ANKLE MUSCLE ACTIVATION DURING UNILATERAL AND BILATERAL
LOWER BODY STRENGTH EXERCISES

Adam Reeder

Thesis

Approved: Advisor
Dr. Ronald Otterstetter

Interim Dean of the College
Dr. Roberta DePompei

Accepted: Committee Member
Mrs. Stacey Buser

Dean of the Graduate School
Dr. George Newkome

Committee Member
Mrs. Rachele Kappler

Date

School Director
Dr. Victor Pinheiro
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CHAPTER I
INTRODUCTION

Lower body strength has been shown to be beneficial in virtually every population of people. In a study of over 1,200 males over the age of 30, researchers demonstrated a positive correlation between an individual's lower body strength and their physical health component score (Hall et al. 2011). Yang et al. (2011) demonstrated that lower body strength has a positive effect on locomotion in individuals suffering from a spinal cord injury. Evidence also suggests that lower body strength training can help improve athletic performance. The researchers suggest a relationship between strength training and a reduction in the incidence of injuries among rowing athletes (Lawton et al. 2011). The ankle joint is one of the most important joints in the lower body. Because the ankle is one of the primary joints responsible for control over ground-reaction forces, soft tissue surrounding the ankle is of the utmost importance.

Individuals who suffer from ankle injuries can encounter many specific difficulties. Willems et al. (2002) studied proprioception and muscle strength in people with chronic ankle sprains and instability and found that individuals with ankle stabilizer weakness had a higher tendency toward chronic ankle instability. There is an infinite amount of exercises that can be used to enhance lower body strength. The squat is a very commonly used strength training exercise for individuals of all ages,
needs, and situations. Common squatting variations include exercises such as the back squat (BS), and front squat (FS). These lower extremity strength-training exercises are variations of the two-legged squat (TLS).

According to McCurdy et al. (2010), “Although most skills in athletic competitions are performed unilaterally...anecdotal evidence has indicated that the 2-leg squat (TLS) is the exercise most commonly used by athletes to increase lower body strength.” These exercises are very common in most strength and conditioning programs and are used not only for training purposes but for common measures of strength and power. These bilateral strength exercises are staples of many fitness programs for the general public as well. Less common are unilateral variations to the squat, such as the one-legged (also known as “Pistol”) squat and the modified single leg squat (MSLS). These unilateral exercises are variations on the traditional TLS. To date, no research has been done to examine the differences between bilateral and unilateral exercises as far as their effects on ankle stabilization in the way that studies have been done on the hip stabilizers. Therefore, the purpose of this study is to compare the effect of the TLS and MSLS on ankle muscle electromyography (EMG) activity.
CHAPTER II

LITERATURE REVIEW

Ankle Muscle Research

In an article published in the New York Times, strength coach Shannon Turley was asked what the N.F.L. scouts should focus on, and his answer was ankle mobility, saying the ankle begins the human chain of movement (Bishop, 2011). Two vital movement components of the ankle joint are plantar flexion and dorsiflexion. Plantar flexion is a sagittal-plane movement where the toes are pressed away from the shin, increasing the angle from the shin to the top of the foot. Muscles involved in plantar flexion include the gastrocnemius, soleus, and peroneals. Dorsiflexion is another sagittal plane movement in which the toes are pulled towards the thin, decreasing the angle between the shin and the top of the foot. Optimal function in these two patterns is important for athletic performance, gait, balance, and quality of life. Stretching and strengthening exercises targeting these muscle groups are often prescribed to improve their function. Radford et al. (2006) concluded that stretching of the ankle muscles could be used to help improve dorsiflexion range of motion, based on their systematic review of studies performed by Bohannon et al. (1994), Knight et al. (2001), Peres et al. (2002), Pratt & Bohannon (2003), and Youdas et al (2003).
Research shows that ankle muscle activity can effect biomechanics at joints above the ankle along the kinematic chain. Tse et al. (2013) showed the role of ankle stabilization during balance tasks and Marcum et al. (2012) performed a study on 30 active individuals in order to examine the effect of ankle muscle stiffness on the knee joint. The participants performed two variations of the two-legged squat. The first variation was with both feet flat on the floor, the second variation involved elevating the heels to a 12 degree forefoot angle, in order to simulate a reduction in plantar flexor flexibility. The results of the study suggested that a decrease in ankle joint function resulted in an increase in knee valgus and medial knee displacement during a two-legged squat.

