotation. Based on the findings of the study, future research may be appropriate to investigate muscle activity in patients with low back pain.

Research Questions

1.) Will LD activation during fixed upper extremity spinal rotation differ significantly than non-fixed upper extremity spinal rotation?

2.) Will LD activity significantly differ than ipsilateral MT and ES activity during fixed upper extremity spinal rotation?

3.) Will LD activity significantly differ than ipsilateral MT and ES activity during non-fixed upper extremity spinal rotation?

4.) Will LD activity significantly differ from MT and ES with spinal rotation at varying degrees of UE fixation at 45°, 90°, and 120° of shoulder flexion?

Null Hypothesis

1.) There is no significant difference in LD EMG activity (%MVC) between fixed and non-fixed spinal rotation.

2.) There is no significant difference in LD activation compared to the ipsilateral MT and ES during fixed upper extremity spinal rotation.

3.) There is no significant difference in LD activation compared to the ipsilateral MT and ES during non-fixed upper extremity spinal rotation.

4.) There is no significant difference in LD activation compared to MT and ES during spinal rotation with UEs fixed at 45°, 90°, and 120° of shoulder flexion.

Alternative Hypothesis

1.) There is a significant difference in LD EMG activity (%MVC) between fixed and non-fixed spinal rotation.

2.) There is a significant difference in LD activation compared to the ipsilateral MT and ES during fixed upper extremity spinal rotation.

3.) There is a significant difference in LD activation compared to the ipsilateral MT and ES during non-fixed upper extremity spinal rotation.

4.) There is a significant difference in LD activation compared to MT and ES during spinal rotation with UEs fixed at 45°, 90°, and 120° of shoulder flexion.

CHAPTER II

LITERATURE REVIEW

Spinal pathologies can be difficult, in that it can be arduous to determine the specific cause, due to many muscular and ligamentous attachments throughout the entirety of the spine. To have positive outcomes and provide an accurate rehabilitation process, it is crucial to have a vast knowledge of spinal anatomy and the function of the various muscles and surrounding structures.

The action of LD, a trunk muscle, on spinal rotation is often overlooked during the rehabilitation process. The LD has a wide range of attachments including thoracic spinous processes, iliac crest, ribs, scapula, and humerus.[7] When looking at the role of the LD during movement, actions on the humerus are often given more attention than any action on the spine. With these attachments in mind, spinal movement is a significant possibility, with its greatest effect on axial rotation.

Trunk rotation is involved in a variety of activities, including walking, taking out laundry, getting groceries off the shelf, lifting and carrying children, as well as sporting activities. With this in mind, trunk rotation is a key risk factor for low back pain and low back injuries. Trunk rotation is a motion that involves thoracic and lumbar vertebrae.[12] Chronic low back pain, particularly of musculoskeletal origin has become a major focus and concern for employers and medical health professionals. Although several factors have been advanced to help explain chronic low back pain, there is little research regarding the specific muscle activity and where the low back pain is originating.

One major theory, the biomechanical model, proposes that chronic low back pain maybe the result of muscle asymmetries or abnormal recruitment of muscles for activities. This theory

suggests that abnormal EMG activity is a result of poor posture and guarding that develops in response to an original injury.[13] It is proposed that having irregular muscle activity contributes to spinal instabilities resulting in nerve endings getting impinged and producing the pain. It is important to evaluate the dynamic positions during EMG activity of the musculoskeletal system rather than just static positions. Static positions are not representative and cannot be generalized to what occurs during movement patterns in activities of daily living.[13]

When it comes to the action of LD, there is a significant lack of information in regards to spinal motion. Research studies that have investigated spinal rotation and the LD have been unsuccessful in determining its role in motion of the spine, because of this, a study is needed to individually assess the role of LD in relation to rotation of the spine.

Spinal Anatomy

The LD is the broadest muscle of the back, spanning from it's inferior origin to the insertion on the intertubercular groove of the humerus. There are multiple points of origin of the LD, including the following: superior iliac crest, lumbar fascia, spinous processes of T7-T12, ribs 9-12 interlocking with the external oblique muscle, and the inferior angle of the scapula.[7] Throughout the muscle, fibers are differentiated by their alignment. Superior muscle fibers are more horizontal, but as one moves closer to the pelvis, fibers become more vertically oriented. The thoracodorsal nerve (nerve roots C6-8) is responsible for innervation of the LD. Actions of the LD when the humerus is not fixed include the following: medial rotation, extension, and adduction of the humerus. When the humerus is fixed, the LD takes on a different role by 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), lateral flexion of the trunk, and hypothesized contralateral rotation of the trunk, and when working bilaterally extension of the trunk.[7] The most powerful actions of the LD are found in overhead activities, such as adducting a raised arm against resistance, and elevation as seen in climbing.[18] It has also been found that LD may have activity during forced expiration during strenuous activity.[19]

With the multiple and broad attachment points in the lumbopelvic region and on the proximal humerus, it is apparent LD has the largest moment arm acting on the spine.[19] Researchers found that 64% of the force generation of the LD comes from the large portion of the muscle located over the lumbopelvic region.[20] Compared to the other posterior trunk muscles, the LD muscle is capable of lumbopelvic movement with increased efficiency, this is due to its long lever arm and broad attachments. By maximizing the distance between the two points of attachment of LD, a tensile force is applied to the thoracolumbar fascia, that has a potential to impact spinal motion.

As stated before, the LD muscle works to extend, medially rotate, and adduct the humerus. These actions are emphasized during bending and lifting tasks; as an object is lifted closer to the body, the lumbar spine extends.[20] Passive movement of the upper extremities occurs during lifting when there is not proper engagement of the LD. Lack of the LD activation leads to decreased control of the object being lifted, which causes increased strain on the extensor muscles of the spine. The LD acts to distribute equal forces on the lumbar spine, specifically during bilateral lifting tasks. Utilization of this information can help minimize spinal pathology by preventing unnecessary stress on lumbopelvic tissues by using correct body mechanics.[19]

Latissimus Dorsi has a prominent influence on the spine, because of this, it is essential to understand the specific spinal anatomy. 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 as a corresponding rib, 5 lumbar vertebrae, 5 sacral vertebrae, and 4 coccygeal vertebrae (sacral and coccygeal segments are usually fused in the adult skeleton). Each vertebrae is abbreviated alphanumerically cranially to caudally, C1-Co4. Intervertebral discs provide shock absorption and distribution of forces and are present between each vertebra throughout the non-fused portion of the spinal column except between the levels of the occiput C1 and C1-C2.[20] Connecting the axial skeleton to the appendicular skeleton occurs at 4 joints, one on each side of the body both superiorly and inferiorly, the sternoclavicular joints superiorly and the sacroiliac joints inferiorly.[20]

Typically vertebral segments are divided into three divisions: body, pedicles, and laminae. The vertebral body is responsible for weight bearing throughout the spinal column. Descending through the spine, the vertebral bodies become progressively large, increasing their ability to bear weight. The vertebral canal lies posterior to the vertebral body; its function to enclose the spinal cord. The posterior portion of the vertebrae is comprised of the spinous and transverse processes, laminae, and articular processes. The spinous and transverse processes are the location of the attachment for various muscular and ligamentous structures. Forming the bridge between the spinous and transverse process is the lamina, whereas the pedicles connect anterior and posterior structures of the vertebrae and act to distribute muscle forces.

The cervical vertebrae are comprised of 7 segments, these vertebrae have a small body, reflecting the fact that they carry the least amount of body weight. Cervical vertebrae usually have a bifid (Y-shaped) spinous process, which is unlike the thoracic and lumbar segments. The spinous processes of the C3–C6 vertebrae are short, but the spine of C7 is much longer. The transverse processes of the cervical vertebrae are sharply curved (U-shaped) to allow for passage of the cervical spinal nerves. Each transverse process also has an opening called the transverse foramen to allow for the vertebral artery to run through. The first and second cervical vertebrae anatomically differ than the others, giving each a distinctive appearance. The first cervical (C1) vertebra is also called the atlas, because this is the vertebrae that supports the skull on top of the vertebral column. The C1 vertebra does not have a body or spinous process. Instead, it is ring-shaped, consisting of an anterior arch and a posterior arch. The transverse processes of the atlas are longer and extend more laterally than the transverse processes of the other cervical vertebrae. The superior articular processes face upward and are deeply curved for articulation with the occipital condyles on the base of the skull. The inferior articular processes are flat and face downward to join with the superior articular processes of the C2 vertebra. The second cervical (C2) vertebra is called the axis, because it serves as the axis for rotation when turning the head toward the right or left. The axis resembles typical cervical vertebrae, but is easily distinguished by the dens (odontoid process), a bony projection that extends upward from the vertebral body.

The dens joins with the inner aspect of the anterior arch of the atlas, where it is held in place by transverse ligament. [23]

Cervical vertebra C3-C6 change structure when compared to C1 and C2. The C3-C6 vertebrae have vertebral bodies that are small with the superior surface being concave and the inferior surface convex. The concave and convex portions of the vertebral body are designed to accommodate the cervical intervertebral (IV) discs. The IV disc thickness, disc orientation, and small amount of surrounding mass in the neck give the cervical region the greatest range of motion of all the spine. The vertebral foramen also widens at this point to accommodate for the cervical enlargement of the spinal cord. The superior facets of the articular processes are oriented superoposteriorly and the inferior facets are directly inferoposteriorly. These vertebrae also have bifid spinous processes which allow muscles to attach bilaterally. The C7 vertebrae is named vertebra prominens due to its long spinous process and is not bifid. Vertebra C7 has large transverse processes with smaller transverse foramina and begins the transition to the thoracic vertebrae.[21]

Inferior to the cervical vertebrae are the thoracic vertebra. Thoracic vertebrae have transverse processes which are larger in size than the lumbar and cervical vertebrae (excluding C1); these transverse processes provide support for the rib cage due to their articulation with the ribs. The thoracic vertebrae have spinous processes which are angles inferiorly into the transverse plane of the vertebrae below and pedicles that are pointed directly posterior.

