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A Deeper Look into the Vastus Medialis: A Stabilizer for the Knee

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A DEEPER LOOK INTO THE VASTUS MEDIALIS: A STABILIZER FOR THE KNEE

by

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ABSTRACT

Anterior cruciate ligament tears are one of the most common injuries that occur, especially in female athletes. It requires surgery and months of physical therapy to get these athletes back in playing condition. The angle of women's hips and lack of strength of inner quadriceps muscles enhances the risk of injuries to the knees. One specific muscle that is known for being a stabilizer of the knee and may help in preventing ACL tears is the vastus medialis. By understanding what exercises activate this muscle the most, conditioning plans and preventative workouts need to be created to help female athletes stabilize the knee. Therefore, this research could impact the prevention of ACL tears in female athletes. By taking a generalized approach, a variety of exercises in each of the three muscle contractions: concentric, eccentric, and isometric, will be evaluated by a Vernier Electromyography system. For this research, one female will be tested doing all the movements three times to measure the average peak muscle activation for each exercise. This will help prevent outliers and human error. For this study, variables such as percent body fat, BMI, history of exercising, and previous strength were ignored.

DEDICATION

I would like to dedicate this project to my family. My husband is so understanding and willing to help me with anything that I needed. He helped me with my poster and didn't complain during any of it. I would also like to thank both of my parents who taught me at a young age to value my education. I have received a ton of support from my sister, brother, and my step-mom throughout my college career as well. Thank you all for your example, love, and encouragement.

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Introduction:

Anterior Cruciate Ligament: Injuries are a part of an athlete's life. One wrong move, one rough tackle, or one wrong landing, can put a player out for months. One of these common injuries is the tearing of the anterior cruciate ligament (ACL). When researching the prevalence of ACL tears, there appeared a pattern that females had a higher risk of ACL injury than men. Dr. Timothy Hewett said that it's due to a decrease in neuromuscular control of the trunk which leads to the knees having a valgus torque (Hewett, 2010). Valgus torque refers to the movement of the knee coming inward toward the body. In fact, "female athletes who participate in jumping and pivoting sports are 2 to 10 times more likely to sustain a knee ligament injury, such as an anterior cruciate ligament (ACL) injury, than male athletes participating in the same sports" (Hewett, 2010). Women typically have a greater angle from hip to knee, therefore, it causes a greater risk for the knee to move inward while landing, twisting, or changing direction. It is very common to hear a popping noise when the ACL tears. Once an ACL tear is diagnosed through an MRI, a person has a few options. They can refuse surgery and just work on strengthening knee muscles, which was not unheard of in the past. However, ACL reconstructive surgery has progressed a lot in the last few years with using autografts and allografts. Most rehabilitation for after the injury includes rest and an exercise program.

This injury however, might be preventable. The Mayo Clinic has even said, "A proper training program may help reduce the risk of an ACL injury" (ACL, 2017). Obviously there are many focuses that could be incorporated in the training program such as flexibility, balance, strength, and awareness. In fact, a recommendation from the Hospital for Special Surgery is to "develop body awareness, strength, and balance to support your knees and ankles. Always jump, land, stop, and move with your knees directly over your feet. Do NOT let your knees collapse inward" (Chiaia et al., 2009). It is a recurring warning to not let the knees move inward in that

valgus direction mentioned earlier. This same article mentioned strengthening hip and thigh muscles as a good focus in prevention (Chiaia et al., 2009). So in doing further research, the vastus medialis and its relationship to the vastus lateralis may not only influence the risk of ACL tears but other problems like the patellofemoral pain syndrome and pain in the knee.

