

UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

ELECTROMYOGRAPHIC COMPARISON OF THE HAMSTING MUSCLES
DURING VARIOUS EXERCISES

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree
of Master of Science in Clinical Exercise Physiology

Kayla M. Schmitt

College of Science and Health
Clinical Exercise Physiology

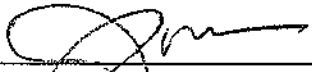
December, 2017

ELECTROMYOGRAPHIC COMPARISON OF THE HAMSTRING MUSCLES
DURING VARIOUS EXERCISES

By Kayla Schmitt

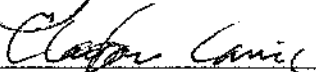
We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

The candidate has completed the oral defense of the thesis.




John Porcari, Ph.D.
Thesis Committee Chairperson

5/5/17
Date



Clayton Camic, Ph.D.
Thesis Committee Member

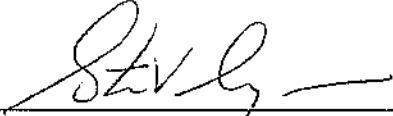
5/5/17
Date



Attila Kovacs, Ph.D.
Thesis Committee Member

5/5/2017
Date

Thesis accepted



Steven Simpson, Ph.D.
Graduate Studies Director

6/24/17
Date

ABSTRACT

Schmitt, K. M. Electromyographic comparison of the hamstring muscles during various exercises. MS in Clinical Exercise Physiology, December 2017, 36pp. (J. Porcari)

The purpose of this study was to compare muscle activation during various hamstring exercises using electromyography to determine which exercise activated the biceps femoris (BF) and semitendinosus (ST) to the greatest extent. Sixteen subjects performed five repetitions of the following exercises: seated leg curl, glute-ham raise with equipment, Romanian deadlift (RDL), stability ball leg curl, reverse hip raise, glute-ham raise without equipment, prone leg curl, kettlebell swings, and single arm/single leg Romanian deadlifts. Electromyography between exercises was compared to the prone leg curl using a one-way ANOVA with repeated measures for each muscle. The seated leg curl, glute-ham raise with equipment, RDL, stability ball leg curls, reverse hip raise, and glute-ham raise without equipment produced significantly lower activation than the prone leg curl for the BF. The stability ball leg curl, reverse hip raise, and glute-ham raise without equipment produced significantly greater activation than the prone leg curl for the ST. Based on these results it seems that the prone leg curl, kettlebell swings, and single arm, single leg RDLs activate the BF and ST to the greatest extent, when collectively focusing on hamstring activation.

TABLE OF CONTENTS

	PAGE
ABSTRACT.....	iii
TABLE OF CONTENTS.....	iv
LIST OF APPENDICES.....	v
INTRODUCTION.....	1
METHODS.....	4
Subjects.....	4
Procedure.....	4
EMG ANALYSIS.....	9
STATISTICAL ANALYSIS.....	10
RESULTS.....	11
Table 1. Descriptive characteristics of subjects.....	11
Figure 1. Comparison of Biceps Femoris Muscle Activation.....	12
Figure 2. Comparison of Semitendinosus Muscle Activation.....	13
DISCUSSION.....	14
REFERENCES.....	17
APPENDICES.....	19

LIST OF APPENDICES

APPENDIX	PAGE
A. Pre-Exercise Health Screening Questionnaire.....	19
B. Informed Consent.....	21
C. Review of Literature.....	24

INTRODUCTION

Resistance training provides many benefits, including improving body composition and glucose tolerance, decreasing blood pressure, and increasing bone density (Westcott, 2012). The American College of Sports Medicine (ACSM) recommends that individuals resistance train 2-3 days a week using multi-joint exercises which focus on the large muscle groups (Thompson et al., 2014). Leg exercises, specifically, are an important component of any resistance training program because they are often overlooked (Thompson et al., 2014). The hamstring muscles play an important role in strengthening the upper leg.

The hamstring muscle group, which is located on the back of the thigh, is comprised of three muscles: biceps femoris (BF), semitendinosus (ST), and semimembranosus. The hamstrings are often 50-80% weaker relative to the quadriceps muscles, which are on the anterior side of the thigh (Rosene et al., 2001). Strengthening the hamstring muscles can make performing activities of daily living easier, especially in older individuals, as well as decreasing pain in those who have tightness in the low back (Balachandran et al., 2016). Strengthening the hamstring muscle group should be done with resistance training exercises that have been shown to be effective. A technique that analyzes how a muscle recruits motor units is called electromyography (EMG).

Electromyography measures the amount of electrical activity in a muscle as the result of nervous stimulation.

For instance, the harder the muscle is working, the more motor units recruited. Once all motor units have been utilized the muscle increases firing frequency to continue contracting. When muscle fatigue sets in larger motor units are recruited, causing amplitude of electrical impulses to increase, but frequency to decrease. Researchers often use EMG to determine how well an exercise activates a muscle.

