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Different Effects of Static and Vibrating Foam Rollers on Ankle Plantar Flexion Flexibility and Neuromuscular Activation

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DIFFERENT EFFECTS OF STATIC AND VIBRATING FOAM ROLLERS ON ANKLE PLANTAR FLEXION FLEXIBILITY AND NEUROMUSCULAR ACTIVATION

by

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Under the Direction of Dr. Daniel Czech and Dr. Li Li

ABSTRACT

The relatively new implementation of vibration into foam rollers was developed in response to the positive feedback of whole-body vibration treatment and foam rolling therapy. The purpose of the study is to research the changes in range of motion and myoelectric activity of the ankle plantar flexors in female NCAA Division I swimmers when using a vibrating foam roller in comparison to a static foam roller. Combining the self-myofascial release with the increased blood flow and muscle temperature exerted from vibration could possibly enhance the effects of foam-rolling treatment. The different effects of ankle flexibility and motor unit activation after static and vibrating foam rolling was measured with a sample size of 15 female collegiate swimmers. Resting flexibility was measured upon arrival and the participant then rolled from their popliteal fossa to the middle of the Achilles tendon for 30 seconds, three times, with a 15-second break in between each trial. Flexibility was measured immediately after the foam rolling procedure. Neuromuscular data was recorded using electromyography (EMG) during both an isokinetic and isometric ankle joint force production test using the Biodex dynamometer. The data was analyzed with a paired, one-tail, T-test for the difference between static and dynamic of the difference between post intervention and pre-intervention. Significant interaction in range of motion was found using a two-way ANOVA with repeated measures with a T-test value of 0.039. No significant interaction and no significant difference were found between the pre and post testing results of EMG data.

INDEX WORDS: Exercise Science, Foam Rollers, Flexibility, EMG, Plantar flexors, Muscles

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INTRODUCTION

Foam rolling is a self-myofascial release technique in which a roller tool is used by an individual to apply a compressive force to the muscles and fascia. Self-myofascial release (SFMR) can produce a range of effects, including increasing flexibility, both acutely and chronically, and increasing neuromuscular muscle efficiency. SMFR has also demonstrated effects on arterial and vascular wall function. Which mechanism of SFMR, such as foam rolling, that leads to these effects has been extensively studied and reviewed in literature, but no consensus has been found (Beardsley & Škarabot, 2015). The anatomy and physiology of muscles and fascial tissues in the human body provide clues to how foam rolling, and other SFMR techniques, exert their influence on muscle function.

Superficial fascia, defined by Dr. Mike Benjamin in the Journal of Anatomy as, "…a layer of areolar connective or adipose tissue immediately beneath the skin". Deep fascia, a dense, tougher tissue, is generally found in sheets around muscles and tendons beneath the superficial layer (Benjamin, 2009). These layers of fascia slide together during motion, specifically during contraction or relaxation of the muscles). Self-myofascial release, like foam rolling, applies pressure to the fascia has been predicted to stimulate the "…contractile cell activity, affect tissue hydration and microarchitecture of cell cytoskeleton or muscle filament mechanical properties, and thereby alter tissue stiffness" (Krause et. al., 2017). Therefore, in relation to the plantar flexors of the foot, a moving compression force potentially loosens the connective fibers that form the fascia in the tibialis anterior, the extensor hallucis longus, and the extensor digitorum longus muscles. Because both superficial and deep fascia creates a film of tissue between adjacent muscles, reducing stiffness in the cytoskeleton promotes movement, increasing joint flexibility (Krause et. al., 2017). Although foam rolling exerts a high pressure on the target connective tissue and surrounding bones, muscles, nerves, and blood vessels, no references have been reviewed that concern any harmful effects of foam rolling (Freiwald et. al., 2016).

In order to quantify the effects of self-myofascial release on the muscle fibers, surface electromyography can be used. Electromyography (EMG) is a technology, that when applied to the surface of the skin, can indicate the start of muscle activation, providing "…the timing sequence of one or more muscles performing a task" (De Luca, 1997). EMG information can also record the number of active motor units in a muscle, the motor unit force-twitch, interaction between muscle fibers, the motor unit firing rate, and the recruitment stability of motor units. The effect of all these factors can be generalized by the amplitude, frequency, and peak height of the EMG signal, captured by electrodes on the skin and relayed to the corresponding computer system. These effects are important in understanding muscle function and correspond with individual muscle force production and nervous system function. The nervous system always controls the contraction and relaxation of muscles "…and is dependent on the anatomical and physiological properties of muscles" (Reaz et.al., 2006). These properties can be largely affected by self-myofascial release, including foam rolling, raising the question concerning how foam rolling influences the nervous system in muscle fibers. Many studies have been published concerning the relationship between SMFR and EMG, producing a range of results. Macdonald et. al. measured neuromuscular activity following post-exercise foam rolling and found that muscle activation, recorded by EMG, improved after SMFR. Similar results were found by Helperin et. al., Bradbury et.al., and Sullivan et. al., providing significant evidence that foam rolling increases neuromuscular activity.

This study is going to assess the flexibility and neuromuscular change when implementing two mechanisms of self-myofascial release: static foam rolling and vibrating foam rolling. Examining the various techniques and previously studied results from foam rolling and reviewing the methods of the measurement of range of motion, application of electromyography, and analysis of the collected data provides additional reliability and validity for the study.

METHODS

Arrangements for Conducting the Study

The study researched the changes in the range of motion in the ankle plantar flexors after static or vibrating foam rolling will be conducted on the campus of Georgia Southern University in Statesboro, Georgia. The researchers included two undergraduate exercise science majors involved in the Georgia Southern University Honors Program. The researcher focusing specifically on the flexibility and neuromuscular changes conducted the research in the biomechanics laboratory in Hanner Fieldhouse. The laboratory contained the equipment and space needed to perform the experiment. The vibrating foam rollers was provided by the Georgia Southern Exercise Science Department, along with the measuring tape and latex therapy band. No other materials were needed for the range of motion portion of the study. The neuromuscular changes was measured as the participant exerts isokinetic and isometric force using the Biodex dynamometer machine. Electromyography (EMG) signals were collected using the Delsys Trigno Wireless EMG system with the Windows 10 computer download. In accordance with the schedules of the participants, the research took place throughout April 2018. The data collection sessions were offered Monday through Friday between 12:00-3:00 in the afternoon. Additional sessions were offered if the time conflicted with a specific patient. Each participant was required to attend only one session during this time period, but multiple sessions were encouraged in order to increase the validity of the study.

Selection of Subjects

The sample chosen was due to convenience and with the intention to increase the availability of research on the specific population. Because the researcher is a part of the woman's Georgia Southern University Swimming and Diving Team, the study has access to NCAA Division I athletes, while also conducting a study on an underrepresented population in sport research: swimmers. The goal was to collect data from 15 female swimmers, anticipating no more than 5 participants missing one or more testing sessions. The sample represented over 70% of the population of varsity swimmers at the university and the age range of the participants selected would be between 18 and 23-years old. The sample selection was based on the athlete's type of training and willingness to participate. The athletes with sprint-oriented training were prioritized in the selection in order to control any external effects on the range of motion during testing. The sprint-oriented training at Georgia Southern University consists of 20 hours of training a week, broken down into 4.5 hours of weight training and 15.5 of swimming training. If not all 15 of the participants engaged in sprint-oriented training, then distance swimmers were selected. The distance swimmers train the same number of hours as the sprint group, but with only 3 hours of weight training and 17 hours of swimming.

Instrumentation

The equipment included in the data collection was a vibrating foam roller, tape measure, metronome, latex thera-band, self-adherent wrap, Biodex Dynamometer, and Delsys Trigno Wireless EMG system provided by the Georgia Southern Exercise Science Department. The vibrating foam roller implemented was the "Vulken 4 Speed High Intensity 17" Vibrating Foam Roller". The roller features four vibration speed settings, ranging from 1200 RPM to 3600 RPM, but can also be switched off to produce the standard static foam rolling treatment. The roller also includes a surface pattern in the high-density foam to mimic a therapist's hand during a massage. The battery is rechargeable and can last up to 2 hours of continuous treatment. The 400-pound weight limit, along with the additional features, grounds the roller to be suitable for the experiment at hand. A metronome was implemented to maintain a constant pace of rolling at 30 beats per minute. The patient rolled from the ankle to the knee within 1 beat. The measuring tape was 150cm and measured the range of motion to the nearest millimeter. Implementing a cloth measuring tape allowed the tape to be repositioned easily and it was more comfortable for the participants. A latex thera-band was also be implemented in the experiment to act as a secondary measurement for peak range of motion. The band was placed under the participant's foot, so if the heel raised off the ground it would snap off. Its function of monitoring heel-raise indicated that the patient reached maximum ankle flexibility. The Biodex Dynamometer was implemented to produce isokinetic and isometric exercises that were the source of muscle contractions for EMG recording. The Delsys Trigno Wireless EMG system was downloaded using the Windows 10 system and was the main source of EMG data. Coban self-adherent wrap was wrapped around the participant's lower leg, ensuring that the electrodes remained in place and increased the signal strength between the electrode and nearby muscle fibers. The Delsys analysis application was used for data analysis and measurement.

