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The Effect of Foam-Rolling on Vertical Jump and Range of Motion of the Hip and Ankle

Katie Davis
Western Michigan University, katiedavis574@gmail.com

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Abstract

Foam-rolling (FR) has gained popularity among many fitness enthusiasts, but whether it is beneficial or not is still being investigated. A number of studies researched its effect on recovery for athletes such as runners and bodybuilders, but the effects of the foam-rolling process was only assessed following a workout. This study was designed to evaluate the effect of foam-rolling prior to activity and whether it enhanced performance for a vertical jump and/or range of motion (ROM) in the hip and ankle joints. Thirty-four subjects were recruited from Western Michigan University and performed all necessary conditions in the Human Performance Lab on Western Michigan University's campus. Participants began their first day without incorporating foam-rolling previous to the two exercise assessments. This will be referred to as the first condition, or C1. Subjects were given instruction on how to perform a vertical jump on the *Just Jump* mat and also a ROM test for both the hip and ankle. Tests were performed three times consecutively and the best score was recorded. The second time participants completed the assessments was referred to as the second condition, or C2. Participants had to come into the lab within a seven-day period to complete the two conditions. C2 began with a 12-minute foam-rolling routine of the quadricep muscle group, hamstring muscle group, gluteal muscles, and calves. C1 was the initial, baseline, assessment of vertical jump and ROM while C2 included foam-rolling (FR) prior to those same assessments. Participants began on their left side and rolled out their left buttock for thirty seconds, moved onto their left hamstring group for thirty seconds, next their left calf for thirty seconds and lastly their left thigh for thirty seconds. This was a two-minute routine repeated three times for a total of 6-minutes. Participants then moved onto their right side and repeated the same routine. Afterwards, vertical jump and ROM were assessed and the best score of three was recorded for analysis.

BACKGROUND

Flexibility and range of motion (ROM) are aspects of fitness that tend to be overlooked yet are critical components for having a safe and effective workout. Flexibility training helps eliminate inefficient movements with exercise (Malek, 2012). Flexibility is the ability of a joint or series of joints to move through an unrestricted and pain-free range of motion (American, 2018). Range of motion (ROM) is the arc of motion that occurs at a joint, or how far a person can move or stretch a certain joint. The range of motion is influenced by the mobility of the soft tissues such as ligaments, tendons, muscles, and skin that surround each joint (American, 2018). The starting position for measurement is the anatomical position (Norkin, 2009). Anatomical position is where the body is standing upright, legs parallel to each other, arms hanging at the sides, and palms facing forward. Static stretches are slow stretches of a muscle or tendon held for a certain amount of time (American, 2018). These stretches should be completed after a workout as they do not prepare muscles to do any sort of physical activity or exercise. Static stretches are the most beneficial after an individual finishes physical activity because they help the body gradually slow down and guide the muscles that were just exhausted to relax (American, 2018). Prior to exercising, doing more dynamic movements that get your body moving through different motions can better prepare the muscles and joints for work. An example of some dynamic movements that can be done prior to exercise are lunges with a spinal twist, leg swings, or arm circles.

Inadequate flexibility negatively affects the body in a variety of ways. Joints need to be able to move through a full ROM in order to maintain the health of the cartilage by increasing the blood flow to those areas (Malek, 2012). Additionally, muscles that are inflexible will tire more quickly which makes antagonist muscles work harder; the resulting muscular fatigue can potentially lead to injury. Antagonist muscles are those that work opposite to the primary muscle being used. For example, if you are doing a bicep curl, the antagonist muscle is the triceps brachii. Simple stretching is an effective way for increasing joint range of motion while simultaneously warming up muscles to do work to prevent any injury. It is also valuable in aiding recovery afterwards by releasing tension that may have built up.