A study by McAllister et al. (2014) found that the Romanian deadlift is an exercise that shows the greatest muscle activation for the semitendinosus. The study also found that the glute-ham raise high activation for both the biceps femoris and semitendinosus. In addition, both the Romanian deadlift and glute-ham raise presented more activation than good mornings and prone leg curls for those two muscles.

Additionally, Oliver and Dougherty (2009) compared the razor curl and prone leg curl to determine which was better at activating the hamstring muscles. It was found that the razor curl was better at activating the hamstring muscle group. The razor curl was performed in a functional position which is important for sports training, whereas the prone leg curl was not. Zebis et al. (2012) used EMG testing to determine how well kettlebell swings and Romanian deadlifts activated the biceps femoris and semitendinosus. It was found that both exercises activated the semitendinosus significantly greater than the biceps femoris. In contrast, the supine leg curl and hip extensions activated the biceps femoris more than the semitendinosus.

Very little research has been done comparing the effectiveness of several different hamstring exercises. Additionally, clients often cite lack of time as a main reason not exercising, personal trainers are looking for the single best hamstring exercise that is both time efficient and effective.

The purpose of this study was to determine which of nine hamstring exercises would be most effective at activating those muscles. The nine exercises compared were:

1. Prone leg curl using a machine
2. Seated leg curl using a machine
3. Single-arm/single-leg RDL
4. Glute-ham raise with a machine
5. Glute-ham raise no equipment
6. Reverse hip raise
7. Kettlebell swings
8. Stability ball hamstring curl
9. Romanian deadlift

METHODS

Subjects

Sixteen volunteers (8 male, 8 female) between the ages of 18 to 25 were used as subjects (Table 1). Each subject was required to have previous resistance training experience. The knowledge of resistance training allowed the subjects to perform the exercises with proper technique and reduced the chance for injury. The study was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects and each subject provided written informed consent prior to participating in the study.

Procedure

Each subject attended two separate sessions, each lasting approximately 1 hour, with at least three days of rest between each session. During the first session, one repetition maximum (1RM) was determined for the prone leg curl using a machine, seated leg curl using a machine, Romanian deadlift, and single-arm/single-leg Romanian deadlift. One repetition maximums were determined by progressively adding weight to the barbell or machine until only one repetition was achieved, with a one-minute rest period between 1RM attempts. From the 1RM values, a weight that corresponded to 70% of 1RM was calculated for use during subsequent testing. Literature has shown that a contraction greater than 50% of maximal contraction results in an increase muscular strength. Seventy-percent was determined because most resistance trainers lift that amount during an average exercise routine. Glute-ham raise using a machine, glute-

ham raise without equipment, kettlebell swings, stability ball hamstring curl, and reverse hip raise, involve solely body weight or a fixed weight, so 1RM determination was not needed. During the second session, subjects performed a maximal voluntary contraction (MVC) along with the nine exercises, in random order. To perform the MVC, the subject started by lying on a mat on the floor with their right knee flexed at a 90-degree angle. The subject pulled their foot towards their glutes as the research assistant pulled the subject's foot in the opposite direction. For the biceps femoris, the subject's foot was twisted laterally. For the semitendinosus, the subject's foot was twisted medially. This position was held for 3 seconds. A description of the nine exercises that were compared in the study are presented below.

1. Prone leg curl using a machine: The subject laid on their stomach on the machine.

The subject positioned the back of their lower legs under the resistance pads, with the resistance pad just above the heel. After grasping the available handles for stabilization, they pulled their heels toward their gluteus maximus until the knee was bent to 90 degrees. The subject then slowly lower their heels back to the starting position.

2. Seated leg curl using a machine: The subject was seated on the machine with the back of their lower leg on top of the padded lever and with the lap pad secured against their thighs, just above the knees. They then grasped the handles on the machine for stability. They started with their legs straight out in front of them. The subject then pulled the lever back towards their posterior thigh, while keeping their torso stationary. Once the lever was pulled back as far as possible, they slowly release the lever and returned to the starting position.

3. Romanian deadlift: The subject started with a pronated grip on a barbell with the hands about shoulder-width apart. They had a slight bend in their knees, with their feet hip-width apart, and their back straight with a neutral spine. They then lifted the barbell to the front, upper part of their thighs. Once their legs were fully extended, the subject lowered the barbell by hinging at the hips and bending their knees. When the barbell was lowered to approximately their mid-calf, or they feel tension in their hamstrings, the subject pressed their heels into the floor, pushed their hips forward, and pulled back on their knees, while keeping a neutral spine, until they returned to the starting position.
4. Single-arm/single-leg Romanian deadlift: The subject balanced on their right leg while they held a dumbbell in their left hand; their right knee was slightly bent and their back straight. They then leaned forward on the right hip while keeping their left arm straight, so that the dumbbell was lowered directly in front of their left leg. Once the dumbbell was lowered almost to the floor, the subject pushed their right foot into the floor and lowered their left leg until they were in an upright position.
5. Glute-ham raise using a machine: The subject positioned themselves on the machine with their feet placed against the footplate and their ankles between the rollers; their knees were just behind the pad of the machine and arms were crossed in front of their body. The subject started with their torso perpendicular to the floor and knees bent. The subject then descended until their torso was parallel to the floor. They then contracted their hamstrings and core muscles to rise into the upright position.
6. Glute-ham raise without equipment: The subject started by kneeling on a mat with their knees bent and arms crossed. A research assistant held the back of the subject's