The total expenditure of the instrumentation included in the experiment ranged from \$400 to \$500. Four vibrating foam rollers were purchased due to the arrangement of the data collection sessions and to prepare for possible technological malfunction. All other equipment was provided by the Georgia Southern Exercise Science department and did not require payment.

Procedures for Collecting Data

When conducting my study on the different effects of static and vibrating foam rolling on the flexibility and myoelectric activity of the plantar flexors, I implemented similar quantitative methods described in the previous research (Appendix B). I established a treatment group for both static and vibrating foam rollers, alternating the treatment for both groups. The vibrating foam roller was switched on and off according to the treatment assigned in order to reduce variance due to the external composition of the foam roller. Establishing a varying order in which the static and vibrating treatments were applied ensured that the variability in the range of motion between the two treatments is due specifically to the intervention being recorded.

The swimmers who consent to participate in the research partook in testing sessions during the month of April. Participants were numbered based off the order in which they signed the consent form and filled out the PAR-Q. Odd-numbered participants started with the static roller intervention, progressing through the testing and ending with the dynamic intervention. Even-numbered participants did the opposite, starting with dynamic rolling and ending with the static treatment. A similar grouping procedure was applied to the order of isokinetic and isometric force exertion during EMG data collection. Odd-numbered participants began with the isokinetic movements and even-numbered clients began with isometric movements.

Before beginning data collection, each client signed a consent form and filled out a PAR-Q. The PAR-Q was assessed by the researcher before allowing the client to participate. Anthropometric data was collected including height, weight, and age. This information was used to determine the average characteristics of the sample population (see table 1). Data collection began with measuring resting flexibility arrival using the weight-bearing lunge technique and a tape measure. To begin measurement, the patient's dominant foot was determined. The researchers determined the participant's dominant foot by asking the specific swimmer which foot they use to lead off of a swimming start. Whichever foot the patient used to lead off a swimming start was their dominant foot. The dominant foot was the foot placed forward in the weight-bearing lunge used to determine ankle range of motion.

The weight-bearing lunge technique involved the subjects lunging their knee to make contact with the wall. The researchers encouraged them to use their hands for balance. The non-dominant foot was placed 10cm away from the wall and both of their knees are to be in line with the second toe. The 10cm distance away from the wall was marked with a piece of painter’s tape. With both heels in contact with the ground at all times, the dominant foot was to be as far away from the wall as possible without lifting the heel from the ground. If the participant could not touch their knee to the wall without keeping their back heel down in the initial 10cm position, the participant was allowed to move their foot toward the wall, 1 cm at a time. This variation was recorded. The maximum range of motion was verified by implementing a thera-band. One end of latex band was placed under the patient’s back heel and the other end was stretched into the researcher’s hand. If the patient’s heel lifted off of the ground, the band snapped back towards the researcher, verifying that the participant reached maximum ankle flexibility. The linear distance between the patient's back foot big toe and the wall was measured in nearest millimeters with a cloth measuring tape.

Immediately after ROM measurement, the EMG electrodes were placed on the participant. There will be an electrode on the soleus and medial portion of the gastrocnemius. The electrode placement followed the ordination of the muscle fibers according to each muscle. The top of the electrode was marked with a pen in order to standardize placement. When conducting tests using electromyography, the placement of the probes is vital is obtaining reliability. The user must properly determine the location of the soleus and gastrocnemius in the participant to properly place the EMG probes. The administrator ensured that the probes were placed properly by determining the muscle location using the same procedure for each patient. By asking the participant to step on their toes, their ankle plantar flexors are activated, allowing the tester to locate the gastrocnemius. The first probe was placed on the medial portion of the gastrocnemius, on the belly of the muscle with the electrodes facing the trend of the muscle fibers. The second probe was placed about 2cm below the ridge of the activated gastrocnemius.

The researcher then wrapped Coban self-adherent wrap around the participant’s lower leg, holding the electrodes in place. The participant was asked to sit in the chair connected to the Biodex dynamometer, placing their dominant foot on the system’s foot attachment. The participant was asked to wear athletic shoes prior to the data collection. The researcher then strapped the participant's foot tightly so that the patient was unable to lift their foot off the pad. With the EMG system on, the researcher collected data on the isometric and isokinetic movements of the ankle joint. The isometric movement was collected at 90 degrees for 5 seconds 3-times, with 5 seconds rest in between measurements. The isometric movement was collected on ankle extension force. The isokinetic measurement obtained both concentric and eccentric contraction data, with the patient cycling 3 ankle movements from full extension to full flexion at 60 degrees per second. The participant was instructed to apply maximum force to the machine in order to get an accurate EMG reading. Oral commands were used to encourage the patient.

The participant then used the assigned roller setting for 30 seconds, three times, with a 15-second break in between each trial. The patient rolled from their popliteal fossa to the middle of their Achilles tendon on their dominant foot at 30 beats per minute. A metronome was used to maintain a constant pace for each participant. The patient rolled from the ankle to the knee within 1 beat. The patient was given 10 seconds before rolling to become familiar with the pace of the metronome. The non-dominant foot was placed across the dominant foot, applying body weight pressure to the roller. The range of motion was measured immediately after the foam rolling procedure, employing the same weight-bearing lunge technique. The identical EMG collection procedure occurred for post-rolling data. Following the Biodex procedure, the patient rested for 15 minutes. The rest is required to ensure recovery of the muscles after the first rolling intervention. The 15-minute period was determined from analysis of previously published literature (Appendix B). After the break, the researcher collected the resting range of motion data again and obtained initial EMG data prior to the second intervention. The participant then used the foam roller for the second time, applying the opposite setting. The range of motion and EMG data was collected for the last time after the second rolling intervention. The order of movement procedures on the Biodex machine remained consistent for the entirety of an individual's testing session. Repeated sessions for each participant was encouraged in order to increase validity. The data was recorded and analyzed to determine the different effects of flexibility between static and vibrating foam rollers.

RESULTS

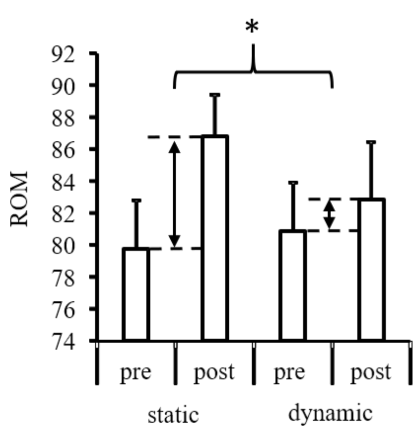
Table 1: Mean and standard deviation of participant anthropometric characteristics

	Mean	SD
Age (years)	19.5	1.3
Height (cm)	169	3.4
Body Mass (kg)	66.2	4.2

Range of Motion

The dynamic rolling intervention neither depleted or improved the range of motion in the ankle plantar flexors in comparison to the static rolling method. The range of motion differences between dynamic and static rolling is displayed in Graph 1.1. Significant interaction and significant difference were found between pre and post test results concerning ROM after a two-way ANOVA test with repeated measures was performed to determine significant difference.

