2017

The Effect of Stretching the Gastrocnemius on Electromechanical Delay and Decreased Muscle Power Production

Kolyse E. Wagstaff
Georgia Southern University

Recommended Citation
Wagstaff, Kolyse E., "The Effect of Stretching the Gastrocnemius on Electromechanical Delay and Decreased Muscle Power Production" (2017). *Honors College Theses*. 564.
https://digitalcommons.georgiasouthern.edu/honors-theses/564

The Effect of Stretching the Gastrocnemius on Electromechanical Delay and Decreased Muscle Power Production

An Honors Thesis submitted in partial fulfillment of the requirements for Honors in
Health and Kinesiology.

By

Kolyse Wagstaff

Under the mentorship of *Dr. Li Li and Dr. Daniel Czech*

ABSTRACT

Previous studies in the field of biomechanics have determined that statically stretching muscles before explosive athletic events decreases muscle power production during performance. However, current research does not explain why muscle power production is lessened due to static stretching. Electromechanical delay (EMD) is the delay between muscle stimulation and force, and the purpose of this research is to determine if the decrease in muscle force production is due to a lengthened EMD of the muscle, potentially caused by static stretching. To test this, participants jumped on force plates and jump power produced by the gastrocnemius was calculated, with stretching and without stretching the muscle, while force and EMG of the gastrocnemius were being recorded. It was hypothesized that stretching would create a lengthened EMD of the muscle, and the resulting power from jumping would be less than the power created without stretching, resulting from a lengthened EMD. While the power decreased after static stretching, the EMD of participants who stretched decreased instead of increasing as hypothesized, and the EMD of control participants who did not stretch increased, although there was no change in jumping.

Thesis Mentor: ____________________

Dr. Daniel Czech

Honors Director: ____________________

Dr. Steven Engel

April 2017

Health and Kinesiology

University Honors Program

Georgia Southern University

Acknowledgements

This project could not have been completed without Dr. Li spending hours teaching us the biomechanics behind the study, and coming up with the idea for the research thesis.

A huge thank you to Dr. Czech, who supported us and checked in constantly to make sure that we were not overwhelmed and were on track with the project, and for challenging us to submit our presentation for a conference at Harvard University.

A special thank you to Klarie Ake, Dr. Li's graduate assistant who spent hours with us in the lab, teaching us to use unfamiliar equipment and always being available for advice and support.

Introduction

Stretching before athletic events has been commonly looked at as helping athletes to achieve best performance by improving range of motion in joints, lessening stiffness, and helping to prevent injury (Costa et al, 2012). However, studies are showing that passive stretching can reduce the amount of force produced by the stretched muscle, hurting performance of the athlete. Therefore, many studies have looked at the different effects of statically stretching muscles before athletic events based on stretch types, extent, and effectiveness, yet there are none explaining why the loss of muscle power production occurs (Cramer, et al. 2005; Curry, et al. 2009; Behm, et al. 2004; Kay, et al. 2013; Simic, Sarabon, & Markovic, 2013; Behm, Bambury, Farrell, and Power, 2004). Athletic events requiring explosive muscle power production are negatively impacted through passive stretching, as muscle power produced during the event is decreased. Passive stretching also changes the stiffness of the muscle-tendon unit, which is strongly related to electromechanical delay (EMD). EMD, the delay between muscle stimulation and force production, may play a role in decreasing the amount of power produced by the muscle.

One study published in the European Journal of Applied Physiology tested changes caused by passive stretching in EMD contributors that are contractile and viscoelastic on the medial head of the gastrocnemius muscle of physically active males. EMD is affected by a variety of factors, including electrical, chemical, and mechanical mechanisms. When data was collected, the MTU stiffness showed to affect EMD while muscle neural activation did not contribute to the change. The muscle tendon unit has both excitation-contraction coupling and viscoelastic characteristics which were affected differently by the stretching. Results of the study showed that peak tetanic force was reduced by 31% and remained decreased throughout the recovery time. When compared with the EMG and force delays, data shows that the peak tetanic force reduction occurred in conjunction with a lengthened EMD (Esposito, Limonta, & Ce, 2011).