In the lumbar region, wide vertebral bodies are required to support the weight of the upper body and form a strong base of support. Short and thick pedicles and lamina in the lumbar region create a stable and sturdy posterior wall of the vertebral canal. Lumbar transverse processes project laterally whereas the broad, rectangular shaped lumbar spinous processes project straight posteriorly. A collection of nerve roots called the cauda equina occurs at the base of the spinal cord which is housed within the spinal canal. The cauda equina begins around the level of L2 and extends into the triangular sacral canal which provides the protection the nerve roots require to remain functional.[21]

The sacral portion of the spinal column follows the lumbar region. A typical sacrum is fused and composed of five vertebral segments whose main purpose is to transmit the weight from the vertebral column to the structures of the pelvis. The superior sacrum displays a large broad surface area to articulate with the 5th lumbar vertebrae. The pedicles of the sacrum are thick and extend laterally which allows them to increase support and stability in the region. Along with increased pedicle support, several connective tissue structures and muscles attach to the sacrum and vertebrae to provide additional stability and movement. The coccyx is attached to the inferior end of the sacrum.

The main joints located in the lumbopelvic region are the zygapophyseal joint, intervertebral joints, and sacroiliac joints. The structures share a common function of allowing the body weight, frictional, and ground reaction forces to be transferred throughout the entire lumbar spine.[20] The intervertebral discs are also important structures in assisting in distribution of force and shock absorption.[21] The discs contain the nucleus pulposus which is the viscous center portion and is surrounded by dense, protective annulus fibrosus which functions to contain the nucleus pulposus within the intervertebral disc. The nucleus pulposus shifts when weight is distributed to the intervertebral disc and adjusts to allow for better distribution of the forces acting on the body.[21]

Due to the amount of support supplied by the lumbosacral spine, increased stabilization is needed in this region. The increased stabilization is provided by an aponeurotic connective tissue called the thoracolumbar fascia (TF) which is the main component of the fascial structure that surrounds the ES muscles to provide additional support and stability for the lower spinal segments. The TF also plays an important role in the stability of bilateral sacroiliac joints through the attachments of the LD and gluteus maximus.[21] The LD takes origin from the TF, which attaches to the lumbar spinous processes, therefore giving the LD an indirect articulation with the lumbar spinous processes. This fascia also attaches to the ilium near the posterior superior iliac spine as well as the sacrum and provides a cover to the posterior surface of the ES. There may be many factors contributing to tension and stiffness of the TF due to the multiple insertions into this

broad connective tissue structure. Limited range of motion of the lumbar spine is often a result of stiffness and tension of the TF.[22]

Other relevant musculature of the posterior trunk that may also contribute to spinal rotation are the MT, ES, and the multifidus/rotatores. The MT has similar muscle fiber alignment to the superior portion of the LD. The trapezius is comprised of upper, middle, and lower fibers. The middle fibers run laterally from the T1-5 spinous processes and supraspinous ligaments, the origin, to its insertion on the superior lip of the crest on the spine of the scapula and the medial acromial margin. Cranial nerve XI (spinal accessory nerve) provides motor innervation to the MT which is active during scapular retraction, scapular stabilization.[19]

The ES group is divided into three separate muscles (lateral to most medial): iliocostalis, longissimus, and spinalis muscles. The origin of the ES muscles is a broad tendon that attaches to the posterior iliac crest, sacrum, sacroiliac ligaments, sacral and inferior lumbar spinous processes, as well as supraspinous ligaments. Dissection of the iliocostalis insertion by spinal section is as follows: the lumborum portion inserts on the angle of ribs 7-12, the thoracic portion inserts on the angle of ribs 1-6 and transverse process of C7, and the cervical portion inserts on the transverse processes of C4-C6. The longissimus insertions are dissected by spinal section as well, the thoracic portion inserting on the transverse process and ribs in the thoracic region, the cervical portion insertion on the transverse processes in the cervical region, and the capitis portion inserting on the mastoid process. Lastly, the thoracis and cervicis portion of the spinalis muscle inserts on the spinous processes of the middle to upper thoracic spine and the capitis portion continues to blend with semispinalis capitis. For the purpose of this study, these muscles will be referred to as a group called the ES.[7]

The ES group has been found to be the most prominent stabilizer of the lumbar spine when the muscles contract isometrically.[23] The ES works bilaterally to extend the head, neck, and trunk. The whole muscle group works eccentrically to control the descent of the trunk when bending forward. When working unilaterally, the ES laterally flexes and ipsilaterally rotates the spine. While deeper musculature aid in anchoring the lumbar vertebrae to the ilium, the ES aides

in rotation of the lumbar spine through its prominent lever arm from its centrally located origin to its laterally located insertion. The ES muscles have a posterior direction of pull to reduce anterior shearing forces that may occur between lumbar vertebrae and the sacrum. The ability to check rotary forces and increase compressive forces between various vertebral segments are added functions of the deep ES muscles in the lumbar region.[19] With the ES muscular anatomy and functions in mind, we analyzed the ES muscles utilizing EMG.

Surface Electromyography

Surface EMG is a noninvasive technique used to measure muscle activation. Action potentials are produced by local muscle fibers in their respective motor units.[17] With more motor unit recruitment, more action potentials are released, and the increased number of action potentials lead to a greater external force produced by the given muscle. The action potentials are picked up by electrodes on the surface of the skin. Those electrodes pick up the sum of the action potentials signals and are amplified using a EMG instrument to give the conduction volume. The measured volume does not directly measure the amount of force that the respective muscle produces, but the overall electrical conduction and activation that is produced giving a glimpse of the muscle's innervation. For this reason, to compare a muscles external force and electrical activity, maximal voluntary contractions (MVC) must be performed under EMG. This allows a relationship between muscle activity measured by EMG and muscle force through all submaximal movements.

The placement of electrodes is very important and should be directly over the underlying motor unit. This will reduce the interference of signals picked up from surrounding muscles. Ideally, placement of electrodes should be aligned parallel to muscle fibers in a position with the least amount of tissue between the target muscle fibers and the electrode.[8]

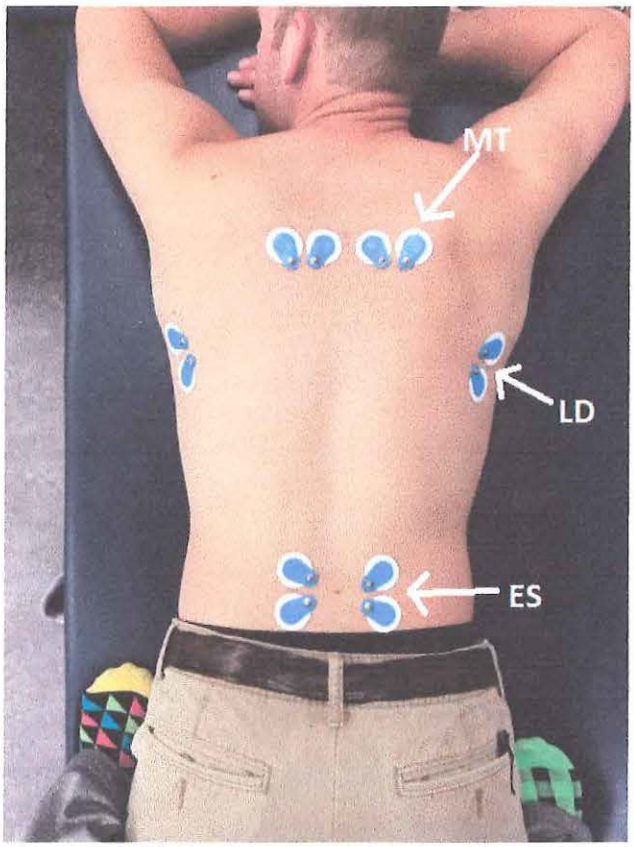


Fig. 1: Posterior surface anatomy of LD, MT, and ES

Skin impedance is a possible factor for skewed data associated with EMG. Skin impedance is the resistance of the tissue directly under the electrode to the direct current.[8] Direct current is affected by the moisture of the skin, oil, hair, adipose tissue, dead skin cells, or anything between the electrode and the target muscle. Optimal skin impedance should be as low as possible. For research purposes, impedance at each electrode site should be less than 10,000 Ohms.[8] To reduce impedance factors, the skin should be shaved, abraded with fine grit sandpaper, and cleaned with alcohol. Once the skin is properly prepared, the electrodes are inspected to ensure that the conductive medium is not dry and that the adhesive property of the electrode will allow a secure fit. Following the application of proper electrode placement, a maximal voluntary contraction (MVC) was performed by the subject.[15]

Maximal Voluntary Contraction

An MVC is the largest amount of force that a muscle is able to generate with an isometric force. The International society of Electrophysiology and Kinesiology sets the standards for documenting the force created by a muscle. A subject should practice creating a MVC prior to collecting the MVC data. Research has shown that there is a 20-30% decrease in MVC performance if proper training is not initiated prior to collecting data. Feedback, such as verbal and visual cueing has been found to impact MVCs, therefore should be avoided in order to minimize negative effects of feedback on the MVC, so that the data collection is accurate.

