REVIEW

The Evidence Behind Foam Rolling: A Review

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ABSTRACT

Self-myofascial release (SMR) with tools like the foam roller has become increasingly popular amongst active populations to self-treat areas of myofascial restriction and positively affect sporting performance. SMR achieves its effect through various mechanisms, such as altered connective tissue properties, improved neuromuscular and arterial function, autonomic nervous system stimulation, increased hydration and altered fascial piezoelectric function. In recent years, multiple studies have demonstrated that the effects of SMR include improved range of movement (ROM), increased muscle performance, enhanced recovery after exercise, and reduced stress. However, there is great heterogeneity amongst current research, which makes it difficult to reach a consensus regarding the protocols and parameters to follow in order to achieve beneficial results. Larger longer-term studies which repeat current protocols would significantly add to the current body of literature. This study reviews the literature on the effects of SMR on ROM, muscle performance, post-exercise recovery, balance and stress.

Keywords: Myofascial, Self-Massage, Physical Performance, Range of Movement, Foam Roll.

INTRODUCTION

Over the past decade, there has been a significant increase in the usage of foam rollers or roller massagers (see Figure 1) as a form of manual therapy to reduce myofascial tightness, most notably in rehabilitation and fitness environments (Cheathem et al., 2015; Peacock et al., 2014). This myofascial tightness develops over time as a result of muscular microtrauma or after acute injury, both of which lead to scarring or thickening of fascia. Scarring in turn, contributes to reduced range of movement (ROM); neuromuscular dysfunction; joint, nerve and vascular compression; reductions in strength; and pain and injury - all of which negatively affect physical performance (Healey et al., 2014; Barnes, 1997; Schroeder and Best, 2015; Curran et al., 2008; Mauntel et al., 2014).

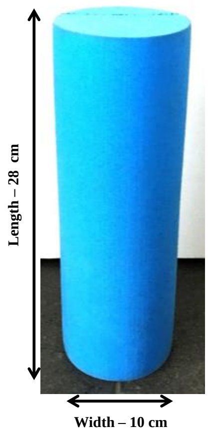

Figure 1. A Foam Roller

Foam rolling describes a form of self-massage that uses body weight in conjunction with a device such as a foam roller or roller massager to apply pressure to tight tissues. This is done in order to increase myofascial compliance and optimize muscle length-tension relationships (Curran et al., 2008; Healey et al., 2014). As a form of massage, Schroder and Best (2015) note that foam rolling may have similar effects, namely reduced muscle tension and stiffness; decreased pain, swelling and muscle spasm; increased flexibility and ROM; enhanced healing of ligament and muscle injuries; and improved athletic performance. The authors also mention the cost-effectiveness of self-massage insofar as the individual is able to self-treat, eliminating the need for a clinician. In recent years, there has been increased focus on the effects of foam rolling and its applications to physical activity. Thus, this paper aims to (i) explain the proposed mechanisms behind myofascial release; (ii) review the evidence for self-myofascial release (SMR) using tools like foam rollers while discussing its effects on physical performance; and (iii) make suggestions for further research that address current gaps in the literature.

THE PROPOSED PHYSIOLOGICAL AND MECHANICAL EFFECTS OF MYOFASCIAL RELEASE (MR)

Connective Tissue Properties

The human body contains a continuous network of fascia, which is a kind of connective tissue integral to providing structural support for the body while allowing for efficient movement. The development of restrictions or tightness in this fascial network has a direct effect on muscular and fascial (myofascial) efficiency and movement (Barnes, 1997). One of the primary theories behind the mechanism of MR is the changing of fascia from a solid gel-like state to a more fluid 'sol' state by introducing energy in the form of heat or mechanical pressure; i.e. thixotrophy (Schleip, 2003a). Research suggests that SMR may increase ROM by elevating tissue temperature, reducing fascial adhesions, and altering the viscoelastic and thixotropic properties of the fascia (Cheathem et al., 2015; Barnes, 1997; Saxton, 1995; Knight et al., 2001). However, Schleip (2003a) notes that the thixotrophic, or gel-to-sol, effect of MR is quite short lived with tissues returning to their original solid state within minutes of ceasing application. Therefore, although this provides one explanation for the immediate tissue-release effects seen with MR, there are several other explanations, one of which is improved neuromuscular function.