In a similar study comparing the effects of passive stretching on EMD between genders, researchers had women and men passively stretch the soleus muscle. Five electrical stimulations sent both before and after stretching allowed EMD to be measured, and the results may suggest that in the group of women the decrease in MTU stiffness could help explain the acute increase of their EMD (Costa et al, 2012).

A study completed by twelve participants looking at passive muscle tension on the biceps brachii utilized contractions caused electrically in the elbow flexion range of 120 to 20 degrees. The results of this study showed a much longer EMD at 120 degrees, which lends itself to the suggestion that different muscle passive tension may not be causing differences in between-muscles, but instead is due to architectural differences of the muscles (Lacourpaille, Hug, & Nordez, 2013).

Stretching before athletic events is a common practice to help prevent injury, increase range of motion, and decrease joint stiffness (Costa et al., 2012). While studies in the field of biomechanics are showing that the static stretching of muscles before explosive athletic events decreases the muscle power production, there is a gap in the literature when it comes to explaining why the power production is lessened after the stretching. One possible cause of lowered muscle power production is a lengthened electromechanical delay for the muscle caused by passively stretching the muscle. When the muscle is stretched, both the passive and elastic components are affected. Stretching moves the curve of contraction for force production to the right, so it takes longer for the passive component to contract after the stretch. The contractile component of the muscle then needs more effort to produce the same amount of force, explaining the decreased power production. This is based off of the stretch reflex, in which the central nervous system generates a protective mechanism which reduces muscle power for protection (Costa et. al, 2012).

The information acquired during this study will help researchers searching for an explanation of why muscle power production decreases after static stretching of the muscle. By understanding what causes the loss of power production, this information can be used by athletes, coaches, athletic trainers, physical therapists, and others working with athletes requiring optimal muscle power production to help athletes reach their full potential. If the hypothesis is correct, this research will help others know where to focus their efforts and future studies when looking at how stretching affects power production and help guide research when looking for the most effective way to help athletes prevent injury but receive maximum potential muscle power production.

The purpose of this study is to determine whether stretching the gastrocnemius before jumping lengthens the electromechanical delay of the muscle when muscle power production is decreased. Our hypothesis for this study is that participants will have a prolonged electromechanical delay observed after passively stretching the gastrocnemius when compared to not stretching the gastrocnemius. It is also expected that the stretching of the gastrocnemius be effective, increasing range of motion by greater than three percent. There also will be observable reduced power output of the gastrocnemius, showing that muscle power production is decreased, and measured by reduced flight time when the participant jumps on the force plate.

Methods

Participants:

Participants recruited for this study were between the ages of 18 and 28 years, both male and female. The recruitment process on the Georgia Southern campus occurred through speaking to health and kinesiology classes and asking students to participate. Participants were given information regarding informed consent and the ability to ask questions before beginning the study. Participants were required to fill out the informed consent, including a list of PAR-Q questions, and an answer of yes to any of the questions was exclusion criteria. Additionally, present or previous injury to the legs resulting in the inability to jump or stretch using the knee, ankle, foot, gastrocnemius, or other involved areas resulted in exclusion from the study. In total, the study utilized 17 participants, with twelve experimental participants completing stretching between jump series, and five control participants who did not stretch between jump series. 00

Electromyography (EMG):

To measure the electrical activity of the gastrocnemius, Delsys Trigno System Wireless EMG electrodes were placed on the lateral and medial heads of the gastrocnemius. To obtain the location of the lateral and medial heads of the gastrocnemius, a tape measure was used to mark the location which was 30% proximal on the connecting line between the popliteal crease and the center of the lateral and medial malleolus on each participant’s right leg (Edama, M., et al., 2015, Abellaneda, S., et al., 1998). To ensure that the EMG was securely attached to the skin without interference, approximately a 1.5-inch circle was required to be shaved on both the lateral and medial heads of the gastrocnemius. A 1.5-inch square of very fine sandpaper was used to exfoliate the skin, and an alcohol pad was utilized to cleanse the skin of any lotions or creams, ensuring the EMG remained firmly secured to the skin throughout the testing protocol.