Some athletes or individuals who exercise regularly may further their workout with the inclusion of massage after their typical exercise. Massage is defined as the "the rubbing and kneading of muscles and joints of the body with the hands, especially to relieve tension or pain" (Dupuy, 2018). According to the American College of Sports Medicine (Stretching, 2021), exercise is a type of physical activity consisting of planned, structured, and repetitive bodily movement to improve and/or maintain one or more components of physical fitness. Massage has become very popular for its proposed benefits on muscle recovery and soreness. Massage may relieve the muscle of lactic acid buildup during a workout or to possibly improve recovery. Dupuy (2018) completed a meta-analysis consisting of 140 research studies to investigate the impact of different recovery techniques on perceived fatigue, muscle damage, inflammatory markers, and delayed onset muscle soreness (DOMS). The meta-analysis compared the impacts of a single session of different kinds of recovery techniques after physical exercise such as active recovery, stretching, massage, massage combined with stretching, compression garments, electrostimulation, immersion, contrast water therapy, cryotherapy, and hyperbaric therapy. Massage was the most beneficial method for reducing DOMS and perceived fatigue regardless of the subject type such as an athlete versus sedentary person (Dupuy, 2018). Post-workout massages that are 20-30 minutes in time help to release tension and tightness which may improve the muscle's ability to move through a certain range of motion. Dupuy stated that post massage therapy can be a recovery strategy and that massage therapy is effective in reducing delayed onset muscle soreness and perceived fatigue after exercise (Dupuy, 2018). The foam-rolling routine used in the current study was a total of 12 minutes but can become longer when the individual proceeds to move to the upper body to get that 20-30 minute mark as Dupuy found has a positive impact on recovery.

The practice of massage has slightly declined for active individuals while foam-rolling has become very popular within the last decade. Foam-rolling (FR) was created in the 1980's by a physical therapist who used it for a self-massage tool. This type of manual therapy quickly became popular within dance studios and other types of therapies such as physical therapy clinics (*Let's Roll*, 2016). In the past 10 years, foam-rolling has been linked to improving the connective tissues such as tendons and ligaments by putting direct pressure and a sweeping motion to those areas which results in myofascial release. It is described as a form of self-massage that uses body weight in conjunction with a device such as a foam roller to apply pressure to tight tissues and bring blood flow to specific areas for a myofascial release (Cole, 2018). The motion of rolling places both direct and sweeping pressure on the soft tissue, stretching it and generating friction between it and the FR device. Consequently, FR can be considered a form of self-induced massage because the pressure that the roller exerts on the muscles resembles the pressure exerted on the muscles through manual manipulation by the user themself (Wiewelhove, 2019). Without proper blood flow to muscles, recovery cannot happen properly, therefore, doing a self-myofascial release (SMR), such as foam-rolling, may be helpful (*Let's Roll*, 2016). Foam-rolling is done to increase myofascial compliance and optimize muscle length-tension relationships (Cole, 2018). As with any sort of stretching or massage, mild discomfort should take place, however, the discomfort should not be excessive. There are a multitude of shapes and firmness in foam rollers, so finding something suitable for the individual is important whether you are just beginning or not. With foam-rolling, the amount of pressure can be controlled by adjusting the amount of body weight placed on the roller. The 2021 ACSM Guidelines recommend that flexibility training, which includes foam-rolling, should be done two to three days each week to maintain ROM. Increasing flexibility training, massage therapy, or foam-rolling may have similar benefits. Foam-rolling is a good choice for individuals versus massage therapy because FR is a form of self-massage which cuts the cost of a clinician and makes it more cost-effective (Cole, 2018). However, each is important for a safe, effective workout when done prior to exercise and to aid in recovery time following an exercise bout.