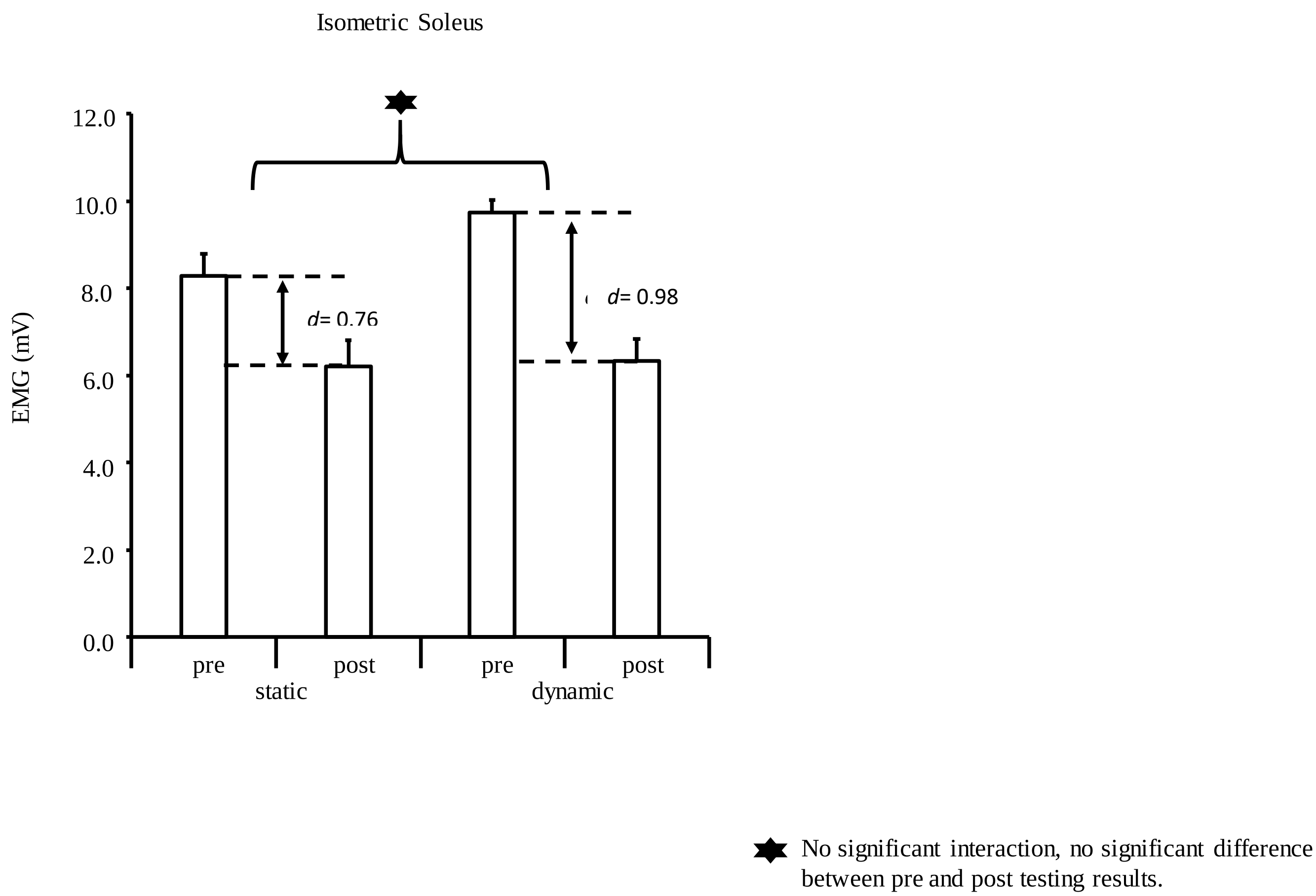
Graph 1.1: ROM differences between conditions



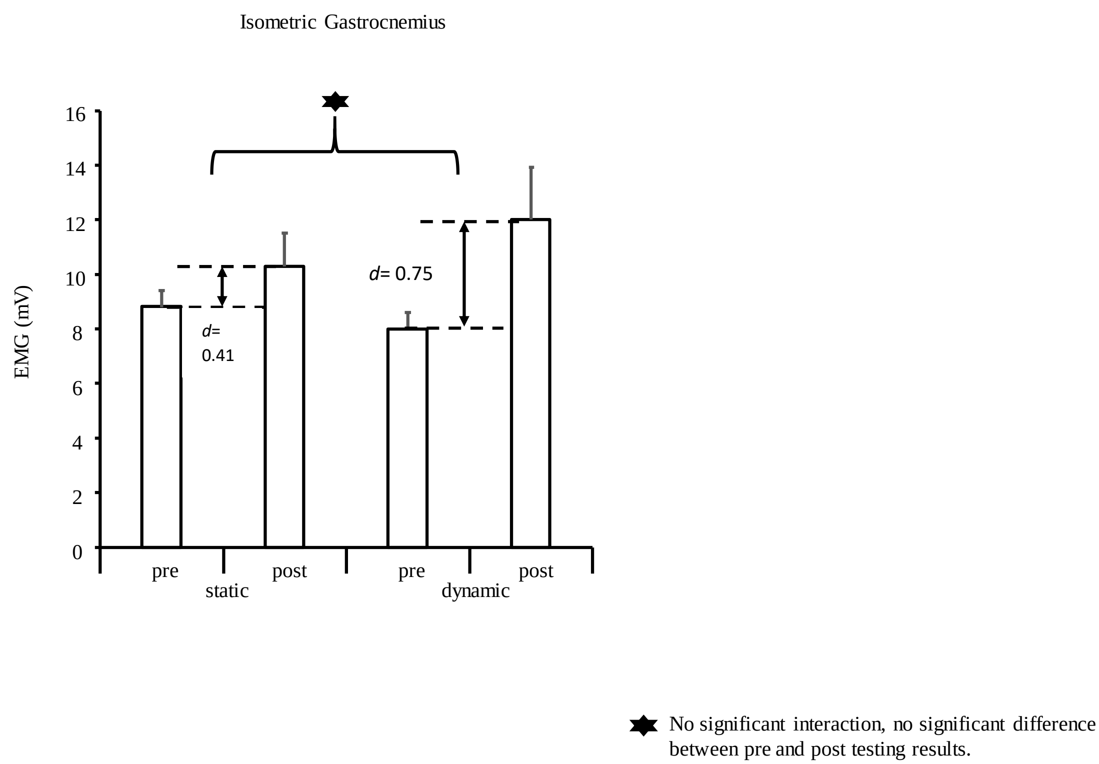
Electromyography

The rolling interventions did not decrease neuromuscular activation, but either allows it to stay the same or increase. No significant difference in (electromyography) EMG was found between the pre and post-tests after conducting a two-way ANOVA test. It can be assumed that the dynamic roller produces more neuromuscular changes than the static roller because the calculated Cohen's *d* values were consistently larger for the dynamic rolling intervention. The static isometric and isokinetic pre and post-tests displayed small differences ($0.2 < d < 0.5$), corresponding with the ANOVA results. The dynamic isometric and isokinetic may have had larger differences ($d > 0.8$) between the pre and post-tests. In Graph 2.1 the neuromuscular differences between conditions during the isometric contraction of the soleus is displayed. The Cohen's d value for the static measure was 0.76 and 0.98 for the dynamic measure. This indicates a large difference despite the lack of significance according to the two-way ANOVA procedure. Similar results were obtained in the isometric contraction of the gastrocnemius (Graph 2.2), with static and dynamic Cohen's d values of 0.41 and 0.75, respectively. In Graph 2.3, both the static (d= 0.42) and dynamic (d= 0.22) roller produced a small difference. Graph 2.4 displays the medium difference within the static and dynamic conditions of isokinetic contractions of the gastrocnemius (d= 0.54, d=0.62) despite having no significance according to the two-way ANOVA. These Cohen's d values, along with mean, standard error of the mean, and standard deviation are displayed in Table 2.1 and Table 2.2 for the isometric and isokinetic contractions.

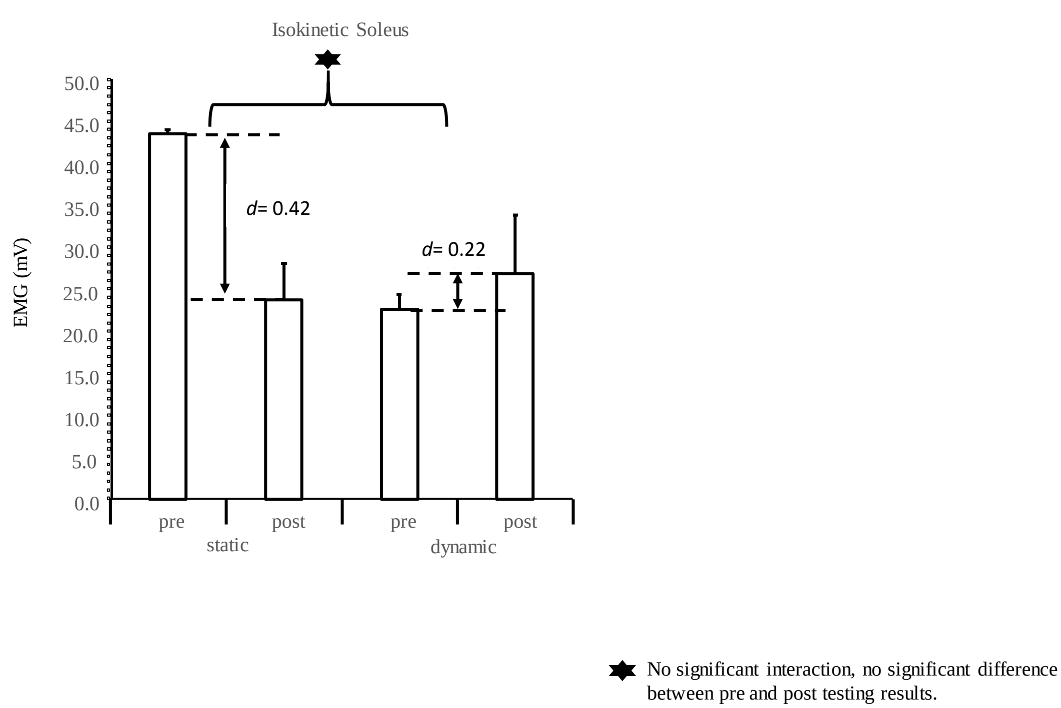
Graph 2.1: EMG differences between conditions and Cohen's d values during the isometric contraction of the soleus.



Graph 2.2: EMG differences between conditions and Cohen's d values during the isometric contraction of the gastrocnemius.



Graph 2.3: EMG differences between conditions and Cohen's d values during the isokinetic contraction of the soleus.



Graph 2.4: EMG differences between conditions and Cohen's d values during the isokinetic contraction of the gastrocnemius.