Collecting MVC data requires the subject to exert maximal effort in a specific motion. The best test position for LD activation is conventional shoulder extension in the prone position. Researchers found the average MVC was 92.62% in this position, while other positions such as caudal shoulder depression in prone, body lifting with shoulder depression in seated, and trunk bending to the right in lateral decubitus position each averaged a lesser force. It was concluded that these findings are relevant and were appropriate to include in the present study.[15]

Testing the ES MVC uses traditional manual muscle testing (MMT) positions. The subject lies in prone position with hands placed at their side. The researcher stabilizes at the ankles and pelvis. The subject is instructed to raise their chest off the table using extension of the spine as far as they are able.[16] Testing the MVC for MT is done also using the traditional approach of MMT. The subject is placed in prone position with upper extremities abducted to 90 degrees. Resistance is applied by a researcher at the distal elbow. The opposite side of the trunk is stabilized during the muscle contractions.[16]

Muscle Function

The low back is a large area of the body very susceptible to pain and injury. It is important to be cognizant of which forces are acting during a movement pattern on different areas of the body to determine where the dysfunction or pain is originating from as well as understanding that poor motor control may lead to common pathologies. Furthering the

knowledge and research about how the LD, MT, and ES function during spinal rotation will allow for advanced interventions and targeting the muscles that may be a source of pathology.

Muscles are able to contract in three ways, concentric, eccentric, and isometric. Concentric meaning the muscle shortens against a force and the distal segment moves toward the proximal segment. This is typical of muscles that contract due to the sliding filament mechanism, and it occurs throughout the muscle. Such contractions also alter the angle of the joints to which the muscles are attached, as they are stimulated to contract according to the sliding filament mechanism.[14] Eccentric is the opposite of concentric, so the muscle lengthens against a force and the distal segment moves away from the proximal segment. Such contractions decelerate the muscle joints acting as "brakes" to concentric contractions and can alter the position of the load force. These contractions can be both voluntary and involuntary. During an eccentric contraction, the muscle elongates while under tension due to an opposing force which is greater than the force generated by the muscle. Rather than working to pull a joint in the direction of the muscle contraction, the muscle acts to decelerate the joint at the end of a movement or otherwise control the repositioning of a load.[14] Lastly, isometric contractions occur when the muscle generates a force without shortening or lengthening the muscle. The force generated during an isometric contraction is wholly dependant on the length of the muscle while contracting. Maximal isometric tension is produced at the muscle's optimum length, where the length of the muscles sarcomeres are on the plateau of the length-tension curve.[14]

Testing Positions

The ability of muscles to function in both non-fixed and fixed positions affects how a muscle can operate. This refers to a muscle being in a closed-chain movement vs as open-chain movement. Though there is limited data regarding closed-chain and open-chain movements with the LD muscle, there are plenty of other studies in other areas of the body looking at the effect of closed-chain and open-chain movements. It is thought that closed-chain movements stabilize the moving joint more so than open-chain movements which means closed-chain movements may be less demanding on the moving joint when compared to open-chain movements. It has been shown

that during closed-chain movements of the tibiofemoral joint, more balanced muscle activation and more stabilization for the joint in motion occur as compared to open-chain movements.[24] Though the tibiofemoral joint is not directly related to the LD, the muscle under investigation in this study, this information provided a good foundation of what to expect from different closed-chain and open-chain test positions.

Right Non-Fixed Position: The subject was in the standing position with their feet shoulder-width apart and arms crossed in front of their chest. The subject moved the right side of their pelvis posteriorly in the horizontal plane to initiate right lumbar spine rotation relative to the participant's shoulders. The subject's feet remained planted while they completed this motion.

Left Non-Fixed Position: The subject was in the standing position with their feet shoulder-width apart and arms crossed in front of their chest. The subject moved the left side of their pelvis posteriorly in the horizontal plane to initiate left lumbar spine rotation relative to the participant's shoulders. The subject's feet remained planted while they completed this motion.

Right Fixed Quadruped Position: From a quadruped position, the subject lifted their right knee off of the surface so that the knee moved as far as possible. This caused right spinal rotation relative to the shoulders.

Left Fixed Quadruped Position: The subject is in the quadruped position. The subject then lifts their left knee off of the surface so that the knee moved as far as possible. This caused left spinal rotation relative to the shoulders.

Right Standing Fixed Position at 45°, 90°, and 120°: The subject was in the standing position with their feet shoulder width apart. The trunk was fixed with the upper extremities placed at varying degrees of shoulder flexion (45°, 90°, and 120°) while they held onto a specialized bar (Fig. 2). The subject moved the right side of their pelvis posteriorly in the horizontal plane to initiate right lumbar spine rotation relative to the participant's shoulders. The subjects feet remained planted while they completed this motion.

Fig. 2: Specialized bar utilized during our study

Left Standing Fixed Position at 45°, 90°, and 120°: The subject was in the standing position with their feet shoulder width apart. The trunk was fixed with the upper extremities placed at varying degrees of shoulder flexion (45°, 90°, and 120°) while they held onto the specialized bar. The subject moved the left side of their pelvis posteriorly in the horizontal plane to initiate left lumbar spine rotation relative to the participant's shoulders. The subjects feet remained planted while they completed this motion.

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). 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.

Eight healthy subjects (4 female) volunteered to participate in the study. The subject demographics for age, height, and weight are listed in Table 1. Subjects were recruited by placement of fliers throughout the University of North Dakota School of Medicine and Health Sciences during the months of May-June 2018. 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 A) and signed a consent form (Appendix B) prior to participation in this study. A copy of the consent form was provided to the subject if they desired one.

Table 1. Subject Demographics

	Mean	Median	Standard Deviation
Age (Years)	23.38	24	1.50
Height (Inches)	69.23	68	2.45
Weight (Pounds)	171.92	170	19.76

Instrumentation

Instrumentation used for this study was wireless electromyography 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 research team set up and tested the EMG equipment to ensure proper signal reception and transmission. The research testing was conducted in a private room in Grand Forks, North Dakota at the University of North Dakota School of Medicine and Health Sciences. This location ensured confidentiality and privacy for each participant involved in this study. Prior to the study, participants were given a verbal explanation of the study and were allowed to ask any questions or express concerns regarding the procedure. Participants each completed one session that lasted approximately 75-minutes. To allow for direct skin contact of the electrodes, participants were asked to wear shorts to the session. Male subjects were asked to remove their shirt and female subjects were asked to wear a tank top, halter top, or swimsuit top to allow direct skin contact for each electrode. The researchers follow the Cram's Introduction to Surface Electromyography guidelines for preparation and placement of electrodes.[8] The EMG procedure required electrode site preparation, placement, and proper application of equipment for collection of EMG data. Electrode site preparation was prepared in a standardized manner for all applications.[8] The skin preparation consisted of the removal of excess hair (if necessary) using an electric razor, wiping the surface of the skin with 400-grit sandpaper, and then followed by wiping with isopropyl alcohol pad.[8]

The same researcher measured and applied each electrode to the participants in order to increase reliability and decrease error in the study. Electrodes were placed over the LD, MT, and ES muscles parallel to the muscle fibers while the patient remained in prone position with head

neutral and arms in anatomical position (Fig. 1). For the LD, the electrodes were placed over the muscle belly 5 cm below and 3 cm lateral to the inferior angle of the scapula along a line connecting the most superior point of the posterior axillary fold and S2 spinous process.[9,10] For the MT, the electrodes were placed horizontally 4 cm lateral to the spinous process of T3.[11] For the ES, the electrodes were placed vertically, parallel with the L3-4 interspaces, 4 cm lateral to midline.[8] A Noraxon impedance analyzer[8] (Noraxon USA, Scottsdale, AZ) was placed over each pair of electrodes to measure impedance. Skin impedance was assessed to be less than or equal to 10 kOhm for each pair of electrodes.[8] The electrodes were connected to the Telemyo 900 transmitter, which is attached to the subject's skin using double sided tape. The EMG signals were transmitted to the Telemyo 900 transmitter, and stored on a laptop computer for later analysis (Hewlett Packard, Palo Alto, CA).

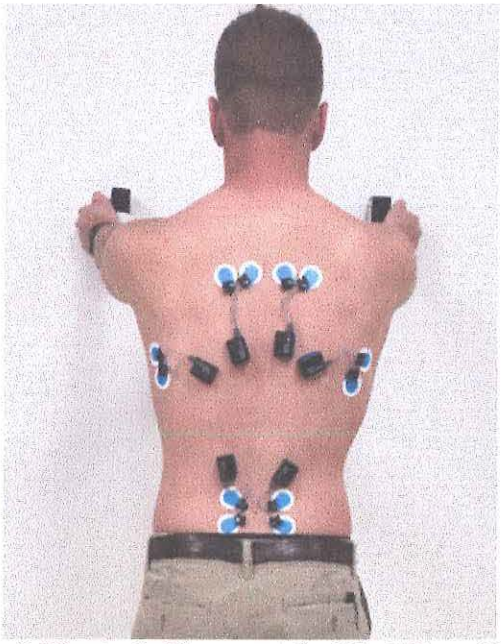


Fig. 3: Electrode Placement for LD, MT, and ES.

Reflective markers were placed bilaterally over the anterior superior iliac spine (ASIS) and bilateral acromion processes to assess rotation. The testing positions were video recorded for reference during motion analysis. Using a meter stick attached perpendicular to a six-inch wooden box, a vertical point of reference was developed for the study to determine the amount of

spinal rotation for the video recording. After the electrode placement was completed, maximal voluntary contraction (MVC) was collected for each muscle.