Neuromuscular Function

Schleip (2003a) suggests the possibility of a central nervous system (CNS) effect whereby mechanical force applied to the tissue stimulates intrafascial mechanoreceptors, which affects the proprioceptive input sent to the CNS. This then alters the regulation of tone of the associated motor units within the fascia. Other researchers have summarized this effect with the phrase, "Afferent stimulation frequently results in efferent inhibition" (Shah and Balara, 2012, p. 72). Put simply, mechanical pressure applied to fascia sends a neural signal to the CNS, which sends a neural signal in return to reduce tone in the associated muscles. Not only does MR affect tone, but Peacock et al. (2014) suggest that SMR may improve power production by stimulating the neural system to increase its firing rate and recruitment patterning. This may be the mechanism by which foam rolling influences muscle performance. Bradbury-Squires (2015) found improved neuromuscular efficiency, measured by reduced EMG activity in quadriceps during a lunge, after rolling the quadriceps muscles. Halperin et al. (2014) also found small improvements in plantarflexor muscle force after foam rolling the calf muscles, although their results were not statistically significant.

Nevertheless, these findings speak to the communication between the muscular and neural systems to optimize neuromuscular function.

Stimulation of the Autonomic Nervous System

Staubesand and Li (1996) discovered the presence of smooth muscle cells embedded within fascial collagen fibres and suggested that these muscle cells allow the autonomic nervous system to regulate fascial tone independent of muscular tone. Schleip (2003b) further suggests that mechanical stimulation of intrafascial mechanoreceptors causes the autonomic nervous system (ANS) to change the tone of intrafascial smooth muscle. Slow mechanical pressure to tissues is thought to activate the parasympathetic nervous system, which then results in a reduction in muscle and fascial tone.

This effect may explain why some studies demonstrate an increase in ROM (Kelly and Beardsley, 2016) and reduced muscle soreness (Jay et al., 2014) after SMR, even in the non-massaged limb. That is, the benefit may be due to stimulation of the parasympathetic nervous system, which creates a more global release effect. These findings are interesting and may be relevant to unilateral conditions or restrictions where treatment of the injured limb proves difficult due to immobilization or neurological deficits (Kelly and Beardsley, 2016). In these cases, SMR on the contralateral limb may prove valuable in achieving release in the injured limb. Two studies (Grieve et al., 2015; Do et al., 2018) have demonstrated significantly increased lumbar and hamstring flexibility, as measured by sit-and-reach and passive straight leg raise, immediately after SMR of the plantar fascia. This supports the theory that release may occur via more widespread mechanisms than local structural change in the fascia.

The ability of SMR to stimulate the parasympathetic nervous system may also be beneficial in treating conditions characterized by increased sympathetic drive, such as stress, coronary artery disease, and fibromyalgia. The literature dealing with this topic is quite sparse. However, for individuals suffering from myofascial pain dysfunction syndrome, one study did find positive effects on pain and physical function with the addition of SMR and an exercise component to a 2-week program of treatment with physical modalities (Chan et al., 2015). Further studies looking at the application of SMR to these types of conditions is warranted.

Arterial Function

Most studies investigating foam rolling as a form of SMR have measured aspects of physical performance, but one study examined the effects of foam rolling on cardiovascular parameters and found acute improvements in brachial-ankle pulse wave velocity (baPWV) and plasma nitric oxide concentration (Okamoto et al., 2014). The authors concluded that foam rolling can be beneficial in reducing arterial stiffness and improving vascular endothelial function. Schleip (2003b) describes the effect that myofascial release has on stimulating interstitial tissue receptors and Ruffini nerve endings. This affects the autonomic nervous system, and can lead to a decrease in sympathetic tone and beneficial changes in the pressure of fascial capillaries and arterioles. The net result is a decrease in myofascial tone and improved arterial function (Peacock et al., 2014). Further research regarding the long term effects of SMR on cardiovascular function is needed, but it has the potential to add to the management of individuals suffering from vascular conditions like hypertension or coronary artery disease.

Tissue Hydration

Fascial stiffness is in part dictated by water content. The more 'dehydrated' the tissue the stiffer it is. When compressed, fascia has been shown to extrude water, which may suggest that compression applied during SMR could increase fascial compliance by temporarily changing water content levels. In turn, this facilitates increased movement and mobilization (Chaitow, 2009).

Piezoelectric Function of Fascia

Piezoelectricity describes an electric charge produced by certain structures in response to mechanical stress. Using this definition, it has been proposed that pressure applied to fascia creates an intrafascial electric charge, which stimulates fibroblasts and fibroclasts within the tissue to create and digest collagen fibres for fascial remodeling (O'Connell, 2003). These findings suggest that SMR can actually effect change at a cellular level.

