Effects of Foam Rolling versus Static Stretching on Recovery of Quadriceps and Hamstrings Force

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ABSTRACT

Background: There is greater interest in the clinical significance of fascia due to recent findings document efficacy of concerning various myofascial release techniques including static (SS) and dynamic stretching, foam rolling (FR), and massage therapy on muscle performance after exercise. Increased range of motion, decreased fatigue, and optimized performance are some potential benefits of myofascial release techniques. Aim: To compare effects of myofascial release techniques via foam roller (FR) application and static stretching (SS) on the recovery of quadriceps and hamstring muscle force production after intense exercise.

Methods: Fourteen active men (mean age and mass BMI = 23.3 ± 3.0 yr and 84.6 ± 25.0 kg) initially completed a test of muscular strength testing using an isokinetic dynamometer—consisting of five repetitions of maximal knee extension and flexion of the dominant leg at a contraction velocity equal to 60 degrees * sec^{-1}. Seven days later, subjects participated in a 1 hr bout series of intense lower extremity exercises focusing on the lower extremities and were randomly assigned to SS or FR treatment instituted immediately after exercise. Twenty four hours after this bout, muscle strength was reassessed subjects repeated the strength assessment and were asked to evaluate perceived soreness of the leg was evaluated on a 1-10 scale. Subjects repeated the intense exercise protocol 7 days later at the same time of day and immediately after exercise performed the other rehabilitative technique was performed. Analysis of variance with repeated measures was used to detect differences in muscle performance between rehabilitative-treatments.

Results: Results revealed a main effect of treatment on knee extension torque (F=10.09, p<0.0501) and a trend in treatment of knee flexion torque (p=0.0052). Posthoc analysis revealed that knee torque was lower in response to SS (data as mean SD 118.9 ± 22.0) versus baseline (data 132.9 ± 20.5).
or FR (data 129.7 ± 21.0), with showing a trend no difference (p >= 0.052) in knee flexion torque across treatment after MF. When compare to baseline, 94% vs 86% of knee extension force was preserved in FR versus only 86 % for and SS, respectively, in KE. 98% vs 89% of force was preserved in KF in SS and FR when compared to baseline. SS revealed less soreness than MF in quadriceps (25.5 %) and hamstrings (11.3%); if you did not use a validated soreness scale, don’t even use these data.

**Conclusion:** Application of myofascial release via foam roller after intense exercise may help to preserve muscle force on the day following exercise compared to traditional static stretching. *Note that these are typically limited to 250 words so it may have to be condensed.*

**Key words:** muscle strength; foam rolling; stretching; isokinetic dynamometry; fatigue
INTRODUCTION

Myofascial release has been widely researched due to its potential to relieve pain (Sanchez et al., 2011), increasing range of motion (Davis et al., 2002), decreasing fatigue (Healey et al., 2011) optimizing performance (Yamaguchi et al., 2005, Little et al., 2006, Yamaguchi et al., 2005, Herda et al., 2008 chronological list) and improving overall quality of life (Davis et al., 2002, Adelaida et al., 2011, Davis et al., 2002, Sanchez et al., 2011 chronological).

During myofascial release, the Golgi tendon organ (GTO) which regulates muscle tension is activated which in turn activates the muscle spindle. The GTO regulates muscle tension and the muscle spindle which detects changes in muscle length. Their activation causes a decrease in muscle tension, which contributes to muscle lengthening in a process known as autogenic inhibition (Fama et al., 2011).

Even though there is insufficient scientific evidence exists to explain myofascial releases's physiological effects there are a variety of myofascial release techniques available including cryotherapy, massage/manual therapy, static (SS), dynamic stretching, acupressure, and foam rolling (FR).