Dragert and Zehr (2001) published an article examining the effects of high-intensity unilateral dorsiflexion resistance training on tibialis anterior and soleus muscular strength and H-reflex excitability in the trained and untrained limbs. The study found that after 5 weeks of training, dorsiflexion strength was significantly enhanced in both trained and untrained individuals. Additionally, Behm and colleagues (2002) investigated the effect of stability on muscle recruitment during the TLS, finding a significantly lower degree of quadricep activity and force output, but not a significant decrease in hamstring activity and output.

Krause et al. (2011) used dorsiflexion (DF) range of motion as a dependent variable to determine the effects of the independent variable: range of motion measurement techniques. The study consisted of 39 healthy subjects and their dorsiflexion range of motion was tested using several methods: active range of motion with 0 degrees of knee flexion, passive range of motion with 0 degrees of knee flexion,
active range of motion with 90 degrees of knee flexion, passive range of motion with 90 degrees of knee flexion as well as in a modified lunge. The modified lunge used in this study followed the same technique described by Denegar et al (2002). In his study examining the effect of lateral ankle sprain on dorsiflexion range of motion, posterior talar glide, and joint laxity. In Krause's study (2011), the modified lunge position produced the greatest percentage of EMG activity out of all of the testing positions and demonstrated the greatest degree of reliability and validity. The authors explained these results by reasoning, “Given the weight-bearing nature of the lunge position, it may represent functional DF requirements such as walking, stair climbing, and squatting more accurately than the other techniques.

Lower Body Stabilization Research

Muscle stabilization has become an area of significant focus in the world of functional training. Weakness in the hip-abductor muscles has been linked to various ailments including patellofemoral pain syndrome, iliotibial pain syndrome, anterior cruciate ligament injuries and ankle instability. Boudreau et al. (2009) examined the activation levels of the hip stabilizers during functional exercises. Their study showed a greater degree of hip stabilizer activation during exercises in which the base of support is limited compared to traditional bilateral exercises. Specifically, activation levels of the gluteus medius were high during exercises such as the side bridge, unilateral squat, and lateral step up. The researchers aimed to compare the activation levels of the specific hip muscles between three functional exercises: the lunge (LUN), the single-leg squat (SLSQ), and the step-up-and-over (SUO). The muscles being studied were the gluteus
maximus (GMX), adductor longus (ADD), rectus femoris (RF) dominant-limb gluteus medius (GMed_D) and non-dominant limb gluteus medius (GMed_ND). The researchers hypothesized that the single leg squat would exhibit the greatest degree of hip muscle activation while the step-up-and-over would exhibit the least amount of the three exercises (Boudreau et al. 2009).

This study did not involve testing procedures between groups nor did it examine pre- and post-intervention results. Instead, the dependent variable of this study was muscle activation represented as a percentage of a reference voluntary muscle contraction (%RVC) with the independent variable being the 3 exercises. The idea behind this method was to determine the degree of impact the stabilizers had on the movement as a whole, the whole being represented as the Reference Voluntary Contraction.

Forty-four healthy individuals took part in the study, 22 men and 22 women. The researchers used a 16-lead EMG to record muscle activity. To allow for comparison between subjects, the EMG data was normalized according to %RVC. Electrodes were placed on the belly of each muscle in question and activity was recorded using an oscilloscope. After the subjects learned proper technique for the 3 exercises, the subjects performed a 5-minute warm-up followed by a static lower extremity flexibility program. Each participant performed the exercise as instructed and his or her EMG data was recorded. The single-leg squat produced the greatest amount of muscle activity for the RF, GMX, and GMed_D muscles. The Step-Up-And-Over exercise produced the greatest amount of muscle activity for the ADD muscle while the Lunge produced the greatest amount of muscle activity for the GMed_ND (Boudreau 2009).
The study was beneficial because future researchers will not have a reference point as to the degree of involvement for the various hip-stabilizing muscles during important functional exercises. This study affirmed a commonly held belief in the functional training community that the single-leg squat requires a very high degree of activation of several hip stabilizer muscles and could possibly be too much for a beginning exerciser to start out with. This study provides a progression system of sorts, suggesting that the most proper way to progress through these exercises would be to move from the step-up to the lunge and finally to the single-leg squat.