Jumping:

Participants were asked to complete a series of six jumps, both before and after going through an effective stretching protocol. A treadmill consisting of two forceplates (one in the front and one in the back) was utilized to record forces as the participant jumped. The forceplate was zeroed before and between each participant using the auto-zero feature of the forceplates. Each participant was asked to stand still on the forceplate while 2-4 seconds of a static stance was recorded. Set up next to the forceplate was a Vertec, which was used to record participant jump height. The lowest paddle on the Vertec was adjusted the participant’s maximum fingertip height when standing flat-footed on the forceplate with one arm fully extended (and fingertips fully extended). This correlated to zero on the Vertec, so when the participant jumped the highest paddle which they hit was recorded as the height in inches that they jumped from the forceplate.

Participants were instructed to jump with maximum effort, using only the gastrocnemius and excluding using the thigh muscles. In an effort to isolate the gastrocnemius, participants were told not to bend or use their knees when jumping, and to keep them locked. Therefore, the jump was more of a bounce off of the toes and would be much less high than a normal vertical jump maximum, since half of the leg was not being utilized. Participants could complete practice jumps one or two times, until they felt comfortable with the jumping protocol and the researchers assessed that the participant understood the jump instructions.

The two types of jumps recorded for the study included single jumps and rapid jumps. The single jump was one bounce off from the toes and ended when the participant landed back on the forceplate. The rapid jump had the same instructions as the single jump, but it required the participant to immediately “bounce” back into the air after landing on the force plate for two to four more jumps, continuing to hit the Vertec on each jump until the participant felt as though he/she had reached the maximum possible jump height without using other muscle groups. The participant alternated jumping styles for a total of six jumps pre-stretch and six jumps post-stretch. This series of jumps began with a single jump, then rapid jump, then single, then rapid jump, for a total of six jumps. This jump series was also repeated post-stretching, requiring the recording of a total of twelve jumps per participant in the study.

When recording data, the participant was given a count of “3…2…1” to jump, and was instructed to begin jumping on the number 1. The data collection for the forceplate and EMG was recorded beginning on the number 2 and until the participant landed on the ground (for the single jump the first time, for the rapid jump on the final landing). The jump height from the Vertec was recorded for each jump height into a data file.

Control Participants:

To ensure that the stretching was indeed the cause of the decreased muscle power production, and not simply due to completing the first set of jumps and factors such a tiring or practice, a group of five control participants completed the jump series described, then waiting a similar period of time as the experimental participants before getting on the forceplate and completing a second series of jumps (without stretching the gastrocnemius). Data was recorded in the same manner as the experimental participants.

Stretching Protocol and Demonstrated Effectiveness:

Static stretching was performed by having each participant place his/her foot on one of three increasing positions on an incline/slant board. The participant was required to maximally dorsiflex the ankle joint, while keeping the bottom of their foot flush with the board's surface and the knee fully extended (Cornwell, A., Sidaway, B., Nelson,A. 2002). Participants were required to stretch using one of the positions on the board for 30 seconds three times, taking a break of ten seconds between stretching periods. Participants could move up or down between increasing inclines after holding a position for the 30 seconds, if needed or desired to increase or decrease the stretch of the gastrocnemius.

To determine that the stretching was effective for the participant, the range of motion for the individual was measured both before and after static stretching. The range of motion was determined with the use of a weight bearing lunge (Konor, 2012). The weight bearing lunge was performed in a standing position, with the heel in contact with the ground, the right knee in line with the second toe, and the great toe 10 cm away from the wall (Konor, 2012). The distance was measured with the use of a centimeter measuring strip secured to the floor. Balance was maintained by allowing contact with the wall using two fingers from each hand (Konor, 2012).

