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Foam Rolling as a Warm-up: The Effect on Lower Extremity Flexibility Compared to Aerobic and Stretching Protocols

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FOAM ROLLING AS A WARM-UP: THE EFFECT ON LOWER EXTREMITY FLEXIBILITY COMPARED TO AEROBIC AND STRETCHING PROTOCOLS

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ABSTRACT

Foam rolling has recently become popular in the realms of athletic training, strength and conditioning, and fitness enthusiasts as a means to decrease stiffness, improve flexibility, and manage pain . However, little is known about the physiological effects of foam rolling or its role in improving flexibility pre- or post-exercise. The purpose of this project is to examine and compare the effects of foam rolling, aerobic cycling, and stretching on lower extremity flexibility. Nineteen participants (10 female, 9 male) volunteered to test sit-and-reach flexibility after performing four different warm-up protocols on different days. The warm-up protocols were: Foam rolling for five minutes, aerobic cycling for five minutes, stretching for five minutes, or lying supine for five minutes (control). A one-way repeated measures ANOVA test was used to determine significant difference ($p > 0.05$) compared to the control group. Results indicate that foam rolling, cycling, and stretching significantly improved lower body sit-and-reach scores over the control. No significant differences were found between protocols.

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Introduction

Foam rolling has recently become popular in the realms of athletic training, strength and conditioning, and fitness enthusiasts as a means to decrease stiffness, improve flexibility, and manage pain (Curran, 2008; Stone, 2000, Arroyo-Morales, 2008). Also known as self-myofascial release (SMFR), foam rolling is a method to simulate massage and treat muscular and other soft-tissue restrictions by means of pressure, stretching, and the application of mechanical force to generate friction and heat (Sefton, 2004; Curran, 2008, Stone, 2000). Typically participants use their body weight on a circular cylinder (usually made of dense foam, plastic, or PVC) to exert pressure on the tissue. Users can vary body positions to treat desired areas or increase pressure applied to an area (Curran, 2008). To date, there is little evidence to suggest the efficacy of foam rolling on increasing tissue extensibility, improving flexibility or mobility of a joint, or increasing performance or recovery. Despite a lack of evidence many coaches and athletes use foam rollers to aid performance pre- or post-exercise.

While foam rolling has not received much examination, more research exists for manual myofascial release (MFR) techniques performed by a therapist. Myofascial Release techniques are similar to massage in which the therapist moves or glides through tissue in order to restore length and smoothness to fascia, collagen, and other soft-tissue surrounding muscle. There is evidence to suggest these techniques improve cardiovascular recovery after exercise, improve postural and skeletal muscle asymmetries, increase elasticity in muscle and connective tissue, and help treat musculo-skeletal deformities such as scoliosis and pelvic misalignment (Arroyo-Morales, 2008; LeBauer, 2008; Barnes, 1997; Remvig, 2008).

Some randomized controlled trials suggest these techniques work to increase softness and pliability of the muscle and surrounding tissue, however they are generally used by trained therapists (Sefton, 2004; Remvig, 2008). Self-myofascial release by means of foam rolling has become a method to achieve these same results in the absence of a therapist, however there have been no studies to examine the comparison of SMFR to MFR techniques. Though massage techniques are often used as a warm-up, little is known as to the effectiveness of foam rolling techniques compared to traditional methods of warm-up and recovery such as stretching and aerobic exercise (Galloway, 2004; Hunter, 2006; Huang, 2010; Paolini, 2009).

Traditional Methods of Warm-Up

Stretching is defined as the systematic elongation of musculotendinous units and connective tissue to create a persistent length of the muscle and a decrease in passive tension (ACSM, 2006; Knight, 2001). The application of stretching can result in a longer length of the muscle at a lower tension, which is generally regarded as improved flexibility (ACSM, 2006). There is ample evidence to suggest that regular stretching over a long period of time improves flexibility. Some report a five to twenty percent increase in static flexibility in as little as four weeks of training (Bandy, 1997; Handel, 1997; Wallin, 1985; Knudson, 1999). In addition, it has been reported that as little of 10 seconds per muscle group is adequate to provide a training effect over time (Borms, 1987), though most recommend between 15 and 30 seconds (ACSM, 2006; Knudson, 1999).

