UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

THE ACUTE EFFECT OF FOAM ROLLING ON RANGE OF MOTION, FLEXIBILITY, AGILITY AND VERTICAL JUMP HEIGHT

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

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THE ACUTE EFFECT OF FOAM ROLLING ON RANGE OF MOTION, FLEXIBILITY, AGILITY, AND VERTICAL JUMP HEIGHT

By Carley J. Henning

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

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ABSTRACT

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This study was designed to evaluate the acute effects of foam rolling (FR) on range of motion, flexibility, agility, and vertical jump height. Nineteen subjects (8 male, 11 female) completed a 15-minute FR session and a control condition on two separate days. Pre and post-testing evaluation included ankle dorsiflexion range of motion (ROM), knee flexion range of motion, sit-and-reach, agility t-test, and vertical jump height. There were no statistically significant differences for any of the variables ($p<.05$). Consequent to the FR session, subjects in the present study felt as though FR increased ROM in the ankle and knee as well as increased hamstring flexibility. Thus, it was concluded that FR may provide some psychological benefit but appears to have no physiological benefit as a warm-up modality.

ACKNOWLEDGEMENTS

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I would like to thank the participants that were willing to be involved in the study. It is not easy to be as committed and as flexible with their schedules as they were. I commend them for their devotion. It was great getting to know all of you.

I would like to send great appreciation to my family, especially my mother and father. Thank you for always being there for me no matter what. I will continue to keep making you proud each and every day. I love you both.

Lastly, I would like to extend a sincere thank you to my thesis advisor Dr. John Porcari. Your help and expertise allowed me to realize what a research thesis is all about. Your supervision allowed me to successfully conduct and write this study. Thank you for all that you have done. I would also like to extend my thank you to my committee members, Scott Doberstein and Kari Emineth, for helping when needed. It was a privilege to learn from the both of you.

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INTRODUCTION

The foam roller was created by Moshé Feldenkrais in the early 1970s and he is widely known for the *Feldenkrais method*, which aims to reduce pain and increase mobility issues while improving physical function through awareness of one's own body (Heffernan, 2016). In 1987, a physical therapist and student of Feldenkrais, Sean Gallagher, began to use a foam roller as a self-massage tool (Heffernan, 2016). Since that time, the popularity of foam rollers as a self-myofascial release (SMR) tool has emerged as the 14th hottest worldwide fitness trends in 2019 (Thompson, 2018).

A foam roller is a cylindrical tube made of foam and is used as a warm-up and recovery tool. Foam rollers come in a wide variety of sizes, surface textures, and densities. By placing the foam roller underneath an individual, one is able to achieve a myofascial release by slowly rolling over the tender or stiff areas of the body. An individual may start at the proximal portion of the muscle, working down to the distal portion or vice versa. The friction generated between the tissue and the foam roller causes warming of the fascia (MacDonald et al., 2013). This increase in temperature causes the tissue to become more fluid-like (known as thixotropic property) which purportedly reduces adhesions and scar tissue (MacDonald et al., 2013). At a cellular and physiological level, foam rolling (FR) has been shown to alleviate arterial stiffness, improve vascular endothelial function, and increase blood flow (Okamoto, Masuhara, & Ikuta, 2014). It is also reported that FR can correct muscular imbalances, alleviate muscle soreness, relieve joint stress, improve neuromuscular efficiency, and increase range of motion (ROM) (MacDonald et al., 2014).

There have been a number of research studies conducted to examine the acute effects of SMR via FR but collectively, there are many gaps in the literature and thus, the results are inconclusive. Su and colleagues (2017) compared the acute effects of FR, static stretching, and dynamic stretching during warm-up on flexibility and strength in young adults. The study found that FR increased flexibility of the quadriceps and hamstrings to a greater degree compared to static or dynamic stretching. MacDonald et al. (2013) also investigated the acute effects of FR before physical activity. It was found that FR resulted in significant increases in ROM for the knee joint at 2 (10%) and 10 (8%) minutes post-FR, respectively. Another study by MacDonald et al. (2014) examined the effects of FR as a recovery tool after an intense bout of physical activity. It was concluded that FR was beneficial in decreasing muscle soreness, while improving vertical jump height, muscle activation, and passive and dynamic ROM. Couture, Karlik, Glass, and Hatzel (2015) studied the effect of FR duration on hamstring ROM. They found no significant differences between baseline knee extension ROM and the ROM after either short (2 sets of 10 seconds) or long (4 sets of 30 seconds) FR sessions.

Škarabot, Beardsley, and Štirn (2015) compared the effects of FR and static stretching on ankle dorsiflexion ROM in adolescent athletes. Subjects were randomized into one of three conditions: (1) FR, (2) static stretching, and (3) FR plus static stretching. It was found that static stretching increased ROM by 6.2% and FR plus static stretching increased ROM by 9.1%. However, there were no increases in ROM with FR alone.

Because the results of previous studies are inconclusive, the purpose of this study was to investigate the acute effects of FR on ankle and knee ROM, lower back and hamstring flexibility, agility, and vertical jump height.

METHODS

Subjects

Nineteen volunteers (8 male, 11 female) from the University of Wisconsin- La Crosse campus participated in this study. Due to the physical demands of the testing and training procedures, participants were required to be at least recreationally active (i.e., exercise at least three times per week for at least 30 minutes), and not have sustained any lower-leg injuries within the last six months. Potential subjects completed the Physical Activity Readiness Questionnaire (PAR-Q) and a health history questionnaire to screen for cardiovascular and orthopedic contraindications to exercise. Those eligible also provided written informed consent before undergoing any testing or training procedures. The protocol was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects.

Procedures

All subjects attended an initial orientation session where the purpose and procedures of the study were explained. At this session, subjects were taught and practiced all of the tests administered as part of the study. Height was measured using a wall-mounted stadiometer. Weight was assessed using a Rice Lake 150-10-7 Floor Level Digital Scale (The Rice Lake Weighing System, Rice Lake, WI). Subjects completed a 5-minute warm-up on a Schwinn Airdyne (Nautilus Inc., Vancouver, WA) bike at a self-selected speed. Following the warm-up, subjects were immediately assessed for ankle and knee ROM, lower back and hamstring flexibility, vertical jump height, and agility. All the tests were administered in the same order listed above.