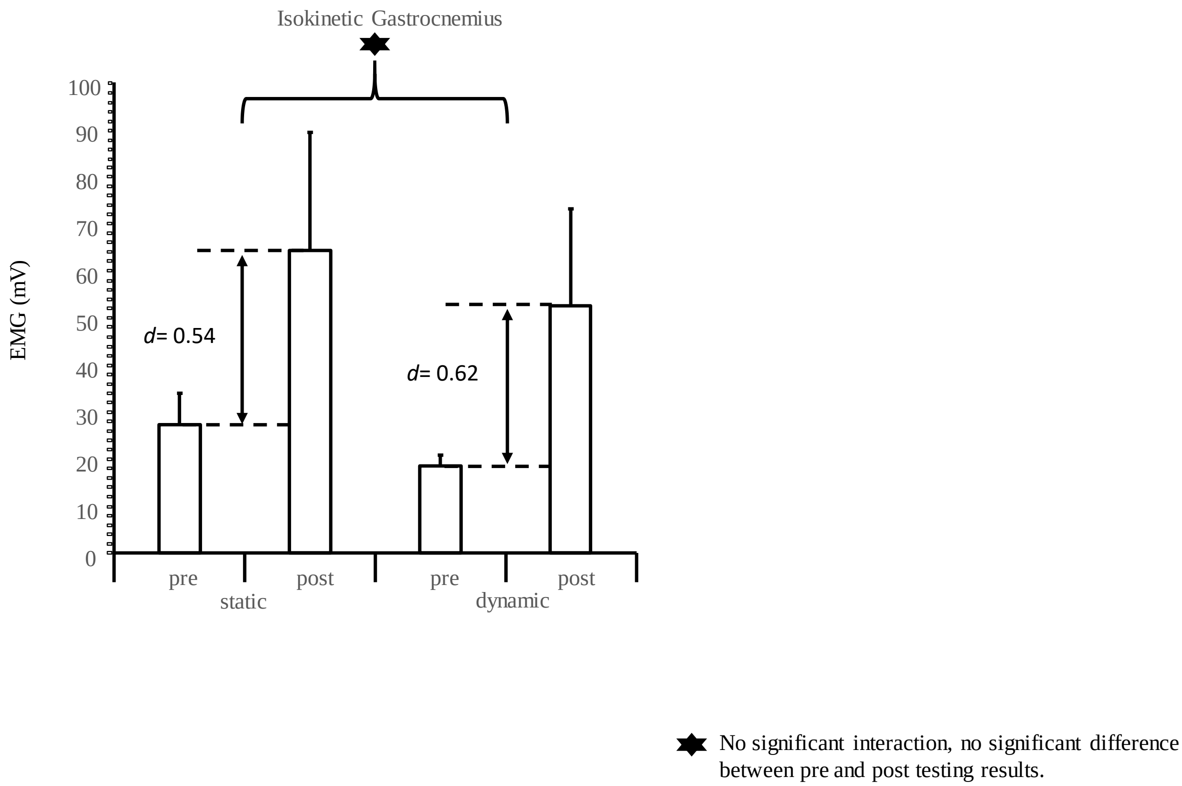


Table 2.1: Mean, standard error of the mean, standard deviation, and Cohen's d value of the soleus and gastrocnemius during the isometric contractions between conditions.

Soleus		mean	SEM	SD	Cohen's d	Gastrocnemius		mean	SEM	SD	Cohen's d
static	pre	8.26	0.50	3.55	0.76	static	pre	8.79	0.60	2.25	0.41
static	post	6.19	0.60	1.45		static	post	10.28	1.23	4.58	
dynamic	pre	9.71	0.30	3.83	0.98	dynamic	pre	7.97	0.65	2.42	0.75
dynamic	post	6.32	0.50	3.02		dynamic	post	11.98	1.93	7.20	

Table 2.2: Mean, standard error of the mean, standard deviation, and Cohen's d value of the soleus and gastrocnemius during the isokinetic contractions between conditions.

Soleus		mean	SEM	SD	Cohen's d	Gastrocnemius		mean	SEM	SD	Cohen's d
static	pre	43.55	0.50	64.46	0.42	static	pre	27.41	6.77	25.32	0.54
static	post	23.78	4.38	16.37		static	post	64.39	25.16	94.13	
dynamic	pre	22.61	1.85	6.91	0.22	dynamic	pre	18.61	2.15	8.05	0.62
dynamic	post	26.84	6.87	25.71		dynamic	post	52.50	20.63	77.20	

DISCUSSION

The research aimed to study and compare the different effects of static and vibrating self-myofascial release on the electromyography and flexibly in the ankle plantar flexors. After specifically analyzing the effects on the soleus and gastrocnemius on the client's dominant side, a variety of interactions was determined. Both the static and vibrating foam roller increased the range of motion with significant interaction, but with no significant difference between static and vibrating procedures. The electromyography procedure indicated no significant difference and no significant interactions between pre and post tests within the rolling conditions. The goal of the research was fulfilled as a better understanding of the effects of two rolling conditions were determined.

The significant interaction between pre and post tests in the range of motion of the ankle plantar flexors confirms the roller's positive impact on flexibility. The increase in range of motion correlates with the widely studied and practiced static stretching, which has proven to lengthen muscle tendons, cross-bridge attachments, and connective tissue, leading to an overall increase in flexibility (Youdas et. al., 2003). The implementation of foam rollers to increase flexibility was also confirmed in a review by Chris Beardsley and Jakob Škarabot, with a conclusion that foam rollers lead to acute increases in range of motion in the majority of investigations (Beardsley & Škarabot, 2015). The study at hand further confirms these findings.

The significant interaction between before and after the rolling interventions occurred with both static and dynamic rollers. The range of motion benefits, however, did not increase with the implementation of the dynamic roller. Because the vibrating aspect of self-myofascial release has not been reviewed in literature, these findings have contradicted the roller's advertising. Although there was no increase in range of motion with the dynamic roller, no decrease was observed as well. This assures that dynamic rolling is not harmful to range of motion. Because the static and dynamic rollers produced the same result in range of motion, the decision to implement one or the other is dependent on other factors, such as cost, comfort, and availability. Further research on the reversal of fatigue, strength loss, and hormonal changes after applying a dynamic treatment in contrast to a static roller could be useful in rehabilitation and athletics (Bosco et. al., 1999).

In contrast to the range of motion findings, no significant difference and no significant interaction was found between pre and post tests and between static and dynamic rolling in the electromyography of the ankle plantar flexors. Previous literature has identified a concern in the inhibition of neuromuscular response after foam rolling (Cavanaugh et. al., 2017). An inhibition of this response can result in the stimulation of pain receptors, a decrease in force, and a decrease in muscular activation. In the study at hand, neuromusualr activation remained constant between the variables and testing procedures. This concludes that the length-tension changes associated with foam rolling may not have a negative effect on the cross-bridge overlap that occurs during muscle activation.

In addition to the consistency found between pre and post testing, both the static and vibrating procedures produced the same electromyographical data. Previous literature has focused on static rolling, so the addition of a vibrating roller had unknown effects. Because the dynamic roller did not inhibit neuromuscular response, it has the same effect on the ankle plantar flexors on range of motion and electromyography. The study, however, did not identify any benefits to neuromuscular activation following the rolling interventions. Some previous literature has identified an increased neuromuscular efficiency. These studies have applied the rolling pressure to other areas of the body, including the quadriceps and knee-joint (Bradbury-Squires et. al., 2015). Increasing neuromuscular activation is beneficial in proprioceptive control and muscular force production, which is beneficial to many exercise science fields. Additional research concerning a dynamic roller's effect on electromyography should be performed, targeting a variety of muscle groups rather than just the ankle plantar flexors.

The application of the foam rolling interventions increased range of motion without decreasing neuromuscular activation. These findings support previous literature that self-myofascial release is a superior form of stretching compared to static stretching (Roylance et. al., 2013). The consistent increase in range of motion with self-myofascial release differs with the implementation of static stretching. Static stretching is highly dependent on the technique and intensity of the stretch. Additionally, pain tolerance in individuals varies greatly, affecting the impact of static stretching on flexibility (Halperin et. al., 2014). Foam rolling, in contrast, is applied with body weight, eliminating the intensity variable. Rolling technique varies among professionals and researchers have confirmed that an individual's technique and body mass, and may influence the outcome from foam rolling (Murray et. al., 2016). The addition of research, such as the study at hand, can provide exercise professionals with correct foam rolling technique. Providing additional evidence that the self-myofascial release technique can improve flexibility in the plantar flexors is vital to the increase in the use of foam rollers, both static and vibrating, in rehabilitation and athletic settings.

The analysis of a relatively homogenous population could indicate that not all populations would respond in a similar fashion. The population of the study was selected based on the implementation of the ankle plantar flexors in their sport. Swimmers, in particular, benefit from an increased ankle flexibility as it is vital for all of the strokes (Škarabot et. al., 2015). Improving ankle range of motion, in all populations, helps reduce the chance of injury and risk of ACL injuries. Because our study confirmed that both static and vibrating foam rolling improves range of motion, the swimmers in the study benefited from a decreased inflammation and risk for injuries. The application of other populations, including both athletes and non-active persons, may continue to confirm the effects of static and dynamic rollers on range of motion.