There are a few limitations to this study that call into question some of the validity and bring about reason for further research. For instance, the degree of knee flexion for each participant was not normalized to accommodate different body structures. Subjects were instructed to simply descend “as far as they could” before returning to the top of the movement. Due to flexibility issues, this could cause a skew in the data. It is commonly believed that a greater degree of flexion would result in a higher degree of stabilizing muscle activation. To correct this flaw, researchers could have instructed the participants to squat to a box that placed their femur parallel to the floor. This would have eliminated the question of flexibility and would have reduced the skew for taller individuals. Taller individuals with long femur bones tend to have difficulty reaching femur-parallel during a single leg or even bilateral squatting movement. By providing a box to which the subjects could sit, the researchers could have ensured that the subjects all traveled a relatively constant distance from the top to the bottom of their squat, relative to their height. In doing so, the researchers would have reduced the possibility that the differences in hip activation activity came from the subject’s range of motion, rather than the exercise itself. While this may or may not have changed the actual
outcome of the study, hip and knee range of motion from start to finish is a variable that was not well controlled for in this study.

Many theories exist in regards to the best, most effective way to strengthen the lower body. Lower body strength training plays an extremely critical role in athletics as well as rehabilitation. Many current lower body strength-training programs place a heavy focus on squatting movements as a mode of strengthening the quadriceps and hamstrings of the upper leg.

Previous studies such as McCurdy et al. (2010) have shown that performing single leg movements can increase the neuromuscular demand of the stabilizing muscles of the hip. However, since true single leg movements involve a very unstable stance, large amounts of force are difficult to produce, reducing the ability to develop explosive strength needed on the athletic field. One way to get the best of both worlds is to use what the researchers refer to as a modified single leg squat (MSLS), also known as a rear-foot elevated split squat. According to the researchers, “Moderately unstable exercises [such as the MSLS] appear to be best suited for athletes to gain strength by challenging the neuromuscular system to control the resistance at higher loads.” The purpose of the McCurdy (2010) study was to compare EMG activity of selected hip and knee muscle groups in female athletes while they performed the MSLS and the two-leg squat (TLS) at the same relative intensity.

Eleven female athletes from various sports took part in this study. All 11 had previous resistance-training experience and were proficient at the TLS, but had little or no experience with the MSLS. Subjects were taught the proper technique for each lift and after a practice session, a 3-repetition max (3RM) was determined for both the TLS and
the MSLS. For the MSLS, subjects placed their back foot on a 12-inch box and descended until the thigh reached a parallel position to the floor. The dominant leg was used as the lead leg for the MSLS. For the TLS, the subjects’ anterior knee translation was subjectively assessed to correct excessive translation past their toes. To assess knee anterior translation on the MSLS, the distance between the front edge of the box supporting the trail leg and the lead toes (39–45 in) that simulated the TLS knee position over the toes was determined for each subject and used for each trial during the test.

EMG data was collected on the gluteus medius, rectus femoris, and biceps femoris of the dominant leg for each exercise. The subjects performed a test of 3 repetitions at 85% of their 3RM on each exercise, with a 5-minute break between exercises.

EMG activity suggested a statistically significant increase in muscle activation from the TLS to the MSLS for the mean gluteus medius, the mean peak gluteus medius, mean hamstring, and mean peak hamstring while the TLS showed a significant increase in muscle activity of the quadriceps as well as the quadriceps compared to the hamstring. According to the research, “During a squat motion, higher hamstring and lower quadriceps activity are suggested to occur with greater hip flexion because of an increase in the moment of force at the hip and a decrease at the knee.” There is a commonly held belief that hamstring activity is increased and quadricep activity is decreased when the amount of hip flexion (and therefore trunk inclination) is increased. The results of this study are evidence that this may not be true. The TLS produced a greater degree of trunk inclination than the MSLS, while the MSLS produced greater hamstring activity. The reduced base of support from TLS to MSLS seemed to have a greater effect on hamstring to quadricep ratio activity than hip flexion or trunk inclination (McCurdy et al. 2010).
This is an incredibly important study to both the athletic and rehabilitative worlds. Many chronic overuse injuries as well as postural and muscular imbalance issues result from over-development of the anterior portion of the body when compared to the posterior side. Developing the posterior chain should be a primary focus of any strength and conditioning program, and this is exponentially more important when the program is being applied to an athletic population.