Maximal Voluntary Contraction

A MVC was obtained bilateral for LD, MT, and ES for all subjects. Testing the MVCs began by positioning the participant in prone with the head resting in neutral. Participants were instructed to exert their 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 each time to ensure consistency and increase reliability. A metronome was set to a speed of 60 beats per minute for consistent timing. Each participant had one second to move into the appropriate MVC testing position, hold the MVC for three seconds, and return to the starting position in one second. Each participant was allowed to practice the MVC testing position until they felt comfortable.

A computer generated randomization was used for the MVC testing positions for each participant. Three trials were performed for each MVC testing position with a 30 second rest between each trial. Subjects were instructed to give their best effort during each trial. After each trial, participants were informed of their resistance values in order to encourage full MVC. No additional encouragement was given to participants during the actual contraction. The participants were reminded to contract slowly and fully without jerking, in order to produce the best results. MicroFET2 values were recorded in each testing position for reliability. All trials were required to be within a 5-point-interval. If a trial fell outside the 5-point-interval, it was repeated until there were three trials recorded within the interval of each other for each testing position.

Latissimus Dorsi (Fig. 4): The lateral deltoid of the side being tested was in line with the edge of the plinth and upper extremity placed off the plinth in a dependent position. The participant was then asked to flex their elbow to 90 degrees and extend their shoulder to be parallel with the trunk. The researcher, using MicroFET2, applied resistance to the distal humerus during upper extremity adduction and extension. Stabilization was applied to the ipsilateral scapula and contralateral pelvis with the patient looking towards the arm that was contracted.

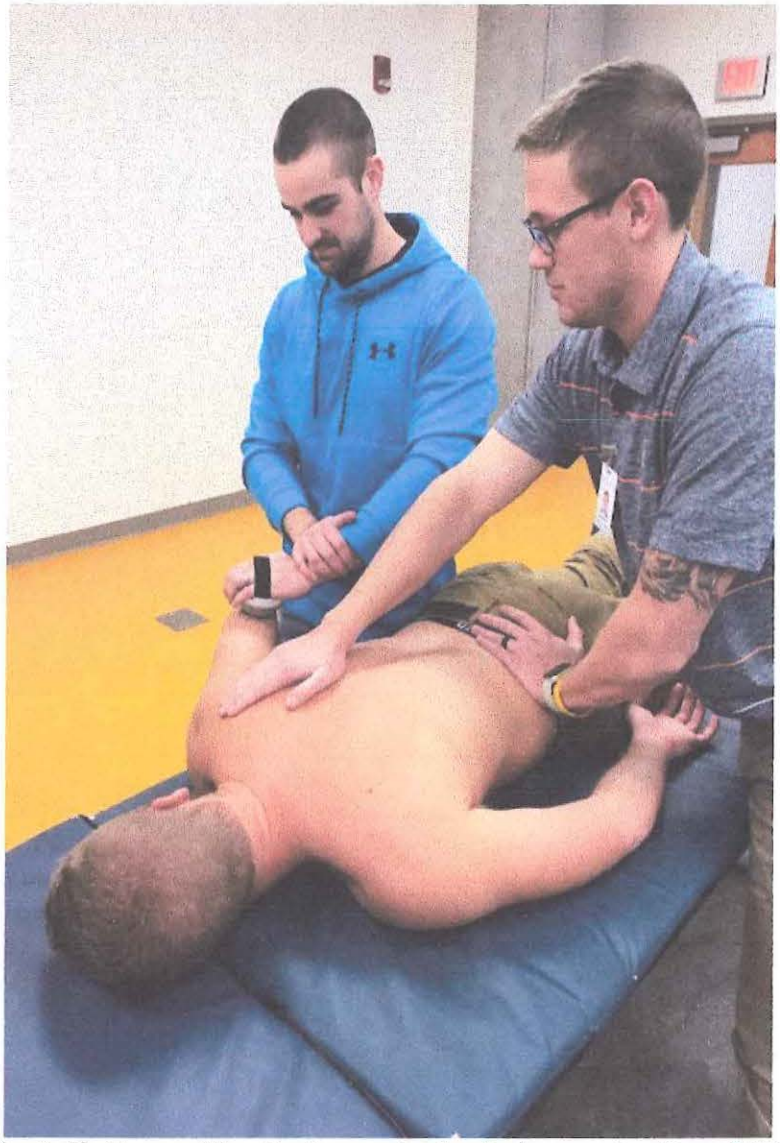


Fig. 4: Testing position for the maximal voluntary contraction of LD.

Middle Trapezius (Fig. 5): The participant's upper extremity was placed in 90 degrees of abduction, neutral rotation, and 90 degrees of elbow flexion. The same researcher, using the MicroFET2, applied resistance to the distal humerus during scapular adduction. Stabilization was applied to the contralateral scapula and bilateral pelvis with the patient looking towards the arm that was being tested.

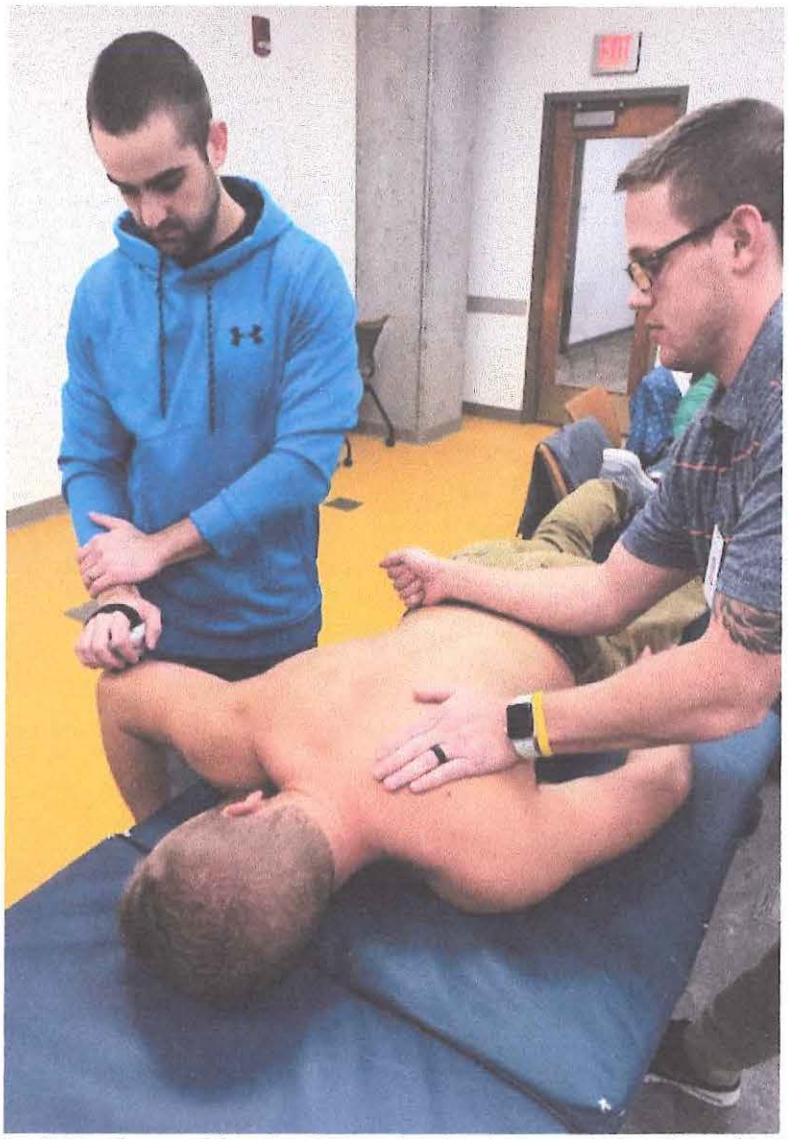


Fig. 5: Testing position for the maximal voluntary contraction of MT.

Erector Spinae (Fig. 6): The participant's upper extremities were placed at their sides. The pelvis and lower extremities were stabilized using the velcro belts attached to the plinth. Additional stabilization was applied to the participant's ankles by a researcher. The participant was instructed to lift their chest off the plinth into trunk extension through full range of motion while maintaining a neutral head position. Resistance was applied by the same researcher to bilateral scapula in a downward motion. Consistent effort was measured by assessing full range of motion prior to testing and ensuring full range of motion was achieved with each trial. Following MVC testing, experimental testing began.

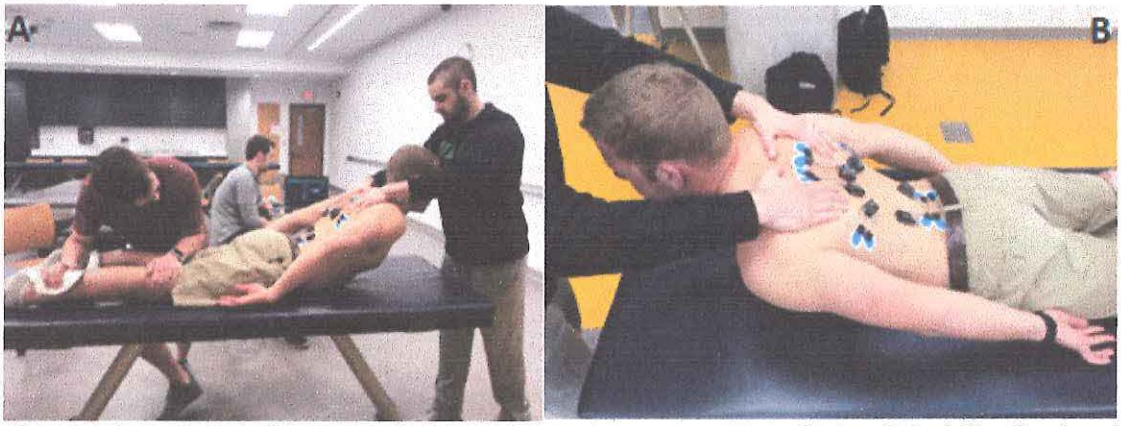


Fig. 6: (A) Testing position for the maximal voluntary contraction of ES. (B) Stabilization hand placement.