Ankle dorsiflexion and knee flexion, on the right leg, were measured using a Medigauge 900105 Dual-scale Electronic Digital Goniometer (Taylor Toolworks LLC, Columbia, MO). To measure ankle dorsiflexion, subjects sat on a table in an upright position with their legs straight while their ankles were off the edge of the table. Instructions were given to dorsiflex their ankle as far back as possible. A measurement was taken when they could not go any further. The test was performed three times and the two closest measurements were averaged and used for data analysis. To measure knee flexion, subjects laid in a prone position with their knees at the edge of the table. The subjects were instructed to flex their knee as far back as possible. A measurement was taken when they could not go any further. The test was performed three times and the closest two measurements were averaged for data analysis.

Flexibility of the lower back and hamstrings were measured using a sit-and-reach test. Subjects removed their shoes and sat with their hips against a wall, legs extended straight out in front of them, with their feet flat against the sit-and-reach box (Novel Products Inc., Addison, IL). The subject slowly reached forward as far as possible with their hands stacked on top of each other. Instructions were given to not lead with one hand or use jerky movements in an attempt to reach further. The investigator placed her hands on the subject’s knees to ensure the legs did not bend or leave the ground during the reach (ACSM, 2018). The test was performed three times and the average of the two closest measurements was used in the data analysis.

Vertical jump was measured using a Just Jump Meter mat (Probotics Inc., Huntsville, AL). The mat was placed flat on a hard surface and was programmed on "1 jump mode." Subjects were instructed to stand with both feet flat on the mat, shoulder width apart. Instructions were given to jump as high as possible and land with both feet on the mat. The subjects were encouraged to use countermovement during their jumps. The test was performed three times with a 30-second rest between each jump. The two closest measurements were averaged and used for data analysis.

Agility was measured using a T-test (American Council on Exercise, 2014) which includes forward, lateral, and backward movements (See Figure 1). Cones were set up at each point. Subjects were told to start behind the first cone. Subjects would sprint from cone A to cone B, side step from cone B to cone C, side step from cone C to cone D, side step from cone D to cone B, and backpedal from cone D to cone A, all as fast as possible. The subjects were told to touch each cone and were advised to not cross their feet when sidestepping. Timing was measured using an Accusplit 740mx Turbo stopwatch triggered by an IRD Wire (Brower Timing Systems, Draper, UT). The test was performed three times with a 2-minute rest period between trials. The average of the two closest times was used for data analysis.

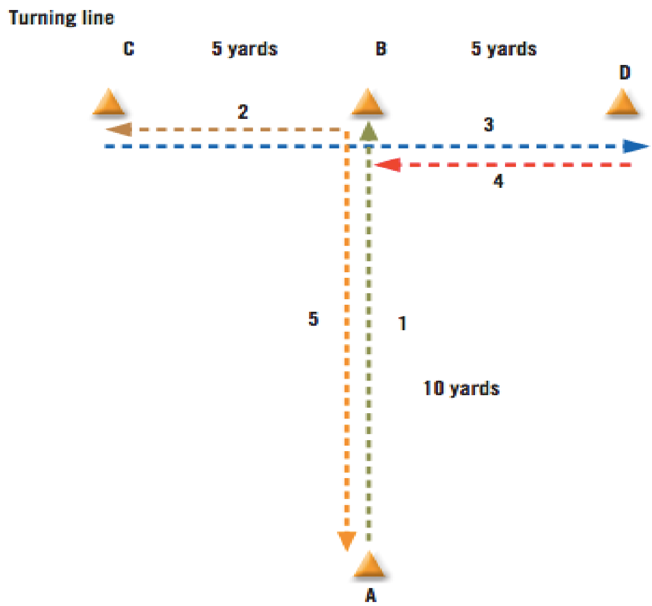

Figure 1. T-test procedure

Following the pre-testing, subjects performed a FR session or the control condition. The two conditions were held on separate days by at least 48 hours.

For the FR condition, subjects participated in an instructor-led FR session for 15 minutes. The foam roller used during this study was a 5.5” x 13” GRID foam roller (TriggerPoint, Durham, NC). Prior to performing the FR condition, subjects were given specific instructions on how to foam roll each body part, including demonstrations by the researchers to ensure correct technique. Subjects then foam rolled their lower back, bilateral gluteus maximus, quadriceps, hamstrings, calves, and iliotibial band. Each body part was foam rolled for 20-seconds. The entire sequence was repeated three times. For the control condition, subjects were instructed to sit quietly in a chair for 15 minutes. After each condition was completed, subjects performed the same tests as were administered during the pre-test. Additionally, subjects in the FR condition were asked to fill out a Perceived Performance Improvement Questionnaire that consisted of the six questions listed in Table 3.

STATISTICAL ANALYSIS

Differences in age, height, and weight were compared between males and females using independent samples t-tests. A two-way (pre-post x condition) ANOVA with repeated measures was used to determine differences for each variable between conditions (FR vs. sitting quietly). Significance was set at an α level of 0.05 to achieve statistical significance. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, Version 25; SPSS Inc., Chicago, IL.)

RESULTS

Nineteen subjects participated in this study. Twenty subjects were recruited but one female did not complete the study due to an illness. Descriptive characteristics of the subjects, subdivided by gender, are presented in Table 1. Males and females were similar in age, but the males were significantly taller and weighed more than the females.

Table 1. Descriptive characteristics of subjects (N=19).

	Males (n=8)	Females (n=11)
Age (yrs)	21.5 ± 1.77	20.2 ± 1.54
Height (cm)	179.4 ± 2.69	165.6 ± 6.64*
Weight (kg)	81.9 ± 8.13	64.0 ± 7.64*

Values represent mean ± standard deviations.
*Significantly different than males ($p<.05$).