The biggest limitation of this study was simply the small sample size. The results of eleven well-trained athletes may very well be a statistical quirk, not applicable to the general population. Further research is needed to examine the effects on a larger sample size, as well as different populations.

These unilateral variations are less common, and in most strength and conditioning programs, are viewed as secondary or accessory exercises, to be performed after the athlete has already completed one of the more “core lifts” such as the bilateral squat.

The reasons for this discrepancy between the use of bilateral strength exercises and unilateral strength exercises are many. One of the main reasons for favoring of bilateral exercises over unilateral exercises as the primary focus of a lower body strength program is the ability of the athletes to use a greater load during bilateral exercise. Many athletes are able to handle double their bodyweight or more on the traditional back squat. This leads many strength and conditioning coaches to believe that their athletes must lift this much weight in order to fully develop their lower body strength. However, there is a growing trend within the strength and conditioning world that suggests emphasizing unilateral lower body strength training can lead to as good or better results among
athletes than traditional lower body training. In fact, there is an overwhelming amount of evidence found in our functional anatomy that supports this idea.

A complete lower body strength-training program will develop the anterior and posterior sides of the lower extremities equally, as well muscles of the lateral subsystem. Muscles of the lateral subsystem include the gluteus medius, the hip adductors, and the quadratus lumborum. In his book, *Advances in Functional Training*, strength coach Michael Boyle says, “When we stand on one leg, as in a one-leg squat, we engage these three muscles we don’t use much in a two-leg squat” (Boyle, 2010). Boyle goes on to say that “Unilateral exercise forces the adductors to balance the abduction and external rotation component of the glute max” (Boyle, 2010).

McCurdy’s study from 2005, which found that incorporating unilateral strength work did not reduce short-term maximum bilateral strength and power gains, as well as his aforementioned 2010 study combine to support the use of unilateral strength training. These two studies suggest that unilateral strength training can not only produce similar strength and power results when compared to bilateral training, but it may also have the potential to increase the amount of hip stabilization muscular activity, increasing the overall effectiveness and usefulness of the exercise.

In addition to McCurdy’s research, a growing body of evidence is leading researchers to conclude that greater strength can be achieved by using unilateral exercises. Teixeria et al. (2014) found that a bilateral deficit exists during maximal isometric knee extension in trained men, meaning that the sum of unilateral strengths on a particular exercise was greater than the bilateral strength of the same exercise. This study
aims to build on the base of knowledge in regards to the effectiveness of unilateral strength training in the world of strength, conditioning, and fitness.
CHAPTER III
METHODS

Approach

To determine if the use of unilateral lower body strength exercises would significantly effect the EMG activity of the ankle-stabilizing muscles, twenty participants were recruited to perform one bilateral squatting exercise (the TLS) and one unilateral exercise (the MSLS). Of the twenty participants recruited for the study, sixteen met the qualifications to be involved in the study. EMG activity was recorded for the gastrocnemius (GN) and tibialis anterior (TA) muscles. Initially, the plan was to also examine the peroneals and soleus muscles, but after performing several trial experiments, it was determined that the measurement of these muscles encountered too much interference from the GN and TA for the data to be considered reliable.

Participants

Ten men and ten women between the ages of 18 and 35 were recruited to participate in the study. After IRB approval from The University of Akron for the study, consent forms were distributed to the participants, all of whom volunteered their participation. Each participant was screened for the following exclusionary criteria: any current or previous anterior cruciate ligament injury, reports of self-limiting anterior knee pain, a current ankle or hip injury, current low back pain or disorder, and any current
lower extremity muscle strain or ligament sprain. All participants had previous resistance-training experience of at least one year and reported to be proficient in the TLS. Additional exclusionary criteria included the use of the Functional Movement Screen (FMS) prior to the study. The FMS will be described in greater detail in the procedures section of this report. Four of the twenty recruits were deemed ineligible for the study based on the exclusionary criteria. Table 1 shows the descriptive characteristics of the participants.