Experimental Testing

The experimental testing was performed following completion of all MVC testing. A computer generated the random sequence of testing conditions for each participant to eliminate bias of selection. Before beginning the first testing condition and between each preceding experimental testing condition, one to two minutes of rest was allowed for the participant. Participants were able to practice each testing motion until they felt comfortable with the motion. A 30 second rest period was given before performing the first trial. Each movement was paced to a metronome set at a speed of 92 beats per minute.

Following the beat of the metronome, participants were instructed to move three counts into their full range of rotation followed by three counts back to the neutral starting position. A researcher verbally cued to the participant during the motion to the beat of the metronome, saying, "Back, Two, Three, Forward, Two, Three…" The participant completed three trials of five repetitions for each movement. There was a rest period of 30 seconds between each trial. A six-inch wooden block with a meter stick attached perpendicular to the testing surface was placed on the testing side to allow for visualization of spinal rotation.

Standing non-fixed position (Fig. 7): Participants were asked to stand with feet flat on the floor, shoulder-width apart, and arms crossed over their chest. A researcher stabilized the participant's shoulders to avoid movement of the upper trunk. The participants were instructed to rotate their pelvis by bringing their right ASIS posteriorly and left ASIS anteriorly (Rotation of

Pelvis to the Right). This was repeated on the opposite side by bringing the left ASIS posteriorly and right ASIS anteriorly (Rotation of Pelvis to the Left). The rotation was performed keeping their feet in contact with the floor and knees straight. The video camera was placed at the height of the participant's ASIS for consistency.

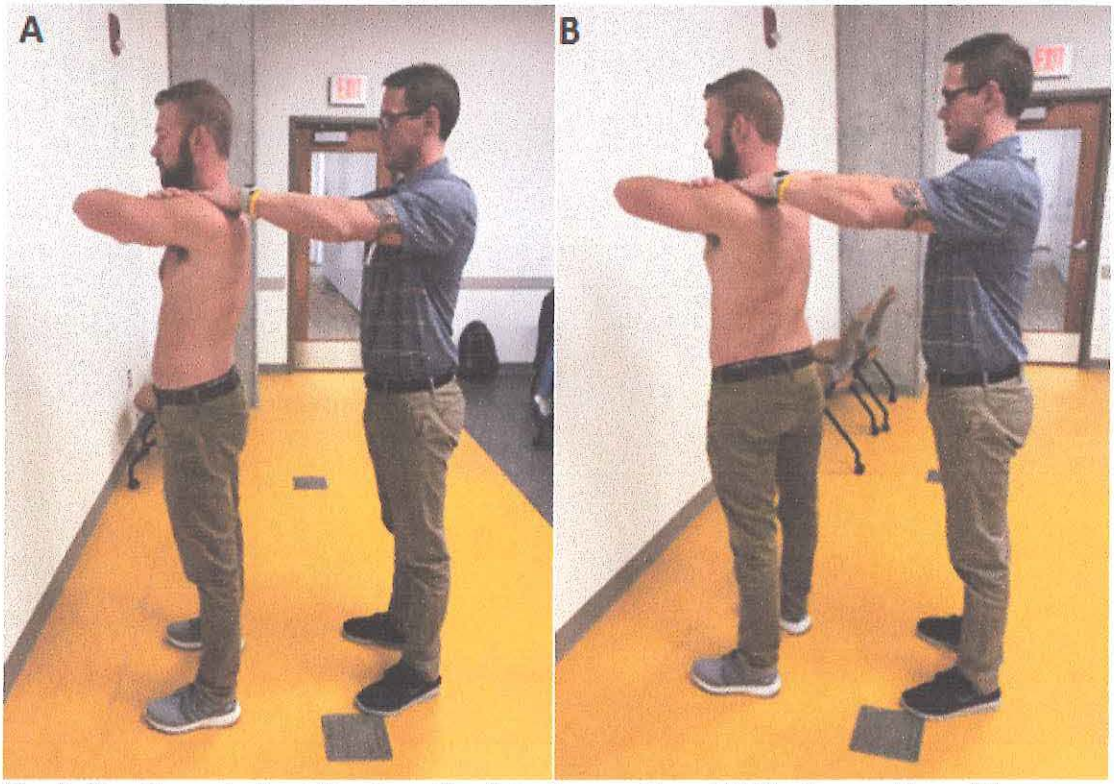


Fig. 7: Standing spinal rotation (non-fixed) testing position. (A) Starting position of the standing test position. (B) Maximal rotation before return to starting position.

Quadruped fixed position (Fig. 8): For this testing position, participants were in quadruped with hands and knees shoulder-width apart. The six-inch wooden box was placed adjacent to the participant's knee on the testing side. A towel was placed between the box and the participant's leg for greater ease of movement. The participants were asked to lift their knee off the plinth while maintaining contact with the box to prevent abduction of the thigh and to promote spinal rotation.

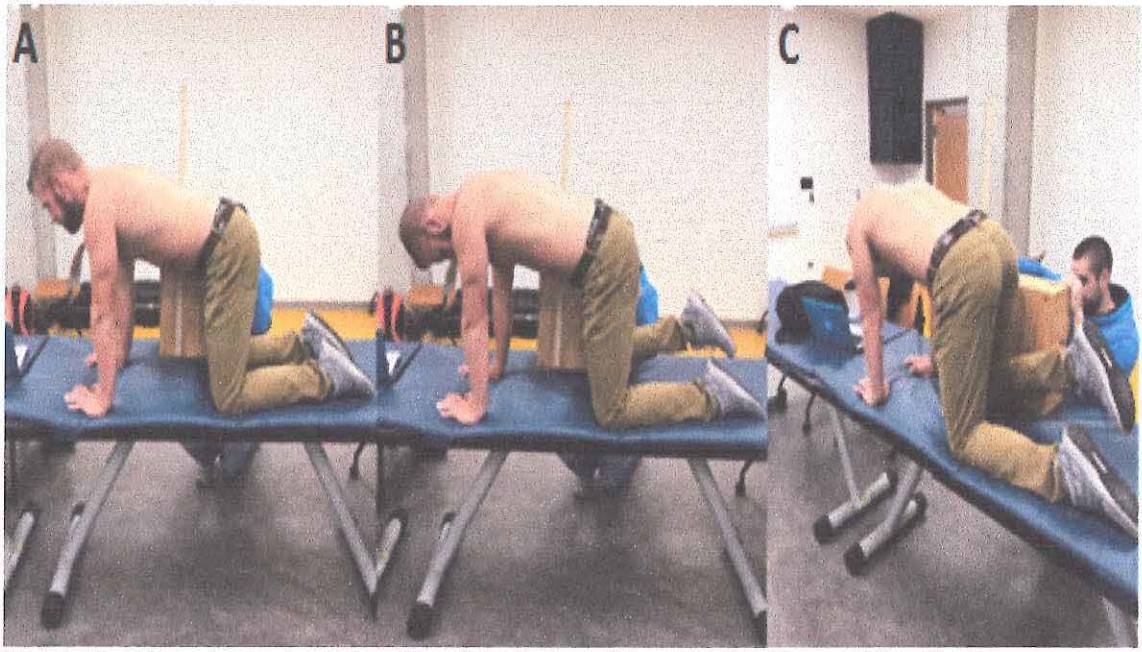


Fig. 8: Quadruped spinal rotation (fixed) testing position. (A) Starting position for the quadruped test. (B) Lateral view of maximal rotation. (C) Posterior-Lateral view of maximal rotation.

Standing fixed position at 45°, 90°, and 120° of shoulder flexion (Fig. 9-11): For this testing position, participants were asked to stand with feet flat on the floor, shoulder-width apart, while holding the specialized bar against the wall. The subjects were asked to direct their force against the wall and toward midline as in attempting to squeeze the ends of the bar together. No additional stabilization was applied to the shoulders (Fig. 3). The participants were instructed to rotate their pelvis by bringing their right ASIS posteriorly and left ASIS anteriorly (Rotation of Pelvis to the Right). This was repeated on the opposite side by bringing the left ASIS posteriorly and right ASIS anteriorly (Rotation of Pelvis to the Left). The rotation was performed keeping their feet in contact with the floor and knees straight. The video camera was placed at the height of the participant's ASIS and lateral to the participants tested side for consistency.