The main findings from the study not only answer the research problem, but provides exercise professionals with information on the emerging vibrating foam roller technology. Although vibration treatments have been evaluated by previous researchers (Kerschan-Schindl et. al., 2001), the lack of research on dynamic rollers justified the need for the study at hand (see Appendix A). The dynamic roller proved to be a significant form of self-myofascial release when aimed to improve range of motion. The addition of the vibration treatment did not decrease neuromuscular activation, providing similar electromyographical data as the static foam roller. Due to the limitations of the study, only the ankle plantar flexors were evaluated, with emphasis on the soleus and gastrocnemius. Time constraints prevent the researchers from identifying how long the improved range of motion lasted (see Appendix A). Further research identifying how long the effects of the dynamic roller, compared to the static, lasted on each individual would continue to provide more information on the treatment. Although our data found the dynamic roller to produce similar effects as the static roller, it is only the interpretation of our results. Different experimental procedures, additional trials, a more heterogeneous sample population, and the addition of other muscle groups would be required to reveal the overall impact of dynamic and static self-myofascial release on neuromuscular activation and range of motion.

APPENDIX A

RESEARCH QUESTION/EXCUSION CRITERIA/ RISK

Statement of the Problem

Muscle recovery treatment seeks to reduce physical pain, speed up recovery time, increase strength, and increase flexibility. Specifically, flexibility reduces the risk of injury in athletes. Tightness in the plantar flexors can lead to knee valgus during squatting or jumping. Increased knee valgus, especially in sports such as basketball or soccer, is a risk factor for ACL injuries. By improving ankle Plantar flexion ROM, the chance of lowering the risk and rate of injury in both athletes and recreationally active persons increases (Halperin et. al., 2014). However, the most effective treatment for increasing muscle flexibility without inhibiting muscle force production remains inconclusive. Many researchers report the effectiveness of self-myofascial release in increasing ankle flexibility, whereas other researchers support a whole-body vibration treatment. The latest recovery treatment combines vibration into foam rolling, but literature has yet to be published assessing the therapy.

In addition to an increase in flexibility, an increase in neuromuscular activity can aid in muscle recovery. As oxygen demand increases during exercise, blood flow and muscle fiber recruitment increases along with it. The increase in blood flow during and post-exercise increases VO2, aiding in muscle function. This increase is related to neuromuscular activity because as fast-twitch muscle fibers fatigue, slow-twitch muscle fibers are activated in order to maintain a constant power output (Shinohara & Moritani, 1992). The information received from electromyography can also be used as a medical tool in pain assessment, neuromuscular diseases, motor control, and prosthetics (Raez et. al., 2006). There is no research concerning the effects of vibrating foam rollers on electromyography and previous literature indicates that static foam rolling slightly improves neuromuscular communication, but a conclusive consensus has not been reached.

In response to this problem, our study proposes to investigate the different effects of static and vibrating foam rolling on the range of motion and myoelectric activity of the ankle plantar flexors. A treatment order for both static and vibrating foam rolling intervention will be established, along with a control trial before the intervention for statistical comparison. The same vibrating foam roller will be switched on and off according to the assignment treatment in order to reduce variance due to the external composition of the foam roller. By conducting this research, we would not only verify the previous results of research studying static foam rolling's effect on a range of motion and motor unit recruitment but also establish original data for the effects of vibrating foam rollers on the ankle Plantar flexion ROM and neuromuscular activity.

Purpose of the Study

The purpose of the study is to assess the flexibility and neuromuscular change when implementing two mechanisms of self-myofascial release: static foam rolling and vibrating foam rolling. Vibrating foam rollers are a relatively new intervention in the recovery and therapy disciplines. While not previously studied, the implementation of vibration into foam rollers was developed in response to the positive feedback of whole-body vibration treatment and foam rolling therapy. Combining the self-myofascial release delivered in foam rolling with the increased blood flow and muscle temperature exerted by vibration could possibly enhance the effects of foam-rolling treatment. This new mechanism gives researchers a justification to investigate the effects of vibrating foam rollers. The study at hand focuses on the flexibility and myoelectric changes in skeletal muscle in response to foam rolling. Specifically, the goal is to identify the changes in the range of motion and motor unit recruitment in the ankle plantar flexors after static and vibrating foam rolling, with an aim to compare the effectiveness of the two treatments. Studying this new device could demonstrate the unknown effects of vibrating foam rollers, providing a gateway to further muscle recovery treatment research.

Need for the Study

Connective tissue and facial treatments have been an increasing topic of focus in sports medicine in recent years. Despite the inconclusive results concerning the mechanisms of fascia that inhibit muscle function, foam rolling has proven to be a successful exercise in increasing range of motion and neuromuscular communication in both therapy and sport. The initial desire for treatment of the muscle fascia is due to the injury and/or inflammation caused by intense exercise, particularly in sport. These symptoms can "…decrease flexibility, strength, endurance, motor coordination and lead to high amounts of physical pain" (Sullivan et. al., 2013). Limited flexibility in athletes increases their risk for injury, including ACL injuries in soccer and basketball players. Decreased myoelectric activity can inhibit sufficient blood flow to affected muscles, decreasing athletic performance and mobility during everyday life. Our study seeks to investigate ankle ROM and EMG improvement in female NCAA Division I swimmers. Although swimmers do not engage in the planting and cutting motion that is known to cause ACL injuries," …it has been reported that swimmers may specifically benefit from increased ankle flexibility and that this may improve performance"

(Škarabot et. al., 2015). The lack of research conducted on swimmer's ankle range of motion and myoelectric activity allows them to be a good source for this research and future studies.

The results of the study will benefit not only sports medicine researchers, but strength and conditioning specialists, coaches, physical and occupational therapists, exercise physiologists, and athletes, specifically swimmers. Research on the effects of a vibrating foam roller contributes to muscle recovery treatment and future development of equipment and techniques used to increase muscle flexibility and treatments for neuromuscular dysfunction.

Delimitations

Boundaries are set for the study purposefully in order to reduce cost, time consumption, and confounding variables. The study is specifically measuring the participants change in ankle Plantar flexion range of motion and myoelectric activity, with an emphasis on the tibialis anterior, the extensor hallucis longus, and the extensor digitorum longus muscles. Other areas are not being measured in order to reduce overcomplexity and the possible alteration of flexibility due to the additional measurements. Change in force production will be measured in a separate study with the same participants, but this review will emphasize the effects of foam rolling on range of motion and neuromuscular changes in order to enhance the specificity of the study and to exhaust all the details leading up to the results.

The published literature reviewed on behalf of the study only included studies within the past 25 years. Outdated papers were not reviewed to avoid analyzing inaccurate or outdated information. Contemporary research on self-myofascial release and foam rolling has proven may older articles wrong and they include modern techniques proven to enhance flexibility and neuromuscular activity. The literature reviewed had an emphasis on the effects of static stretching on flexibility, the effects of foam rolling on flexibility, muscle response to vibration exposure, range of motion measurements, EMG measurements, foam rolling in athletes, and the effects of static stretching, vibration, and foam rolling on myoelectric responses. Papers focusing on the lower extremities and ankles were prioritized because that most closely relates to the study at hand. Although many papers had reviewed the effects of foam rolling on flexibility, force production, and EMG changes, the flexibility, and neuromuscular portions were taken into greater consideration in order to obtain previous methods and data concerning our study.

When choosing the population, the selected participants will be strictly female swimmers at Georgia Southern University. Because the variation in male and female myofascial physiology in uncertain, the requirement for the participants to be female eliminates a possible confounding variable. These athletes are between the ages of 18 and 22 years old and the athletes with sprint-oriented training will be prioritized in the selection in order to control any external effects on the range of motion during testing. If not all 20 of the participants engage in sprint-oriented training, then distance swimmers will be selected and the variation will be included on the possible sources of error.

The swimmers who consent to participate in the research would partake in four testing sessions. Sessions A and B will include static rollers, with sessions C and D implementing vibrating rollers. The session order chosen for each participant will be randomized. The randomization of the patients reduces bias and the placebo effect. The same foam roller will be used for each participant, with a switch to activate or deactivate the vibration mode. The vibrating foam rollers will be switched on and off according to the assignment treatment in order to reduce variance due to the external composition of the foam roller.

Limitations

The sample included in our research is due to convenience sampling. Because the sample is limited to a specific group of people, the only population that the results could be applied to are collegiate female swimmers. The swimmers included in the study could also be subject to self-reporting. The researchers cannot control the amount of force placed on the foam roller by the patient, so some patients could experience a greater increase in flexibility or motor unit recruitment if they applied greater pressure while foam rolling. A pain scale will be implemented in order to encourage the participants to apply an amount of pressure that produces a set amount of discomfort for each patient. Similar scales will be implemented during EMG data collection. While applying force using a dynamometer, the researchers will encourage the participants with identical commands and chants in order to inspire maximum force production from the patient.