Previous research done by Anthony D'Amico (2019) showed foam-rolling enhances recovery of the muscles from exercise-induced muscle damage when done immediately after a workout. D'Amico tested muscle soreness, hip abduction ROM, hamstring muscle strength, and vertical jump immediately following and four days following a repeated sprinting protocol designed to induce muscle damage followed by five consecutive days of non-fatiguing performance test battery. The sprinting protocol consisted of 40, 15-meter sprints with a 5-meter deceleration zone. Eighteen participants foam-rolled (FR) prior to testing each day and nineteen served as the non-FR control group. All participants were male. The experiment was completed over a two week period. Week one included subjects getting assigned to either the FR or control group. After assignment, the control group completed a warm-up followed by a non-fatiguing testing battery. The FR group completed a warm-up, were oriented with the FR protocol, then completed the non-fatiguing testing battery (D'Amico, 2019). Both groups were given identical instruction; however, the control group was not given any instruction to the FR protocol. This protocol was completed three times in week one. Week two subjects attended the lab for five consecutive days for the sprinting protocol where the experimental group underwent the FR intervention following it and the control group did nothing. The FR intervention was timed using a metronome, so each subject rolled the same amount (D'Amico, 2019). Subjects in both the FR and control group experienced "strong" to "very strong" perceptions of muscle soreness. FR was shown to expedite recovery of agility recovery after exercise-induced muscle damage following a sprinting activity, but no other factor was shown to have a significant effect between the two groups (D'Amico, 2019). The agility T-test time impairment was lower in the FR group compared to the control group. Neither group improved in the T-test, the FR group's performance was impaired to a lesser extent. (D'Amico, 2019). Mean values for agility changes from baseline in CON were 0.52 s, 0.82 s, 0.78 s, 0.45 s, and 0.32 s on the day muscle damage was induced, and over the four days following, respectively. Mean values for agility changes from baseline in FR on those days were 0.11 s, 0.17 s, 0.06 s, 0.12 s, and -0.13 s, respectively. These findings indicate that FR may help maintain agility performance following exercise-induced muscle damage (D'Amico, 2019).

Foam-rolling has been shown to bring blood flow to the worked areas and causes myofascial release to decrease tension in muscles (Cole, 2022). A decrease in muscle tension along with increased blood flow allows the muscles to move more freely in their ranges of motion. That suggests that doing so prior to activity could help individuals go about their physical activity and exercise routines with more range of motion to prevent the risk of injury further. The earlier study by D'Amico did FR after exercise, however, the current study is looking at FR before exercise because FR is going to increase blood flow to the muscles, decrease tissue stiffness, reduce tissue adhesion, decrease tension and increase ROM. That being stated, pre-exercise FR will help performance first and foremost. Choosing the hip and ankle for

ROM assessment is due to the hip being a major joint for many exercises individuals choose to do during their exercise sessions. Ankles are another important joint to look at in exercise. Whether it be running or performing a back squat, the body hinges from the hip and ankle often. Vertical jump was researched to see if the increased blood flow and ROM would improve the height and explosiveness of the jump.

The purpose of the current study was to determine foam-rolling's effect on performance when done immediately before an activity. Anaerobic power was assessed using a vertical jump test on the *Just Jump* mat and ROM was measured at the hip and ankle joint using a goniometer. Tests were administered in the Human Performance Research Lab in the student recreation center of Western Michigan University.

METHODS

Participants

Thirty-four students were recruited from undergraduate classes at Western Michigan University to participate in the study to determine whether or not 12-minutes of FR before exercise was beneficial for anaerobic power (Watts) and range of motion (degree). Participants were contacted through email and word-of-mouth. An email was sent to the chair of various WMU departments to send out a mass email to their department's student population. WMU departments contacted were the department of Human Performance and Health Education, department of Biological Sciences, department of Dance, and department of Nursing. The rationale for selecting behind these specific departments was the willingness to participate in a research study within the science field. The email included the basis of the study, research question, the time commitment, and a contact email to set up an introductory appointment for individual participants. Three instructors allowed a brief five-minute class visit for recruitment, consisting of an overview of the study.

Individuals between 18-60 years of age could participate in this study. Inclusion criteria was participation in at least 150 minutes per week of moderate physical activity, absence of upper or lower extremity musculoskeletal injury or surgery in either of these areas in the previous 6 months. These inclusion criteria were used to decrease the risk of unintended injury. The participants were given a demonstration of the foam-rolling exercises as well as the tests to be completed by the researcher prior to performing it on their own.

Thirty-four participants (61.7% female, 38.3% male) participated in this study. Demographics for overall participants can be viewed in *Table 1* while demographic data for male versus female participants can be viewed in *Tables 2* and *3*.