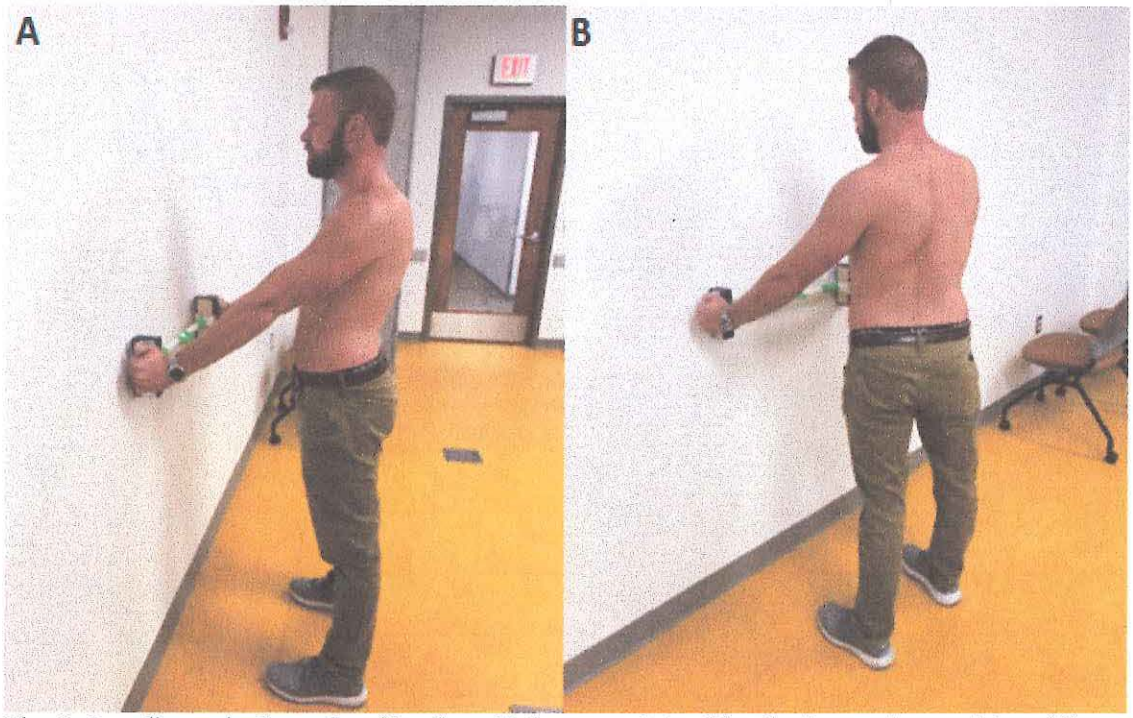


Fig. 9: Standing spinal rotation (fixed) at 45 degrees of shoulder flexion testing position. (A) Starting position. (B) Posterior-Lateral view of maximal rotation.

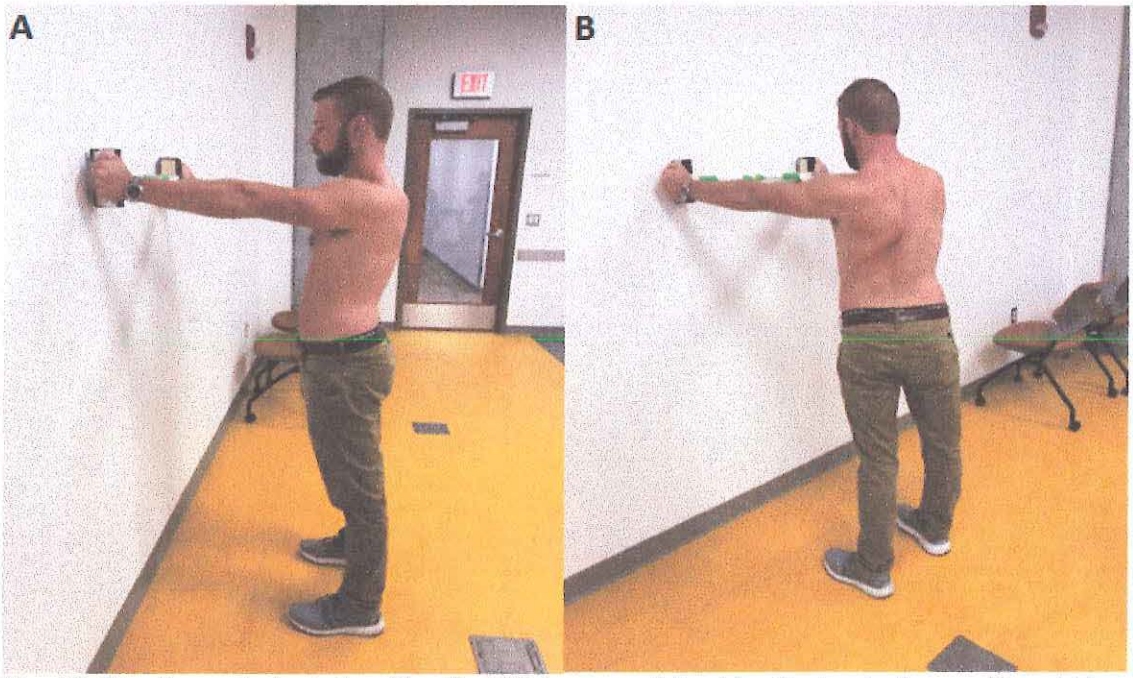


Fig. 10: Standing spinal rotation (fixed) at 90 degrees of shoulder flexion testing position. (A) Starting position. (B) Posterior-Lateral view of maximal rotation.

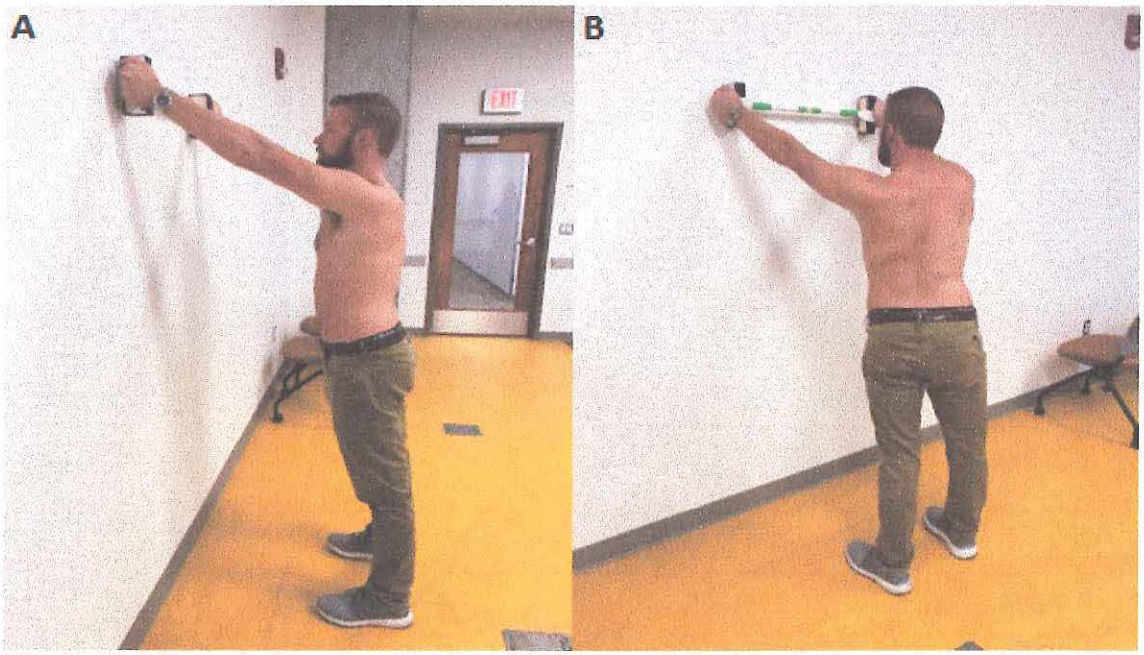


Fig. 11: Standing spinal rotation (fixed) at 120 degrees of shoulder flexion testing position. (A) Starting position. (B) Posterior-Lateral view of maximal rotation.

Data was collected during the entire cycle for each MVC and three trials of each testing position were stored in separate files. Once all data collection was completed, the electrodes and motion analysis reflectors were removed from the subject, and the skin was cleaned with isopropyl alcohol.

Data Analysis

Data analysis occurred using the MyoResearchXP software. The collected EMG data was transported, rectified, and normalized to the MVC for each muscle by the Noraxon MyoResearchXP software (NoraxonUSA, Inc., Scottsdale, AZ). The EMG data was recorded in 5-count intervals during every muscle contraction for the MVCs. The EMG data was recorded in 3 count intervals for forward and back for testing positions. Rotations 2-4 were utilized for analysis of each of the experimental trials. Once these values were obtained, all data was transferred to the Statistical Package for Social Sciences for Windows, Ver. 24. (IBM, Armonk, New York, USA) for analysis. To determine a significant effect of each muscle in a fixed and non-fixed position on the EMG activity, a repeated measures ANOVA was used (α=0.05). A Bonferroni post hoc test was utilized to find significant differences between muscles.

CHAPTER IV

RESULTS

A repeated measures ANOVA with Bonferroni post hoc analysis test was used to research each of the questions presented to analyze significant differences in EMG activity for specific muscles under the previously explained conditions. A least significant difference Bonferroni post hoc test was used to compare the planned pairwise comparisons to determine where there were significant differences.

The right and left LD EMG function was compared under differing conditions of movement and degrees of upper extremity fixation. This was done to investigate our first research question. There was a significant difference found in the right LD when we compared non-fixed right and left rotation with fixed right rotation. On the other hand, no significant difference was found in any fixed or non-fixed positions for the left LD. (Table 2)

The second and third research questions compared the EMG activity of the LD, MT, and ES in the following positions: right and left spinal rotation non-fixed standing position, and a fixed quadruped position. Differences in the LD compared to MT and ES were addressed utilizing a Two-Way Repeated Measures ANOVA to compile specific pairwise comparisons. The Repeated Measures Analysis demonstrated differences in normalized EMG activity between muscles under the conditions of right and left spinal rotation while the upper extremities are fixed and non-fixed regarding research question number two and three. There was a significant difference found in the right MT when fixed left rotation was compared to non-fixed right and left rotation as well as fixed right rotation. As for the left MT, significant differences were found when non-fixed right rotation was compared to fixed right and left rotation. There

was also a significant difference found for left MT in non-fixed left rotation compared to fixed right and left rotation. (Table 3)

Table 2: Repeated Measures T-test: Difference of EMG activity in non-fixed and fixed positions for R and L movement for the right and left LD.