Vastus Medialis: The vastus medialis has a specific portion that is called the VMO (vastus medialis oblique). "The VMO represents the distal portion of the vastus medialis (VM) and it is defined by an increased obliquity of the muscle fibers, which originate largely from the adductor magnus" (Belli et al., 2015). "VMO is important in keeping the kneecap tracking correctly" (Vastus Medialis Oblique Rehab). It is a stabilizer of the knee and helps prevent lateral deviation of the patella. "Weakening of the vastus medialis oblique (VMO) muscle attached to the upper interior corner of the patella does not contribute to dynamic medial stabilization and causes lateral deviation of the patella" (Kang et al., 2017). "Miss-firing and weaknesses in the VMO cause mal-tracking of the patella and subsequent damage to surrounding structures and aching pain" (Vastus). These findings are not just for ACL tears but other injuries such as dislocation, patellofemoral pain syndrome, and medial collateral ligament (MCL) tears.

The vastus medialis also has a proximal part called the vastus medialis longus (VML) that has more vertical fibers. "While the VML participates in knee extension, the VMO acts as a medial stabilizer of the patella by opposing its lateral dislocation" (Belli et al., 2015). For this study the focus is on the VMO due to the stabilizing effect it has for the knee. Furthermore, the weakening of the VMO is more relevant to imbalance of strength in relation to the VL, because the VMO is a harder area of the muscle to strengthen.

VMO/VL Ratio: The VMO/VL ratio is an index into the activation of two quadriceps muscles. The closer it is to one the better for the knee stabilization. “The imbalance between vastus medialis oblique (VMO) and vastus lateralis (VL) strength is one of the main factor for patellofemoral pain syndrome (PFPS) onset, related to improper alignment of the patella” (Belli et al., 2015). In one study they found that, “patients with PFPS were found to have a lower muscle activity ratio between the VMO and the vastus lateralis (VL) than healthy subjects. Therefore, correction of the balance between the VMO and VL should be a goal in rehabilitation programs for patients with patellofemoral pain, in order to determine the appropriate exercise for preventing PFP” (Kang et al, 2017).

The above two studies mentioned the muscle activity ratio between the two muscles. However, it is believed that there might be some influence into the timing/ firing of the two muscles that influence the tracking and alignment of the patella. “One of the etiological factors of PFPS, the pain due to a lateralization of the patella [is] caused by the late activation of the VMO relative to the VL” (Santos et al., 2008). This is confirmed by another study when they said, “the abnormal relationship in the activation pattern of the vastus medialis obliquus (VMO) and vastus lateralis (VL) can alter the dynamics of the patellofemoral joint” (Kuriki et al., 2011). The onset and pattern of activation might cause issues in addition to the amount of activation. There are a lot of different and inconclusive findings as to the real effect that this has. However, the “vastus medialis (VM) delayed onset in relation to vastus lateralis (VL) has arisen as a promissory hypothesis due to the influence of these muscles on patellar stabilization” (Briani et al., 2015). It will be riveting to see in the near future what studies will be done to help dispel or prove that PFPS might be caused by the imbalance of the VMO/VL ratio or the delayed onset of the VMO to the VL.

The VMO/VL ratio not only has a potential ramification in PFPS, but it plays a part in the preventing the valgus movement mentioned earlier in regards to ACL tearing. If the VMO can be strengthened and trained to reach sooner in relation to the VL, it would allow the knee to withstand the instability that comes from pivoting and landing incorrectly. This is not saying that all that needs to be fixed in order to never tear the ACL is strengthening the VMO. No, this is saying that bridging the gap in the ratio would help decrease the risk of ACL injury. Instead of women having 2 to 10 times the risk as men of sustaining a knee ligament injury, maybe this could lower those numbers.

Electromyography: "Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control them (motor neurons). Motor neurons transmit electrical signals that cause muscles to contract. An EMG translates these signals into graphs, sounds or numerical values that a specialist interprets" (Electromyography, 2017). When using and EMG, electrodes are the device used to capture the signals being transmitted. They are placed on the surface of the skin in the area of the testing. It is more accurate when testing if the electrode is placed on the body of the muscle. "In the last 20 years the electromyography (EMG) analysis has been widely used to evaluate quadriceps activation during open/closed kinetic chain exercises and some researchers have defined a specific index named "VMO/VL ratio." Therefore, VMO/VL ratio underlines how much quadriceps contraction can activate a muscle more than the other" (Belli et al., 2015). This is why this study decided to use EMG as the method of testing. The instrumentation is accurate with testing a muscle of the quadriceps, and the testing can be furthered with more research and experimentation of the vastus lateralis and vastus medialis in the future.