Table 1: Total Participant Demographics

Overall Participants (n=34)	**Mean (SD)**
Age (years)	21.59 +/- 2.21
Height (cm)	171.84 +/- 8.71
Weight (kg)	75.06 +/- 16.80
BMI (kg/m^2)	25.21 +/- 4.34
SD= standard deviation	

Table 2: Male Demographic Data

Male Participants (n = 13)	Mean +/- SD
Age (years)	22.62 +/- 2.47
Height (cm)	179.04 +/- 6.04
Weight (kg)	85.02 +/- 8.25
BMI (kg/m^2)	26.58 +/- 2.85
SD= standard deviation	

Table 3: Female Demographic Data

Female Participants (n=21)	Mean +/- SD
Age (years)	20.95 +/- 1.76
Height (cm)	167.38 +/- 6.87
Weight (kg)	68.89 +/- 17.76
BMI (kg/m^2)	24.36 +/- 4.85
SD= standard deviation	

The participants were informed of the purpose, procedures, and risks of participation at the introductory appointment. The signed informed consent documents were obtained from each participant; a copy was provided for their personal record. All procedures were approved by Western Michigan University's Institutional Review Board.

Research Procedure

The participants arrived at Western Michigan University's Human Performance Lab on the first floor of the Student Recreation Center at their scheduled time. Participants were asked to come to the lab for a total of two visits, approximately 1hour/visit. The minimum time between C1 and C2 was 24 hours, however, both conditions were completed within seven days. The first meeting included an overview of the study, answering all questions, and if the individual agreed to participate, an informed consent document was completed. Once confirmed eligible, the participant was familiarized with the equipment used and a demonstration of FR and the vertical jump was provided. Subjects performed a vertical jump and then a range of motion (ROM) test at the hip and ankle joints. The assessment protocols were obtained from Peter J. Maud's textbook, "Physiological Assessment of Human Fitness" (Maud, 2006). C1 did not include any sort of warm-up or stretching, but the C2 incorporated foam-rolling as an act of warming up the muscles.

Vertical Jump Test: The participant was asked to stand on the *Just Jump* vertical jump testing mat with feet shoulder-width apart. Subjects then bent into a squat position (knees bent to 90 degrees) and jumped as high as possible to measure the time in air. The participant repeated this process three times and the best score was used for analysis. Anaerobic power was calculated from jump height using the following equation:

$$\left(\textit{Power (W)} = 21.67 \times \textit{mass(kg)} \times \textit{vertical displacement (m)}^{0.5}\right)$$

The *Just Jump* vertical jump mat automatically calculates jump height by measuring the time that the feet are not in contact with the mat, and from this, calculations for explosive leg power from the equation above was completed. Anaerobic power and vertical jump height were used for analysis as separate factors. Anaerobic power and vertical jump height strongly correlate with one another, so if power increased then so did the height of the jump and vice versa.

Hip ROM Test: To measure active ROM at the hip, the participant was to lay in a supine position (face up) on a table. The researcher placed the goniometer on the greater trochanter of the femur with the stationary arm aligned with the lateral midline of the pelvis while the movement arm was aligned with the lateral midline of the femur. The participant then performed hip flexion and brought their leg up with their knee straightened and foot dorsiflexed until the first sign of resistance. The measurement was taken in degrees. This was done three times for each hip and the best score was kept for analysis. There was no warm-up prior to the measurement of ROM for C1, but C2 included the FR routine as a form of "warm-up."

Ankle ROM Test**:** Both active dorsiflexion and plantarflexion of the ankle were assessed. To measure ankle dorsiflexion, the participant sat up on the edge of the table with their shin hanging over the edge and knee bent to 90 degrees and ankle at 0 degrees inversion/eversion. The plantar surface of the foot was parallel to the ground. The fulcrum of the goniometer was placed on the lateral malleolus and the stationary arm parallel to the lateral midline of the fibula. The movement arm was aligned parallel with the lateral aspect of the fifth metatarsal. Then the participant dorsiflexed their ankle and ROM was measured in degrees. This was done three times for each ankle and the best score was kept for analysis. The researcher repeated the same goniometer set-up process as dorsiflexion, however, the participant performed plantarflexion of the ankle rather than dorsiflexion.