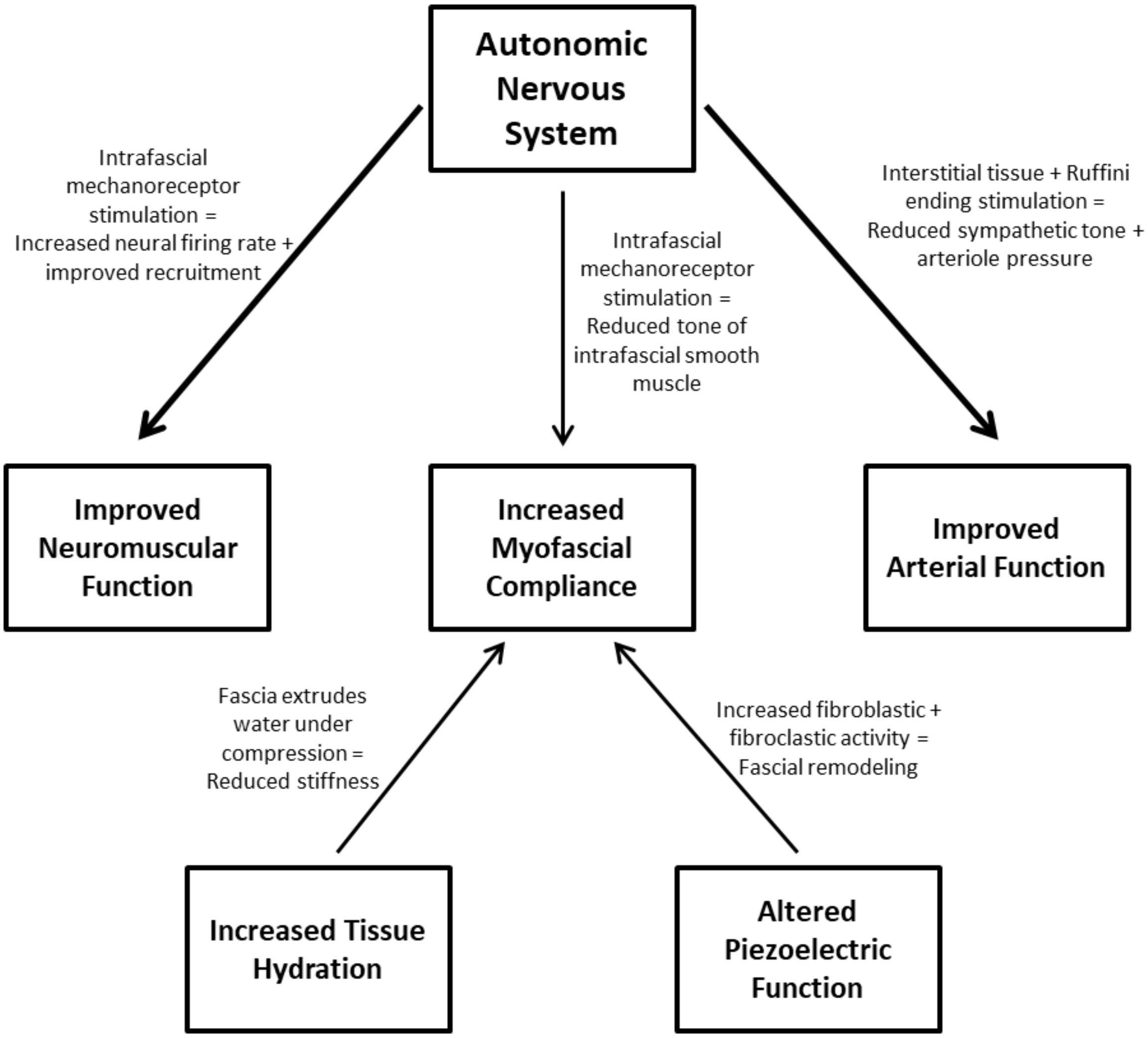

Figure 2. The Proposed Physiological and Mechanical Effects of Self-Myofascial Release

EFFECTS ON PHYSICAL PERFORMANCE

Manual therapy has become increasingly popular amongst sports medicine practitioners, strength and conditioning coaches and athletes all over the world. The aim is to promote efficient movement by improving ROM and muscular function, as better movement efficiency is associated with a lower risk of injury (Mauntel et al., 2014). More and more athletes and coaches are using manual therapy in the form of SMR or foam rolling as an easy and cost-effective way to achieve this aim (Schroder and Best, 2015). The following section will review the evidence for SMR in improving ROM, muscle performance, post-exercise muscle soreness, balance and stress.

See Table 1 for a summary of the literature.