Condition	n	Mean	SD	F	p	Eta^2	Power	Sig dif. Between conditions
Right Latissimus Dorsi (Non-Fixed / Fixed)								
1. NF Right	8	7.095	5.82	10.679	P<.001	.604	.995	1&3 2&3
2. NF Left	8	7.85	4.73					
3. F Right	8	19.51	10.94					
4. F Left	8	12.51	7.51					
Left Latissimus Dorsi (Non-Fixed / Fixed)								
1. NF Right	8	12.65	13.01	2.386	.166	.254	.267	None
2. NF Left	8	9.78	7.22					
3. F Right	8	15.68	10.02					
4. F Left	8	24.68	20.39					

*Bonferroni post hoc analysis

Table 3: Repeated Measures T-test: Difference of EMG activity in non-fixed and fixed positions for R and L movement for the right and left MT

Condition	n	Mean	SD	F	p	Eta^2	Power	Sig dif. Between conditions
Right Middle Trapezius (Non-Fixed / Fixed)								
1. NF Right	8	4.704	2.59	20.495	P<.001	.745	1.000	1&4 2&4 3&4
2. NF Left	8	6.53	4.05					
3. F Right	8	8.79	4.54					
4. F Left	8	17.93	7.802					
Left Middle Trapezius (Non-Fixed / Fixed)								
1. NF Right	8	4.901	2.23	13.648	.008	.661	.884	1&3 1&4 2&3 2&4
2. NF Left	8	3.804	1.26					
3. F Right	8	20.05	12.49					
4. F Left	8	9.36	3.80					

*Bonferroni post hoc analysis

Significance was not found in right and left LD (Table 4) or right and left MT (Table 5), in the 45, 90, and 120 degree positions. On the other hand, significance was found in the right ES when comparing right rotation at 45° to left rotation at 45° and 90°, as well as right and left rotation at 120°. Results were also significant in the right ES when comparing right rotation at 90° to right and left rotation at 120°. As for the left ES, results were significant when comparing left rotation at 45° to left rotation at 90° and 120°. (Table 7)

Table 4: Repeated Measures T-test: Difference of EMG activity in fixed shoulder flexion at 45, 90, and 120 degree positions for R and L movement for the right and left LD.

Condition	n	Mean	SD	F	p	Eta^2	Power	Sig dif. Between conditions
Right Latissimus Dorsi (45° / 90° / 120°)								
1. Rot. R 45°	8	8.705	4.6545	2.432	.163	.258	.272	None
2. Rot. L 45°	8	11.800	9.657					
3. Rot. R 90°	8	16.775	8.783					
4. Rot. L 90°	8	16.527	12.357					
5. Rot. R 120°	8	15.161	11.762					
6. Rot. L 120°	8	13.560	11.590					
Left Latissimus Dorsi (45° / 90° / 120°)								
1. Rot. R 45°	8	7.361	3.878	2.406	.165	.256	.269	None
2. Rot. L 45°	8	21.957	33.523					
3. Rot. R 90°	8	21.355	22.707					
4. Rot. L 90°	8	28.843	31.969					
5. Rot. R 120°	8	24.239	29.105					
6. Rot. L 120°	8	21.677	23.783					

*Bonferroni post hoc analysis

Table 5: Repeated Measures T-test: Difference of EMG activity in fixed shoulder flexion at 45, 90, and 120 degree positions for R and L movement for the right and left MT.

Condition	n	Mean	SD	F	p	Eta^2	Power	Sig dif. Between conditions
Right Middle Trapezius (45° / 90° / 120°)								
1. Rot. R 45°	8	7.949	3.355	3.34	.014	.323	.847	None
2. Rot. L 45°	8	10.993	5.370					
3. Rot. R 90°	8	8.883	4.409					
4. Rot. L 90°	8	11.620	5.952					
5. Rot. R 120°	8	8.275	4.077					
6. Rot. L 120°	8	9.218	4.130					
Left Middle Trapezius (45° / 90° / 120°)								
1. Rot. R 45°	8	12.333	6.749	1.921	.208	.215	.225	None
2. Rot. L 45°	8	10.162	6.075					
3. Rot. R 90°	8	14.717	14.914					
4. Rot. L 90°	8	9.223	5.741					
5. Rot. R 120°	8	13.460	14.474					
6. Rot. L 120°	8	7.809	4.633					

*Bonferroni post hoc analysis

Moreover, question number 4 addresses LD activity in comparison with MT and ES during spinal rotation at varying degrees of upper extremity fixation at 45°, 90°, and 120° of shoulder flexion. When we looked at the results, there were no significant differences noted for right or left ES in any fixed and non-fixed positions when tested. (Table 6)

Table 6: Repeated Measures T-test: Difference of EMG activity in non-fixed and fixed positions for R and L movement for the right and left ES.

Condition	n	Mean	SD	F	p	Eta^2	Power	Sig dif. Between conditions
Right Erector Spinae (Non-Fixed / Fixed)								
1. NF Right	8	14.67	8.56	2.683	.145	.277	.294	None
2. NF Left	8	9.24	4.57					
3. F Right	8	12.37	5.85					
4. F Left	8	9.71	4.896					
Left Erector Spinae (Non-Fixed / Fixed)								
1. NF Right	8	10.19	7.44	1.775	.187	.200	.391	None
2. NF Left	8	12.54	6.58					
3. F Right	8	7.999	3.42					
4. F Left	8	9.07	5.998					

*Bonferroni post hoc analysis

Table 7: Repeated Measures T-test: Difference of EMG activity in fixed shoulder flexion at 45, 90, and 120 degree positions for R and L movement for the right and left ES.

Condition	n	Mean	SD	F	p	Eta^2	Power	Sig dif. Between conditions
Right Erector Spinae (45° / 90° / 120°)								
1. Rot. R 45°	8	18.869	8.684	13.389	.008	.657	.879	1&2 1&4 1&5 1&6 3&5 3&6
2. Rot. L 45°	8	12.015	8.707					
3. Rot. R 90°	8	13.2793	5.541					
4. Rot. L 90°	8	7.831	3.797					
5. Rot. R 120°	8	8.389	6.012					
6. Rot. L 120°	8	5.762	3.304					
Left Erector Spinae (45° / 90° / 120°)								
1. Rot. R 45°	8	13.513	6.268	9.434	.018	.574	.750	2&4 2&6
2. Rot. L 45°	8	17.564	9.793					
3. Rot. R 90°	8	10.529	5.913					
4. Rot. L 90°	8	13.616	9.764					
5. Rot. R 120°	8	6.632	3.142					
6. Rot. L 120°	8	7.212	5.049					

*Bonferroni post hoc analysis

CHAPTER V
DISCUSSION and CONCLUSION

Discussion

The purpose of this study was to analyze EMG activity during spinal rotation with and without upper extremity fixation of the LD, MT, and ES muscles. While past research has shown the LD does not play a significant role in spinal rotation, our findings support the previous three pilot studies stating that the LD does in fact contribute to contralateral spinal rotation when in the quadruped position.[25-27]

In the fixed position, the right LD and right MT were significantly more active than the right ES during spinal rotation to the left, although the activity of the right LD is significantly less than the activity of the right MT. This correlates with the previous pilot studies, confirming the contralateral LD does in fact have a role in fixed spinal rotation, but may not consistently be the prime mover. The findings may be attributed to differences due to sample size and gender. With the humerus fixed, movement at the insertion was limited, which caused concentric shortening to take place from the origin to insertion of the LD. This contraction resulted in contralateral spinal rotation. However, the most recent pilot study did not show left MT activation at a significance level with fixed rotation and the current study did find left MT significantly active in fixed rotation. The fixed position places the lumbar spine in a flexed posture with flexion of the hips, favoring the LD as a contralateral spinal rotator in comparison to the ES and MT.

In agreement with a previous study conducted by Kumar et al.[2] the LD muscle has significant influence on spinal rotation, specifically in the fixed quadruped position. Kumar et al.[2] focused their attention on the isometric rotation of LD during lifting

activities; whereas, the present study tested positions more closely related to exercises and functional movements practiced in a physical therapy setting.

When evaluating the left side musculature in the non-fixed position, the ES had significantly more EMG activity than either the LD or MT in either left or right rotation on both left and right sides. The LD and MT did not significantly differ in both left and right rotation on both left and right sides. This lack of significance suggests the LD is not in a favorable position or length tension relationship to contribute torque during non-fixed spinal rotation. The non-fixed spinal rotation testing position may also allow for greater compensatory movement via lumbar extension, placing the ES in a favorable position to activate in comparison to the LD. The findings are consistent earlier studies and with the research limitations stated below, resulting in various subjects activating different musculature throughout the prescribed movement patterns.

In this study, several limitations were present. First off, the study included a very small sample size of only 8 individuals who volunteered to be participants. The demographics of these 8 subjects were fairly similar ranging in ages from 20-25, and were healthy, active, student health professionals at the University of North Dakota School of Medicine and Health Sciences. There was an equal number of male subjects and females and each participant was right hand dominant. Although similar in demographics, each individual displayed different body characteristics including postural alignment, muscular development, as well as coordination and awareness of body proprioception. Moreover, other confounding variables may have influenced the experimental procedures. These variables include decreased practice time of testing the movements in order to have the participants perform their natural movement patterns and the inability of the researcher to consistently apply pressure into the dynamometer in order to counteract the participant's maximal force. At times, a participant may not have been able to produce their maximal amount of force during their MVC due to discomfort that the handheld dynamometer caused at the placement site.