While stretching may sometimes be used prior to exercise, aerobic activity if often the warm-up protocol of choice as it is a convenient way to increase muscular temperature and metabolism prior to exercise and reduce lactate production in strenuous exercise (ACSM, 2006; Ingjer, 1979; Martin, 1975). General aerobic exercise is considered an active warm-up and is usually performed at a lower intensity than the planned training session (ACSM, 2006; Bishop, 2003; Ingjer, 1979). There is evidence to suggest that aerobic activity is equivalent to stretching in improving muscular length prior to exercise (Wiliford, 1986). However little evidence exists to compare stretching and aerobic exercise to massage or myofascial release.

Statement of Problem

Currently there is scarce information regarding the effects of foam rolling on lower body flexibility. The purpose of this study is to examine how foam rolling affects lower body flexibility compared to aerobic and stretching protocols.

Research Hypothesis

Based on available literature, there are two hypotheses for the effectiveness of foam rolling. The first hypothesis is that foam rolling will increase sit-and-reach flexibility over a control group of no warm-up. The second hypothesis is that there will be no significant difference between warm-up protocols of cycling, stretching, or foam rolling.

Definitions

Aerobic Activity – A continuous low to moderately high intensity activity in which oxygen is readily available for consumption, allowing for an increase in heart rate, muscular temperature and other physiological properties.

Flexibility – The ability to move a joint through its entire range of motion.

Foam Roller – A cylindrical device made of dense compact foam designed for self-myofascial release techniques.

Foam Rolling – A form of self-myofascial release in which the user applies pressure to body parts via a circular cylinder made of foam, plastic, or PVC.

Myofascial Release – The systematic application of pressure to soft-tissue to reduce stiffness and improve compliance of fascia and connective tissue surrounding muscle.

Self-myofascial Release - A form of self-therapy which uses a device to apply pressure to targeted tissue to simulate the effects of myofascial release.

Static Stretching – A slow, controlled method of stretching which does not force the joint past it's normal range of motion.

Stretching – A systematic elongation of musculotendinous units and connective tissue to create a persistent length of the muscle and a decrease in passive tension.

Warm-Up – A physiological increase in muscle temperature and function to improve exercise performance.

Limitations

Aerobic exercise and stretching are easily recognized and performed due to the simplicity of the activity. Foam rolling, however, is not widely recognized and requires practice to perform correctly. In addition, foam rolling requires advanced core strength, upper body strength, overall stability, kinesthetic awareness, and balance. Not all individuals are capable of sufficiently producing these qualities, thus the effects of foam rolling may be lost.

Significance of Study

Results of this study could aid in determining the full benefits of foam rolling and provide coaches, therapists, and athletes further information regarding the effects of self-myofascial release.

Literature Review

In order to compare aerobic activity, stretching, or foam rolling, it is important to determine individual effectiveness in increasing flexibility. To date, very few studies have compared foam rolling and the subsequent changes in ROM to other warm-up methods. There have, however, been some studies that examine professional massage, stretching, and aerobic exercises and the resulting effect on acute flexibility.

One study done by Wiktorsson-Moller et al. (1983) examined lower limb flexibility and strength after four different warm-up protocols: Aerobic warm-up only, aerobic warm-up with massage, massage only, and aerobic warm-up with PNF stretching. Eight healthy male volunteers were examined for lower limb ROM in six different directions: Hip flexion, hip extension, hip abduction, knee flexion, and ankle dorsiflexion. Hip abduction was measured with a double protractor goniometer and the other movements were measured with a flexometer. Lower limb strength was also measured with a Cybex-II isokinetic dynamometer at different speeds (30°/s and 180°/s). Measurements were taken before and after experimental procedures. General aerobic warm-up procedures were done at 50W for 15 minutes, massage was performed by a trained therapist on lower limb muscles for no more than 15 minutes, and PNF stretching was performed on six major leg muscles for a total of 15 minutes. The results show that massage and aerobic warm-up, separately or in combination, provided no significant changes in ROM. Only aerobic warm-up paired with stretching gave any significant changes in lower-limb ROM for all directions. However, this study did not examine the effects of stretching alone as a warm-up protocol.