There were no significant differences in the responses between males and females, thus data was collapsed across genders presented in Table 2 and Figures 1 through 5, respectively. There were no significant differences in ankle and knee ROM, sit-and-reach scores, agility, or vertical jump height consequent to either condition.

Table 2. Difference before and after an acute bout of foam rolling (N=19).

	Foam Rolling		Control	
	Before	After	Before	After
Ankle ROM	109.7 ± 3.43	110.2 ± 4.44	110.0 ± 4.01	108.6 ± 3.75
Knee ROM	127.6 ± 5.34	129.0 ± 5.62	128.8 ± 5.18	128.7 ± 4.78
Sit-and-Reach	29.9 ± 7.92	30.8 ± 8.13	29.7 ± 7.74	29.9 ± 7.61
T-Test	11.2 ± 1.31	11.2 ± 1.36	11.0 ± 1.34	11.2 ± 1.40
Vertical Jump	49.8 ± 12.67	50.2 ± 13.64	50.9 ± 13.39	50.2 ± 13.37

Values represent mean ± standard deviation.

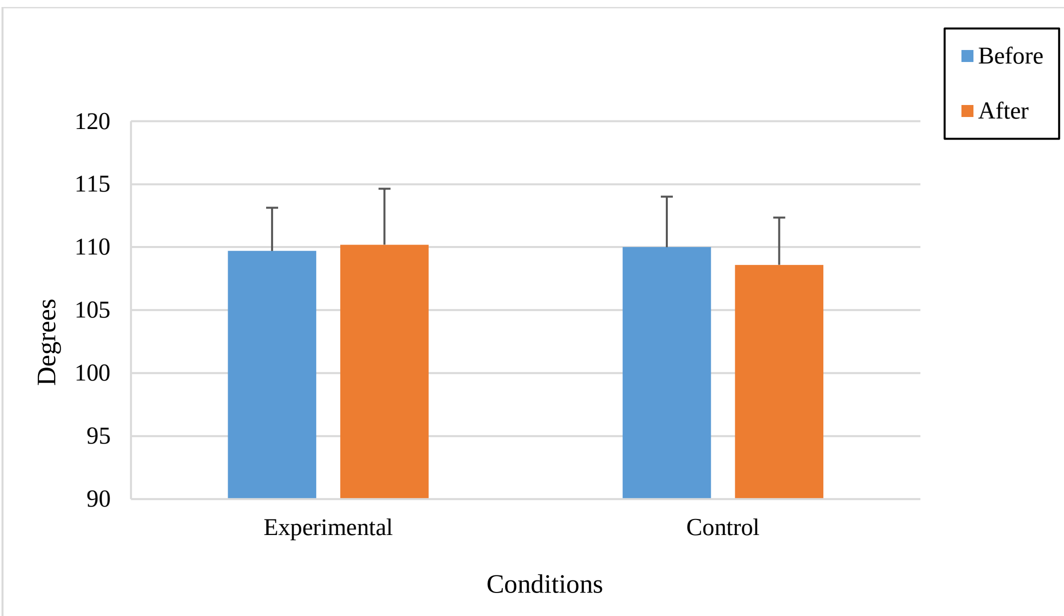

Figure 2. Ankle dorsiflexion range of motion before and after foam rolling vs. sitting quietly.

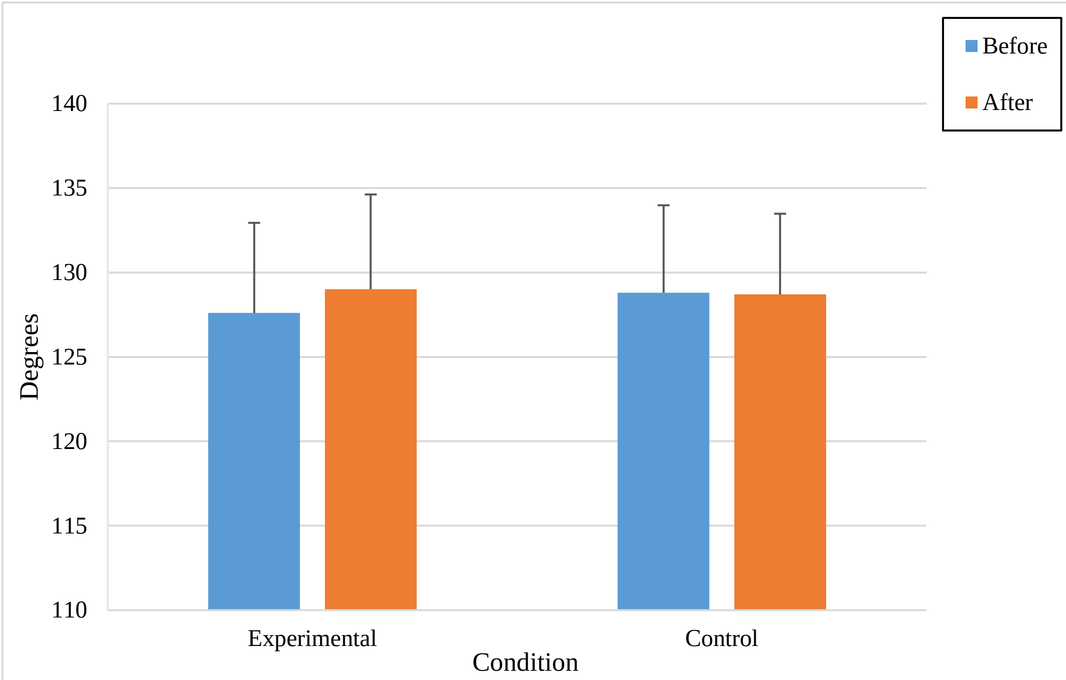

Figure 3. Knee flexion range of motion before and after foam rolling vs. sitting quietly.