Range of Movement (ROM) and Flexibility

This is by far the most researched effect of SMR, with multiple studies demonstrating improvements in ROM after SMR for the ankle, hip, knee, hamstring and lumbar areas (Bradbury-Squires et al., 2015; Bushell et al., 2015; Halperin et al., 2014; Jay et al., 2014; Peacock et al., 2015; MacDonald et al., 2013; MacDonald et al., 2014; Mohr et al., 2014; Sullivan et al., 2013; Grieve et al., 2015; Kelly & Beardsley, 2016). However, there are also studies detailing no beneficial effects on ROM (Couture et al., 2015; Peacock et al., 2014; Skarabot et al., 2015).

Mauntel et al. (2014) published a systematic review that looked at the effectiveness of multiple myofascial release techniques on joint ROM, muscle force, and muscle activation. They included active release technique (ART), trigger point therapy, SMR, and positional release therapy, and the authors found that collectively, these therapies resulted in a significant improvement in ROM but no significant improvements in muscle function after application.

Bushell et al. (2015) looked specifically at hip extension ROM in the lunge position after foam rolling the anterior thigh. Participants underwent three testing sessions, all one week apart, with foam rolling taking place in sessions 1 and 2 as well as in the week between those sessions. No rolling was performed between sessions 2 and 3. The authors found a significant improvement in hip extension ROM in session 2, but this returned to baseline at session 3. They concluded that consistent foam rolling of the anterior thigh muscles is beneficial in improving hip extension ROM, although this effect seems to disappear when SMR is suspended. Jay et al. (2014) echo this finding in their study of sit-and-reach ROM after SMR of the hamstrings after exercise. They found that ROM improvements did not persist past 10 minutes. In another study, Kelly and Beardsley (2016) note that although ankle dorsiflexion after SMR of the calf lasted approximately 20 minutes, measurements were already returning to baseline after 10 minutes. Similar short-term effects have been shown by MacDonald et al. (2013), Skarabot et al. (2015) and Halperin et al. (2014), which suggests a short-lived effect on ROM after SMR. Perhaps regular SMR over a longer period would result in longer-lasting improvements as scar tissue or myofascial restrictions are broken down over time, but longer-term studies are needed to determine whether this is the case.

The evidence suggests a dose-dependent effect on ROM. In the systematic review by Mauntel et al. (2014), the authors found that although increases in ROM were evident with as little as 20 seconds of myofascial release, improvements were more common with longer durations of treatment ranging from 1.5 to 3 minutes. Sullivan et al. (2013) demonstrated greater improvements in sit-and-reach ROM with 10 second bouts of SMR as opposed to 5 second bouts. Bradbury-Squires et al. (2015) revealed that 20 seconds and 60 seconds of quadriceps rolling increased knee flexion ROM by 10% and 16%, respectively. Greater ROM improvements in the 60-seconds group may be explained by this dose-dependent effect of myofascial release on connective tissue, with longer and more forceful applications resulting in a greater increase in fascial release (Schleip, 2003a).

Bradbury-Squires et al. (2015) also measured maximal isometric voluntary contraction (MIVC) and found that during the SMR, electromyography (EMG) activity in the quadriceps and hamstrings was 7-8% of MIVC. The researchers postulated that this may have been due to increased pain perception, especially with longer durations, as the discomfort associated with foam rolling can be high. These low-level contractions may have helped relax the muscles by releasing heat, which reduces muscle and connective tissue viscoelasticity and thereby increases blood flow. They may also have turned fascia from a solid ‘gel’ to a fluid ‘sol’ state (Cheathem et al., 2015). Moreover, these micro-contractions might have increased ROM in the same manner as contract-relax proprioceptive neuromuscular facilitation (PNF) techniques (Sharman et al., 2006).