- ankles as the subject lowered their torso until it was parallel to the floor. They then contracted their hamstrings and core muscles to rise into the upright position.
7. Kettlebell swings: The subject held the kettlebell with both hands so it was hanging between their legs. Their knees were slightly bent and arms straight as they pushed their hips forward and swung the kettlebell out in front of them until it reached shoulder height. The legs were to be kept straight. They then pushed their hips back and returned to the starting position with the kettlebell between their legs.
 8. Stability ball hamstring curl: The subject started by lying on their back on a mat. They then placed their heels on the top of the stability ball and raised their hips so there was a straight line from their hips to their shoulders. Their arms were extended out to the sides for stability. The subject then slowly bent their knees and pulled the ball toward their hips until the soles of their feet were on top of the ball. Their hips were still in a straight line with their shoulders. Once the subject's soles were on top of the ball, the subject slowly rolled the ball out until their knees were straight again.
 9. Reverse hip raise: The subject laid face down on the edge of a lifting bench so their hips and legs were not touching the bench. The subject gripped the bars underneath the bench for stability. They then lifted their legs in the air, with their knees together, until their legs were in a straight line with their torso. Then the subject slowly lowered their legs and returned to the starting position.

Before the second testing session began, wireless surface electrodes were affixed to the skin directly over the biceps femoris and semitendinosus. The semimembranosus could not be tested due to its deep location. Prior to electrode placement, the skin was prepared by removing any hair in the area with a razor and cleansing the area with

alcohol to remove any dead skin or body oils. The electrode for the biceps femoris was located halfway between the ischial tuberosity and lateral epicondyle of the fibula. The electrode for the semitendinosus was placed halfway between the ischial tuberosity and the medical epicondyle of the tibia (Criswell & Cram, 2011; Sensor Locations, n.d).

EMG ANALYSIS

Electrical activity of the biceps femoris and semitendinosus was recorded and stored on a personal computer. The EMG signal was preamplified (gain 900x) using a differential amplifier (Delsys Trigno Wireless Systems, Boston, MA; bandwidth 20-450 Hz). Raw EMG signals was digitized at 2000 Hz. The EMG amplitude (microvolts root mean square [μV_{rms}]) values was calculated for each trial and represented as a percentage of the maximal RMS value recorded during the MVC trial. Five repetitions were recorded for each exercise. The middle three repetitions were used for analysis.

STATISTICAL ANALYSIS

Differences in EMG activity between exercises and gender were compared using a two-way mixed factorial ANOVA for the biceps femoris and semitendinosus. There was no significant difference in EMG activity between exercises for males versus females, thus data were collapsed across gender. Differences between exercises were determined using Fisher's LSD post-hoc tests. Alpha was set at 0.05 to achieve statistical significance.

RESULTS

Sixteen apparently healthy men (8) and women (8) between the ages of 20 -25 completed the study. Descriptive characteristics of the subjects are presented in Table 1.

Table 1. Descriptive characteristics of the subjects (N=16)

	Females (n=8)	Males (n=8)
Age (yrs)	22.5 ± 1.85	22.6 ± 1.69
Height (in)	63.6 ± 1.51	69.9 ± 2.88
Weight (kg)	69.4 ± 9.80	77.1 ± 7.12

Values represent mean ± standard deviation.

All exercises were compared to the prone leg curl, which is a common hamstring exercise and elicited relatively equal activation of both the BF and ST. Biceps femoris activation for each exercise is presented in Figure 1. Semitendinosus activation for each exercise is presented in Figure 2. For the BF, the seated leg curl, glute-ham raise with machine, RDL, stability ball leg curl, reverse hip raise, and glute-ham no machine elicited significantly lower muscle activation than the prone leg curl. None of the exercises had significantly higher muscle activation than the prone leg curl. For the ST, stability ball leg curls, reverse hip raise, and glute-ham raise no machine all elicited significantly greater muscle activation than the prone leg curl. None of the exercises had significantly lower muscle activation than the prone leg curl.