Fascia, Latin for band, is a term used to describe the tissue that wraps around specialized organs of the body (Benjamin et al., 2009). Fascia consists of four main types of tissue; dense and non-dense areolar connective tissue, superficial fascia, and deep fascia (Langevin et al., 2009). This fibrous tissue forms adhesions called trigger points when irritated such as...
in response to high-force exercise?, limiting circulation and interfering with elasticity, function, and motion (Vernon et al., 2009, Fama et al. 2011, Vernon et al., 2009). It has been suggested (ref?) that these trigger points are associated with (elicit) decreases in muscle function after acute exercise, with preliminary data showing that use of ice (ref?), massage (ref?), and typically express/demonstrate mixed (equivocal) results on muscle force production. Although, due to limited research, we can only speculate about how MRT helps to release trigger points and adhesions within the fascia—To the best of our knowledge, there are no articles related to changes in muscle force production in response to self myofascial release techniques.

Paragraph 1 here.

In a clinical and athletic setting, individuals are required to complete intense exercise which may elicit muscle damage for several days after the initial exercise bout which is detrimental to muscle function (ref?). However, the optimal modality used to lessen this muscle damage is unknown. Soften this text and preserve muscle function and resultant performance subsequent to exercise is unknown.

The aim of the present study was to observe the effects of two myofascial release techniques, via FR application and static stretching, on changes in the recovery of quadriceps and hamstring force after intense exercise. It was hypothesized that compared to baseline, FR will diminish reductions in force of the increase recovery of knee extension and flexion force versus SS. To our knowledge, no study has examined alterations in muscle force through utilization of the act of SS and FR after the quadriceps and hamstring post-exercise.

METHODS

Subjects
Fourteen active men (N = 14) from California State University San Marcos participated in study. They habitually participated in resistance training, aerobic exercise, and/or recreational sport. Subjects were active 3-5 days a week although none was considered trained. Their age, mass, height, and BMI were equal to 23.3 ± 3.0 yr, 84.6 ± 9.2 kg, 1.8 ± 0.07 m, and 24.95 ± 2.8 (kg/m²), respectively. All subjects were fully informed of all experimental procedures and potential risk, which were approved by the University Institutional Review Board, and written informed consent was obtained from all subjects.

Exercise Protocol

Subjects were studied on five different days, 3 days of laboratory testing and 2 d of intense exercise. Subjects did not participate in exercise of the lower extremities 24 hours before baseline testing or intense exercise protocolall visits. Laboratory tests of muscular strength preceded intense exercise meetings by 24 h and were held at the same time of day within subjects. During the first meeting, peak torque was determined using an isokinetic dynamometer (Biodex, Shirley, New York). Subjects warmed up for 2 minutes on a stationary bike (Monark 829e, Vansbro, Sweden), then performed one bout of five repetitions of maximal knee extension and flexion at 60 degrees/sec. Peak and average knee flexion and knee extension torque (ft-lbs), total work (ft-lbs), and power (W) were recorded for knee flexion and knee extension from all bouts.

Seven days after baseline testing, men performed a 5 minute warm-up on a treadmill (m'tr city, st), followed by 30 squat jumps, 30 air squats, and a 30 second wall sit, which were performed consecutively or with recovery between exercises. Afterwards, subjects performed two exercise circuits targeting the lower extremity. Circuit 1 was performed three times in order and consisted of step ups, dead lifts, lunges, hamstring curls and wall sits. (Table 1, Table 2). After a 1
min rest, subjects completed Circuit 2 consisting of _three_ sets of leg extension (Cybex, Medway, Massachusetts), seated Leg Press (Cybex, Medway, Massachusetts), seated Leg Curl (Cybex, Medway, Massachusetts), and Physioball Hamstring Curl (Power Systems, Knoxville, Tennessee) (Table 2). Both circuits were performed while under supervised by exercise professionals. Subjects reported perceived soreness of quadriceps and hamstring on a 0-10 scale 24 hours after this bout again, validated scale or not? How much recovery was allotted between sets? Exercises? circuit 1 and 2? List above in text.