Technological errors could influence the results of the study. If the foam roller fails to produce a vibrating effect for a consistent time on one patient but is fully functional on another, the variance due to error increases. A tape measure is being used to measure resting and post-intervention flexibility, so the precision of the measurements could be reduced due to the lack of advanced materials. Multiple measurements will be taken and the average value found will be recorded in order to accommodate this limitation.

Time constraints greatly affect any study. Our study only has a maximum of 3 weeks to collect data, and the data collection period is limited to April of 2018. The extremely short time in which the data will be collected is due to the schedules of the researchers and the participants and will decrease the complexity of the study. The participants will only be asked to participate if they can attend all the data collection periods in order to eliminate insignificant data. Repeated sessions will be encouraged in order to increase validity Additionally, time constraints cause the results to be dependent on the conditions during that time. Because the study is conducted during a time of low-intensity training for the athletes, the results could vary from what would occur if the data was collected in the winter. To accommodate for this, the researcher will recommend the creation of future studies assessing the variation in flexibility during different training periods for athletes.

Assumptions of the Study

It is assumed that the participants will behave appropriately and follow the given directions during the data collection. The patients will be asked to measure their flexibility to their full potential and sincerity during the intervention is expected. Participants are expected to apply full force on the dynamometer during collection of the electromyographical data. Participants are also assumed to have a genuine interest in the study at hand, rather than an ulterior motive, such as having access to advanced equipment.

These assumptions are most likely proven to be true, otherwise, the study cannot progress. Anonymity and confidentiality will be preserved throughout the data collection and participants are permitted to withdraw from the experiment at any time with no consequences. A control group will be included in the study for statistical comparison.

APPENDIX B

REVIEW OF RELATED LITERATURE

Effects of Static Stretching on Flexibility

Static stretching is the most common form of treatment used to elongate connective tissue. Unlike foam rolling, static stretching does not utilize a tool or place any added pressure on the muscles to reduce the stiffness in muscle fascia. Provided that the resistance and duration of a passive muscle stretch are sufficient, the muscle tendon, cross-bridge attachments, proteins within the myofibril, and the connective tissue are thought to lengthen, increasing flexibility (Youdas et. al., 2003). Mayo Clinic researchers James W. Youdas, David A. Krause, Kathleen S. Egan, Terry M. Therneau, and Edward R. Laskowski, performed a randomized trial to examine the effects of a 6-week static calf muscle stretching program on the range of motion (ROM) in the ankle joint. One hundred and one healthy adults were randomly assigned to either a control group or one of three experimental groups, each with different stretch duration lengths. The standing wall stretch was implemented in the study and it was observed that there was no significant effect on the range of motion in the ankle joint after static stretching, no matter the duration. Contrasting results obtained from researchers at the University of Ljubljana found an initial 0.9 ± 0.67cm change in ankle Plantar flexion range of motion after static stretching. This statistical difference could be due to the type of stretch performed in the study, which consisted of '…the subjects [standing] with one leg on the edge of a bench, extended [their] knee and dorsiflex[ing], pointing their heel towards the ground" (Škarabot et. al., 2015). Similarly, the original research obtained from Israel Halperin and colleges found a significant improvement in plantar flexor range of motion by 14% but performed a stretch implemented an anaerobic step and wall-lean. The various results gathered from static stretching studies signify how technique and intensity of a static stretch could influence the range of motion variability. Some researchers have suggested that the main reason for the improved range of motion after static stretching has to do with the participant's pain tolerance associated with stretching, therefore producing different results from study to study. Additionally, musculotendinous stiffness has been measured to return to its baseline value after static stretching from times between 30 seconds to one hour, reducing the reliability that static stretching for a short period of time truly has a lasting effect on the range of motion in the ankle joint (Halperin et. al., 2014).

This raises the question about how would foam rolling's effect on a range of motion differ from static stretching. Could the self-myofascial release create a greater change in flexibility? The prior research of static stretching leads researchers to develop more progressive ways of increasing ROM, such as foam rolling.

Effects of Foam Rolling on Flexibility

Implementing a foam roller into self-management of flexibility and recovery has become increasingly popular in athletics and therapy. Similar to a massage, foam rolling is thought to provide relief to muscle stiffness and increase flexibility. The foam roller itself is a "dense foam cylinder that a person rolls their bodyweight over to increase ROM for a specific body region, as a type of self-massage" (Sullivan et. al., 2013). Foam rolling is an increasingly popular treatment, with the first publication concerning its effects on the human body in 2013. Due to its underrepresentation in academic research, foam rolling continues to be a debated topic on the effects it elicits on muscle and fascia. In a study conducted by Jakob Škarabot, Chris Beardsley, and Igor Štirn, eleven train swimmers were instructed to use The Grid Roam Roller on their dominant leg 3 times for 30 seconds, with a 15-second rest between sets. The subjects were instructed to roll from their popliteal fossa, at the back of the knee, to their Achilles tendon by placing their non-dominant foot over their leg being rolled, and propelling their lower body forward and back on the roller with their arms extended and firmly planted on the ground. Foam rolling was determined to have a 0.4 ± 0.67cm increase in ROM initially after the intervention, much less than the static stretching exercise performed in the same study, but the effects of the foam rolling were the same even 20 minutes post-rolling. Similar results were produced by researchers at Brigham Young University, who implemented a foam rolling technique where both of the calves were placed on a roller, with the arms propelling the body back and forth. The study only analyzed the short-term increase in ROM after foam rolling but provided additional evidence that the self-myofascial release technique can improve flexibility in the plantar flexors (Roylance et. al., 2013).

Although much research has confirmed that foam rolling improves ROM, a study conducted by academics at the University of Oregon argues otherwise. Twelve teenage athletes were tested for flexibility in their hip flexors and quadriceps before and after 60 seconds of rolling. Force applied to the roller by the participant was measured by a force plate on the ground. There was a change in flexibility for some participants in the hip flexors after foam rolling, but there was no effect on the quadriceps. Overall, the results produced displayed that "flexibility was statistically greater in the treatment condition in practical terms, [but it was] insignificant as it [was] within the published coefficient of variation for the test" (Murray et. al., 2016). The lack of significant results of this study could have been due to the uncontrolled force placed on the roller by the patient, the time period, the rolling technique, and the area in which the rolling was performed. The researchers of the study even stated that "differing forces through the roller and subsequently delivered to muscle vary based on individual's technique and body mass, and may influence the outcome from foam rolling" (Murray et. al., 2016). The results of the study led future research to add a force control scale, such as a numeric pain scale, to reduce the chance of unmeasured variability.

Despite contrasting study results, the systematic review published by Chris Beardsley and Jakob Škarabot concluded that "…a foam roller appears to lead to acute increases in flexibility in the majority of investigations" (Beardsley & Škarabot, 2015). The previous findings act as a platform for the research question: Do vibrating foam rollers alter the change in the range of motion of the ankle joint in comparison to static foam rollers? Because vibrating foam rollers are a relatively new alteration to the original foam rollers, the research currently published on them is almost absent. This raises questions about which forms of measurement are most reliable to produce the initial data concerning vibrating foam rolling intervention.

Muscle Response to Vibration Exposure

Although literature reviewing the effects of a vibrating foam roller on muscle range of motion has not yet been published, many researchers have studied how the muscle responds to body and local vibration. Vibration has been a widely used tool for enhancing physical performance, whether through muscle force production, velocity, or flexibility (Fagnani et. al., 2006). While the exact mechanism that adapts to vibration in the muscle is unknown, gravitational effects on the body after intense exercise such as fatigue, strength loss, and hormonal changes has been proven to be reversed after whole body vibration treatment (Bosco et. al., 1999). These changes were researched by Kerschan-Schindl and colleagues by observing the alterations in muscle blood flow to the quadriceps and gastrocnemius after low-frequency vibration treatment. The Galileo 2000 device administered whole-body vibration to 28 healthy subjects in three different positions for 3 minutes in each position. Blood flow was measured in the popliteal artery with a Doppler ultrasound machine. Blood circulation rate before and after the treatment lead "…to an increase in the relative moving blood volume of quadriceps and gastrocnemius muscles" (Kerschan-Schindl et. al., 2001). The controlled rhythmic muscle contractions that the vibration produced suggested that peripheral resistance was reduced, increasing blood flow and reducing muscle fatigue. The increase in circulation to the muscles produced by vibration also allows the muscle to produce more force due to the activation of muscle spindles in and around the targeted area (Kerschan-Schindl et. al., 2001).