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Descriptive Statistics-Men

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<td>Weight (lb.)</td>
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Procedures

After gaining approval from the facility owner, participants and researchers met at A.S.A.P. Fitness in Rocky River, Ohio at an assigned date and time. Upon arrival, participants were asked to report if they had experienced any of the following exclusionary criteria: any current or previous anterior cruciate ligament injury, reports of self-limiting anterior knee pain, a current ankle or hip injury, current low back pain or disorder, and any current lower extremity muscle strain or ligament sprain. The participants were then weighed using a Detecto 439 mechanical beam scale to determine body weight at the time of the study. In addition to the self-reported exclusionary criteria mentioned above, the FMS was used to determine whether the participants had adequate movement quality to perform the TLS and MSLS. The researcher is a certified FMS professional and administered the FMS to each participant on the day of their participation in the study. The FMS is scored from 0 to 3, with a 3 representing a perfect movement pattern, a 2 representing a sufficiently functional movement pattern, a 1 representing a severely restricted movement pattern, and 0 representing pain produced by the movement pattern. The scores are based on specific grading criteria, as judged by the certified FMS Professional. The screen consists of 10 tests: Deep Squat, Hurdle Step,
Inline Lunge, Shoulder Mobility, Impingement Clearing, Active Straight-Leg Raise, Trunk Stability, Press-Up Clearing, Rotary Stability, and Posterior Rocking Clearing. All participants who report pain on any of the movements were to be excluded from the data, as were any subject who scores a 1, representing a severely restricted movement pattern. However, no participants had to be excluded from this study based on their FMS. The FMS was used as a way to decrease the possibility that EMG readings might be affected by an individual’s movement quality in order to ensure more accurate and reliable results. Mean and peak EMG activity was recorded on each participant in both the MSLS and TLS. Participants were measured on their dominant side, as determined by the leg they would use to kick a ball, and performed three measured trials of each exercise. Prior to measurement, participants will go through a brief introductory period to familiarize themselves with the exercise and to maintain perfect technique.

For the TLS, individuals placed their feet in a shoulder-width stance with their toes pointed directly forward. They were asked to squat to a box and then return to a standing position, with their arms extended in front of them so that their elbows were fully extended and their shoulders flexed to approximately 90 degrees with their hands in line with their shoulders. The box height was such that the top of the subject’s quadriceps muscle was parallel to the floor when they reached the bottom position of their squat. This was determined by having the subject sit with a proper stance, and then adjustments were made to the box accordingly, based on visual observation. The subjects’ knees were subjectively monitored to correct excessive anterior translation past their toes. Subjects were instructed to descend for three seconds, and then return to the starting position.
under control. Subjects were instructed to maintain an upright posture and to maintain proper ankle and knee alignment, with the knees tracking the toes (Figure 1).

Figure 1. Two-Legged Squat

For the MSLS, subjects elevated their rear (non-dominant) foot to a height of 12 inches using a platform. They began the exercise with their non-dominant knee resting on a balance pad on the floor in front of the platform. The balance pad was used for cushioning the back knee and stopping it from hitting the floor. Their dominant foot (the front foot) was placed in front of the pad, with their dominant knee bent to a 90-degree angle. This start position was used to help prevent against excessive knee anterior translation past the front toes. Subjects were asked to ascend from the bottom position to a point of full front-knee and hip extension, and then descend for three seconds under
control, with their arms extended in front of them so that their elbows were fully extended and their shoulders flexed to approximately 90 degrees with their hands in line with their shoulders. Subjects were instructed to maintain an upright posture, and to maintain proper ankle and knee alignment, with the front knee tracking the toes (Figure 2).

Figure 2. Modified Single Leg Squat

Subjects were permitted to go through a practice period on both exercises, allowing for proper technique instruction as well as verbal explanations of the EMG procedures. Subjects were asked to demonstrate at least three consecutive properly executed repetitions of each exercise before their testing period begins.
Before electrode placement, each subject’s skin was lightly abraded and then cleansed with an alcohol wipe. For the TA muscle, two active electrodes were placed 2 cm apart, parallel to and just lateral of the medial shaft the tibia, at approximately one-quarter to one-third the distance between the knee and the ankle. Participants were asked to flex the TA muscle, and the electrodes were placed over the largest muscle mass (Criswell & Cram, 2011). General recordings of the GN muscle were measured by placing one active electrode in the center of each head of the GN muscle, approximately 2 cm away from the midline and distal to the knee. The final ground electrode was placed on the lateral malleolus. Before EMG analysis, the subject dorsiflexed the foot while standing to detect the presence of TA activity and plantar flexed the foot to detect the presence of GN activity. A marker was inserted into the raw sEMG signal to designate the beginning and end of a 15-second standing baseline measurement, as well as a beginning and end of the TLS and MSLS portions of the study. The electrode placement procedures followed the Atlas for Electrode Placement procedures found in Criswell and Cram’s Introduction to Surface Electromyography, second edition.