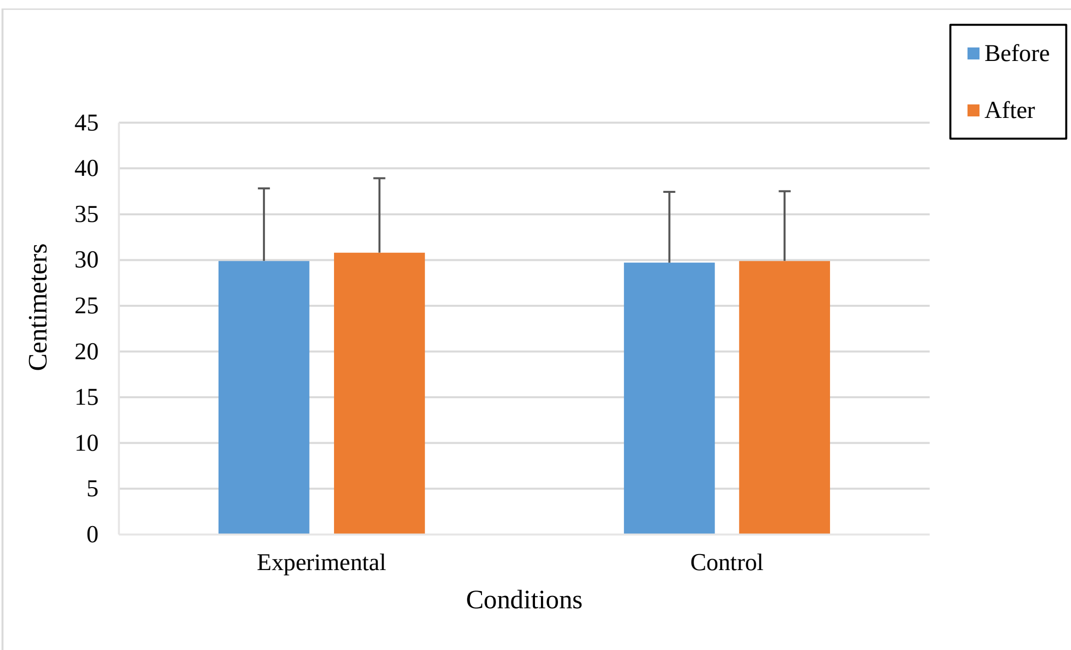

Figure 4. Sit-and-reach scores before and after foam rolling vs. sitting quietly.

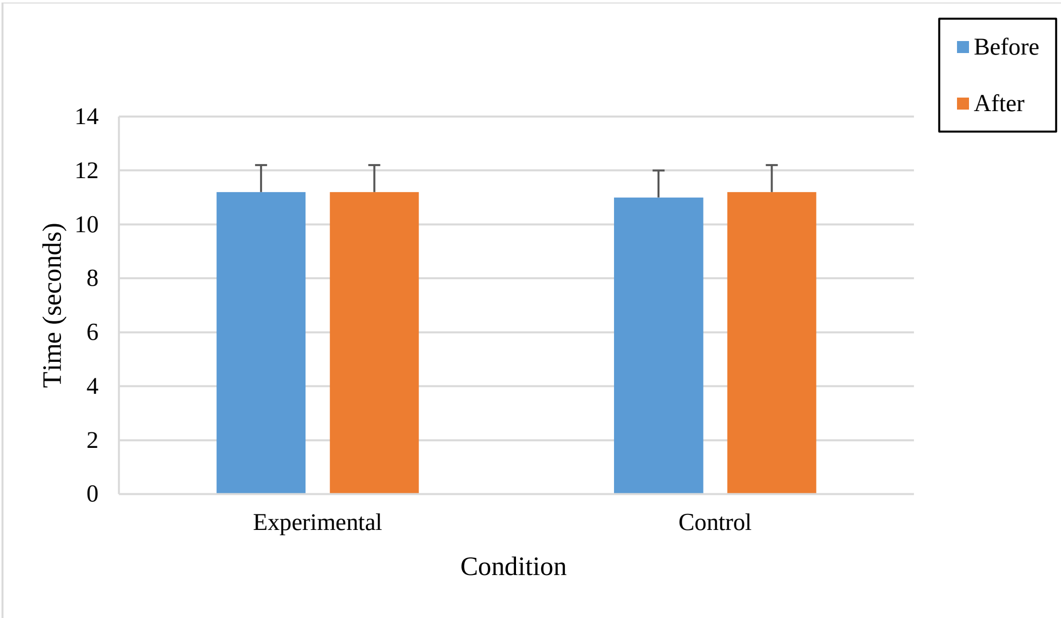

Figure 5. T-test times before and after foam rolling vs. sitting quietly.