In a different study, de Weijer et al. (2003) examined the separate and combined effects of static stretching and aerobic warm-up on hamstring length over a 24 hour period. Fifty-six participants (18-24 years old) with limited hamstring length were assigned to one of four groups: Aerobic warm-up with static stretch, static stretch only, aerobic warm-up only, and control. The aerobic warm-up protocol consisted of 10 minutes of stair climbing at 70% of maximum heart rate. The static stretching protocol consisted of a single session of three 30 second passive stretches of the hamstring. Flexibility was tested using the active knee extension test (AKE test) pre- and post-intervention. Aerobic with stretching and stretching alone were the only two protocols to show significant changes in hamstring length. Aerobic warm-up only showed no changes. The studies by Wiktorsson-Moller and de Weijer both suggest that aerobic exercise combined with stretching is the most effective warm-up protocol to increase flexibility of the lower body. However, de Weijer et al. suggest stretching alone may significantly increase flexibility.

While stretching may help improve flexibility, there have been studies to suggest myofascial release performed by a therapist may provide similar benefits. Kain et al. (2009) compared myofascial release techniques to hot packs for increasing range of motion of the shoulder in 31 participants. Subjects were assigned to one of two protocols: Myofascial release for three minutes or hot pack application for 20 minutes. Both treatments increased passive joint ROM, however there was no significant difference between the hot pack application and myofascial release. In addition, Hanten and Chandler (1994) compared hip range of motion between myofascial release and PNF stretching of the lower body in 75 non-disabled women using inter-subject testing and a control treatment. Both groups showed improvement over the control treatment (lying supine quietly for 5 minutes), though the stretching protocol showed a greater increase over the myofascial release.

These two studies suggest that myofascial release as a warm-up protocol may improve flexibility of a muscle or increase a joint range of motion. However, both studies suggest that while MR may be effective, it is not more effective than other warm-up protocols.

While studies examining myofascial release may be limited, aerobic exercise as a warm-up protocol has received extensive review in the literature. Active aerobic warm-ups have been shown to increase both exercise performance (Faigenbaum, 2006; Ingjer, 1979; Woods, 2007), as well as muscle extensibility (Knight, 2001).

Faigenbaum et al. (2006) examined different warm-ups in relation to anaerobic exercise performance in 18 female high-school students. It was suggested that the best warm-ups mimic the activity to be performed by increasing core temperature and improving kinesthetic awareness of the activity. Furthermore, Knight et al. (2001) compared various methods of warm-ups to the extensibility of the plantar flexors using 97 subjects with limited ROM in the ankle. The authors concluded that all methods of increasing muscular temperature increased joint ROM significantly over the control group. However, the naturally limited range of motion of the ankle joint may have provided a ceiling effect on the results.

In a similar study, Mills (1994) observed the effects of low-intensity aerobic exercise on muscle strength, flexibility, and balance in sedentary elderly persons. Twenty elderly subjects participated in an 8 week exercise program and were compared to a control group of 27 subjects. The post-treatment group experienced a significant improvement in knee and ankle flexibility after the intervention. The results of Mills (1994) and Knight (2001) suggest that aerobic exercise, both acute and long-term, can increase joint ROM via tissue extensibility.

There is currently little evidence to suggest that warm-up procedures should vary between healthy elderly and young populations. Generally aerobic warm-up procedures are classified as low- to moderate-intensity (Mazzeo, 2001; Bishop, 2001; Bishop, 2003[2]; ACSM, 2006) and the use of heart rate is a common objective standard of measurement for exercise intensity, with 55-70% of maximal heart rate corresponding to "moderate" intensity (Mazzeo, 2001). Because true maximal heart rate cannot always be determined, the traditional age-predicted equation (220-age) is used for estimating maximal heart rate. However, this equation has been suggested to be inaccurate for older adults (Mazzeo, 2001). Tanaka et al. (2001) propose a more accurate regression equation: 208-(0.7 x age) for healthy adults. Additionally, the use of medication such as beta-blockers can influence maximal heart rate (ACSM, 2006; Tanaka, 2001; Mazzeo, 2001).

To date, no studies review foam rolling as a warm-up procedure, though several studies have examined the various effects of massage on acute flexibility. Barlow et al. (2004) examine the effects of a single treatment of massage prior to a sit-and reach test, though they did not compare the flexibility results to any other warm-up procedure. The study used 11 healthy, active males (mean age 21) with no history of musculoskeletal disorders. Subjects were randomly assigned to two test sessions, separated by one week, where they would randomly receive one of two treatments. The first treatment was a specific hamstring massage to both legs performed by a trained therapist. The second treatment was supine rest. Sit-and-reach measurements were taken pre- and post-treatment. Interestingly, participants were blindfolded while testing to remove psychological influences, and the best of three attempts (separated by 30 seconds of rest) was chosen.