Participants were asked to lunge forward, directing their knees towards the wall until there right knee touched the wall (Konor, 2012). The foot was progressed away from the wall 1 cm at a time if the subject was able to touch the wall at 10 cm (Konor, 2012). If the subject could not reach the wall at 10 cm then the subject was progressed towards the wall 1 cm at a time (Konor, 2012). The subject was required to be able to touch the wall with their right knee without lifting the heel from the ground (Konor, 2012).

The stretch was determined to be reliable with a 1 cm increase in the weight bearing lunge before and after static stretching. The increase of 1 cm of distance between pre- and post- measurements equals 4.1 degrees of dorsiflexion ROM (Konor, 2012). If the static stretching after the initial 30 seconds for a total of three times was not deemed effective for the participant, the individual was required to be stretched again for another three sets of 30 seconds, and completed the measurements again until the range of motion had increased to show effectiveness of the stretching protocol.

Data Analysis:

To determine the EMD of the muscle during the jump, the EMG data collected was graphed with the forceplate data collected over the same time period, as shown below in Figure 1. The point at which muscle stimulation began was marked using the EMG data and was defined as the first “peak” above the normal line. The onset of force production was marked as the lowest point in the first downward slope of the force line (generated by the participant's force on the forceplate), as after this point the participant began pushing off from the plate and moving upwards in a jump. The difference between the time of these two events, the beginning of muscle stimulation and the onset of force production, was obtained and presented as the EMD of the lateral/medial head of the gastrocnemius.

To determine the power produced by the participant's jump from the forceplate, the formula Ground Reaction Force (vertical) – Weight = mass*acceleration was used. This equates to acceleration = [GRF(v) – weight] / [weight / gravity]. Since power equals force multiplied by velocity (Power = force * velocity), the participant's jump on the forceplate allowed us to utilize the weight and force to calculate total maximum power produced by the jump.

Results

Subject	WBL pre-stretch (in)	WBL post-stretch (in)
1	9	11
2	9	11
3	7	8
4	11	12
6	13	14
9	6	7
13	11	13

Table 1. Shows experimental participants weight-bearing lunge measurements before and after stretching, to demonstrate that the stretching protocol was effective at increasing the range of motion.

Table 2. *Weight Bearing Lunge Measurement Averages +/- SD for Static Stretching Reliability.*

Weight Bearing Lunge (WBL)	Mean ± SD (cm)
WBL pre-stretch	9.423±2.44
WBL post-stretch	10.86± 2.54

Table 3. Values of experimental participants' jump heights in inches for single and rapid jumps, pre- and post-stretching.

Subject	Pre-stretch Single Jump Height (in.)	Post-stretch Single Jump Height (in.)	Pre-stretch Rapid Jump Height (in.)	Post-stretch Rapid Jump Height (in.)
1	9.5	9.5	9.5	9.5
2	7.5	9	9	6.5
3	10	9	13.5	10
4	12	14.5	14.5	14
5	5	5	4.5	3
6	7	6.5	9	9
7	3.5	3.5	7	6.5
8	3.5	4	5.5	7
9	6.5	7	6.5	6.5
11	11.5	13.5	12	14.5
12	8	10	9.5	11
13	8	9.5	14	12

Table 4. Values of control participants jump heights in inches for single and rapid jumps, with a period without stretching between.

Subject	Pre-stretch Single Jump Height (in.)	Post-stretch Single Jump Height (in.)	Pre-stretch Rapid Jump Height (in.)	Post-stretch Rapid Jump Height (in.)
10	5.5	6.5	5	5.5
14	10.5	10	9	10.5
15	7	8.5	7.5	10
16	6.5	11.5	10	12
17	5	4.5	4.5	5

Table 5. Muscle power production (in N) of experimental participant jump heights, who correctly followed protocol.