Table 1. Circuit 1 of lower body intense exercise. *Put in word file by itself.*

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Repetitions</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step Up left leg</td>
<td>20</td>
<td>Body Weight, 9 risers</td>
</tr>
<tr>
<td>Step up right leg</td>
<td>20</td>
<td>Body Weight, 9 risers</td>
</tr>
<tr>
<td>Romanian Dead Lift</td>
<td>10</td>
<td>10-RM</td>
</tr>
<tr>
<td>Forward Lunge</td>
<td>6 per leg</td>
<td>10-RM</td>
</tr>
<tr>
<td>Hanging Hamstring curl</td>
<td>10</td>
<td>10-RM</td>
</tr>
<tr>
<td>Wall Sit</td>
<td>3 x 30 sec</td>
<td>Body weight</td>
</tr>
</tbody>
</table>

Table 2. Circuit 2 of lower body intense exercise.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Repetition</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Press</td>
<td>3 x 10</td>
<td>10-RM</td>
</tr>
<tr>
<td>Hamstring Curl</td>
<td>3 x 10</td>
<td>10-RM</td>
</tr>
<tr>
<td>Leg extension</td>
<td>3 x 10</td>
<td>10-RM</td>
</tr>
<tr>
<td>Physioball Hamstring Curl</td>
<td>3 x 10</td>
<td>Body weight</td>
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<tr>
<td>Wall Sit</td>
<td>3 x 30 sec</td>
<td>Body weight</td>
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</table>
What if you constructed a figure in Powerpoint showing these? May be more effective than Word table? Use arrows and text boxes; you can describe the reps and intensities in corresponding text at bottom of page 6.

Within 5 min after intense exercise, subjects were randomly assigned to undergo a post-exercise rehabilitative treatment of either SS or FR to target the quadriceps and hamstrings. The identical bout of intense exercise was repeated 7 d later and subjects underwent the other post-exercise rehabilitative treatment.

**Stretching Protocol**

Subjects performed 2 sets of 30 seconds of sit and reach hamstring stretch, supine straight leg hamstring stretch, supine bent knee hamstring stretch, prone quadriceps stretch, and standing quadriceps stretch under researcher supervision. There was a 5-second rest period between stretches and they were performed to a light to moderate discomfort.

**Self Myofascial Release Protocol**

During this procedure, subjects laid prone with the dominant leg on Round High Density Foam Roller (Power Systems, Knoxville, Tennessee) 2 cm superior to the knee joint. Subjects then crossed the non-dominant limb over the dominant limb, putting all body weight on the foam roller. Subjects rocked across the transverse plane of the quadriceps five times, then rolled from 8 cm superior to 2 cm inferior and back to the starting point five times. This process was repeated at the middle of the quadriceps and 8 cm inferior to the origin of the rectus femoris. This FR procedure was performed 3 times in order at all sites.
Myofascial release of the hamstrings began by placing the foam roller on the belly of the hamstrings. The subject then crossed the non-dominant limb across the dominant limb treated do you mean dom and non-dominant? limb across treated limb while body weight was supported with their arms. Subjects then rolled the foam roller proximal and distal from origin for 30 s, and this was repeated 3 times. Was the stretch and FR duration similar? If not, cite in limitations as maybe this is the reason why strength was preserved with FR…is the SS protocol you employed typically done in practice/clinical settings?

Data Analysis

Data are reported as mean ± standard deviation and were analyzed using SPSS software version 20.0 (IBM, Armonk, New York). A one-way repeated measures ANOVA was used to examine differences in peak extension and flexion force between baseline and post MR and SS. Tukey’s Post Hoc test was used to find differences between means when a significant F-ratio was obtained. Statistical significance was accepted at P < 0.05.

RESULTS

Effects of MR and SS on Muscle force.

Data revealed a main effect of treatment on knee extension torque (F=10.09, p=0.003, report exact p value..?~0.05). Post hoc analysis revealed that knee extension torque was lower in response to SS versus baseline as seen in Figure 1, with no difference in knee flexion torque after MR treatment (Figure 2). Compared to baseline, there was a 94.1% preservation of peak KE torque after MR, compared to only 85.9% (p < 0.05) after SS. Use the same abbrev’ns throughout..remember what MF means!! Use MR only…
Effects of MR and SS on Work and Power Output

Work and Power Output were also noted. Work output extension preserved 79% of the total work with no significant difference for SS extension. Flexion work output preserved all of the total work in addition to a 2% increased for MF treatment, with no significant difference in SS flexion (Figure 4).