Data Collection

The materials involved in collecting EMG data included the following: Lenovo laptop computer with LabScribe2 installed, the iWorx IWX/214 data acquisition unit and power supply, a USB cable to connect the IWX/214 to the computer, the C-AAMI-504 ECG cable and electrode lead wires, as well as disposable electrodes provided by the University of Akron. The researcher followed the procedures described in LabScribe2’s setup for Muscle Physiology.
CHAPTER IV
RESULTS

The dependent variables analyzed in this study were the mean and mean peak EMG activity of the gastrocnemius and tibialis anterior muscles. Sixteen subjects, 8 males and 8 females were included in the study results. The data was analyzed using Microsoft Excel. A paired T-Test was performed to assess significance with significance level set at P<.05. Reported EMG activity (converted into millivolts (mV)) indicated a difference between the TLS and the MSLS for all of dependent variables in question. The MSLS produced a significantly different EMG response in Mean TA activity (P=.011), Mean Peak TA (P=.016), Mean GN (P=.03) and Mean Peak GN (P=.001). Results are provided in Table 4.

Table 4
EMG (mV) Amplitude, Mean

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<td>Mean Peak TA</td>
<td>65.45</td>
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<tr>
<td>Mean GN</td>
<td>34.48</td>
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<td>Mean Peak GN</td>
<td>71.20</td>
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Figure 3. EMG Amplitude (mV)
CHAPTER V
SUMMARY

The results of this study reveal a greater degree of gastrocnemius and tibialis anterior muscle activation during the MSLS when compared to the TLS at the same relative intensity. This study adds to the growing body of evidence such as the results found in McCurdy et al (2010), suggesting that reducing the base of support during lower body strength training exercises requires the individual to engage muscles of their lower limbs to a greater degree. The reduction in mediolateral support appears to demand higher neuromuscular activity in order to keep the body upright and functional.

While previous studies have shown an increase in muscular activity by using a “true” unilateral exercise such as the “Pistol” one-legged squat, the researcher in this study decided to use the MSLS as a way to reduce the base of support without limiting the amount of data that was able to be collected. A properly performed one-legged squat is a highly technical movement, requiring a great degree of practice, balance, and stability in order to perform. While the MSLS does keep approximately 15% of an individual’s body weight on the non-test leg (McCurdy et al 2010), this reduction in base of support was enough to elicit a statistically significant change in muscle activity.

The implications of this study, along with studies performed by Behm et al. (2002), McCurdy et al. (2010), and others, can be applied to a variety of populations and
fitness levels. During rehabilitation programs, the MSLS could make for a logical progression from the more stable TLS in order to gradually progress a client’s strength levels around their knee, hip, and ankle. In a general fitness population, this MSLS could be used as an intermediate exercise progression, following more stable exercises such as the TLS and a split squat with both feet on the floor, and preceding more advanced exercises such as lunges and one-legged squats. The MSLS should elicit similar muscular effects as the lunge pattern, with less impact on the joints of the lower body due to their stationary base of support.

As with most lower body exercises, individuals should follow a proper progression plan, beginning with the TLS before progressing to the flat split squat and the MSLS as the movement pattern improves. An individual should master each exercise using only their body weight before adding additional load to the exercise. The researcher has found that mastery of the MSLS using only the individual’s body weight as resistance could take anywhere from one to six weeks, depending on the individual’s weight, athleticism, frequency of practice, and a variety of other factors. The researcher suggests that at an appropriate stage, an individual may begin to add external load to the MSLS, preferably in a front-loaded position in order to help maintain proper posture and alignment throughout the movement. At no point should an individual sacrifice exercise technique in order to add more additional load to the movement.