As research continues to progress, incorporating new evidence-based knowledge of which muscles fire in each position will give clinicians the ability to provide the best course of

therapy for patients with or without low back pain. Areas of new research include assessing LD length for each individual to see if that had an effect on results if a subject had a shortened LD muscles. With this in mind, a trend at fixed rotation at 90 degrees, but not at 45 degrees and 120 degrees. To compensate for this in future research, degrees closer to 90 degrees, such as 60 and 105 degrees, could be incorporated in the testing positions. Future studies could also include functional degrees in daily life such as shopping cart and stairway railings that are regulated due to safety standards. When performing the fixed rotational positions against a wall, future studies may find a benefit by cuing the subjects to start with a neutral pelvis, spine, and overall postural alignment. Muscle fatigue could have played a role in skewing the statistics, as all the MVC testing positions were completed first and these require the most muscle contraction at one time. Subsequent research, could include analyzing the standing fixed/non-fixed rotational positions to assess if the subjects were maintaining full/consistent rotation throughout the trials. In the future, adjusting for this and performing the other testing positions first may be a beneficial addition. Furthermore, increased sample size, which includes more broad spectrum of the general population, would increase the statistical significance of the results. Also, assessing hand dominance (all of our participants were right hand dominant) and gender differences in muscle activation. Eventually, investigating patients with LBP and performing LD exercises in physical therapy and measuring their outcomes would be helpful to further the knowledge base of spinal pathologies and available treatments for healthcare professionals. Further research using the same methods and positions with increased number of participants is recommended to fully determine significant results. Adjustments to the positions, as noted above, are recommended if muscle activation during rotation continues to be nonsignificant in regards to research the question.

After analyzing the data from the research, different trends in left and right LD, left and right MT, and left and right ES activation in each of the testing positions were found. Based on certain actions of each tested muscle, the highest activation for LD and MT muscles was expected to be contralateral rotation and the highest activation for ES muscles to be ipsilateral rotation. As compared to the previous pilot studies, there were added testing positions that included fixed

rotation at 45, 90, and 120 degrees of shoulder flexion to see if there was a correlation between the muscle length tension relationship and the activation of LD during spinal rotation. Trends were found that correlated with what was anticipated. These trends are discussed further below.

Non-Fixed and Fixed rotation:

- Right LD: In the non-fixed rotation testing position, the right LD followed the trend of activating more in left rotation. In the fixed rotation testing position, the right LD did not follow expected trends and activated more in right rotation. Possible explanations for this include the studies small sample size and limitations previously noted. The force of muscle activation was greater in the fixed rotation testing position.
- Left LD: Followed the same trends as right LD listed above with opposite rotation respective to the side.
- Right MT: In the non-fixed and fixed rotation testing positions, the right MT activation followed the expected trend of activating more in left rotation. The force of muscle activation was greater in the fixed rotation testing position.
- Left MT: Followed the same trends as right MT listed above with opposite rotation respective to the side.
- Right ES: In the non-fixed and fixed rotation testing positions, the right ES activation followed the expected trend of activating more in right rotation. The force of muscle activation was greater in the non-fixed rotation testing position.
- Left ES: Followed the same trends as right ES above with opposite rotation respective to the side.

Fixed rotation at 45, 90, and 120 degrees:

- Right LD: In the fixed rotation at 45 degrees testing position, the right LD followed the expected trend of activating more with left rotation. In the fixed rotation at 90 and 120 degrees testing positions, the right LD did not follow expected trends and activated more in right rotation. Possible explanations for this include the studies small sample size,

limitations previously noted and high standard deviation for each testing position. The force of muscle activation was greatest in 90 degrees → 120 degrees → 45 degrees.

- Left LD: In the fixed rotation at 120 degrees testing position, the left LD followed the expected trend of activating more with right rotation. In the fixed rotation at 45 and 90 degrees testing positions, the left LD did not follow expected trends and activated more in left rotation. Possible explanations for this include the studies small sample size, limitations previously noted and high standard deviation for each testing position. The force of muscle activation was greatest in 90 degrees → 120 degrees → 45 degrees.
- Right MT: In the fixed rotation at 45, 90, and 120 degrees testing positions, the right MT activation followed the expected trend of activating more with left rotation. The force of muscle activation was greatest in 90 degrees → 45 degrees → 120 degrees.
- Left MT: In the fixed rotation at 45, 90, and 120 degrees testing positions, the left MT activation followed the expected trend of activating more with right rotation. The force of muscle activation was greatest in 90 degrees with 45 degrees and 120 degrees having similar muscle activation but there was greater standard deviation at 120 degrees.
- Right ES: In the fixed rotation at 45, 90, and 120 degrees testing positions, the right ES activation followed the expected trend of activating more with right rotation. The force of muscle activation was greatest in 45 degrees → 90 degrees → 120 degrees.
- Left ES: In the fixed rotation at 45, 90, and 120 degrees testing positions, the left ES activation followed the expected trend of activating more with left rotation. The force of muscle activation was greatest in 45 degrees → 90 degrees → 120 degrees.

Conclusion

In conclusion, the LD was found to be more active during fixed positional movements, moving the spine contralaterally to the active muscle. The LD also showed a trend of more muscle activation during fixed spinal rotation with the arms at 90 and 120 degrees, which leads to our prediction of a possible length tension relationship with the LD muscle activation and future research needs to be conducted. The MT and ES were found to have a greater function on

spinal rotation during standing, non-fixed rotation. The ES muscles have a greater effect than the LD due to their increased activity in lumbar extension during standing, which may be a compensatory motion, and possible future subject cuing may correct. The MT is also more active than the LD in standing, non-fixed rotation, possibly due to subjects retracting their scapula during motion and the limited practice of the movement allocated. Increased MT activity with rotation to the opposite side may stem from greater initiation of spinal rotation in the upper thoracic and cervical spine, versus only the lumbar spine, isolating more specific LD muscle activity.

The contributions of the LD muscle in spinal rotation is highlighted in this study and the previous three pilot studies. It is a part of ongoing research concerning rotational movement strategies, which the LD may play a role in with individuals with and without low back pain. Many activities of daily living require rotation of the spinal musculature for increased quality of life. Interventions for low back pain often includes both standing and quadruped exercises. In the future, the LD and spinal rotation should be evaluated when assessing a client with low back pain.

APPENDIX A

ID # 15

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 B

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 50 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 60 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: NOV 21 2017
Expiration Date: NOV 20 2018
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. A device to measure the amount of rotation will be placed along the spine in the low back area. The data collecting devices will be attached by lead wires to a transmitter which will be attached around your waist by a belt. Electrical 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 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 with you selecting a card to determine the order of the activities. 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.

Date_____
Subject Initials: _____

WHAT ARE THE BENEFITS OF THIS 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 article 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

Date_____
Subject Initials: _____

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.

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-subjects/research-participants.cfm

I give consent to be videotaped during this study.

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

Approval Date: NOV 21 2017
Expiration Date: NOV 20 2018
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

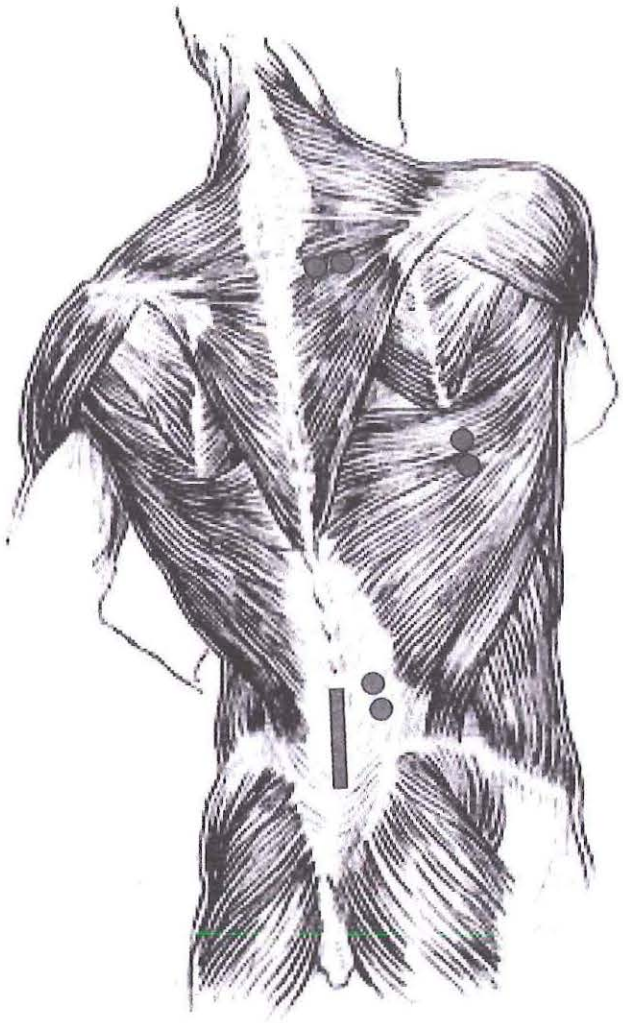
I have discussed the above points with the subject or, where appropriate, with the subject's legally authorized representative.

_____ _____
Signature of Person Who Obtained Consent Date

Approval Date: NOV 21 2017
Expiration Date: NOV 20 2018
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). The large bar indicates the position of the joint angle measurement tool.



Date_____
Subject Initials: _____

APPENDIX C

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.

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.

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