The effects of vibration on muscle flexibility and performance hypothesized by Kerschan-Schindl and colleagues was also verified by researchers in *The American Journal of Physical Medicine & Rehabilitation.* An 8-week whole-body vibration treatment was implemented on 26 female athletes in order to investigate muscle force production and range of motion. Two positions were measured while in contact with the Nemes LCB-040 vibration device. Three sets of 20 seconds, three sets of 15 seconds were performed for the first and second week, with treatment time increasing in 10 second intervals throughout the 8-week period. Muscle power was measured before and after the therapy using an Isokinetic leg press and flexibility was measuring using a sit-and-reach test. The vibration treatment statistically increased muscle force and flexibility in the lower-body. The 13% increase in flexibility in these subjects can be explained by the involvement of "neural circulatory and thermoregulatory factors" (Fagnani et. al., 2006). The flexibility changes are due to increased blood flow, as discussed by Kerschan-Schindl and colleagues, was further clarified by

Fagnani and colleagues to evoke a heating effect on the muscle, adding to the heat produced by the muscle fibers. The increase in heat generation increases muscle fiber relaxation, improving flexibility.

Long-term and short-term effects of vibration therapy on flexibility in the lower body was studied by Sands and colleagues. With an emphasis on athletes who require a high range of motion, 10 Olympic-level male gymnasts were tested. The participant's flexibility was measured before and after the intervention by executing "a forward split position with the rear leg flexed at the knee and the shank held vertically against a matted block" (Sands et. al., 2006). The vibration treatment was given in two different positions, stretching each leg for one minute in each position. Acute effects of the treatment displayed significantly large increases in range of motion. The long-term study, which extended the therapy for 4 weeks, only displayed significant increases in flexibility on one side. The study, like others previously published, accredited the changes in range of motion to both the increase and blood flow and local muscle temperature caused by the vibration technique. Sands and colleagues concluded that the experiment presented "…a promising use of vibration in the enhancement of flexibility in acute and long-term training (Sands et. al., 2006).

In addition to flexibility, vibration treatments have been proven to improve movement velocity, muscle force, and muscle power. A study in Rome examined these changes in 6 female volleyball players. The participants warmed up on a cycle ergometer for 5 minutes and statically stretched their upper leg for 5 more minutes. Initial force production was measured and the Galileo 2000 whole-body vibration machine was used for ten 60 second repetitions with 60 seconds rest in between each set. It was determined that the whole-body vibration statistically improved movement velocity and muscle force and power (Bosco et.

al., 1999). Literature, like the published study from Bosco and colleagues, has reviewed the various effects of vibration therapy on muscles, verifying the improvement in flexibility and other factors on the targeted area. While not previously studied, the implementation of vibration into foam rollers was developed in response to the positive feedback of whole-body vibration treatment. Combining the self-myofascial release delivered in foam rolling with the increased blood flow and muscle temperature exerted from vibration could possibly enhance the effects of foam-rolling treatment. Studying this new device could demonstrate the unknown effects of vibrating foam rollers, providing a gateway to further muscle recovery treatment research.

Range of Motion Measurements

A variety of methods exist concerning the measurement of the ankle Plantar flexion range of motion. Four researchers at Creighton University measured the plantar flexor's ROM in a weight-bearing lunge using a standard goniometer, digital inclinometer, and a tape measure. A goniometer a common instrument used to measure angles, with two arms aligning at a fulcrum. Alternatively, digital inclinometer includes "…a dial, bubble, or digital display to provide the angle of the slope relative to the ground" (Konor et. al., 2012). The study recruited twenty healthy participants to perform a weight-bearing lunge against a wall and a measurement of the maximal ankle Plantar flexion ROM was taken with each tool on both ankles. The measurements were repeated 10 minutes after the first trial. All three forms of measurement were found to be reliable and low in measurement error, with the inclinometer resulting in a higher reliability and the goniometer with the lowest. The digital aspect of the inclinometer was believed to reduce reading error because of the digital display. Overall, the "…findings suggest that an individual with little training can obtain reliable measures of weight-bearing ankle Plantar flexion ROM utilizing a goniometer, inclinometer, or tape measure" (Konor et. al., 2012).

The utilization of the weight-bearing lunge was also included in the study conducted by Škarabot and colleagues. Specifically, the subjects lunged their knee to make contact with the wall, using their hands for balance. The leading foot was placed 10cm away from the wall and the knees were instructed to be in line with the second toe. Both heels should be in contact with the ground, with the foot being measured as far away from the wall without lifting the heel from the ground. If the participant could not touch their knee to the wall without keeping their back heel down in the initial 10cm position, the participant moved their foot toward the wall 1 cm at a time. Ankle ROM was measured in this position by the "reference to the linear distance between the big toe and the wall" (Škarabot et. al., 2015). Konor and colleagues followed the same procedure when leading the patients into a weight-bearing lunge. It is a commonly used method to measure ankle Plantar flexion ROM because it reflects "…functional activities such as walking, running, or stair ambulation, and may be more reliable than measures obtained in a non-weight-bearing position" (Konor et. al., 2012). Resistance bands have also been implemented by researchers at the Memorial University of Newfoundland to monitor heel raise. The band was placed under the measured foot as the tester pulled on it, so if the heel raised off the ground it would snap off, indicating maximum ROM had been reached ((Halperin et. al., 2014). The proven reliability of the weight-bearing lunge method in multiple accredited studies validates its chance for success in future research.

Effects of Foam Rolling on EMG

Self-myofascial release is hypothesized to stimulate mechanoreceptors, inducing psychological changes in the muscles. Foam rolling, specifically, applies a constant pressure that temporarily loosens muscle fascia, possible inhibiting neuromuscular response and activation forces (Cavanaugh et. al., 2017). Researchers have studied the extent and variety of neural responses to foam rolling, linking it with an increased range of motion and force production. Cavanaugh and colleagues researched the muscle activation of the hamstring and quadriceps after 4 sets of 45-second foam rolling, with 15 seconds of rest in between each set. The study found a significant decrease in activation of the biceps femoris, but only when the muscle was rolled alone and not in combination with the hamstrings. The difference in results when the quadriceps were foam rolled individually was attributed to “foam rolling a larger volume of muscle such as the quadriceps stimulated a diverse and more extensive array of sensory afferents” (Cavanaugh et. al., 2017). Stimulation of more pain receptors by singling out a specific muscle during foam rolling can result in a greater inhibitory effect of muscle activation according to the study.

Varying results were produced by MacDonald and colleagues after analyzing motor unit activation following foam rolling of the quadriceps. The participants were instructed to roll for 1 minute, twice, with 30 seconds of rest in between the rolling periods. The researchers measured motor unit activation through right knee extensor force production, with surface EMG electrodes placed on the rectus femoris. There were no changes in neuromuscular force production or activation determined, despite the increase in ROM. EMG levels were recorded for a short duration and the elimination of a prolonged foam rolling procedure could be accredited for the consistent activation (MacDonald et. al., 2013). Similar results were recorded by Halperin et. al. in the plantar flexor muscles. Two surface EMG electrodes "…were placed 2 cm apart over the midpoint of the muscle bellies of the tibialis anterior and soleus with a ground electrode placed on the head of the fibula" (Halperin et. al., 2014). The electromyography values remained unaffected by the rolling intervention in the study, further concluding that the length-tension changes associated with foam rolling may not have a negative effect on the cross-bridge overlap that occurs during muscle activation.

Researchers Bradbury-Squires and colleagues obtained an increase in neuromuscular efficiency during their study of the quadriceps and the knee-joint. The study implemented a roller massage procedure in which pressure was applied for 5 repetitions of 20 second or 5 repetitions of 60 seconds, depending on the group of study. Bipolar surface EMG electrodes were used to measure all EMG signals. The study measured muscle activation before and after the roller intervention during a dynamic lunge movement. The study concluded that both durations of roller-massage application increased neuromuscular efficiency during the lunge, compared to the control (Bradbury-Squires et. al., 2015). The efficiency increase was attributed to the muscle attempting to protect itself from the roller pressure, contraction due to the anticipation of potential discomfort, and "through similar mechanisms as contract-relax proprioceptive neuromuscular facilitation" (Bradbury-Squires et. al., 2015). The varying results obtained by researchers concerning muscle activation and EMG data in response to foam rolling can be contributed to many factors such as different experimental designs, targeted muscles, and SMFR interventions.

Effects of Vibration on EMG

Research on exposure to vibrating foam rolling procedures has yet to be published, but there is a wide variety of published research concerning the effects of whole-body and local vibration. Collectively, lower body skeletal muscle EMG data has found increases in muscle activity following whole-body vibration exposure. Researchers Hazell et. al. measured EMG changes in 10 healthy male university students during "…three distinctive unloaded actions: isometric semi-squat, dynamic leg squats, and static and dynamic bilateral bicep curls" (Hazell et. al., 2007). Following the whole-body vibration procedure, the semi-squat condition resulted in a significant increase in muscle activity and EMG amplitude (mm). Similar results were found during the leg squats and bicep curls, suggesting that vibration exposure has a great ability to increase both lower and upper-body muscle activity dynamic and static conditions. Similar results were obtained by Piotr Krol and colleagues in a study concerning whole-body vibration exposure in female athletes. Frequency and amplitude of myoelectric activity of the vastus lateralis and vastus medialis in 29 females were measured with the use of EMG. Data was recorded over 8 different trials, with each trial assigned specific vibration intensities. The participants squatted at a 90-degree angle in order to induce muscle activation. The study concluded that myoelectric activity increased as vibration intensity increased, with the lowest vibration setting showing little change in muscle activation (Krol et. al., 2011).