The results of the study indicate that a single massage did not significantly alter sit-and-reach performance. However, it seems that participants with relatively long reaches to begin with were least affected by the treatment. The author cites Sinclair (1993) who suggests that hip flexion contributes only 60% to sit-and-reach measurements, with the rest derived from spinal column flexion. This study, combined with the results from Sinclair (1993), suggests that sit-and-reach is not an optimal measurement of hamstring flexibility but rather the measurement of a functional movement and combined lower-body flexibility.

Although sit-and-reach tests (SR tests) may measure both lower back and hamstring flexibility, some researchers suggest that it is primarily used for hamstring flexibility (Hui, 1999; Sinclair, 1993; Jackson, 1986; Adams, 2008). Secondarily, it is a test for the erector spinae, gluteus maximus and medius, and gastrocnemius (Adams, 2008). The reliability of the SR test can be as high as .98 correlation, (Liemohn, 1994), though it typically falls between .70 and .91 (Adams, 2008). In addition to the accuracy of the SR test, it is a relatively easy procedure to administer, as it requires little material (Adams, 2008). Thus it is an ideal test to use for this project.

Methods

All participants were members of the Washington Regional Center for Exercise. Twenty-two members volunteered, three dropped from testing due to an inability to use the foam roller. Ten female and nine male (ages 59 ±7 years) volunteers completed all testing protocols for stretching, cycling, foam rolling, and a control. Participants were excluded if they had any major surgery or critical injury in the lower extremity in the past six months, or if they were currently taking medication which prevented heart rate from rising above 120 beats per minute. Each participant completed an informed consent prior to testing and were administered verbal and visual instructions. In addition, all were instructed and asked to practice foam rolling at least 24 hours prior to their first testing session to ensure there was no unexpected pain or discomfort, and that they could physically perform the protocol. All testing sessions were performed and supervised by an NSCA certified strength and conditioning specialist to ensure proper form and safety.

Each participant was tested during four different sessions with at least two days separating each session. Testing sessions began with a sit-and-reach test followed by one of the randomly assigned protocols (stretching, foam rolling, aerobic, or control), and ended with a sit-and-reach post-test. Testing orders were stratified to reduce the effect any specific order may have on flexibility. All testing protocols and personal information (name, test scores, test dates, etc.) were kept confidential and approved by the University of Arkansas IRB.

Warm-Up Protocols

Aerobic

After testing initial sit-and-reach flexibility, participants used a SciFit recumbent cycle ergometer (Model: OSI 7000R) for five minutes at the necessary wattage and speed to reach 55-70% (moderate intensity) of their estimated maximal heart rate based on the suggested regression equation presented by Tanaka et al. (2001): 208-(0.7 x age). Heart rate was measured using available built-in heart rate monitors on the SciFit equipment.

Figure 1 - Aerobic Activity on SciFit Recumbent Bike

Stretching

After measuring initial sit-and-reach flexibility, participants spent five minutes stretching using 10 different stretches. The stretching protocol consisted of a specific order of stretches, with each lasting 30 seconds, as illustrated in figure 1 below. The order of stretches was: Seated with feet together, seated with feet apart, supine cross-leg stretch, supine leg raise with towel, seated calf stretch with towel, seated feet together, and seated feet apart.

Seated feet together and seated feet apart were performed twice, once at the beginning of the sequence and again at the end. All other stretches were performed for thirty seconds on left and right sides.

Figure 2 - Stretching Protocol

Foam Rolling

Due to the lack of previous research on foam rolling as a means of warm-up, this project presents a five minute foam-rolling protocol for lower body posterior muscles. The protocol includes rolling five separate segments of the lower body: Hamstrings, calf & solues, gluteal muscles, and erector spinae & lower back. Sixty seconds was allotted for each segment. Foam rolling was performed using a Bio-foam Roller (15.24cm diameter, 30.48cm length) from

Perform Better; Cranston, RI. The mean pressure exerted by the foam roller has been estimated to be 33.4 ± 6.4kPa (Curran, 2008).

As illustrated by figure 3, the foam rolling protocol was: Lumbar & erector spinae (60 seconds), left and right gluteal muscles (30 seconds each side), hamstring groups for 60 seconds, left and right hamstrings with legs crossed (30 seconds each side), calf & solues (60 seconds), and lumbar & erector spinae again for 60 seconds. The lumbar & erector muscles were massaged first and last. Hamstring groups were performed both together and again separately with legs crossed. Crossing the legs allowed more pressure to be applied to the hamstring group of the targeted leg.