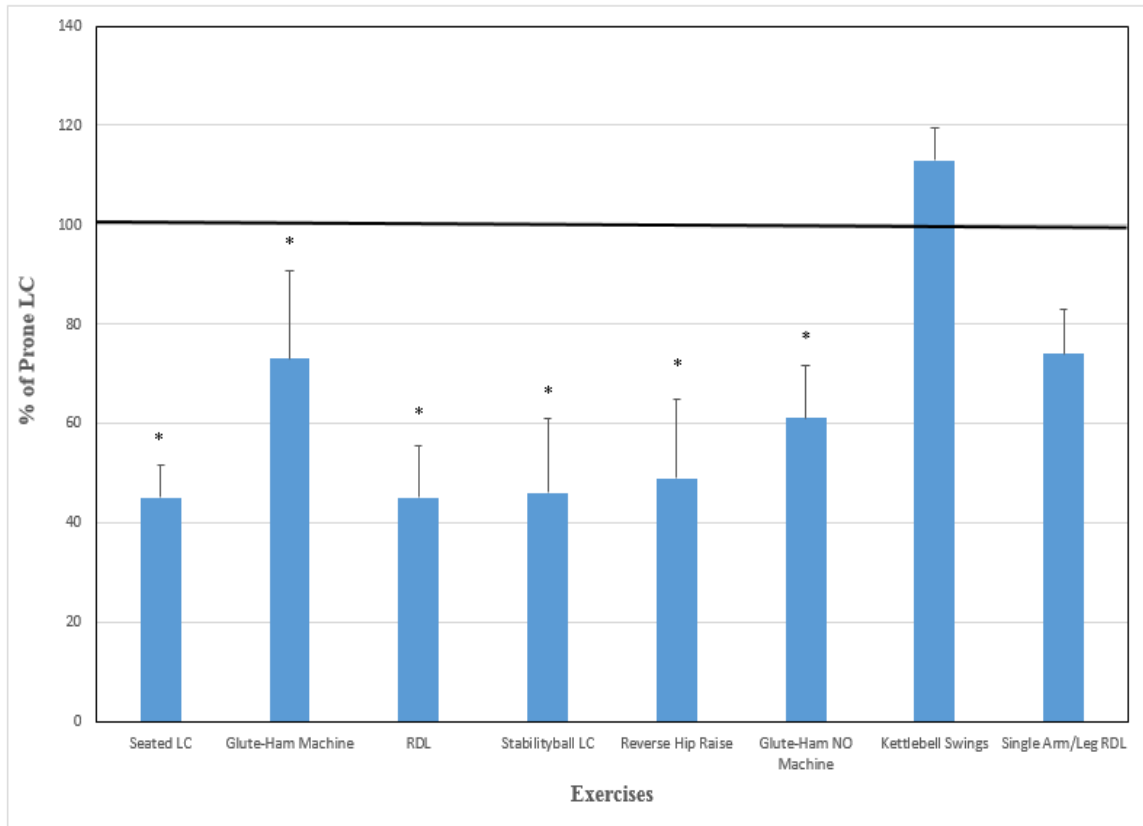


Figure 1. Comparison of biceps femoris activation for the various exercises compared to the prone leg curl. The heavy black line represents the prone leg curl.
 * Significantly less than the prone leg curl ($p < 0.05$).