Table 1. Summary of the Literature

Study/Authors	Type of Study	Subjects	Intervention	Variables Studied	Outcome Measures	Findings
Bradbury-Squires et al. (2015)	Within-subjects design	N = 10 (10M)	Quadriceps FR for 5 × 20 sec OR 5 × 60 sec	Pain during FR Muscle performance ROM	- VAS - EMG VL and BF during rolling - Knee flexion ROM	- Increased pain perception with longer durations of rolling - VL and BF EMG 7-8% of MVIC during rolling - Lower VL EMG during lunge - Increased ROM with longer durations of rolling
Bushell et al. (2015)	RCT	N = 31 (12M 2F)	FR anterior thigh for 3 × 60 sec OR No FR	ROM	Hip extension ROM in lunge	FR increased hip extension ROM
Couture et al. (2015)	Within-subjects design	N = 33 (14M 19F)	FR hamstrings for 2 × 10 sec OR 4 × 30 sec	ROM	Passive knee extension ROM	Neither intervention improved ROM
Grieve at al. (2015)	Pilot RCT	N = 24 (8M 16F)	Foam rolling plantar surface of foot OR No FR	ROM	Sit-and-reach for hamstring and lumbar spine flexibility	Improved sit-and-reach ROM after FR
Do et al. (2016)	RCT	N = 31(19M 12F)	FR plantar surface of foot for 5 min OR Passive ankle mobilisation	ROM	- Toe touch test - Passive SLR	Significant improvement after FR for both outcome measures
Halperin et al. (2014)	Randomised crossover design	N = 14 (12M 2F)	3 × 30 sec FR plantarflexors OR 3 × 30 sec SS plantarflexors	Muscle performance Balance ROM	- MVC force and F100 - EMG soleus, tibialis anterior - Single limb balance - DF ROM in lunge	- FR improved MVC force compared to SS - No significant effects on F100, EMG or balance - Both interventions improved DF ROM similarly
Healey et al. (2014)	Randomised crossover design	N = 26 (13M 13F)	30 sec FR to lower limbs and back OR Multiple reps of 30 sec planking	Muscle performance	- Vertical jump height - Vertical jump power - Pro-agility test - Isometric squat force	- Neither intervention had any effect on performance measures - Increased fatigue after planking
Jay et al. (2014)	Randomised crossover design	N = 22 (22M)	FR lower limb for 10 min after inducing DOMS in hamstrings OR No FR	Pain ROM	- VAS and PPT - Single leg sit-and-reach for hamstring flexibility	- Reduced VAS and increased PPT after FR - Reduced soreness in contralateral limb - Increased ROM after FR
Peacock et al. (2014)	Crossover within-subjects design	N = 11 (11M)	Dynamic warm-up + total body FR OR Dynamic warmup alone	ROM Muscle performance	- Sit-and-reach test - Vertical jump - Standing long jump - Pro-agility test - Indirect 1-RM bench test - 37m sprint	- No difference in ROM - Significant improvement in all performance measures after FR

Table 1. continued

Peacock et al. (2015)	Within-subjects design	N = 16 (16M)	Foam rolling body along a mediolateral axis OR anteroposterior axis	ROM Muscle performance	- Sit-and-reach test - Vertical jump - Broad jump - Pro-agility test - Bench press	- Significant increase in ROM after mediolateral FR - No significant difference between groups on performance measures
MacDonald et al. (2013)	Within-subjects design	N = 11 (11M)	FR quadriceps 2 × 1 min OR No FR	ROM Muscle performance	- Knee flexion ROM in kneeling lunge - Knee extensor force - RFD - EMG quadriceps	- Increased knee flexion ROM after FR at 2 and 10 min - No effect on performance measures in either group
MacDonald et al. (2014)	RCT	N = 20 (20M)	FR thigh and gluteals for 2 × 60 sec OR No FR	Muscle soreness ROM Muscle performance	- BS11 Numerical Rating Scale - Quadriceps and hamstring ROM - PTF - EMD - RFD - Voluntary muscle activation - MVC isometric knee extension - Vertical jump height	- FR reduced muscle soreness after inducing DOMS - Improved ROM after FR - Decrements in PTF and RFD after FR - Shorter (improved) EMD after FR - Greater muscle activation after FR - No difference in MVC between groups - Improved vertical jump height after FR
Mikesky et al. (2002)	Within-subjects design	N = 30 (7M 23F)	2 min of FR with The Stick OR Visualisation OR Mock electrical stimulation	ROM Muscle performance	- Hamstring flexibility - Vertical jump - Isokinetic concentric knee extension - Flying-start 20-yard-dash	No performance measures affected significantly by FR with The Stick although there was a trend towards improved 20-yard-dash with FR
Mohr et al. (2014)	RCT	N = 40 (40M)	60 sec FR posterior thigh OR SS OR FR + SS	ROM	Passive hip flexion ROM	Increased ROM after all interventions, FR +SS showed the greatest improvement
Okamoto et al. (2014)	Randomised control crossover design	N = 10 (7M 3F)	20 reps of FR on adductors, hamstrings, quadriceps, iliotibial band, and trapezius	Vascular function	- Brachial-ankle pulse wave velocity (baPWV) - Plasma nitric oxide (NO) concentration	FR produced acute improvements in baPWV and NO
Pearcey et al. (2015)	Randomised crossover design	N = 8 (8M)	20 min FR lower limbs after inducing DOMS OR No FR	Pain Muscle performance	- PPT - 30 m sprint - Standing broad jump - Change-of-direction T-test - Barbell back squats	- FR increased PPT 24 and 48 hrs after DOMS - FR resulted in less of a decline in performance of 30 m sprint, standing broad jump and back squats after inducing DOMS

