THE EFFECTS OF PRESSURE DURING FOAM ROLLING ON DELAYED-ONSET MUSCLE SORENESS AND RANGE OF MOTION

A Thesis

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Kevin Michael Lennon

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Department of Kinesiology

Abstract

of

THE EFFECTS OF PRESSURE DURING FOAM ROLLING ON DELAYED-ONSET MUSCLE SORENESS AND RANGE OF MOTION

by

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Introduction

Self-myofascial release (SMR) in the form of foam rolling has shown to have positive effects on delayed-onset muscle soreness (DOMS), range of motion (ROM) and athletic performance measures. Specific parameters related to foam rolling may provide a quicker recovery of measures such as range of motion, muscle soreness and overall athletic performance.

Purpose

Assess the effectiveness of different applied pressures during a session of foam rolling on range of motion and delayed-onset muscle soreness.

Methods

Twelve healthy female subjects from a university Division I soccer program volunteered to participate in the study. The effectiveness of two different pressures were measured using a Visual Analog Scale (VAS) for muscle soreness and a weight-bearing lunge for ankle range of motion (ROM). Participants performed a delayed onset muscle soreness (DOMS) protocol consisting of two sets of concentric/eccentric calf raises on a single leg until failure. Following, subjects performed either performed Single-leg (light pressure) or Double-leg (deep pressure) foam rolling treatment based upon their group. Each foam rolling treatment consisted of three sets of 30 seconds with a rest interval of 30 seconds between sets. Measurements were collected for muscle soreness and ROM at 0, 24 and 48 hours post-DOMS. The following week the protocol was repeated on the opposite leg with the opposite treatment. A repeated measure two-way ANOVA was used to calculated significance between time and treatment for both foam rolling treatments. Paired T-tests with a Bonferroni correction were used to further investigate any significant values at specific data collection marks.

Results

Two-way ANOVA results showed a significant interaction effect for treatment and time on ROM. Analysis revealed significant (P= .006) improvements in ROM for light pressure at 48-hours post muscle damage in comparison to deep pressure.

Two-way ANOVA results show no significant interaction effect (P=.965) between time and treatment for the VAS scores. The main effect for treatment was not significant (p=.254). The main effect for time reached a significant value (p=.001). For time, from baseline VAS scores post muscle damage a significant increase was observed (p=.0002). VAS scores remained elevated at 24-hours and decreased to baseline levels by 48-hours.

Conclusion

The results of the study suggest light pressure helps improve ROM at 48-hours compared to deep pressure, but pressure does not have an effect on VAS.

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Chapter 1

INTRODUCTION

Foam rolling is a type of self-myofascial release (SMR) and is an alternative modality proposing an increase in acute range of motion, athletic performance and delayed onset muscle soreness, also known as DOMS (MacDonald, Button, Drinkwater, Behm, 2013b; Skarabot, Beardsley, Stirn, 2015; Mohr, Long, Goad, 2014; Cheatham, Kolber, Cain, Lee, 2015; MacDonald et. al., 2013a; Pearcey et. al, 2015; Peacock, Krein, Silver, Sanders, Von Carlowitz, 2014; Bushell, Dawson, Webster, 2015; Courture, Karlik, Glass, Hatzel, 2015). Through foam rolling, SMR adds pressure to the underlying soft tissue, creating similarities between this treatment modality and massage. Many of the perceived benefits of foam rolling are derived from massage. During a bout of foam rolling individuals use their own body mass to exert pressure on soft tissues (Cheatham, et. al., 2015). This pressure exertion can be considered a self-induced massage because the body pressure resembles the pressure exerted on the muscles through manual manipulation by a massage therapist (Pearcey et. al., 2015).

Varying types of massage have shown to increase blood flow related to inflammation, provide muscle inhibition and increase muscle regrowth (Weerapong, Hume, Kolt, 2005; Golberg, Sullivan, Seaborne, 1992; Morelli, Seaborne, Sullivan, 1990; Miller et. al., 2017; Waters-Bankers, Dupont-Versteegden, Kitzman, Butterfield, 2014; Crane et. al., 2012). Furthermore, massage has shown decreases in muscle soreness, while increasing range of motion (ROM) and athletic performance (McKechnie, Young, Behm, 2007; Clarkson & Sayers, 1999; Farr, Nottle, Nosaka, Sacco, 2002; Hilbert, Sforzo, Swensen, 2003). A great deal of research has been focused on the physical effects of foam rolling, similar to that of massage. Results have shown, in congruence with static or dynamic stretching, foam rolling has acute effects on ROM but no long term effects noted (MacDonald et. al., 2013b; Skarabot et. al., 2015; Mohr et. al., 2014; Cheatham et. al., 2015). Additionally, there have been increases in ROM without a decrease in force production when foam rolling (MacDonald et. al., 2013a). Foam rolling has also shown increases in athletic performance in relation to power, speed and agility (MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014). It also seems to quicken the recovery from DOMS (MacDonald et. al., 2013b, Cheatham et. al., 2015; Pearcey et. al., 2015).