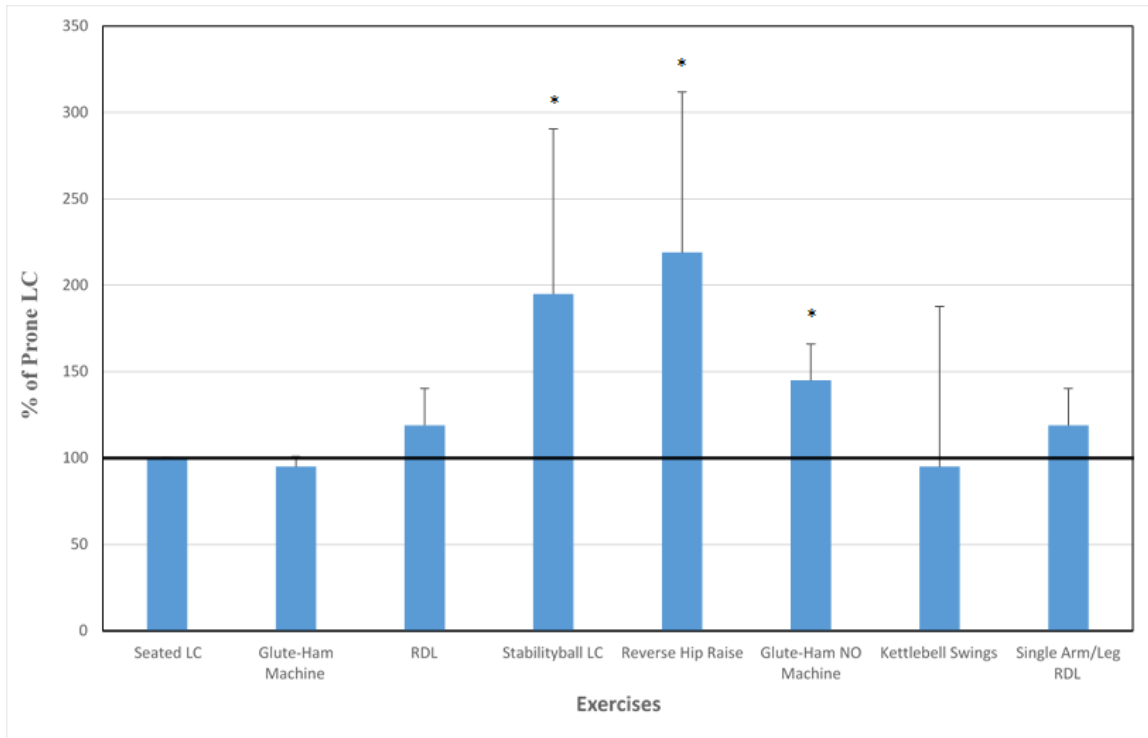


Figure 2. Comparison of semitendinosus activation for the various exercises compared to the prone leg curl. The heavy black line represents the prone leg curl.

* Significantly greater than the prone leg curl ($p < 0.05$).

DISCUSSION

One of the main findings of this study was that none of the exercises activated the BF to a significantly greater extent than the prone leg curl. There was no significant difference between the prone leg curl and kettlebell swings and single arm and leg RDLs. This suggests that performing kettlebell swings and single arm and leg RDLs would activate the BF to a similar extent as the prone leg curl. The other six exercises (i.e., seated leg curl, glute-ham raise with machine, RDL, stability ball leg curl, reverse hip raise and glute-ham raise no machine) all resulted in lower activation of the BF compared to the prone leg curl. Therefore, those exercises do not activate the BF to the greatest extent.

The other main finding of this study was that the stability ball leg curl, reverse hip raise, and glute-ham raise without equipment activated the ST to a significantly greater extent than the prone leg curl. Therefore, those three exercises could be performed instead of prone leg curls to get better activation of the ST. Seated leg curls, glute-ham raise no machine, RDL, kettlebell swings, and single arm and leg RDL resulted in similar activation of the ST and could be used interchangeably with prone leg curls.

Several previous studies found opposing results than the current study. McAllister et al. (2014) found that RDLs and glute-ham raises elicited the greatest activation of the BF and ST, and were both more effective compared to prone leg curls. Oliver and Dougherty (2009) found razor leg curls, which was not examined in this study, resulted in greater activation of both muscles than prone leg curls. Zebis et al. (2012) found that

kettlebell swings activated the ST to a greater degree than the BF, which is the opposite of this study. These studies suggest the prone leg curl is not an appropriate exercise to train the BF and ST, but the results from the current study suggest otherwise.

A possible reason as to why previous studies had conflicting conclusions is placement of the electrodes. Schoenfeld et al. (2015) examined different regions of the hamstring muscles to determine if there was a difference between upper versus lower hamstring muscle activation. They compared stiff-legged deadlifts (which are similar to RDLs) and prone leg curls. It was found that the lower hamstring region had significantly greater activation for the prone leg curl, while the upper hamstring region elicited equal activation for the stiff-leg deadlifts and prone leg curl. This is thought to be attributed to the separate single muscle nerves that a signal is produced from. Therefore, if one muscle nerve is firing more often, then one muscle may become hypertrophied. Those findings suggest that placing an electrode on the lower portion of each hamstring muscle might yield a different outcome than if it was placed on the upper portion, which could help to explain varying conclusions from different studies.

Differing results between studies could also be due the fact that people recruit their muscles differently from one another. McAllister et al. (2014) suggests that hip control contributes to muscle recruitment, depending on whether a person is stronger laterally or medially. That difference can be caused by unequal muscular strength, which causes people to internally or externally rotate their hips. If the hips or knees tend to externally rotate, the BF is usually stronger and is therefore recruited first. The same applies for internal rotation, except it contributes more to ST recruitment. The differences in recruitment and rotation are an important factor when collecting EMG data. Because

people might recruit muscles differently, this possibly contributes to variation between study results.

When looking at the data collectively, there were only two exercises, kettlebell swings and single arm and leg RDLs, that had similar muscle activation compared to the prone leg curl. This suggests that those two exercises could be used interchangeably with the prone leg curl. The stability ball leg curl, reverse hip raise and glute-ham raise no machine activated the BF to a significantly greater than the prone leg curl, but these same exercises resulted in a significantly lower activation for the ST.

Time is a valuable thing when it comes to exercises; a workout is usually fit into a 30-45 minute window. Thus, deciding what exercises to use for a specific body part becomes important if an individual does not enough time to focus on the BF and ST separately. The results of this study suggest that the prone leg curl, kettlebell swings, or single arm and leg RDLs stimulate both muscles adequately and equally and can be used interchangeably.