Subject	Pre-stretch Single Jump Power Production (N)	Post-stretch Single Jump Power Production (N)
1	2944.29	2993.15
2	1317.44	1324.9
3	5041.88	4520.49
4	3225.97	2255.92
6	877.24	650.06
9	1006.52	862.39
13	6733.44	3980.86

Table 6. Muscle power production (in N) of control participant jump heights.

Subject	Pre-stretch Single Jump Power Production (N)	Post-stretch Single Jump Power Production (N)
10	1120.57	1146.95
14	2576.43	2310.17
15	1127.09	1285.01
16	1845.79	2647.6
17	500.42	520.55

Table 7. Muscle Power Production (in N) for the maximum height single jump for experimental participants (pre- and post-stretching) and control participants (before/ after a wait period without stretching).

	Pre-stretch / 1st Series Single Jump Power Production (N)	Post-stretch / 2nd Jump Series Power Production (N)
Experimental Mean +/- SD	3020.97 ± 2216.13	2369.68 ± 1524.47
Control Mean +/- SD	1434.06 ± 796.67	1582.06±879.05

Table 8. Electromechanical delay calculated for the medial and lateral heads of the gastrocnemius before and after completing effective stretching protocol.

Subject	Pre-stretch medial EMD length (s)	Post-stretch medial EMD length (s)	Pre-stretch lateral EMD length (s)	Post-stretch lateral EMD length (s)
1	0.114	0.176	0.048	0.177
2	0.2675	0.1375	0.288	0.087
3	0.1775	0.2925	0.1735	0.2825
4	0.1165	0.2085	0.072	0.098
6	0.4485	0.2545	0.326	0.2535
9	0.1045	0.196	0.258	0.2055
13	0.268	0.044	0.2455	0.023

Table 9. Electromechanical delay calculated for the medial and lateral heads of the gastrocnemius for control participants.

Subject	First control medial EMD length (s)	Second control medial EMD length (s)	First control lateral EMD length (s)	Second control lateral EMD length (s)
10	0.0715	0.108	0.051	0.08
14	0.0465	0.0535	0.035	0.029
15	0.275	0.1765	0.1335	0.2145
16	0.0975	0.218	0.217	0.2195
17	0.002	0.0015	0.0435	0.047

Table 10. The mean +/- standard deviation of experimental participant jump series (pre- and post-stretch) and control participant jump series (1st and 2nd jumps spaced apart).

	Pre-stretch (1st) Medial EMD (s)	Post-stretch (2nd) Medial EMD (s)	Pre-stretch (1st) Lateral EMD (s)	Post-stretch (2nd) Lateral EMD (s)
Experimental Mean +/- SD	0.214 +/- 0.125	0.187 +/- 0.081	0.202 +/- 0.107	0.161 +/- 0.095
Control Mean +/- SD	0.099 +/- 0.105	0.112 +/- 0.088	0.096 +/- 0.078	0.118 +/- 0.092