Power output for extension after SS and MF treatment preserved 96% and 94% of the total power respectively. Flexion Power output also preserved total power output for SS and MF treatment in both MF and SS by 96% and 92%, respectively (Figure 5).

No need to put these data in figure. Report include a table showing all force data and use an x-y scatter to show the % change in force across Tx for KE only, as this was the only significant finding, right?

Figure 1: Change in Knee Extension Torque Baseline, MF, SS Peak Torque Need to run statistics to get P values, put Fig. legends at end of paper, after References, and typically figures and tables are in separate files rather than imbedded in text.
Figure 1: Knee Flexion Baseline, MF, SS Peak Torque. *(NEED to run statistics again to get Pvalues)*
get rid of this figure—your text is adequate

Figure 3: Perceived soreness after treatment. MF Quadricep (3.79 ± 1.9), SS Quadricep (2.85 ± 1.7),
MF Hamstring (4.43 ± 1.94), SS Hamstring (3.93 ± 2.3).

**DISCUSSION**

The aim of the present study was to observe the effects of two myofascial release techniques—
via—foam roller application and static stretching, on the recovery of quadriceps and hamstring force
after intense exercise. Our results showed that MRT via FR preserved KE force 24 h after intense
exercise compared to SS, as force was similar to that revealed at baseline. No differences were
observed in hamstring force after either treatment. Perceived soreness levels were lower after SS
than MRT for both extension and flexion. These results can be applied to individuals
working in athletic, recreational, or therapeutic settings who are interested in maintaining muscle force the day after strenuous exercise.

Our intense exercise protocol likely required eccentric contraction which creates
soreness and damage to the muscle fascia of the muscle, causing myofibrils to split, and promoting
muscle repair (Jones et al., 1989). It is speculated that this exercise-induced damage could
potentially be treated with MR to aid in repair and. During FR treatment, several factors including attenuate autogenic inhibition, reduced tension, trigger point release, and increased blood flow to the muscle may occur to which aid in muscle repair. Do you have any data here from human or animal studies that would support this? Present them here. For example, ____ et al. (yr) demonstrated that.

One potential explanation possible reason as to why myofascial release technique MRT spell out via FR was able to preserve muscle force when compared to SS, is trigger points (TrP) and autogenic inhibition (AI). No abbreviations for these words, spell out...brought about by FR pressure seem to be the most likely reason behind this phenomenon. Trigger Points can be very painful, but in many cases, exist dormant and painless within muscle, creating constant tension (Mense et al., 2001). TrPs, existent throughout nearly all skeletal muscles of the body, can result in decreased muscle force during exercise due to an increase in muscle tension and which may decrease length and lead to reductions in muscle force decrease in length (Fama et al., 2011; Dommerholt et al., 2006). However, MRT myofascial release techniques used as TrP release therapy have been shown to increase range of motion and muscle length in what? In response to what ex. mode? (Fama et al., 2011). Both SS and FR have the capability of promoting AI spell out (ref) autogenic inhibition, a process that occurs when a high tension or load is placed on a muscle, causing the golgi tendon organ to activate and inhibit force activation from the muscle spindle. This inhibition allows the muscle to relax and stretch, increasing muscle length and decreasing tension (Davis et al., 2005; Fama et al., 2011). It has been reported that though both treatments in our study had the capability of producing AI, MRT via FR applies significantly more pressure to the muscle than ____, allowing TrP trigger points out to be released more easily (Fama et al., 2011). There are dozens of treatments used in the release of TrP triggerpoints, but it has been noted that some treatments, including MRT myofascial release
techniques, may work more effectively than others (Dommerholt et al., 2011). Since there is little
evidence that FR treatments actually cause AI-autogenic inhibition and release TrPs-triggerpoints, it is
difficult to pinpoint what physiological mechanisms may be affected during MRT-myofascial release
techniques, but it is likely that the pressure exerted by the FR will bring about AI-autogenic inhibition
(Hanten et al., 2000). SS techniques can be very effective, but our stretching protocol may not have
been the best choice in terms of preserving muscle force the following day after intense exercise.