REFERENCES

- Balachandran, A., Martins, M. M., Faveri, F. G., Alan, O., Cetinkaya, F., & Signorile, J. F. (2016). Functional strength training: Seated machine vs standing cable training to improve physical function in elderly. *Experimental Gerontology*, 82, 131-138. doi:10.1016/j.exger.2016.06.012
- Criswell, E., & Cram, J. R. (2011). *Cram's introduction to surface electromyography* (2nd ed). Sudbury, MA: Jones and Bartlett.
- Exercise Library. (2016). Retrieved August 03, 2016, from <https://www.acefitness.org/acefit/exercise-library-main/>
- McAllister, M., Hammond, K., Schilling, B., Ferreria, L., Reed, J., & Weiss, L. (2014). Muscle activation during various hamstring exercises. *Journal of Strength & Conditioning Research*, 28(6), 1573-158. doi: 10.1519/JSC.0000000000000302
- Oliver, G. D., & Dougherty, C. P. (2009). Comparison of hamstring and gluteus muscles electromyographic activity while performing the razor curl vs. the traditional prone hamstring curl. *Journal of Strength and Conditioning Research*, 23(8), 2250-2255. doi:10.1519/jsc.0b013e3181b8d34b
- Rosene, J. M., Fogarty, T. D., & Mahaffey, B. L. (2001). Isokinetic Hamstrings: Quadriceps Ratios in Intercollegiate Athletes. *Journal of Athletic Training*, 36(4), 378-383.
- Schoenfeld, B., Contreras, B., Tiryaki-Sonmenz, G., Wilson, J., Kolber, M., & Peterson, M. (2015) "Regional Differences in Muscle Activation During Hamstrings Exercise," *Journal of Strength and Conditioning Research*, doi: 10.1519/JSC.0000000000000005
- Sensor Locations. (n.d.). Retrieved July 20, 2016, from <http://seniam.org/semitendinosus.html>
- Thompson, W. R., Gordon, N. F., & Pescatello, L. S. (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). Philadelphia: Lippincott Williams & Wilkins, 179-182.

Westcott, W. L. (2012). Resistance training is medicine. *Current Sports Medicine Reports*, 11(4), 209-216. doi:10.1249/jsr.0b013e31825dabb8

Zebis, M. K., Skotte, J., Andersen, C. H., Mortensen, P., Petersen, H. H., Viskær, T. C., Jensen, T. L., Bencke, J., & Andersen, L. L. (2012). Kettlebell swing targets semitendinosus and supine leg curl targets biceps femoris: An EMG study with rehabilitation implications. *British Journal of Sports Medicine*, 47(18), 1192-1198. doi:10.1136/bjsports-2011-0

APPENDIX A

PRE-EXERCISE HEALTH SCREENING QUESTIONNAIRE

Electromyography Analysis of Various Hamstring Exercises

Pre-Exercise Health Screening Questionnaire

Name: _____

Age: _____ Height: _____ Weight: _____ Gender: _____

1. **Have you done strenuous exercise within the past 24 hours (circle one)?**
Yes No
2. **Are you experiencing, or have you previously experienced leg pain which is made worse with exercise? Yes No**

If yes, please explain _____

Subject

Day # 1 Exercises

1. MVC
2. Seated Leg Curl Machine
(Machine)
3. Glute-Ham Raise (No Equipment)
4. Kettlebell Swings
5. Single-arm, Single-leg Romanian Deadlift
Curl
6. Reverse Hip Raise

Day #2 Exercises

1. MVC
2. Glute-Ham Raise
3. Prone Leg Curl Machine
4. Romanian Deadlift
5. Stability Ball Hamstring

APPENDIX B
INFORMED CONSENT

INFORMED CONSENT

Electromyographic Analysis of Various Hamstring Exercises

I, _____, volunteer to participate in a research study being conducted at the University of Wisconsin-La Crosse.

Purpose and Procedure

- The purpose of this study is to record muscle activity (as measured by electromyography) during nine different hamstring exercises, in an attempt to determine the most effective hamstring exercise.
- The exercises being tested include: prone leg curls with a machine, seated leg curls with a machine, Romanian deadlifts, single-arm/single-leg Romanian deadlifts, glute-ham raises with a machine, glute-ham raises without equipment, kettlebell swings, stability ball hamstring curls, and reverse hip raises.
- My participation in this study will require me to complete three sessions, each lasting approximately 1 hour. A minimum of 5 days will be given between exercise sessions to ensure sufficient recovery.
 - During the first session, I will perform each exercise to determine my maximal strength (1RM) for the following lifts: prone leg curls with a machine, seated leg curls with a machine, Romanian deadlifts, and single-arm/single-leg Romanian deadlifts.
 - During the second session, I will perform 5 repetitions for 5 of the 9 exercises at 70% of my 1RM. For exercises using body weight, I will perform 5 repetitions for each exercise.
 - During the third session, I will perform 5 repetitions of the last 4 exercises at 70% of the 1RM.
 - For all testing, adhesive electrodes will be placed on my hamstring muscles (back of the thigh).
- Testing will take place in the weight room located in Mitchell Hall on the University of Wisconsin-La Crosse campus.
- Research assistants will be conducting the research under the direction of Dr. John Porcari, a Professor in the Department of Exercise and Sport Science.