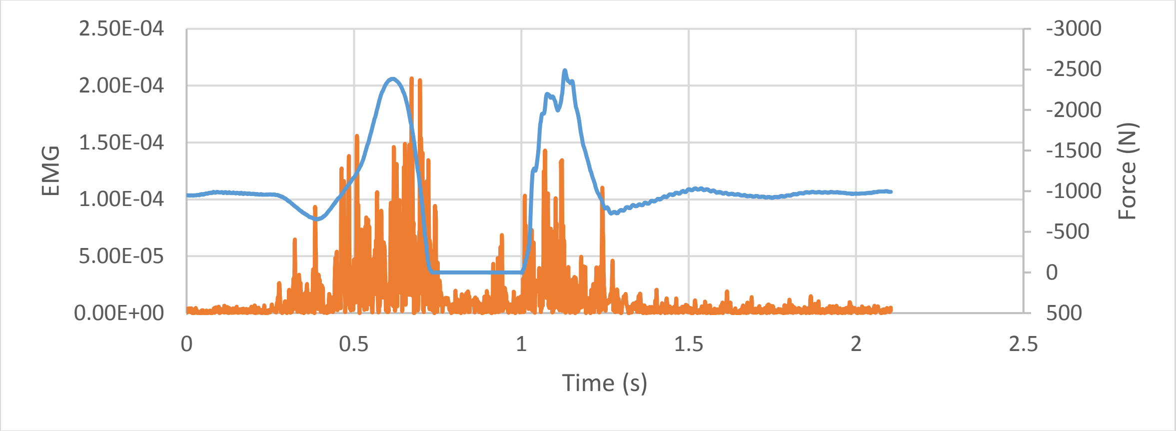

Figure 1. Example of participant data graphed for analysis, including the top force line representing the data collected from the force plate graphed with the EMG data collected to show electrical impulses of the muscle during the participant's jump.

Discussion

The results of this study do not indicate that statically stretching the gastrocnemius produces a lengthened electromechanical delay in the medial or lateral head of the muscle, although power production does decrease after effective stretching when jump protocol is followed appropriately. The results instead showed a decrease in EMD in both the medial and lateral heads after static stretching, and the control group showed an increase in EMD for both the medial and lateral heads for the second jump series without static stretching between jump series.

All calculations and data analysis in this study assume that participants did not bend their knees and utilize leg muscles above the knee when completing the jumping trials. However, when viewing the data from the forceplates for all participant jump trials excluding one, there is a downward curve before the participant begins pushing off the forceplate, indicating at least some knee-bending and use of other muscles when jumping. When this knee-bending occurs, it has the potential to skew the results of the study because the power production is no longer occurring solely from the muscle which is being stretched and analyzed (the gastrocnemius). Due to different factors, such as competition between participants who were competing at the same time, and potentially changing the method of jumping, the data from five experimental participants whose jump heights increased after stretching was excluded from analysis due to failure to execute the jumping trials according to protocol.

In addition, the stretching for experimental participants must be proven effective to demonstrate that it increased the range of motion for the participant. Table 2 shows the mean increase of 1.44 cm after stretching for participants, above the necessary 1 cm increase correlating to a joint ROM increase of 4.1 degrees, equating to an effective stretch (Konor, 2012). In looking at the decreased power production, Table 7 shows the mean decrease of 651.29 N in the experimental group after stretching effectively, which is a significant decrease in power production after stretching the gastrocnemius. In the control group who completed a second series of jumps after a similar break time without stretching, the power production increased by an average of 148 N. This is further evidence indicating that static stretching muscles prior to explosive athletic events results in decreased power production.

The hypothesis for this study that participants will have a prolonged electromechanical delay observed after statically stretching the gastrocnemius did not differentiate between the medial and lateral heads of the gastrocnemius. However, the data collected allowed for analysis of both the medial and lateral sides of the muscle. Table 10 shows that in the experimental group, the mean EMD post-stretching for the medial gastrocnemius decreased by 0.027 seconds. In the control group of participants, this post-stretching medial EMD increased by 0.013 seconds. On the lateral side, the mean EMD post-stretching for the experimental group decreased by 0.041 seconds. The control group mean post-stretching EMD on the lateral side increased 0.022 seconds. This resulting data is exactly opposite of the hypothesis predicting that EMD would lengthen after static stretching of the muscle, as the EMD for the experimental group decreased following effective static stretching of the gastrocnemius. In addition, the control group data shows a slight increase in the length of the EMD without completing any stretching protocol between jumps, yet it would be expected that the EMD remain close to the same between jump series since no changes occurred and the participant completed the same jump series.