There are a few possible limitations to this study. For one, a relatively small sample size was chosen, and testing over a larger sample may produce different results. Also, as seen in the descriptive data table, there was a large variation in participant body weight and since the EMG data was only comparative from exercise to exercise, rather
than normalized from individual to individual, a future study may find that a difference exists when body weight is controlled for. EMG data ran on a constant stream and did not provide a separate analysis of the ascent and descent phases of the exercises and were not synchronized with video. Thus, muscle activation was not analyzed at definitive positions during the exercises. These exercises were also not tested under any external load, which may change the outputs of EMG activity to some degree. Also, only two ankle muscles were tested, while muscles such as the soleus and peroneals also play an important role in ankle stabilization. Finally, the population of participants consisted of 18 to 35 year olds only. Future studies may show a significant difference in age groups such as pre-teens, teens up to 18, middle-aged adults, and seniors.

Based on the results of this study, the MSLS produced a greater degree of muscle activity in the gastrocnemius and tibias anterior muscles when compared to the TLS in individuals aged 18 to 35.
REFERENCES


APPENDICES
APPENDIX A

CONSENT FORM

Department of Sport Science and Wellness Education
College of Education
Akron, OH. 44325-5103
330-972-7738 Office
330-972-5293

The University of Akron
Institutional Review Board

Informed Consent

Title of Study: Ankle Muscle Activation During Unilateral and Bilateral Lower Body Strength Exercises

Introduction: You are invited to participate in a research project being conducted by Adam Reeder for the Department of Sport Science and Wellness Education at The University of Akron. The study will be completed at ASAP Fitness, located in Rocky River, Ohio.

Purpose: The purpose of this study is to measure the effects of single-leg strength training exercises on the stabilizing muscles of the ankle, when compared to two-legged strength training exercises the major hypothesis in this study is that the MSLS will produce a greater amount of EMG activity than the TLS in the ankle stabilizing muscles. The desired sample for this study is ten men and ten women between the ages of 18 and 35, all with at least one year of prior resistance training experience.

Procedures: Participants and researchers will meet at an assigned date and time for baseline measurements. Upon arrival, subjects will complete a health history form in order to screen for the following exclusionary criteria: any current or previous anterior cruciate ligament injury, reports of self-limiting anterior knee pain, a current ankle or
hip injury, current low back pain or disorder, and any current lower extremity muscle strain or ligament sprain. Following the health history evaluation, all subjects will go through a Functional Movement Screen (FMS) to determine that they have sufficient mobility and stability capabilities to complete each exercise. A certified FMS instructor will administer the FMS. The FMS is scored from 0 to 3, with a 3 representing a perfect movement pattern, a 2 representing a sufficiently functional movement pattern, a 1 representing a severely restricted movement pattern, and 0 representing pain produced by the movement pattern. The scores are based on specific grading criteria, as judged by the certified FMS Professional. The screen consists of 10 tests: Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Impingement Clearing, Active Straight-Leg Raise, Trunk Stability, Press-Up Clearing, Rotary Stability, and Posterior Rocking Clearing. All subjects who report pain on any of the movements will be excluded from the data, as will any subject who scores a 1, representing a severely restricted movement pattern. Mean and peak EMG activity will be measured on each subject in both the MSLS and TLS. Subjects will be measured on their dominant side, as determined by the leg they would use to kick a ball, and will perform three measured trials of each exercise. Prior to measurement, subjects will go through a brief introductory period to familiarize themselves with the exercise and to maintain perfect technique.

For the TLS, individuals will place their feet in a hip-width stance with their toes pointed directly forward. They will be asked to squat to a bench and then return to a standing position. The bench height will be such that the top of the subject’s quadriceps muscle is parallel to the floor. This will be determined by having the subject sit with a proper stance, and then adjustments will be made to the bench accordingly based on visual observation. The subjects’ knees will be subjectively monitored to correct excessive anterior translation past their toes. Subjects will descend for three seconds, and then return to the starting position under control. Subjects will be instructed to maintain an upright posture and to maintain proper ankle and knee alignment, with the knees tracking the toes.

For the MSLS, subjects will elevate their rear (non-dominant) foot to a height of 12 inches using a platform. They will begin the exercise with their non-dominant knee resting on an ankle pad on the floor in front of the platform and their dominant foot (the front foot) in front of the pad, with their right knee bent to a 90-degree angle. This start position will help prevent against excessive knee anterior translation past the front toes. Subjects will ascend from the bottom position to a point of full front-knee extension, and then descend for three seconds under control. Subjects will be instructed to maintain an upright posture, and to maintain proper ankle and knee alignment, with the right knee tracking the right toes. Subjects will go through a practice period on both exercises, allowing for proper technique instruction as well as written and verbal explanations of the EMG procedures. Subjects will be asked to demonstrate at least three consecutive properly executed repetitions of each exercise before their testing period begins.
Exclusion:
Participants recruited must be between the ages of 18 and 35, must have at least one year of prior resistance training experience, and must pass all FMS tests with a score of a 2 or better.