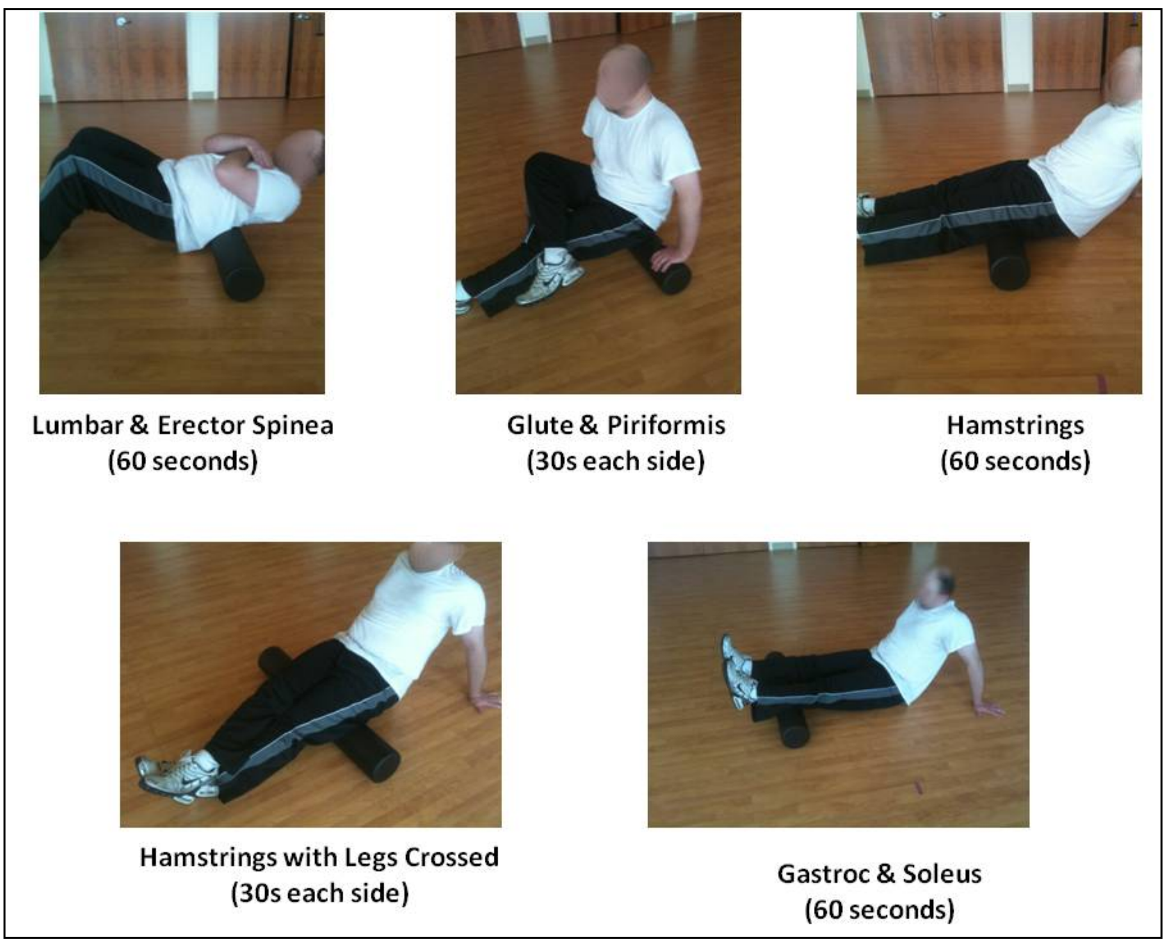

Figure 3 - Foam Rolling Protocol

No Warm-Up

As a control, no warm-up was performed. Participants laid supine for 5 minutes in a quiet, dimly lit room. All participants were instructed to keep movement to a minimum. After 5 minutes participants were retested with the sit-and-reach.

Sit-and-Reach Testing Protocol

The traditional sit-and-reach test was administered before and after each protocol. The sit-and-reach methods were based on guidelines listed in Adams' *Exercise Physiology Laboratory Manual, 5th ed.* (2008). Without shoes, participants sat on the floor with feet against the testing box, legs fully extended, approximately 6-8 inches apart. The tester gently held the participants knees to ensure leg extension and reduce testing error. The participant then extended arms forward with hands placed on top of each other, palms down, slowly bending forward along the scale. This was repeated two more times. The three attempts were recorded and averaged into a single score.