Significant results have been noted related to ROM, athletic performance and muscle recovery, but there has been a lack of focus and control on the application parameters related to foam rolling. In order to truly show effectiveness, a protocol for the application of foam rolling needs to be created. Various application protocols exist, but each one differs in relation to body part, duration, undulation frequency and pressure. Location of each protocol specified muscle groups such as: hamstrings, quadriceps, triceps surae, or as general as full body SMR (MacDonald et. al., 2013a; Skarabot et. al., 2015; Mohr et. al., 2014; MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014; Bushell et. al., 2015; Courture et. al., 2015; Hotfiel et. al., 2016). The application parameter which received the most control was duration. The duration lengths for any bout of SMR ranged from 1-3 sets of 30 seconds to 1 minute (MacDonald et. al., 2013b; Skarabot et. al., 2015; Mohr et. al., 2014; MacDonald et. al., 2013a; Pearcey et. al., 2015;

Peacock et. al., 2014; Bushell et. al., 2015; Courture et. al., 2015; Hotfiel et. al., 2016), with even less focus on undulation frequency. Most research studies specified no control for their protocols (MacDonald et. al., 2013b; Skarabot et. al., 2015; Bushell et. al., 2015), further complicating the understanding of foam rolling. Nonetheless, three studies controlled the rolling frequency ranging from 1 second to 6 seconds (Mohr et. al., 2014; MacDonald et. al., 2013a; Peacock et. al., 2014; Hotfiel et. al., 2016), where two additional studies controlled the frequency using a metronome (Pearcey et. al., 2015; Courture et. al., 2015). In the articles which chose to control frequency, each article lacked reasoning for the specific frequency chosen.

Lastly, the application control which has little to no research in relation to foam rolling is pressure exertion on the underlying tissue. One article researched the comparison of pressure exertion by two different types of foam rollers (Curran, Fiore, Crisco, 2008). They were able to determine a PVC pipe, as known as a rigid foam roller, significantly increased the pressure applied to underlying tissue when compared to a bio-foam foam roller. While this article is important for establishing the best way to increase pressure during foam rolling, the researchers did not look at how the different exerted pressures may affect the muscle from a functional or performance standpoint. Another article used a force plate as a measurement of pressure-pain-threshold for subjects (MacDonald et. al., 2013b). The use of a force plate allowed the authors to gain a baseline pressure exertion. Once baseline measures were collected, the subjects performed the DOMS protocol to induce soreness. Post-DOMS and foam rolling protocol, the researchers determined the foam rolling subjects returned to exerted baseline pressures sooner than the control (MacDonald et. al., 2013b). This provides an emphasis in relation to foam rolling as a recovery from muscle soreness. In addition, a roller massager treatment quantified the pressure exerted on soft tissue as 13 kilograms of force, with the groups being separated by duration and sets (Sullivan, Silvey, Button, Behm, 2013). While this study provided a consistent pressure during treatment, the primary focus was the duration of the roller massager treatment. These are the only studies attempting to quantify pressure exertion while foam rolling. Although these studies provided a value for exerted pressure, they did not examine how their specific pressure may affect the underlying tissue.

Since foam rolling is a relatively new treatment modality and lacks consistent research in relation to parameter controls, individuals can only assume its effectiveness. With little emphasis on the application parameters, it is crucial a protocol be developed, researched and replicated to further identify foam rolling as an effective treatment modality. If there are notable differences in relation to effectiveness when using performing deeper massage pressures, the results could be similar for foam rolling. A more focused approach regarding foam rolling application parameters, specifically pressure exertion, can hopefully identify a consensus relating to the physical and physiological state of muscle.

Purpose

To assess the effectiveness of different applied pressures during a session of foam rolling on range of motion and delayed-onset muscle soreness in NCAA Division 1 female soccer players.

Significance

Attempt to develop a better understanding of the effectiveness of different application parameters related to foam rolling and to establish the importance of why application parameter controls are needed.