Risks and Discomforts:
The risks associated with the study include include muscle soreness, and shortness of breath. To minimize risk investigators are first aid, CPR, and AED certified. the investigator is also a certified personal trainer through the American College of Sports Medicine (ACSM) and a certified FMS professional, therefore, participants will be monitored and instructed on the correct techniques to minimize any associated risks.

Benefits:
The participants may gain a better understanding of the differences between unilateral and bilateral lower body strength training.

Right to Refuse or Withdraw:
Participants are volunteering under their own will, and can withdraw from the study at any time with no penalty.

Anonymous and Confidential Data Collection:
Any identifying information collected will be kept in a secure location and only the researchers will have access to the data. Participants will not be individually identified in any publication or presentation of the research results. Only aggregate data will be used. Your signed consent form will be kept separate from the data, and nobody will be able to link their responses to them.

Confidentiality of records:
All participants will be assigned a number and all data will be stored in a binder that only Adam Reeder, and Dr. Ronald Otterstetter have access to. All data will be kept until the masters thesis process is completed. Data will be then stored at InfoCision Stadium 307J for three years.

Who to contact with questions:
If you have any questions about this study, you may call Adam Reeder at 440-539-3393 or Dr. Ronald Otterstetter at 330-972-7738. This project has been reviewed and approved by The University of Akron Institutional Review Board. If you have any questions about your rights as a research participant, you may call the IRB at (330) 972-7666.
Acceptance & signature:
I have read the information provided above and all of my questions have been answered. I voluntarily agree to my participation in this study. I will receive a copy of this consent form for my information.

________________________________________
Printed Name

________________________________________
Signature                   Date
## APPENDIX B

FUNCTIONAL MOVEMENT SCREEN

### THE FUNCTIONAL MOVEMENT SCREEN

#### SCORING SHEET

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<thead>
<tr>
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<tbody>
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<tr>
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<td>PRIMARY SPORT</td>
<td>PRIMARY POSITION</td>
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<tr>
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<th>COMMENTS</th>
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**Raw Score:** This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

**Final Score:** This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.
APPENDIX C

HUMAN SUBJECTS APPROVAL FORM

NOTICE OF APPROVAL

January 31, 2014

Adam Roeder
24520 Clareshire Drive, Unit E
North Olmsted, Ohio 44070

From: Sharon McWhorter, IRB Administrator

Re: IRB Number 20140114 “Ankle Muscle Activation during Unilateral and Bilateral Lower Body Strength Exercises”

Thank you for submitting an IRB Application for Review of Research Involving Human Subjects for the referenced project. Your protocol represents minimal risk to subjects and has been approved under Expedited Category #4.

Approval Date: January 30, 2014
Expiration Date: January 30, 2015
Continuation Application Due: January 16, 2015

In addition, the following is/are approved:

☐ Waiver of documentation of consent
☐ Waiver or alteration of consent
☐ Research involving children
☐ Research involving prisoners

Please adhere to the following IRB policies:

• IRB approval is given for not more than 12 months. If your project will be active for longer than one year, it is your responsibility to submit a continuation application prior to expiration date. We request submission two weeks prior to expiration to ensure sufficient time for review.
• A copy of the approved consent form must be submitted with any continuation application.
• If you plan to make any changes to the approved protocol, you must submit a continuation application for change and it must be approved by the IRB before being implemented.
• Any adverse reactions/incidents must be reported immediately to the IRB.
• If this research is being conducted for a master’s thesis or doctoral dissertation, you must file a copy of this letter with the thesis or dissertation.
• When your project terminates, you must submit a Final Report Form in order to close your IRB file.

Additional information and all IRB forms can be accessed on the IRB website at:
https://www.uakron.edu/research/compliance/IRBHome.php

Cc: R. Ottenstatter – Advisor
Cc: Valerie Callanan – IRB Chair
☐ Approved consent form/s enclosed

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