While the collected data does not support the initial hypothesis, there may be potential factors of error not foreseen in creation of the study. For some participants, locating the initial peak of EMG for the point at which muscle stimulation began was challenging, as the baseline had more fluctuation than normal. In addition, finding both points (the initial EMG peak and the lowest point on the first force curve down) is a process of “eyeballing” it, and has potential for human error as it is not a set calculation or method ensuring complete accuracy between trials and participants.

Overall, based on the results of this study, there is no evidence to support that a static stretching of the gastrocnemius results in an increased electromechanical delay of the muscle, in either the medial or lateral head. Nor does the data collected throughout the study support the idea that a lengthened EMD correlates with a loss of muscle power production in the gastrocnemius. However, there may still be areas of research to look at other potential contributions that EMD may play in the role of muscle power production. Other studies could look to confirm whether EMD consistently decreases (in other settings and with other muscles) after statically stretching the muscle, and what this decrease could in turn be affecting as a result. To allow other studies of EMD to be more consistent across studies, an improved method of measuring the EMD of the muscles (between jumps/any explosive athletic event), could be developed to increase reliability. EMG offers valuable information about the electrical impulses of the muscle during athletic activities, and should be applied a variety of settings to increase knowledge of muscular activity and the connection between electrical impulses and how the human body moves on a daily basis.

References

Behm, D. G., Bambury, A., Farrell, C., and Power, K. (2004)

Behm, D. G., & Chaouachi, A. (2011). A review of the acute effects of static and dynamic stretching on performance. European Journal of Applied Physiology, 111(11), 2633-2651. doi:10.1007/s00421-011-1879-2

Cornwell, A., Sidaway, B., Nelson,A. (2002). Acute effects of stretching on the neuromechanical properties of the tricep surae complex. *European Journal of Applied Physiology.* 86(5), 428-434.

Costa, P. B., Ryan, E. D., Herda, T. J., Walter, A. A., Hoge, K. M., & Cramer, J. T. (2012). Acute effects of passive stretching on the electromechanical delay and evoked twitch properties: A gender comparison. *Journal of Applied Biomechanics, 28,* 645-654. doi:10.1007/s00421-009-1214-3

Cramer, J. T., Housh, T. J., Weir, J. P., Johnson, G. O., Coburn, J. W., & Beck, T. W. (2005). The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. *European Journal of Applied Physiology*, *93*(5-6), 530-539.

Curry, B. S., Chengkalath, D., Crouch, G. J., Romance, M., & Manns, P. J. (2009). Acute effects of dynamic stretching, static stretching, and light aerobic activity on muscular performance in women. Journal of Strength and Conditioning Research, (6), 1811.

Edama, M., Onishi, H., Kumaki, K., Kageyama, I., Watanabe, H., & Nashimoto, S. (2015). Effective and selective stretching of the medial head of the gastrocnemius.

Scandinavian Journal of Medicine & Science In Sports, *25*(2), 242-250 9p. doi:10.1111/sms.12203

Esposito, F., Limonta, E., & Ce, E. (2011). Passive stretching effects on electromechanical delay and time course of recovery in human skeletal muscle: New insights from an electromyographic and mechanomyographic combined approach. *European Journal of Applied Physiology, 111,* 485-495. doi:10.1007/s00421-010-1659-4

Kay, A. D., & Blazevich, A. J. (2012). Effect of Acute Static Stretch on Maximal Muscle Performance: A Systematic Review. *Medicine & Science in Sports & Exercise, 44*(1), 154-164.

Konor, M. M., Morton, S., Eckerson, J. M., & Grindstaff, T. L. (2012). Reliability of three measures of ankle dorsiflexion range of motion. *International Journal of Sports Physical Therapy, 7*(3), 279-287.

Lacourpaille, L., Hug, F., & Nordez, A. (2013). Influence of passive muscle tension on electromechanical delay in humans. *PLOS ONE, 8,* (1), 1-6. doi:10.1371/journal.pone.0053159

Simic, L., Sarabon, N., & Markovic, G. (2013). Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. Scandinavian Journal of Medicine & Science in Sports, 23(2), 131-148.