Potential Risks

- Muscle fatigue, muscle soreness, and “pulled” muscles are possible risk factors associated with participating in this study.
- Skin irritation from placement of the EMG electrodes is also possible.
- During all testing sessions there will be individuals present who are trained in CPR and Advanced Cardiac Life Support if complications were to occur. There is an AED in the laboratory where testing will take place.
- The risk of serious or life-threatening complications, for healthy individuals, like myself, is near zero.

Potential Benefits

- I, athletes, coaches, and trainers, may benefit from this study by gaining knowledge about which exercise is the most effective for training the hamstrings.

Rights & Confidentiality

- My participation in this study is voluntary.
- I can withdraw from the study at any time, for any reason, without penalty.
- The research findings of this study may be published in the scientific literature and presented at professional meetings using group data only.
- All information will be kept confidential and my data will not be linked with personally identifiable information.

I have read the information provided on this consent form. I have been informed of the purpose of the test, the procedures, and expectations of myself as well as the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that have concerned me and received clear answers to ensure my full understanding of all aspects of the study.

If I have any other questions that arise I may feel free to contact the principal investigator: Kayla Schmitt (608) 415-3809, or her advisor, Dr. John Porcari, 141 Mitchell Hall, (608) 785-8684. Questions regarding the protection of human subjects may be addressed to the University of Wisconsin-La Crosse Intuitional Review Board for the Protection of Human Subjects at (608) 785-8124 or irb@uwlax.edu.

Participant: _____ Date: _____

Investigator: _____ Date: _____

APPENDIX C
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Leg strength is an essential component for everyday living. Specifically, the hamstring muscles are often neglected, leading those muscles to be particularly weak. That could be since there are few exercises that explicitly train the area, or that hamstrings muscles are often overlooked. The American College of Sports Medicine recommends individuals resistance train 2-3 days a week using multi-joint exercises and focusing on the large muscle groups (Thompson et al., 2014). Strong hamstring muscles make tasks like getting out of a chair or bending over to pick up a bag of groceries much easier and painless. Figuring out the exercises that engage the hamstring muscles most can be beneficial to those people that experience weakness in that area. Using electromyography (EMG) as a measuring tool is a great way to determine which exercise would be the best because it measures the electrical activity of a specific stimulated muscle. This review of literature concentrates on the techniques for measuring the biceps femoris and semitendinosus muscles of the hamstring group by means of EMG during different hamstring exercises

Muscles of Interest

There are three muscles that make up the hamstring group: semitendinosus (ST), semimembranosus (SM), and biceps femoris (BF). The two larger muscles that this study will focus on are the ST and BF. The SM is difficult assess with surface because it is located slightly behind the ST (Higashihara et al., 2010). The anatomy of each muscle becomes important when finding the precise location to affix the EMG electrodes. The BF has a long head and a short head. The long head begins lateral of the ischial tuberosity. The short head connects the muscle tissue laterally to the epicondyle of the

fibula, or the outside of the knee. The ST begins medial of the ischial tuberosity, right next to the BF long head, and curves to the inside of the knee, on the medial epicondyle of the tibia. Together, both muscles together make up the majority of muscle tissue on the back of the upper leg.

EMG Electrodes

The electrical activity conducted by a muscle during work is measured using electromyography (EMG). Electromyography electrodes are used as part of a process to obtain an electrical signal from a muscle and record the wave forms on a computer program. Throughout medical history several different electrode models have been used. Kamen and Gabriel (2010) reference two electrode models, indwelling and surface electrodes, with each having their own appropriate uses.

Indwelling electrodes do just as they suggest, they are inserted directly into the muscle. These electrodes record more sensitive, precise information because the electrodes are touching muscle fibers directly. Indwelling electrodes used are mainly used for deep muscles. Measurements are made by either putting a single needle into the muscle or placing two wires in the same location. Indwelling electrodes are typically more painful than using surface electrodes. In addition, it becomes extremely important to sterilize materials when performing the indwelling method because poorly sanitized materials can cause infections or unwanted transfer of bodily fluids.

Surface electrodes are the more favorable electrode type due to their ease of use and noninvasive nature. When surface electrodes first started out they were small metal plates that could only pick up a good electrical signal if electrode gel was first placed on the skin over the desired area. Now, surface electrodes will detect an adequate signal

without electrode gel because the electrodes have a device that amplifies a weak electrical signal from within the electrode itself. The two major downfalls of a surface electrode are that muscle activity is difficult to isolate to just one specific muscle, especially if the muscle is small, and the other downfall is the inability to reach deep, underlying muscles.