Table 1. continued

Skarabot et al. (2015)	Randomised crossover design	N = 11 (6M 5F)	3 × 30 sec FR of calf OR SS OR FR + SS	ROM	Passive ankle DF ROM	- Improved ROM after FR+SS and SS, greater increase with FR+SS - No improvement with FR alone.
Sullivan et al. (2013)	Within-study design	N = 17 (7M 10F)	FR machine on hamstrings for 1 × 5 sec, 1 × 10 sec, 2 × 5 sec and 2 × 10 sec OR No FR	ROM Muscle performance	- Sit-and-reach test - MVC and muscle activation	- All interventions increased ROM with greater increases with 10 sec bouts - No significant differences in MVC or muscle activation
Kelly and Beardsley (2016)	Randomised controlled within-study design	N = 26 (16M 10F)	FR calf for 3 × 30 sec OR No FR	ROM	Ankle DF ROM in lunge	- FR improved ROM in FR leg up to 20 min - FR improved ROM in contralateral leg up to 10min
Kim et al. (2014)	RCT	N = 20 (20F)	30 min FR OR 30 min rest	Stress	Cortisol secretion	Significantly reduced cortisol secretion in both groups
Chan et al. (2015)	Retrospective case-control	N = 63	6 sessions over 2-weeks with physical modalities (heat and TENS) + home self-massage and exercise program OR 6 sessions over 2 weeks with physical modalities	Pain Function	- PPT - NDI - PSFS - HRV	- Significant reductions in pain with added home program - Significant improvement in NDI and PSFS with added home program - Significant increase in HRV with added home program

Key:

FR = foam rolling; ROM = range of movement; VL = vastus lateralis; BF = biceps femoris; MVIC = maximal voluntary isometric contraction; EMG = electromyography; DOMS = delayed onset muscle soreness; SLR = straight leg raise; SS = static stretching; DF = dorsiflexion; MVC = maximal voluntary contraction; F100 = force produced in the first 100 ms of the MVC; VAS = visual analog scale; PPT = pain pressure threshold; 1-RM = 1 repetition maximum; PTF = peak twitch force; EMD = electromechanical delay; RFD = rate of force development; SMR = self-myofascial; TENS = transcutaneous electrical nerve stimulation; NDI = neck disability index; PSFS = patient-specific functional scales; HRV = heart rate variability.

It must also be noted that both the density of the roller and individual technique determine the amount of pressure applied to the tissue (Curran et al., 2008). One of the studies (Couture et al., 2015) demonstrating no effect on ROM utilized lower density foam rollers than those in the aforementioned studies showing ROM benefits, and therefore may not have introduced enough pressure into the tissues to create any change. Although participants were instructed in foam rolling technique, individual pressure on the roller was neither monitored nor standardized, making differing pressures amongst the participants likely. Two studies (Bradbury-Squires et al., 2015; Sullivan et al., 2013) which applied a constant pressure of 25% and 20% of bodyweight through the use of specialized devices found significant increases in knee flexion and sit-and-reach ROM, respectively. Although these specialized pieces of equipment do not mimic everyday life, it is important to take pressure into account as this may change the effectiveness of the SMR technique.

Historically, static stretching has been the preferred method to increase ROM, but this method has been associated with decreased sporting performance (Simic and Markovic, 2013; Kay and Blazevich, 2012). Several studies have compared or combined the two interventions (Halperin et al., 2014; Mohr et al., 2014; Skarabot et al., 2015). Each has shown improved ROM with both static stretching and SMR, with the latter two papers demonstrating a larger increase with the two interventions combined. However, these effects were short-lived nonetheless and not maintained past 10 minutes. Additionally, Halperin et al. (2014) found increases in maximal voluntary contraction (MVC) in the SMR group. Thus, SMR combined with static stretching appears to have an additive effect on increasing ROM. However, SMR may be the preferred method before sporting activity as it is not associated with the same decrements in performance, and in some cases, it actually improves aspects of physical performance. This is discussed in the next section.