Results

All participants were members of the Washington Regional Center for Exercise who were active approximately 2-3 times per week. Nineteen participants (10 female, 9 male) completed testing; mean age was 59 years (±7 years). Participants' pre- and post-test scores were averaged for each protocol as listed in table 1. A one-way repeated measures ANOVA test was used to determine significant difference ($p > 0.05$) compared to the control group.

Participant	Control	Foam	Stretch	Cycle
1	1.33	1.67	3	3.83
2	2.33	2.83	3.83	3.17
3	1.17	0.83	2.33	1
4	1.17	3	1.83	2.67
5	1.17	3.17	1.17	2.33
6	2.5	5.67	4.67	3
7	1.67	2	3.83	2.33
8	0.17	2.17	0.17	2.17
9	0.67	7.17	3.83	4.17
10	1.17	1.83	2.5	2.67
11	0.5	1.33	1.33	1.83
12	1	4.17	1.83	2.5
13	3.17	1.67	3.33	1.67
14	0.67	0.33	4.67	4.67
15	1.83	6	2.67	1.17
16	0.5	3.17	3.67	1.5
17	0.83	4	4.67	2
18	0.33	6.67	2.33	1.33
19	3	2.67	5	0.17

Table 1 - Mean Change in sit-and-reach scores by Participants (in cm)

Heart rate was measured only during aerobic cycling. Each participant was assigned a target heart rate based on the age-regression equation by Tanaka et al. (2001) which is summarized in table 2 below.

Age	Max HR	55%	70%
50	173	95	121
55	169.5	93	118
60	166	91	115
65	162.5	89	113
70	159	87	111
75	155.5	85	108
80	152	83	106
85	148.5	81	104
90	145	79	101

Table 2 - Max HR = 208 - (0.7*age)

Mean age was 59 (±7 years). Participants in the study averaged heart rate ranges between 91-115 beats per minute during aerobic cycling.

Each participant performed three sit-and-reach trials prior to, and after, using a randomly assigned protocol. All three trials for each protocol were averaged into a score to determine pre- and post-test differences. Figure 3 below shows pre- and post-test scores for each warm-up protocol.

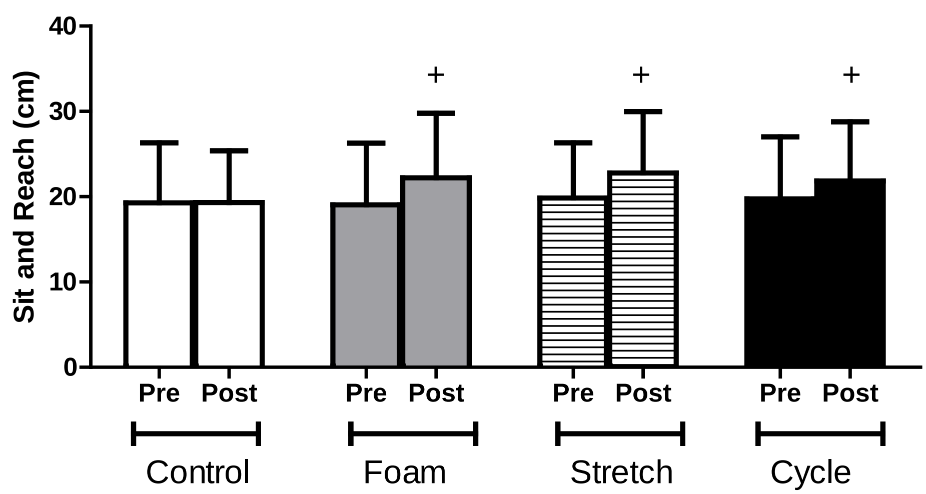

Figure 4: Flexibility scores of pre- and post-tests. Scores are illustrated with a (+) to show significant difference ($p < 0.05$). All sit-and-reach scores were measured in centimeters.

Average scores from figure 1 were compiled for each warm-up protocol. Figure 5 below shows the average change in pre- and post-test scores for each protocol.