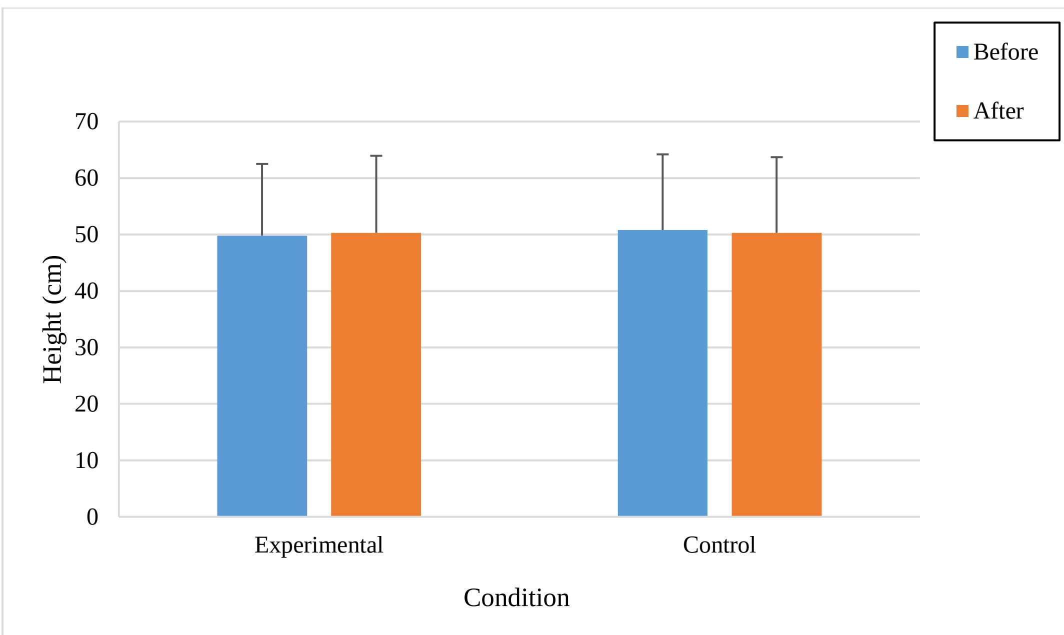

Figure 6. Vertical jump height before and after foam rolling vs. sitting quietly.

Answers to the Perceived Performance Improvement Questionnaire are presented in Table 3. It was found that the FR group felt more flexible and felt like they had more ROM in their ankles and knees.

Table 3. Questionnaire ratings answered after a single session of foam rolling (N=19).

	Yes	No
I feel more flexible	16	3
I feel more agile (T-test)	7	12
I feel like I have more ROM in my ankle	15	4
I feel like I have more ROM in my knee	15	4
I feel stronger	7	12
I feel like I can jump higher	7	12

DISCUSSION

The purpose of this study was to determine the short-term acute effects of FR on ankle and knee ROM, lower back and hamstring flexibility, agility, and vertical jump height compared to a control condition (i.e., sitting quietly). We found no significant differences in any of the ROM or performance measures for FR compared to sitting quietly.

Our results are in agreement with a number of studies that found no statistical differences in ROM or performance tests following a FR intervention. Škarabot, Beardsley, and Štirn (2015) found no difference in ankle ROM following 30-second session of FR the calf region. However, they did find an increase in ankle ROM when FR was combined with a static stretching protocol. Knee ROM was also assessed in a study conducted by Macgregor, Fairweather, Bennett, and Hunter (2018). Following three consecutive days of treatment with well-controlled bouts of FR, they concluded that knee flexion ROM during a modified kneeling lunge position was not significantly improved immediately, 15 minutes, or 30 minutes post-intervention.

Lower back and hamstring flexibility have also been studied by a number of investigators. Peacock et al. (2014) examined the potential benefits of FR in conjunction with a dynamic warm-up. It was found that sit-and-reach scores did not improve, thus it was concluded that adding a dynamic warm-up along with a SMR did not increase hamstring flexibility. Four other studies measured hamstring flexibility using a knee-extension protocol (Mohr, Long, & Goad (2014); Couture et al. (2015); Miller & Rocky

(2006); Morton et al. (2016) and concluded that SMR using a foam roller had no beneficial effect on hamstring flexibility. It should also be noted that the study by Couture et al. (2015) compared varied durations of FR treatments on hamstring flexibility. There was no significant difference following either a short (2 sets of 10s) or long (4 sets of 30s) bout of FR.

The current study also failed to find improvements in agility or vertical jump height. Agility was assessed in a study by Healey et al. (2014) using a 5-10-5 yard shuttle run. There were no improvements in agility following either FR or planking interventions. Two studies also assessed vertical jump height consequent to FR. Healey et al. (2014) and Abels (2013) both failed to find significant improvements in jump height after an acute intervention of FR. It should be noted that Abels assessed jump height using a drop jump technique where the present study used a countermovement jump.

In contrast to the findings of the present study, a number of studies did find significant improvements in ROM following an acute bout of FR. MacDonald et al. (2013) found that FR significantly increased knee ROM 2 minutes (10%) and 10 minutes (8%), post-intervention. Differences between the current study and those of MacDonald et al. (2013) may be due to the researcher’s passively flexing the knee for the subject to the point of discomfort. It is unknown how much pressure the researchers exerted on each of the subjects. The current study had subjects actively perform knee flexion as far as possible, without researchers making contact with the subject. The duration of FR may also have affected results. Subjects in the study by MacDonald et al. (2013) completed two, 60-seconds sessions of FR, whereas the current study had subjects perform three, 20-second sessions of FR.

In contrast to the current study, two studies did find significant improvements in hamstring flexibility. Su et al. (2017) found an increase in hamstring flexibility assessed using a sit-and-reach test. The difference between that study and the present study could be due to the fact subjects rolled the localized muscle groups (hamstring and quadriceps) for a longer duration (30-seconds vs. 20-seconds). MacDonald et al. (2014) also found significant improvements in passive hamstring flexibility. These differences could be due to the fact that straps and braces were used to stabilize the subject while the investigator passively flexed the hip for the subject.

We found no changes in agility as measured by the T-test but a study by Peacock et al. (2014) did find significant improvements in agility, using an 18.3-meter pro-agility test and a 37-meter sprint test. That study included only males who were currently competing or competed in division I and II athletics. Subjects in the current study were not competitive athletes and were only required to be recreationally active.

In contrast to the results of the current study, three studies did find significant increases in vertical jump height consequent to FR interventions (Stewart (2016); MacDonald et al. (2014); Peacock et al. (2014). The differences could be due to a number of factors. The study by Stewart (2016) may have found differences due to the type of foam roller used. Previous research has shown that a more rigid foam roller may provide a greater degree of myofascial release (Curran, Fiore, & Crisco, 2008). They used a more rigid foam roller than the current study. MacDonald et al. (2014) used a different measurement technique than the present study. Researchers visually noted the difference between standing reach height and countermovement height. This methodology could have reliability issues. Peacock et al. (2014) measured vertical jump height using a

Vertec device. Subjects would jump and reach as far as they could with their dominant hand to tap the vanes. The current study used a force plate and had subjects perform a countermovement which had them reach up with both hands to eliminate dominance of one side.