Muscle Performance

There have been multiple studies looking at the effect of SMR on athletic performance measures (Mikesky et al., 2002; Sullivan et al., 2014; Healey et al., 2014; MacDonald et al., 2014; Halperin et al., 2014; Peacock et al., 2014; Bradbury-Squires et al., 2015), and although not all show an improvement, none show any negative effects on muscle performance. This means that at its worst, SMR is not detrimental to physical performance. The exact mechanisms by which foam rolling improves muscular performance is unclear, but it has been suggested that it may work by reducing neural inhibition, which enhances the communication from afferent receptors in the connective tissue (Barnes, 1997). This would explain Bradbury-Squires et al. (2013) finding of improved neuromuscular efficiency as demonstrated by reduced vastus lateralis EMG during a lunge after SMR of the quadriceps.

Healey et al. (2014) examined performance on four athletic tests—isometric squat strength, vertical jump height, vertical jump for power, and the 5-10-5 shuttle run. The tests were conducted in two groups. The first group underwent a standard dynamic warmup and foam rolling session for the quadriceps, hamstrings, calves, latissimus dorsi, and rhomboids. The second group participated in a dynamic warmup followed by 3 minutes of a front plank exercise. No significant difference was seen between groups in results of the athletic tests, but less post-intervention fatigue was reported in the foam rolling group. This may be due to the front plank exercise requiring more muscle co-contraction.

Although Healey et al. (2014) used a dense roller, which should have exerted enough pressure into the tissues; each muscle was rolled for only 30 seconds. This may not have been long enough to effect a change within the myofascial environment. Sullivan et al. (2013) used 5 and 10 second bouts (1-2 times) for hamstring SMR and, although ROM improved, the authors found no significant differences in maximal voluntary contraction (MVC) or muscle activation. Overall, it should be noted that studies demonstrating improvements in muscle performance measures have used interventions of at least 100 seconds (Bradbury-

Squires et al., 2015; Pearcey et al., 2015; MacDonald et al., 2014; Halperin et al., 2014). Peacock et al. (2014) investigated physical performance on multiple tests and found that when compared to a dynamic warmup alone, a bout of full-body foam rolling along with a dynamic warmup significantly improved power, agility, speed and strength as measured by vertical jump, standing long jump, indirect 1-RM bench press, pro-agility test and 37m sprint.

Conversely, Mikesky et al. (2002) conducted SMR on the gluteal muscles, hamstrings, quadriceps and calves using an apparatus called The Stick for at least 2 minutes. Sitting subjects used their upper limbs instead of body weight to apply force to the tissue, which significantly reduced the pressure applied to the muscles and perhaps limited the extent to which fascia turned from ‘gel’ to ‘sol’. Although Mikesky et al. (2002) found no significant differences in ROM or muscle performance measures, there was a trend towards an improved 20-yard dash after SMR.

Thus, the effect on muscle performance might only be seen with longer bouts on the foam roller with enough pressure to effect tissue change. Although Healey et al. (2014), Sullivan et al. (2013) and MacDonald et al. (2013) showed no negative or positive changes regarding muscle performance parameters after SMR, they did demonstrate an increase in ROM. As mentioned in the previous section, this could make foam rolling before an athletic event (to improve ROM) an alternative to static stretching, which has been shown to reduce aspects of neuromuscular performance (Behm et al., 2004).

There is also the question of which muscles to foam roll in order to achieve beneficial effects. Peacock et al. (2015) compared the effects of rolling the body along a mediolateral axis versus an anteroposterior axis. Improvements in sit-and-reach ROM were only found when rolling along the mediolateral axis, which included the calves, hamstrings, gluteals and lower spine muscles. As these are the muscles which one would want to lengthen in order to increase sit-and-reach ROM, it follows that the muscles which one desires to be more flexible should be targeted when focusing on ROM. Interestingly, both conditions demonstrated a significant improvement in physical performance measures, suggesting that the increase in muscle performance may be less structure-specific and due instead to a widespread increase in neuromuscular stimulation.

Delayed Onset Muscle Soreness (DOMS)

It is thought that DOMS, or mild to severe muscle soreness felt after unaccustomed exercise, is caused by damage to muscle and connective tissue. It has been shown to negatively impact physical performance and delay recovery after exercise (Jay et al., 2014; Byrne et al., 2004). Pearcey et al. (2015) add that the detrimental effects on athletic performance include reduced joint proprioception and ROM, overestimation of force production, reduced strength and power, changes in agonist and antagonist strength ratios, alterations in recruitment patterns, compensatory movement patterns, and a higher risk of injury. SMR is suggested to promote recovery and optimize performance after DOMS by influencing the damaged connective tissues through increasing blood flow, which in turn promotes blood lactate removal, oedema reduction, and tissue healing and oxygen delivery to the muscle (Cheathem et al., 2015, Pearcey et al., 2015).