Surface Electrode Placement

Surface electromyography (SEMG) electrodes are a non-invasive tool to measure a muscle's electrical activity. The SEMG electrodes are convenient and easy to use and they cause no harm to the subject. Before the electrodes are attached, the skin should be properly prepared to ensure the electrodes remain stable and eliminate unwanted artifact. Preparation involves shaving any hair in the specific area and cleaning the area with alcohol which cleanses and removes dead skin. (Criswell, 2011; Hermens, 2000). The precise placement of the SEMG electrodes is a critical step in gathering accurate measurements of the muscle's activity. If electrodes are placed in unsuitable areas of the muscle, such as the innervation zone, signals can be erroneously high, therefore causing false data. Additionally, correct electrode placement will eliminate cross-talk between other adjacent muscles (motor units) ensuring accurate data collection (Day, n.d).

Typically, two electrodes are used for the hamstring group; one electrode on each the BF and ST. The proper electrode placement for the BF is located halfway between the ischial tuberosity, right under the gluteus maximus, the lateral epicondyle of the tibia. The proper electrode placement for the ST, is located halfway between the ischial tuberosity and the medial epicondyle of the tibia. Special double-sided adhesive tape is used to attach the electrode firmly to the skin. (Hermens et al., 2000).

Related Studies

The hamstring muscles play a major role in hip extension and knee flexion. Studies have shown that having strong hamstrings can prevent hamstring strains and knee injury, and even help with knee injury recovery. Vegso, Genuario and Torg (1985) explain that the hamstring muscles help with stabilizing the knee during walking, therefore strengthening the hamstring can help with rehabilitation of the knee. Other studies show the hamstring muscles are weaker when performing eccentric movements. Strengthening the muscles is important, thus finding a good exercise to strengthen the muscles is essential.

McAllister et al. (2014) found that the Romanian deadlift elicited the most activation in the semitendinosus and semimembranosus muscles during a concentric contraction compared to the prone leg curl. They concluded that the glute-ham raise resulted in the best overall hamstring muscle activation in both the biceps femoris and semitendinosus. In addition, Ebben (2006) found that the seated leg curl was the best exercises for recruiting the most motor units as compared to good mornings and variations of deadlifts. From these studies, it is clear that a certain exercise can be better for a certain hamstring muscle and not the others. Therefore, it may be difficult to narrow down the best overall hamstring exercise according to EMG measurements.

Summary

Studies have shown that maintaining strong hamstrings can greatly benefit an individual's health. Strong hamstrings are an important muscle group for everyday living. If those muscles become weak then those people tend to lead more sedentary lifestyles. There have been studies completed that compared the activation of the hamstring muscles

using several different exercises, but there has not been a study that takes into consideration more than three to four exercises compared to each other. Finding the best hamstring exercise for overall hamstring strength can be beneficial to maintaining strong and healthy exercising habits.

REFERENCES

- Biceps femoris muscle. (n.d.). Retrieved July 20, 2016, from https://en.wikipedia.org/wiki/Biceps_femoris_muscle.
- Criswell, E., & Cram, J. R. (2011). *Cram's introduction to surface electromyography* (2nd ed). Sudbury, MA: Jons and Bartlett.
- Day, S. (n.d.) "Important factors in surface EMG measurement", Bortec Biomedical Incorporated.
- Ebben, W.P. (2006). Hamstring and quadriceps motor unit activation during resistance training and plyometric exercise. *ProQuest Dissertations and Theses*.
- Guex, K., Degache, F., Gremion, G., & Millet, G. P. (2013). Effect of hip flexion angle on hamstring optimum length after a single set of concentric contractions. *Journal of Sports Sciences*, 31(14), 1545-1552.
- Jönhagen, S., Németh, G., & Eriksson, E. (1994). Hamstring injuries in sprinters: The role of concentric and eccentric hamstring muscle strength and flexibility." *The American Journal of Sports Medicine*, 22(2), 262-6.
- Hermens, H. J., Freriks, B., Disselhorst-Klug, C., Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology*. 10(5):361–374. doi:10.1016/S1050-6411(00)00027-4
- Higashihara, A., Ono, T., Kubota, J., & Fukubayashi, T. (2010). Differences in the electromyographic activity of the hamstring muscles during maximal eccentric knee flexion. *European Journal of Applied Physiology*. 108(355). doi:10.1007/s00421-009-1242-z
- Kamen, G., & Gabriel, D. A. (2010). *Essentials of electromyography*. Champaign, IL: Human Kinetics.
- McAllister, M. (2014). Muscle activation during various hamstring exercises. *Journal of Strength & Conditioning Research* (forthcoming). doi: 10.1519/JSC.0000000000000302
- Semitendinosus muscle. (n.d.). Retrieved July 20, 2016, from https://en.wikipedia.org/wiki/Semitendinosus_muscle
- Sensor Locations. (n.d.). Retrieved July 20, 2016, from <http://seniam.org/semitendinosus.html>

Thompson, W. R., Gordon, N. F., & Pescatello, L. S. (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). Philadelphia: Lippincott Williams & Wilkins, 179-182.

Vegso, J. J., Genuario, S. E, & Torg, J. S. (1985). Maintenance of hamstring strength following knee surgery. *American College of Sports Medicine*, 17(3), 376-379.