There were several limitations of our study which may have impacted our results. One limitation was that researchers did not monitor the physical activity of the subjects outside of the study. Subjects were advised not to exercise prior to being evaluated on the testing days, but this was not monitored. Also, the duration of FR may have been a limitation compared to other studies. The present study had subjects foam roll each muscle for 20-seconds, which was repeated three times. Several other studies which saw improvements typically used longer rolling times.

CONCLUSION

In conclusion, the current study found no significant acute improvements in ankle and knee ROM, lower back and hamstring flexibility, agility, and vertical jump height as a result of a single session of FR. Although no improvements were found, it seems as though FR does not negatively affect performance results and may be beneficial from a psychological aspect. As FR becomes increasingly popular in the fitness industry, additional studies are needed to explore the potential benefits of using a foam roller for SMR, especially as it relates to different FR protocols and standardized performance tests.

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APPENDIX A

INFORMED CONSENT

INFORMED CONSENT

Acute and Chronic Benefits of FR

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

Purpose and Procedures

- The purpose of this research is to compare the potential benefits of FR on flexibility, agility, mobility, and lower-extremity power after a 6-week training program.
- I realize that I may be randomly assigned to either a FR or control group. The FR group will be required to complete three workouts per week for 6 weeks. Each workout will last approximately 30 minutes. Workouts will be held in Mitchell Hall on the UWL campus. If I am assigned to the control group I will be required to maintain my current exercise habits during the 6-week training period.
- My participation in this study will involve the completion of a series of tests before and after the training program. These tests will include:
    - A sit-and-reach test to assess my hamstring flexibility.
    - A mobility test to assess the range or motion in my ankles and thighs.
    - A shuttle run to assess my agility.
    - A vertical jump test to assess my lower body power.
- Total time commitment for this study will be approximately 15 hours, including all of the testing and training sessions.
- Research assistants will be conducting the research under the direction of Dr. John Porcari, a Professor in the Department of Exercise and Sport Science.

Potential Risks

- I may experience muscle fatigue and muscle soreness as a result of completing the exercise tests and workouts used in the current study. However, the risk of serious life-threatening complications (e.g., heart attack, stroke, death) is extremely low (<1/10,000 tests) in apparently healthy adults, but are always possible with any type of exercise.

- All testing and training sessions will be stopped immediately if there are any complications.
- Individuals trained in CPR and Advanced Cardiac Life Support (ACLS) will be available during all supervised training sessions and an Automatic External Defibrillator (AED) is available in both the testing and training facilities. Additionally, the instructors who will be conducting the training sessions have experience in leading exercise using FRs.

Benefits

- As a participant in this study, I will learn by base level of flexibility, mobility, power, and agility.
- As a result of the training sessions I will be participating in, it is reasonable to expect an improvement in at least some of the above measurements.
- I will also receive a FR at the conclusion of the study, regardless of my group assignment.

Rights and Confidentiality

- My participation in this study is entirely voluntary.
- I may choose to discontinue my involvement in the study at any time, for any reason, without penalty.
- The results of this study have the potential of being published or presented at scientific meetings, but my personal information will be kept confidential and only group data will be presented.

Participant: ____ Date:_________________

Investigator: _______________________________________ Date:_________________

APPENDIX B

PERCEIVED PERFORMANCE IMPROVEMENT QUESTIONNAIRE

PERCEIVED PERFORMANCE IMPROVEMENT QUESTIONNAIRE

After a **SINGLE BOUT** of foam rolling….

1. I feel more flexible
    a. Yes
    b. No

2. I feel more agile (T-test)
    a. Yes
    b. No

3. I feel like I have more ROM in my ankle
    a. Yes
    b. No

4. I feel like I have more ROM in my knee
    a. Yes
    b. No

5. I feel stronger
    a. Yes
    b. No

6. I feel like I can jump higher
    a. Yes
    b. No

APPENDIX C

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The purpose of this paper is to review the literature regarding the use of a FR and topics related to the current study: a) history of massage therapy, b) background information of foam rolling (FR), c) fascia, d) self-myofascial release (SMR), as well as e) the acute effects of FR. Previous studies have not clarified whether or not FR can increase range of motion (ROM) or various performance tests. This section will review the literature that has been conducted on this topic.

History of Massage Therapy

The history of massage dates back thousands of years to the ancient cultures that believed in its medical benefits. Early practitioners of massage therapy started to use the practice of touch as a healing method. They believed natural healing and massage could cure injuries, relieve pain, and treat illnesses (Benjamin, 2015). They also believed it helped reduce stress and produced deep relaxation. The first written records on massage were found in China and Egypt and one of the first written texts called "*The Yellow Emperor's Classic Book of Internal Medicine*" was published in English in 1949 (Benjamin, 2015). The Chinese philosophy serves as a foundation for massage therapists today and is referenced in training and teaching textbooks.

Massage therapy was first seen as an occupation during colonial times, specifically in the 1700s. During this era, women with little education were hired by surgeons to treat orthopedic patients. The women possessed a skill with rubbing and friction, therefore they were called rubbers (Benjamin, 2015). In the early 20th century, new types of massage techniques and practices were being used, especially during World War I in patients who suffered from nerve damage and shell shock. As the practice of massage became more prevalent, it led to more states regulation it as a practice. In the 1990s, massage therapy earned its way as a respected form of alternative and complementary form of medicine. Today's massage therapists remain dedicated to a goal that was established by their predecessors before them: to help others heal their physical and emotional well-being and experience a higher quality of life.

Massage therapy is an umbrella-like term, meaning the term covers a broad set of various forms of massage techniques (Beardsley & Škarabot, 2015). Assisted massage consists of either a therapist or professional providing manipulations for an individual. A few examples of assisted massage include hands-on manipulation, cupping, shiatsu, and reflexology. The idea and understanding of myofascial release as a manual-therapy technique was developed by Barnes in 1997 (MacDonald et al., 2013). Since then, many techniques of SMR have evolved in literature. Self-myofascial release is a type of massage where an individual uses their own body mass to provide pressure on the opposing soft tissues. Examples of SMR include FR, roller massage, massage balls, and static stretching.