With increasing numbers of people participating in exercise, there has also been a considerable rise in the popularity of SMR amongst active individuals wishing to enhance recovery, reduce DOMS, and improve physical performance in a manner that allows them to exercise harder and longer. However, there is currently no consensus on the parameters needed to achieve these effects (Schroeder and Best, 2015; Cheathem et al., 2015).

Pearcey et al. (2015) induced DOMS in a small group of eight males and compared a control condition (in which no SMR took place) with 20 minutes of SMR after the exercise protocol. They found that participants in the intervention group had a higher pain pressure threshold up to 48 hours after inducing DOMS, and experienced less of a decline in athletic performance measures comprised of a 30m sprint test, standing broad jump, change-of-direction T-test, and barbell back squats. Similarly, two slightly larger studies by MacDonald et al. (2014) and Jay et al. (2014) found reduced muscle soreness when SMR was included after inducing DOMS, although SMR protocols differed between the studies. Interestingly, Jay et al. (2014) also reported reduced muscle soreness in the contralateral non-massaged limb, which points to more of an autonomic nervous system contribution to reduced pain. These findings may prove useful to athletes participating in multiple or successive events where a quick recovery is desirable, and may allow athletes to increase their training volumes by promoting recovery.

A reduction in DOMS after foam rolling may also have beneficial psychological effects akin to those experienced after massage, namely reduced stress/anxiety, elevated mood, and improved perception of recovery and relaxation (Arroyo-Marales et al., 2008; Tani et al., 2017; Hemmings, 2000). However, the discomfort associated with SMR can be high (Bradbury-Squires et al., 2013; MacDonald et al., 2014), and this may deter individuals from wanting to engage in SMR for fear of pain. In these cases, individuals should be educated as to the beneficial effects of SMR and assured that the temporary discomfort is worth the eventual positive outcomes.

Balance

Few studies have looked at the effect of SMR on balance. Halperin et al. (2014) found no effects on balance after either foam rolling or static stretching, which may be due to the complex nature of balance and the multiple systems feeding into it; i.e. somatosensory, visual and vestibular systems (Grace Gaerlan et al., 2012). SMR may conceivably have an effect on the somatosensory system by stimulating intrafascial mechanoreceptors, but will most likely have no effect on the other two. More research is needed to definitively determine the effect of SMR on balance.

EFFECT ON STRESS

Cortisol is a hormone released by the adrenal glands when under stress, and higher levels of psychological and physical stress are associated with increased cortisol secretion (Tani et al., 2017; Burke et al., 2005). One prominent study that looked at the effect of SMR on stress found that both 30 minutes of foam rolling and 30 minutes of rest significantly reduced cortisol secretion (Kim et al., 2014). Although there was no difference between groups, the results suggest that SMR may be a useful adjunct in dealing with stress and attenuating the effects of stress on the body in conditions like coronary heart disease, post-traumatic stress disorder, autoimmune conditions, and mental health disorders. There is a distinct lack of literature investigating the effects of SMR on stress, and further studies which address specific SMR parameters and its effects on various measurements of stress (e.g., cortisol secretion, perceived stress scales, and mood state or sleep disturbance questionnaires) would add to this body of literature.

CONCLUSION AND RECOMMENDATIONS

SMR is a cost-effective alternative to clinician-led massage and has been shown to improve ROM, flexibility, and aspects of muscle performance. It is the preferred method to increase ROM before sporting activities, as static stretching has been shown to negatively affect muscle performance. Nevertheless, it must be noted that SMR combined with static stretching seems to result in greater increases in ROM. A corresponding suggestion is to use SMR before training and static stretching after completion to maintain or improve ROM. SMR also appears to reduce the effects of DOMS after exercise and allow for a quicker recovery and faster return to exercise. This is especially relevant to athletes with intense training schedules and those participating in multi-day events.

Although most research shows an immediate improvement in ROM after SMR, these effects are not maintained past 30 minutes and the magnitude of effect appears to be mediated by duration, pressure applied and individual technique. There is an acute lack of studies dealing with the long-term effects of regular SMR. It may be that changes in ROM last longer with more frequent bouts of SMR as fascial restrictions are broken down over time, but it is beyond the scope of the current short-term literature to verify this assertion. Longer-term studies would be useful in determining both the long-term effect of SMR ROM, but also its effect on variables like match statistics and injury rates.

There is little homogeneity amongst current research regarding type of roller, pressure applied, duration, repetitions, sets, frequency or cadence of rolling. This makes it difficult to conclude which parameters should be used to achieve beneficial results. Accordingly, more elaborate high-quality studies which repeat some of the protocols of the current body of research would provide more insight in this regard.

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Conflict of Interests

The author declares no conflict of interest.

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