The participants performed each of these sets of tests twice – on day one subjects came in without any warm-up or stretching prior to testing and day two subjects incorporated the foam-rolling routine prior to the tests as a form of warm-up for the muscles. ROM was not reassessed before C2. The comparison was done between the day one results without FR and day two results that included FR. The foam rolling routine was a total of 12 minutes where subjects were monitored during the routine and the researcher used a stopwatch to watch when to switch muscle groups and sides of the body. The participants were demonstrated how to use the foam roller and then foam-rolled their own gluteal muscles, hamstring group, quadricep group, and calves. When the student researcher started the stopwatch, participants began to massage each muscle separately for 30 seconds and then immediately went to the next muscle rotating through the gluteal muscles, hamstring muscle group, quadricep muscle group, and calf group. At the six-minute mark, subjects switched to repeat the same routine on the right side. The routine was 12 minutes, so each muscle group was rolled out the same amount of time. Day one, again, did not incorporate this routine; participants came in to get baseline data of their vertical jump and ROM of their hip flexion, ankle plantarflexion, and ankle dorsiflexion. Day two involved this 12-minute routine and immediately following the foam rolling exercises was testing- vertical jump and ROM. Scores were put into an excel sheet with subjects' names omitted and listed as "subject #." The order of conditions was the same for each participant where they began with C1 and ended with C2. Thus, conditions were not randomized.

Equipment

FR can be done with a variety of different length and shape rollers; however, a firm,12-inch, plain-surfaced foam roller was used to test. The first day of testing, C1, was collecting baseline data that does not incorporate a foam rolling routine prior to the tests. On the second day, C2, the administration of the tests included the FR exercises prior to testing. The duration of FR protocol was measured and kept consistent for each participant because it may create different outcomes on their performance as previous findings have discussed.

Data Analysis

This study was designed to examine whether or not FR is beneficial when assessing anaerobic power (calculated from a vertical jump) and range of motion of the hip and ankle joints. Data analysis was completed using SPSS v19. A dependent t-Test was conducted to determine differences in anaerobic power and ROM with or without foam-rolling prior to activity. Data was considered significant at $p<0.05$.

<u>RESULTS</u>

The data for all fitness assessments were not split into male versus female participants because there were no differences between the two groups in any assessments. All participants that began this research completed both conditions within the necessary time limit of a seven-day time span. Results were calculated from the 34 participants that began this experiment.

Vertical Jump and Anaerobic Power

Vertical jump height results are listed in *Table 4* concluding that there was a statistically significant difference between C1 and C2. It shows higher jump heights following the FR routine. The mean anaerobic power for the non-FR and FR conditions are also shown in *Table 4*. There was a statistically significant difference between conditions indicating a greater capacity to generate power following FR.

ROM : Hip Flexion

There was a significant increase in range of motion of the left ($p=0.001$) and right hip ($p<0.001$) when FR was included. See *Table 4* for the statistical significance of hip flexion when foam-rolling was added in the second condition.

ROM: Ankle Plantarflexion

As shown below in *Table 4*, there was a statistically significant difference between C1 and C2 for ankle plantarflexion for both the left ($p<0.001$) and right ($p<0.001$) ankle.

ROM: Ankle Dorsiflexion

Ankle dorsiflexion results are shown in *Table 4*. There was not a significant increase in range of motion following C2 for the left ankle. The right ankle also did not see a statistical significance when foam-rolling was included prior to the ROM assessment.