Background Information about FR

Foam rollers were invented by Moshé Feldenkrais in the late 20th century (Heffernan, 2016). Moshé was the founder of the Feldenkrais method, which claimed to reduce pain and mobility issues by increasing self-awareness through movement. In 1987, physical therapist and Feldenkrais student, Sean Gallagher, was the first to use a foam roller as a self-massage tool (Heffernan, 2016).

Discovering when foam rollers were first introduced into the weight room is difficult, but many are in agreement that it was the help of Physical Therapist, Mike Clark, during the 1990s (Heffernan, 2016). Slowly, the interest of FR began to increase, especially with athletes looking to reduce the pain of aching muscles and improve athletic performance. Today, there are many types of foam rollers on the market. One can choose a specific density, texture, and size of foam roller depending on individual preference.

A foam roller allows an individual to apply pressure to specific points of the body. There is no gold standard for when to foam roll (i.e., before or after a workout). Literature suggests that FR before a workout allows an athlete to increase his or her volume of training and decreases dysfunctions resulting from the micro-trauma incurred from previous workouts (Healey et al., 2014). Foam rolling may increase ROM and improve flexibility of muscles since the movement relaxes the muscles (Couture, Karlik, Glass & Hatzel, 2015). Undulations created by the foam roller increases the blood flow to muscles, which could decrease muscle recovery time (MacDonald et al., 2013). Using a foam roller is said to be best when treating large muscle groups. There are specific protocols and body positions used to target each muscle group.

Health care professionals and trainers have long known about the potential of FR benefits for physical therapy patients and elite athletes, but experts have now recently learned how valuable they can be for everyone else as a performance enhancing, pre-exercise technique. A foam roller is an inexpensive and highly accessible tool that allows any individual to maintain flexibility and potentially release the patient's myofascial pain.

Fascia

The musculoskeletal system is one of the physiological systems that has been studied extensively (Langevin, 2006). Throughout the body exists a complex, network of connective tissue that integrates the body's mechanical forces with all of the other physiological systems. Within the connective tissue lies a soft, collagenous structure called fascia. Fascia has been described as a tensional network, which consists of collagenous soft tissues, whose fibrous nature is dominantly shaped by tensional strain rather than compression (Schliep & Müller, 2012). Fascia arrangement is densely woven, covering and penetrating every muscle, body, nerve, artery and vein, as well as, all of our internal organs including the heart, lungs, brain, and spinal cord (Barnes, 1997). Fascia plays an important role in the support and function of our body, and is referred to as our *organ of form* (Schliep, 2003).

Healthy, normal fascia is relaxed and exists in a wavy configuration. Once an individual experiences trauma, inflammation, or surgical procedures, the body creates myofascial restrictions. These restrictions can produce tensile pressures of approximately 2,000 points per square inch (Barnes, 1997). Damage to muscle and connective tissue from injury or overstressed muscle fibers results in trigger points (Simons, 1987). Myofascial trigger points lead to involuntary shorting and loss of oxygen and nutrient supply, with increase metabolic demand on local tissues (Hou et al., 2002). Trigger points have a special property called referred pain, which means that a trigger point in one muscle can affect many different muscles. For example, one may have a trigger point in the gluteus maximus and pain will radiate down the hamstring to the gastrocnemius. Myofascial pain syndrome is considered one of the most frequent causes of muscular pain presenting in primary care (Aguilera et al., 2009; Borg-Stein & Simons, 2002). Incidence is important in distinguishing between active and latent trigger points. Active trigger points cause pain, either at rest or in relation to muscular activity, while latent trigger points cause pain with palpation (Travell & Simons, 1999).

Self-Myofascial Release

Self-myofascial release is a type of massage where an individual can provide their own manipulations without the cost or time of a therapist/professional (MacDonald et al., 2013). Examples of SMR include FR, roller massage, massage balls, and static stretching. Self-myofascial release has become more widely used by individuals at all levels of fitness and skill. The simplicity and availability of SMR allow it to be easily implemented in many types of training, maintenance, and rehabilitation programs. Applying pressure to the trigger points appears to cause the Golgi tendon organ (GTO) complex to elicit an inhibitory effect on the muscle; allowing it to become less tense and more pliable. This could lead to an increase in joint ROM (Roylance, 2013). As the fascia becomes warm, the thixotropic property of fascia (fluid-like form) breaks up fibrous adhesions between the layers and restores soft-tissue extensibility (MacDonald et al., 2013). Self-myofascial release has shown to be effective in pain alleviation due to a series of physiological responses (Peacock et al., 2014). The most common response is dilation of the arterial system (Okamoto, Masuhara, & Ikuta, 2014). As vasodilation occurs, an increase in blood flow to the myofascial release sites elicits changes in muscle viscosity properties, which increases nitrogen dioxide and improves vascular plasticity

(Okamoto, Masuhara, & Ikuta, 2014). All of these responses are associated with a positive therapeutic effect on pain and recovery (Peacock et al., 2014).

Acute Effects of FR

As recently discussed, SMR in the form of FR has resulted in multiple positive therapeutic effects on performance and recovery. For anyone who is physically active, the ultimate goal is to stay healthy and injury-free during training. Foam rolling can be implemented into a number of different rehabilitation and training programs to promote soft-tissue extensibility, potentially enhancing joint ROM and promoting optimal skeletal muscle function by releasing fascial adhesions and reducing scar tissue (Junker & Stöggl, 2015). Unfortunately, the literature on the acute effects of FR on ROM and performance improvement are conflicting.

A study by Škarabot, Beardsley, and Štirn (2015) compared the acute effects of SMR and static stretching on ankle dorsiflexion ROM. The study recruited 11 adolescent swimmers who were randomized to one of three interventions (FR, SS, FR+SS). Foam rolling was performed using three sets of 30-second bouts. The static stretching protocol had subjects stretching at a 7 out of 10 pain level. Measurements of passive ankle dorsiflexion ROM were taken during a weight-bearing lunge test immediately post-intervention. It was found that FR+SS resulted in significant improvements compared to the FR condition for increasing passive ankle dorsiflexion ROM. There were no significant increases in post-intervention measurements in the FR group alone.