Methods:

Purpose: The purpose of this experiment was to become familiarized with performing testing with the EMG machine and learning the accurate way of collecting data. This research was to gain knowledge of the vastus medialis activation. This design was meant to be an introduction or a foundation to help with later more detailed research. The exercises that were chosen were meant to cover a variety of muscle contractions such as isometric, eccentric, and concentric.

Subject: For this purpose, the experiment used one subject who did three trials. This way the average could be gathered and help differentiate outliers. The participant that performed the testing was a 23-year-old female who weighed 155 pounds (70.5 kg) with a height of 5'7.5" (171.5 cm). The subject's BMI, body fat, and experience with exercising were factors that were ignored for this testing. Also the subject had a previously injured ACL on her left side, so the testing was performed on the right knee.

Procedure: In order to prepare the subject for testing, she removed the hair where the electrodes of the EMG machine were to be placed on the leg. Then she used rubbing alcohol at those same locations to clean the area, so no interference could occur with the conductance during testing. Once that was performed, the EMG machine calibrated the electrodes, or in other terms it was zeroed out. Then the electrodes were placed on the vastus medialis, which was 3 inches north of the patella and one inch medially from the knee, and the other electrode was placed on the ankle of the right leg. The electrodes had some trouble staying on, therefore, tape was used to keep the electrodes in place during the movements and exercises. The Maximum Isometric Voluntary Contraction (MIVC) was performed first in order to get the measurements that would serve as

100% muscle fiber activation. While the participant performed each movement, the EMG template program showed the results. The exercises were performed on two separate days, where the first day including the MIVC, squat, and sumo squat. The second day of testing measured the stork, front lunge, hip adduction, marching in place, and straight leg raise. Once an exercise was completed three times, the section of the data that occurred during the exercise for each trial was selected to find the peak activation. Then the mean was found for the three measurements recorded for all seven exercises. Each exercise has two different phases, downward phase or the upward phase (except for the stork). For the purposes of this experiment, the peak for the entire movement was used, not the peak for each phase. Following that step, the MIVC was set at 100%, and all the following results were set as a ratio or comparison to that value.

Results:

The results that were recorded are just meant to be an introduction to get an insight into which exercises are the best activators for the muscle fibers of the vastus medialis. No p-value or standard deviation were found due to not enough data collected as a representation of the population. However, in the following data tables, there are slight differences in values that give an indication into which exercise activates the VMO the most. Nonetheless, it is very difficult to pinpoint which type of contraction activated the vastus medialis more than another type of contraction. The squat, sumo squat, and the stork were the top three, however there is not a vast difference from one exercise to another.

Table 1**

Exercise	Trial 1	Trial 2	Trial 3	Average
Maximum Isometric Voluntary Contraction	2.098	2.079	2.083	**2.087**
Stork	2.096	2.066	2.069	**2.077**
Squat	2.100	2.090	2.090	**2.093**
Sumo Squat	2.100	2.110	2.130	**2.113**
Front Lunge	2.008	1.986	1.991	**1.995**
Hip Adduction	1.748	2.101	2.111	**1.987**
Marching in Place	1.950	1.931	1.792	**1.891**
Straight Leg Raise	1.947	2.095	2.091	**2.044**

**All units in Table 1 are in millivolts (mV)

Table 2

Exercise	**Percentage of Maximum Isometric Voluntary Contraction (MIVC)**
Stork	99.54%
Squat	100.32%
Sumo Squat	101.28%
Front Lunge	95.61%
Hip Adduction	95.21%
Marching in Place	90.62%
Straight Leg Raise	97.97%

Discussion:

It was interesting to compare the sumo squat with the regular shoulder width apart squat. "During a squat exercise, a higher concentration of muscle activation was observed in the VMO when the legs were spread at shoulder width than when the legs were spread much wider" (Kang et al., 2017). However, based on this experiment, it seems to have the opposite effect on the VMO. The sumo squat had higher activation than the shoulder width apart squat. Obviously there would need to be more participants in order to see if there's a significant difference and which position of the squat actually activates the VMO more. However, it is worth noting the difference in these findings. The argument could go either way, stating that the legs being spread

further could cause more activation by helping the knee stay in alignment. Nevertheless, shoulder width squats could activate it more due to the position of body weight during the movement. It would be enlightening to see a more detailed study of this.