Table 4: Results of all Factors

Assessment	**C1: No FR (mean +/- SD)**	**C2: FR included (mean +/- SD)**	**Significance (p-value)**
Vertical Jump (cm)	48.57 +/- 13.97	49.78 +/- 14.45	0.016 *
Power Analysis (W)	1122.081 +/- 307.71	1135.782 +/- 312.71	0.022 *
Left Hip Flexion (degrees)	92.94 +/- 13.952	100.06 +/- 12.625	0.001 *
Right Hip Flexion (degrees)	91.29 +/- 15.113	99.32 +/- 13.902	<0.001 *
Left Ankle Plantarflexion (degrees)	60.62 +/- 13.015	66.94 +/- 14.118	< 0.001 *
Left Ankle Dorsiflexion (degrees)	18.03 +/- 4.282	18.00 +/- 3.954	0.481
Right Ankle Plantarflexion (degrees)	63.53 +/- 13.313	69.65 +/- 15.007	< 0.001 *
Right Ankle Dorsiflexion (degrees)	19.47 +/- 7.411	19.65 +/- 4.598	0.446
C1= Condition one C2= Condition two FR= Foam-rolling SD= standard deviation * = there was a statistical significance			

DISCUSSION

This research study looked at the effect of foam-rolling on vertical jump (from that, calculated anaerobic power) and range of motion of the hip and ankle. Throughout this experimental process, it was determined that foam-rolling enhanced the performance of a vertical jump as well as anaerobic power. FR also showed an enhancing effect on the range of motion of the left and right hip to perform flexion, as well as both left and right ankle plantarflexion. There were no improvements to perform dorsiflexion for both the left and right ankles.

Getting blood flow to an area helps eliminate any chance of strain or injury that can be caused from going right into any sort of exercise without warming up the muscles. To help combat incidence of soft tissue injuries, especially those where rapid acceleration is involved such as a vertical jump, pre-exercise procedures such as foam-rolling have gained popularity and are typically recommended by athletic performance or sports medicine professionals (Connolly, 2020). Injuries to the muscles targeted in this study can affect performance. Each muscle group mentioned previously performs specific movements for the body and when injured can decrease performance.

The vertical jump and anaerobic power analysis portion of the study were shown to have an improvement when FR was incorporated. When looking further into how a vertical jump is performed, a person uses their quadricep, hamstring, and calf muscle groups to propel themselves into the air. Seeing that in the current study FR was done to the quadricep, hamstring, and calf muscle groups which brings plenty of blood flow and increased mobility to those areas, it was clear that the vertical jump (and calculated AP) would show an improvement as well as the ROM assessments. Research by Jones investigated the effects of lower body foam-rolling on vertical jump performance for 20 participants where no significant differences in jump height were shown (2015). However, the current study found an increase in jump height for individuals. One difference between the studies was that Jones had both legs rolled out simultaneously rather than separate and participants warmed-up with high knee pulls, Frankenstein's, and forward gate swings for twenty meters each prior to beginning foam-rolling. Furthermore, Jones' routine of foam-rolling used the same muscles, but in a different order. The current study went in the order of buttock, hamstring group, calf group, and front of the thigh while Jones' study began with the calf group, then to the front of the thigh, hamstring group, and finally the buttocks (Jones, 2015). After finishing testing, Jones concluded that the addition of foam-rolling after a dynamic warm-up does not increase vertical jump performance (Jones, 2015). The current study did find that foam-rolling improved performance of a vertical jump when used prior to activity when a dynamic warm-up is not performed. Comparing the two, the current study included both male and female participants, used a different order for rolling out lower body muscles, did the left and right leg separately, and also did not include a dynamic warm-up prior to the assessments. Jones' study did discuss that the sequence of warm-up activities did not increase vertical jump performance, but it did not negatively impact it either (Jones, 2015). The current study did not measure the repetitions of rolling on the foam-roller while Jones' did keep track by using a metronome and participants only got 10 repetitions (Jones, 2015). This could be a factor as to why participants in the current study saw improvement in their vertical jump since no restrictions for how many times each muscle was rolled out but had thirty seconds to freely roll.