Conversely, Halperin et al. (2014) compared the effects of static stretching and self-massage with a roller massage of the calf muscles on the ankle ROM. Each subject performed one of the two interventions in a randomized order on the first day and completed the second intervention 3-6 days later. Both interventions involved three repetitions of 30-seconds. Using a weight-bearing lunge test, both static stretching and self-massage conditions resulted in significant improvements in ankle ROM at 1- and 10-minutes post-intervention.

Macgregor, Fairweather, Bennett, and Hunter (2018) investigated the effects of FR for three consecutive days on muscular efficiency and knee ROM. Sixteen males completed the study. Knee flexion ROM was measured using a modified kneeling lunge position. They found no significant differences in ROM between FR and resting quietly, over time (15 and 30 minutes). Contrary to the results of Macgregor et al. (2018), MacDonald and colleagues (2013) examined the acute effects of FR on force production and knee ROM. Eleven males completed the study and foam rolled their quadriceps for two, 1-minute sessions. Range of motion was measured using a modified kneeling lunge and investigators passively flexed the knee until participant reached a point of discomfort. This finding suggests that the improvement of ROM as a result of FR may improve ROM without a detrimental impact on performance.

Multiple studies found that hamstring flexibility was not improved following FR. Peacock et al. (2015) compared an acute bout of dynamic stretching as well as FR in adjunct with dynamic stretching in 11 professional/collegiate males. The FR protocol targeted six regions and each muscle was rolled for three sets using a 30-second rolling time. Hamstring flexibility was assessed with a sit-and-reach box. Researchers found no significant difference between dynamic stretching alone and dynamic stretching along with FR. Mohr, Long, and Goad (2014) compared FR to static stretching on hamstring flexibility. Forty subjects were split into four groups (FR, SS, FR+SS, C). Investigators measured hamstring flexibility by passively flexing the hip for the subject to the point of discomfort. Results found that subjects in the FR+SS group improved more than the other three groups. It is important to note that subjects in the FR group alone did not improve compared to the control group. A study by Couture, Karlik, Glass, and Hatzel (2015) found no significant improvements between baseline hamstring ROM and the ROM after FR for either a short (2 sets of 10s) or long (4 sets of 30s) duration, in healthy, active, college-aged men and women.

Two studies did find a significant increase in hamstring flexibility. Su and colleagues (2017) concluded that FR as a warm-up significantly increased the flexibility of the hamstrings compared to static stretching or dynamic stretching. Thirty volunteers completed three different testing sessions, performing a different intervention each day

(FR, SS, DYN). Hamstring flexibility was assessed using a sit-and-reach test. The FR protocol involved moving back and forth two times during 30-seconds of FR the quadriceps and the hamstrings. This was repeated three times in rotational order. It was found that the FR condition resulted in significantly greater improvements compared to static stretching and dynamic stretching. Similarly, MacDonald et al. (2014) found that FR as a recovery tool resulted in significant improvements in hamstring ROM. The subjects in the FR group performed five different exercises during two, 60-second sessions. Hamstring flexibility was measured as the subjects stood erect and strapped onto a wooden platform. Researchers would passively flex the subject's hip until a point of discomfort was felt.

One study found that SMR positively affected vertical jump height and maximal force output (MacDonald et al., 2014). Subjects performed a countermovement jump. The difference was taken between the subjects standing height and the vertical jump height. Visual inspection of the marking as it lined up with the tape was recorded to the nearest 0.1 cm. Healey and colleagues (2014) examined the acute effects of FR on vertical jump height and power, isometric force, and agility. The results showed no significant differences in jump height between FR and planking.

One study found that agility scores did not improve after an acute bout of FR (Healey et al., 2014). Agility was assessed using the pro-agility test also known as the 5-10-5 yard shuttle run. The best time of two trials were recorded. The results showed no significant improvements in agility between the two conditions. Conversely, Peacock et al. (2015) found that FR, in addition with a dynamic warm-up, increased agility scores compared to a dynamic warm-up alone. Subjects performed an 18.3-meter pro-agility test. The best of the two trials were recorded as the agility speed.

Many of the studies mentioned employed different exercise protocols, used different types of foam rollers and measured different outcomes, which makes combining data difficult. In a literature review by Schroeder and Best (2015), they noted that three studies concluded that FR increased ROM (MacDonald et al., 2013; MacDonald et al., 2014; Mohr, Long, & Goad, 2006). Two studies showed that FR had positive effects on vertical jump height and maximal force output (Halperin et al., 2014; MacDonald et al., 2014), while others showed no change in muscle performance (Healey et al., 2014; MacDonald et al., 2013). Several studies examined the use of a foam roller on athletic performance (Healey et al., 2014; Su et al., 2017; MacDonald et al., 2013; MacDonald et al., 2014; Schroeder & Best, 2015; Škarabot, Beardsley, & Štirn, 2015). Results of these studies suggest a duration-dependent effect. This gives insight into the beneficial mechanism of SMR, and illustrates the potential value of SMR as part of an individual's pre-exercise routine (Schroeder & Best, 2015; Healey et al., 2014; MacDonald et al., 2013). The studies that found an increase in performance measures had a minimum duration of 90-seconds (MacDonald et al., 2014). This suggests that performance benefits may be duration dependent, but further research is needed.

Despite the popularity of SMR, the physiological effects are still being studied and no consensus exists regarding the optimal program for improving ROM, recovery, and performance. The direct benefits of FR duration remains in question, but it appears to have no negative effect on performance, with a few studies showing an increase in performance (Su et al., 2017; MacDonald et al., 2014). Additional research on the potential benefits of FR and the optimal protocol to be used for various parameters need to be conducted.

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