Maybe delete..?

Godges et al. (1989) reported that SS was the best treatment of choice to improve range of
motion and muscle length in what setting? Describe? , but only when administered 3 setstimes at 2
minute increments. Similarly, Davis et al. (2005) found that assisted static stretching was most
effective to ___? what was measured? yielded the best results when compared to proprioceptive
neuromuscular facilitation (PNF)-and self stretching? in returning hamstrings to optimal functioning
muscle length. In the current study, subjects performed various stretches twice for 30 second
increments, which may have been inadequate duration to apply sufficient tension on the muscle to
allow the muscle to relax and lengthen. Hill’s Length-Tension Muscle mModel indicates that peak
torque occurs at an optimum muscle length and that if muscle is too short or too long, it will not
generate optimal force (Winters et al., 2010; Jones et al., 1989). The length-tension relationship may
be altered by SS and FR, because they both result in muscle lengthening ref? . The FR treatment
revealed greater in preservation of KE force compared to SS, due to the fact but whether this is
because that—FR was more effective at inducing autogenic inhibition AI in a shorter time frame
compared to SS remains to be determined.
Another plausible explanation for the preservation of force brought about by MRT via FR is that the pressure and traction created by this modality application of a FR may increase blood flow to the muscle, which may realign layers of fascia, enhance lymphatic drainage of metabolic wastes, and reset the Golgi Tendon Organ/Muscle Spindle Autogenic inhibition feedback system (Davis et al. 2009; Dommerholt et al., 2006). It may be that increased blood flow ultimately causes the cascade of events that lead to AI activation, reduced triggerpoints occurrence, and eventual lengthening and relaxation of muscle.

One notable observation was the inverse relation between perceived muscle soreness and force output for both the MRT and SS treatment. Muscle soreness appeared to be higher after MRT via FR, although most literature states that perceived soreness is lower after a MRT than for traditional stretching (Fama et al., 2011; Russel et al., 2005). These facts demonstrate that either our FR treatment created soreness or our method of obtaining perceived soreness levels was flawed. Based upon our results, perceived soreness level had no association with force output because MRT was able to preserve more force than SS.

This study presented a few limitations including our use of a small relatively homogeneous sample of young, active men. Results would be more generalizable with a more diverse sample. The FR procedure used on the quadriceps was different than the procedure used on hamstrings, possibly altering force output off the hamstring. Lastly, muscle soreness and damage after intense exercise can exist for 2 – 4 d after exercise, so a better understanding of the effects of myofascial release on force production could be gleaned if strength was assessed daily for several days after intense exercise.
In conclusion, application of myofascial release with a foam roller after intense exercise may help to preserve force production of the target muscle quadriceps on the day following exercise compared to traditional static stretching. However, there was no effect on hamstring muscle strength. These results of this study may be applied to athletic, recreational, and therapeutic settings where it may be of interest to maintain muscle force the day after a strenuous exercise workout. Areas of future research include the following: assessment of different populations (i.e., men and women, elderly), measuring the effectiveness of various techniques and regimes of MRT myofascial release techniques in persons of various age, gender, and conditioning, against other post exercise treatments, and testing muscle performance two days post intense exercise and measuring FR treatment on delayed onset muscle soreness. Another consideration is to compare the effects of different FR designs and their effectiveness on MRT after intense exercise, assessing performance on the Biodex the following day.

References below: select a journal and format references to that journal, which includes this list at end of paper as well as citations in text

Acknowledgements:

REFERENCES


**Figure Legends**