Hip flexion is performed using a few different muscles– all of which are a part of or deep to the quadricep muscle group. As the foam-rolling routine was performed, these muscles were targeted because you are putting pressure not only on the most superficial muscles, but also the muscles deeper than that. For this reason, hip flexion ROM was proposed to have a significant increase with the FR and later seen to do exactly that. A previous research study looked into how a single bout of FR increased flexibility of the hip adductor muscles without compromising strength (Connolly, 2020). While Connolly's study did not look into the same muscle areas as this current research study, it still resulted in an increase of flexibility and ROM of the hip flexors muscle group. Connolly noted that FR is a form of self-myofascial release and FR changes the properties of the fascia surrounding muscles (2020). The act of FR creates directed pressure, heat, and mechanical stress to that fascia which turns the usually thick and viscous state into a softer, gel-like state which is where increased flexibility comes from (Connolly, 2020). FR increased the blood flow to these muscles which allowed it to be used as a warm-up process to perform tasks such as movements for physical activity easier. This supports the hypothesis that foam-rolling the muscles that perform hip flexion will increase ROM.

The findings in the current study also demonstrated that foam-rolling prior to the ROM assessments of the ankle when performing plantarflexion was successful in furthering the degree to which the ankles can move. Plantarflexion of the ankle was measured due to its correlation of use in a vertical jump and overall fitness. During a vertical jump, subjects squat down then jump as high upwards as possible. Plantarflexion involves lifting the whole body, so propelling the body upwards requires explosive ankle plantarflexion. It could be an issue of safety and effectiveness for a workout if the ankles are not flexible enough to allow them to squat into the position needed. Plantarflexion uses the calf muscle group which runs along the posterior part of the lower leg. All muscles associated with plantarflexion were rolled out in the foam-rolling routine both directly and indirectly. Connolly spoke about how friction from the foam-roller has been shown to increase nitric oxide production which reduces arterial stiffness and improves endothelial function (2020). In simple terms, increased blood flow and surface temperature reduces stiffness of arteries and causes improvements in flexibility (2020). The findings from this study were supported from Connolly's research. As stated before, foam-rolling is a great tool to get blood to flow to that specific area and allow the fascia to soften and increase flexibility.

Dorsiflexion ROM of the ankle was the final ROM measure of each leg that was assessed. The primary muscle involved for dorsiflexion is the tibialis anterior which resides on the lower anterior portion of the leg, otherwise referred to as the shin. Our results showed that FR for dorsiflexion did not improve on either ankle. This may be explained in a few different ways. First, it could be human error by the researcher, however all assessments were done by the same researcher. Furthermore, there is a structural limitation when doing dorsiflexion if looking into the anatomy of the ankle. When looking at plantarflexion and dorsiflexion, there is more available space for the foot to point away from the body rather than coming up towards the skin due to the talus bone and the talocrural joint having less ROM overall. Another factor was the assessment chosen to measure ROM. Participants in this study did the ankle ROM assessments with their lower leg hanging freely over the side of the assessment table and then had to bring their ankle up to be dorsiflexed by their own strength. This is known as active dorsiflexion where subjects are doing the motion themselves and not manually having their ankle plantar flexed or dorsiflexed by the researcher. The assessment performed in our lab did not have the researchers assisting the participant's ankles into the furthest position subjects can move to, but rather the participants used their own strength to flex as far as possible. We also did not foam-roll the shin as a part of this experiment which could be another reason as to why dorsiflexion did not see a statistical significance. Other limitations for dorsiflexion are muscle weakness, strenuous activity or exercise prior, genetics, poor healing of previous injuries, scar tissue, and even a tightened joint capsule.

This research experiment showed 6 out of 8 of the assessments had a statistically significant improvement when foam-rolling was done prior to activity. Dorsiflexion of the ankles were not shown to improve with foam-rolling, yet limitations for that may have hindered the current data set and future studies should research it further. Future studies could include re-assessment of ROM on day two. Day one would be the same as it was in the current study but day two could include a re-assessment of the ROM before FR to check whether day one and day two initial ROM assessments were near the same and then compare both of those to the post-FR data. Another aspect that would be interesting to change would be the fashion of ROM assessments of the ankle or if the ROM tests were performed passively rather than actively and how that is affected using a foam-roller.

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