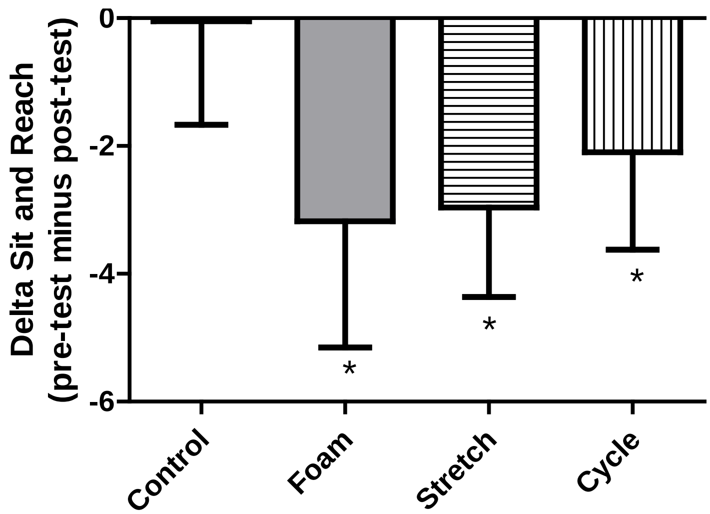

Figure 4 - Mean changes in sit-and-reach scores (pre-test minus post-test).

The control group showed no significant change in flexibility scores. Foam rolling, stretching, and cycling protocols showed a significant change in sit-and-reach flexibility, as illustrated by *.

Foam rolling showed a 16.6% increase in sit-and-reach flexibility, with stretching and cycling showing 13% and 9.6% increase in flexibility respectfully. There was no significant difference in pre- or post-test scores in the control group.

Discussion

The purpose of this study was to determine the effectiveness of foam rolling on lower body sit-and-reach flexibility in comparison to stretching and aerobic cycling. The results suggest all three warm-up protocols increase flexibility significantly over no warm-up in selected participants. However, foam rolling was not shown to significantly increase flexibility any greater than aerobic cycling or stretching. These results confirm the initial hypotheses that foam rolling would increase sit-and-reach flexibility over a control group, but not significantly over other forms of warm-up.

These results contrast with past research of Wiktorsson-Moller (1983) and de Weijer (2003) who found the only warm-up protocols effective at increasing lower body flexibility to be stretching or aerobic activity combined with stretching. In addition, the results agree with Kain (2009) and Hanten and Chandler (1994) who suggest myofascial release can significantly improve joint range of motion and flexibility. However, results from Hanten and Chandler show that certain forms of stretching (proprioceptive neuromuscular facilitation) are better at improving flexibility than myofascial release performed by a therapist in elderly women.

The present study suggests that either foam rolling, stretching, or cycling alone for five minutes is enough to improve lower body flexibility during a sit-and-reach test in participants over 50 years of age, though no group is statistically significant over another. It is important to note that while the results from Hanten and Chandler suggest myofascial release to be effective at increasing flexibility, it is a passive form of myofascial release, rather than an active form of self-myofascial release as done on a foam roller. They also found PNF stretching (a combined active and passive form of stretching with a partner) to be more effective than the passive myofascial release.

Aerobic cycling showed a 9.6% increase in flexibility. These results are almost unanimously consistent with past literature (Faigenbaum, 2006; Ingjer, 1979; Woods, 2007; Knight, 2001; Mills, 1994) which suggests aerobic warm-ups are effective at improving tissue extensibility and general exercise performance. It is generally believed that aerobic exercise increases tissue extensibility, thus leading to greater joint range of motion by increasing core temperature (Knight, 2001).

The stretching protocol performed by all participants increased sit-and-reach flexibility by 13%. These results agree with Wiktorsson-Moller (1983) and de Weijer (2003) who found both aerobic exercise and stretching to be individually effective at increasing lower body flexibility. Faigenbaum (2006) also suggests that the best warm-up is one which mimics the activity to be performed. In the case of sit-and-reach flexibility, the stretching protocol was identical to the sit-and-reach test.

The foam rolling protocol showed approximately 17% greater increase in sit-and-reach flexibility than the control post-treatment, though the exact mechanisms responsible for the improvement are not currently known. There are several theories for the effectiveness of foam rolling. The most popular theory is that the connective fascia becomes fibrous and develops adhesions throughout the connected network, restricting range of motion throughout the entire body. These restrictions can create abnormal strain patterns on the skeletal system causing improper alignment, pain and dysfunction (Barnes, 1997).The systematic treatment of this restriction via foam rolling, massage, or other soft tissue work may improve specific joint range of motion and improve overall flexibility by breaking the adhesions (Curran, 2008; Hopper, 2005; Schleip, 2003; Sefton, 2004). It is believed slow sweeping pressure promotes soft tissue extensibility as long as the pressure is applied to the area for 60-90 seconds (Paolini, 2009).