Something that is relevant to this data and research but was not included is the activation of the vastus lateralis during these same seven exercises. There is a lack of information in regards to the ratio of activation with the vastus medialis compared to the vastus lateralis. Maybe these exercises activate the vastus medialis, but then they also activate the vastus lateralis with relatively the same percentage. The exercises would still be helpful for the vastus medialis, but it might not have as much benefit in helping shorten the gap in the ratio between these two muscles. It is something to consider that based on the comparison of activation, the viewpoint of which exercises would be the most preventative of knee injuries, especially the ACL tear, would need a second look and further analysis.

In need of discussion as well are the other possible errors that might have occurred during this testing. The Vernier EMG System had a few problems when it came to the template. There were a few times where the electrodes had to be reconnected to the computer in order to be read correctly. There were other difficulties as well where the interface did not connect correctly, and thoughts of having some kind of bug influence the template was discussed. Another aspect of the testing that influenced the results dealt with the electrodes' difficulty to stay on the leg. Tape helped for the most part, nevertheless some of the exercises were challenging to do while keeping the electrodes on the ankle. This could have caused differences in the measurements.

Furthermore, this study was done over two days of performing the exercises, three on one day (including the MIVC), five on the other. It was decided to do one exercise three times in a row and getting the results after that. However, it is unknown whether this approach would be

the most accurate and precise. The method could have been where one trial of each exercise was performed on different days throughout a specific period of time. It is an unknown factor if a specific time of the day, day of the week, or day of the month would affect muscle activation on the EMG machine.

The results found in this study lead to a further need to discuss workout plans to utilize the knowledge gathered here. Workout plans involving a mixture of the above exercises would be highly beneficial to female athletes. Having athletes perform and yet be preventative would entail all of these exercises, because none of them showed to be inefficient at activating the vastus medialis. So based on this, having female athletes do multiple sets with a medium amount of repetition would have a positive effect on the muscle strength. Focusing on squats would be wise and doing exercises with more resistance could affect the lower activation exercises such as the marching in place and hip adduction.

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AUTHOR'S BIOGRAPHY

Connie Barnes was born in Belleville, Illinois but grew up in White House, Tennessee. She graduated high school in 2011 from White House Heritage High School in the top ten of her graduating class. Her interest in Physical Therapy developed in high school when she was assigned a project where she interviewed a Physical Therapist. Later, in the summer before her senior year in high school, Connie tore her ACL and attended Physical Therapy as a patient. After this experience, she enrolled as a freshman at Utah State University in the Fall of 2011 as a Human Movement Science Major with an emphasis in Pre-Physical Therapy. She was accepted into the Honors Program and started working on developing ideas for her Capstone Project that all had to do with ACL tears.

During her college time, Connie took a year and a half off to serve a full time mission for the Church of Jesus Christ of Latter-Day Saints where she learned to speak Spanish in the state of California. Connie was already minoring in Business, but her love for Spanish grew and she decided to minor in it as well. Connie has done over 500 hours of volunteer and observation hours in Physical Therapy clinics. She applied for P.T. School in the Fall of 2016 and received news in the beginning of 2017 of her acceptance into the University of Tennessee Health Science Center. She will be attending this Doctor of Physical Therapy Program in the Fall of 2017 and become a member of the D.P.T. class of 2020. After this, Connie will either work in Pediatric Physical Therapy or Orthopedic Physical Therapy clinics. One day she hopes to have her own clinic with aides and assistants that work with her.