Marin et. al. published research analyzing the effects of 30-second vibration treatment for 10 healthy male participants. EMG signals were collected from the vastus lateralis and gastrocnemius while the participant was in a half-squat position. Muscle activation increased following the treatment of both muscles and the highest activation was observed at a 4mm amplitude of vibration (Marin et. al., 2009). Roelants et. al. published similar results in the article "Whole-Body-Vibration-Induced Increase in Leg Muscle Activity During Different Squat Exercises". The study analyzed the rectus femoris, vastus medialis, vastus lateralis, and gastrocnemius muscles. A significant increase in neuromuscular activity of the leg muscles as observed during loaded isometric exercises. Leg muscles closer to the vibration source displayed a greater increase in activation (Roelants et.al., 2006). The overall increase in muscle activation found in the research is because “Mechanical vibrations applied to the muscle or tendon stimulates sensory receptors, and activation of muscle spindles facilitates the activations of alpha-motoneurons, leading to tonic vibration reflex” (Marin et. al., 2009). The abundant research supporting the claim that vibration treatment increases motor unit activation has led researchers to begin studying the use of vibration treatments for clinical and athletic use.

EMG Measurements

Surface EMG is a method of recording neurological information present in nearby muscle tissues that “focuses the algebraic summation of muscle action potentials passing under the recording electrodes or sensor” (Ahamed et. al., 2014). The placement and recording process of electromyography places a large role in the signal collected. The EMG signal is caused by changes in the nerve firing rates and represents the compound motor unit action potential including effects of propagation dispersion and tissue filtering (Reaz et. al., 2006). Research has concluded that placing the EMG electrode on the desired muscle belly produces the most significant signal with the least amount of variability (Ahamed et. al., 2014). This placement has been supported by EMG studies concerning the lower-body, upper-body, and even facial muscles where “variable motor unit distribution resulted in an average optimal electrode position approximately in the muscle’s anatomical center” (Lapatki et. al., 2010). It has been proven that standardizing EMG placement and ordination elicits a consistent pattern of responses that are important in normalizing mean values and increasing validity (Reaz et. al., 2006).

In terms of specific placement, research as determined that placement along the direction of the muscle fibers produced the most accurate signal, but the distance between the muscle fibers and electrode site can consider muscle fibers to be an invariant system during data collection (Ghapanchizadeh et. al., 2017). Usually, functional studies only require one electrode per muscle, so that communication between the electrode and computer system is not inhibited by other nearby electrodes (Lapatki et. al., 2010). Overall, surface EMG electrode placement can be refined for a specific study during pilot tests, but it is vital to ensure that placement remains consistent during data collection for each participant (Reaz et. al., 2006).

Foam Rolling in Athletics

Connective tissue and facial treatments have been an increasing topic of focus in sports medicine in recent years. Despite the inconclusive results concerning the mechanisms of fascia that inhibit muscle function, foam rolling has proven to be a successful exercise in increasing range of motion in both therapy and sport. The initial desire for treatment of the muscle fascia is due to the injury and/or inflammation caused by intense exercise, particularly in sport. These symptoms can "…decrease flexibility, strength, endurance, motor coordination and lead to high amounts of physical pain" (Sullivan et. al., 2013). Specifically, limited flexibility, and therefore ROM, can be a risk factor for injury in athletes. Tightness in the plantar flexors can lead to knee valgus during squatting or jumping. Increased knee valgus, especially in sports such as basketball or soccer, is a risk factor for ACL injuries. By improving ankle Plantar flexion ROM, the chance of lowering the risk and rate of injury in both athletes and recreationally active persons increases (Halperin et. al., 2014). Although swimmers do not engage in the planting and cutting motion that is known to cause ACL injuries," …it has been reported that swimmers may specifically benefit from increased ankle flexibility and that this may improve performance" (Škarabot et. al., 2015). The lack of research conducted on swimmer's ankle range of motion allows them to be a good source for future studies. The application of foam rolling in sport raises the question: how does foam rolling impact one sport in particular and do the effects vary from sport to sport? By conducting research on one particular sport rather than a general group of athletes, additional information about the effects of foam rolling could be obtained.

APPENDIX C

IRB APPROVAL

Georgia Southern University
Office of Research Services & Sponsored Programs

Institutional Review Board (IRB)

Phone: 912-478-5465
Fax: 912-478-0719
IRB@GeorgiaSouthern.edu
Veazey Hall 3000
PO Box 8005
Statesboro, GA 30460

To: Mazzei, Brianna; Cormier, Tanner; Li, Li

From: Office of Research Services and Sponsored Programs

Initial Approval Date: 1/23/2018

Expiration Date: 12/31/2018

Subject: Status of Application for Approval to Utilize Human Subjects in Research – **Expedited Process**

After a review of your proposed research project numbered **H18164** and titled **"Different Effects of Static and Vibrating Foam Rollers on Ankle Dorsiflexion Flexibility and Plantar Flexion Force Production"** it appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable. You are authorized to enroll up to a maximum of 20 subjects.

Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your proposed research. **Description: The purpose of this study is to test if two different foam rollers will produce differential effects when applied to young collegian swimmers.**

If at the end of this approval period there have been no changes to the research protocol; you may request an extension of the approval period. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to notify the IRB Coordinator, so your file may be closed.

Sincerely,

Eleanor Haynes

Eleanor Haynes
Compliance Officer

APPENDIX C

INFORMED CONSENT FORM

COLLEGE OF HEALTH AND HUMAN SCIENCES

SCHOOL OF HEALTH AND KINESIOLOGY

CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY

Title of Project: **Different Effects of Static and Vibrating Foam Rollers on Plantar Flexor's Flexibility and Force Production Capacity**

Brianna Mazzei and Tanner Cormier, Georgia Southern undergraduate students, will be working under Dr. Li Li during the completion of this research. The purpose of this research is to determine if there are different effects on the range of motion and muscle contraction force in the plantar flexors of the ankle when implementing vibrating foam roller treatment in comparison to static foam roller therapy. You will be a part of a sample of twenty female collegiate swimmers at Georgia Southern University. You will participate in the project and be tested according to assigned data collection sessions. You are eligible to participate in the study if you are a female swimmer within the age range of 18 to 28 years old without neuromusculoskelatal pathology within the last six months. If you answered "Yes" for any of the PAR-Q questions, you will be excluded from the project. There are four conditions in one testing session. Conditions A and B will include static rollers and conditions C and D will implement vibrating rollers. There is no difference between conditions A and B, C and D are the same conditions as well. They are created and included to test the effects of different testing sequences. The order of the conditions will be randomly assigned to each participant. Resting flexibility will be measured upon arrival using the weight-bearing lunge technique and a tape measure. Muscle contraction force will be measured using a dynamometer. After 10 minutes rest, the resting flexibility and force production will be measured again in order to evaluate measurement reliability. You will then use the assigned roller for three trials. Range of motion and force production will be measured immediately after the foam rolling procedure and both five & ten minutes post-test. Each session will take no longer than an hour and you will only be required to attend one session.

The minor risks to the study include discomfort and possible pain during data collection. While unlikely, it is possible that you may injure yourself while using the foam rollers, dynamometer, or standing in a weight-bearing lunge position. By signing this consent form, you are agreeing to the following statement: “"I understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided.” To minimize the possibility of the unlikely injury, please listen to the instructions carefully at the beginning of the testing session.

The benefits to you participating in the study include learning personal muscle recovery therapy using advanced equipment. The data collected by the researchers could give you insights to muscle recovery treatments that are most beneficial for your needs. You will also be able to get involved in research that may be beneficial to your program of study. The benefits to the society include providing one of the first published research involving the new technology of vibrating foam rollers and their effects on flexibility and muscle force production. These data can benefit sports medicine researchers, strength and conditioning specialists, coaches, physical and occupational therapists, exercise physiologists, and athletes, specifically swimmers.

You should be aware that deidentified coded data from this study will be stored in a password secured computer in a locked office for three years. All the records will be destroyed three years after the conclusion of the project. Your confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the confidentially of individuals and institutions.

You also have the right to ask questions and have those questions answered. If you have questions about this study, please contact the researchers named above or the researcher’s faculty advisor, whose contact information is located at the end of the informed consent. For questions concerning your rights as a research participant, contact Georgia Southern University Office of Research Services and Sponsored Programs at 912-478-5465.

There will be no compensation for volunteering for the data collection of the research study. You as a volunteer are not required to participate in the research and you may end the testing session at any time by notifying the researcher in charge. There is no penalty for not participating in the study and you may withdraw at any time without retribution. You must be 18 years of age or older to consent to participate in the study. If you wish to consent to participate and to the terms stated above, please sign and indicate the date.

You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number H_18164_.

Title of Project: **Different Effects of Static and Vibrating Foam Rollers on Plantar Flexor's Flexibility and Force production Capacity**

Investigators:

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_______________________________________ _____________________

Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

_______________________________________ _____________________

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