It has also been suggested that fascia exhibits a thixotrophic property in which viscosity is decreased with agitation or pressure during foam rolling (Paolini, 2009). Thus, when direct pressure is applied, friction and heat transition fascia into a more fluid state and allows for increased extensibility of the muscle and increased ROM of the joint (Schleip, 2003).

Another theory for the effectiveness of foam rolling is the breaking of actin-myosin bonds within the muscle fibers (Bishop, 2003). With inactivity, the number of bonds increase and as a result muscle stiffness increases. It is speculated that movement may help improve joint ROM by disturbing the actin-myosin bonds reducing the passive stiffness of the muscle (Wiegner, 1987). However this theory would not be limited only to foam rolling, but rather any type of movement or warm-up. While all three warm-up methods were effective at increasing sit-and-reach flexibility, there was not enough evidence to suggest foam rolling offered a greater increase between pre- and post-test scores.

Even though there was not a significant difference between warm-up protocols, foam rolling may still offer advantages that stretching and aerobic exercise may not. Though research is lacking, many people believe foam rolling offers benefits associated with pain management and a general sense of improved well-being. Most participants in the present study felt "better" after foam rolling, and compared the feeling to a relaxation effect similar to massage. However, due to the lack of research in foam rolling, these effects are still unknown. The results of this study also suggest that foam rolling can be as equally effective as aerobic cycling and stretching at improving flexibility, even when given the same amount of time. Thus, it can be safely used by elderly populations as an alternative means to prepare for activities which require increased flexibility such as yoga or dance.

Limitations

One primary difference between stretching, cycling, and foam rolling is the amount of body awareness and control required to correctly apply self-myofascial release. A large amount of core stability and upper body strength is needed in order for the participant to correctly apply pressure on the roller. Many participants regarded foam rolling as extremely vigorous; more so than cycling or stretching. Even though all participants had practiced rolling techniques prior to testing procedures, many experienced elevated heart rate and exhaustion comparative to if not greater than cycling. However heart rate was not measured during foam rolling protocols, so it is unclear as to comparisons of heart rate intensities between aerobic cycling and foam rolling. While more fit individuals may not exert as much energy while foam rolling, there appears to be a slight heart rate effect and possibly an increase in core temperature due to the physical activity of rolling. This suggests that foam rolling be classified as an active warm-up comparable to aerobic activity, as several studies have suggested passive massage does not affect flexibility.

Previous studies such as Wiktorsson-Moller et al. (1983) found no change in joint ROM after passive massage compared to aerobic or stretching protocols. Barlow et al. (2004) also found no change in sit-and-reach flexibility after massage. However, these studies used passive massages performed by a therapist whereas foam rolling requires much more effort on the participant's part. This difference may account for the increase in flexibility from foam rolling, yet no change in flexibility from massage. However, if physical activity and increased body temperature is responsible for the changes in sit-and-reach results, more intensive aerobic exercise would be needed to compare to foam rolling. While the present study used a relative heart rate intensity based on participants' age, there was no scale to assert the relative intensity of foam rolling. While one individual may be more fit and have little trouble rolling on the floor, another individual may be near 100% maximal effort to support themselves. Thus, participants lacking in strength or coordination may not receive full benefits of SMR techniques if they cannot correctly apply pressure.

Future Studies

Further research is needed to compare foam rolling with intensive exercise to understand the effects of foam rolling and warm-up. This study has established that foam rolling is a safe and effective method for increasing lower body flexibility in elderly adults. While it is the first of its kind more research is needed to fully understand self-myofascial release and foam rolling.

Furthermore, the effectiveness of foam rolling on various populations should be examined to determine if age or activity level varies the effectiveness of foam rolling.

Conclusion

Foam rolling, aerobic activity, and stretching protocols increase sit-and-reach flexibility as when compared to a control group. However, no group showed significantly greater improvement other the other. Foam rolling can be an effective method to increase flexibility in elderly adults, though exact mechanisms remain unknown. Regardless, foam rolling is used by many strength and conditioning facilities, athletic training practices, fitness enthusiasts and weekend warriors. The results of this study may help further understand the usefulness of this practice on athletes looking to increase flexibility or joint ROM between exercise bouts.

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