Definition of Terms

Massage- A mechanical manipulation of body tissues with rhythmical pressure and stroking for promoting health and well-being (Weerapong et. al., 2005)

Foam rolling- A Self-myofascial release technique where the individual uses their own body pressure to provide soft-tissue manipulation through small undulations working proximal to distal across the muscle belly (MacDonald et. al., 2013a)

Hoffman's Reflex(H-reflex)- Hoffman's reflex measures the changes neuromuscular excitability (Weerapong et. al., 2005)

Muscle Inhibition- A decrease in muscular tension in relation to Hoffman's reflex (Goldberg et. al., 1992)

Delayed-onset muscle soreness(DOMS)- Classified as a Type 1 muscle strain which produces tenderness and stiffness to movement and palpation which seems to be amplified with uncustomary exercise (Pearcey et. al., 2015)

Maximal Voluntary Contraction(MVC)- The ability to produce the maximal force of a muscle, as quickly as possible (MacDonald et. al., 2013a)

Undulation Frequency- The action of moving the body part by placing direct and sweeping pressure on the soft-tissue, starting at a proximal bony landmark moving down to the distal landmark of the muscle attachment (MacDonald et. al., 2013a)

Delimitations

Subject Population- All females; College age (18-22 years); NCAA Division 1 soccer players

Body Part- Treatment intervention was performed on the left and right calf muscles for each individual

Time of Treatment- Acuteness; Research was performed during offseason of the 2017 Spring semester, Per NCAA rules and regulations, time limit restrictions are placed on practices for offseason sports preventing accessory activity during data collection

Foam Rolling Device- A hollow PVC pipe with a diameter 4-inches was used to provide the maximal pressure on the muscle (Curran et. al., 2008)

Foam Rolling Application Parameters- 3 sets of 30 seconds, with 30 seconds of rest between sets (MacDonald et. al., 2013a; Skarabot et. al., 2015; Mohr et. al., 2014; MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014; Bushell et. al., 2015; Courture et. al., 2015; Hotfiel et. al., 2016); Undulation frequency controlled using a metronome at 60 rolls per minute (Pearcey et. al., 2015; Courture et. al., 2015)

Limitations

Subject Population- Cannot control aspects of daily living, i.e. activity level or food intake that may affect DOMS

Foam Rolling Experience- Some subjects may be experienced in foam rolling (technique, sensation, rhythm), while others may only know the concept

DOMS- The subjective use of a pain scale, subjects may respond differently to varying levels of soreness

Histological Measures- No blood draws were conducted post-DOMS treatment to measure blood markers related to the inflammatory process (Miller et. al., 2017; Butterfield, Zhao, Agarwal, Haq, Best, 2008; Okamoto, Masuhara, Ikuta, 2013)

Hypotheses

Hypothesis 1: Foam rolling using deep pressure will have no greater effect than light pressure on range of motion.

Hypothesis 2: Foam rolling using deep pressure will have no greater effect than light pressure on delayed-onset muscle soreness.

Chapter 2

REVIEW OF LITERATURE

Athletes and the general public alike may suffer from pain and soreness in relation to exercise. As the type and intensity of exercise increases, this pain and soreness may become worse and effect muscular function (Weerapong et. al., 2005). There are several treatment modalities which can help combat exercise-induced ailments. Self-myofascial release (SMR), in the form of foam rolling, is a popular intervention used by rehabilitation and fitness professionals to enhance mobility (Fieldbauer, Smith, Van Lunen, 2015). Pressure is exerted onto soft tissue in a rolling motion in an effort to enhance recovery and performance with both the physiological and physical effects (Cheatham et. al., 2015). Specifically, researchers have found evidence that foam rolling can enhance joint range of motion (ROM), post-exercise performance and decrease acute muscle soreness and delayed-onset muscle soreness (DOMS) (McKechnie et. al., 2007; Clarkson et. al., 1999; Farr et. al., 2002; Hilbert et. al., 2003; MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014; Cheatham et. al., 2015). Furthermore, massage is believed to benefit athletes by enhancing performance and recovery through biomechanical, physiological, neurological, and psychological mechanisms (Weerapong et. al., 2005).

Since foam rolling is performed by applying pressure on soft tissue, its effectiveness may be related to the effects of massage. Massage involves the application of mechanical pressure on the muscle tissue (Weerapong et. al., 2005). In addition, research has shown massage has positive benefits in relation to blood flow, ROM, muscle recovery and performance (Weerapong et. al., 2005; Waters-Banker et. al., 2014; Crane et. al., 2012). Research shows a decrease in muscle inhibition with varying pressures during massage and muscle regrowth (Golberg et. al., 1992; Morelli et. al.,1990; Miller et. al. 2017). Similar results have been noted throughout foam rolling research when dealing with ROM, performance and muscle recovery (MacDonald, et. al., 2013a; Skarabot et. al., 2015; Mohr et. al., 2014; Cheatham et. al., 2015; MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014; Bushell et. al. 2015; Courture et. al., 2015; Fieldbauer et. al., 2015; Sullivan et. al., 2013). The problem with current research regarding foam rolling is the lack of standard protocol to administer this form of self-induced massage. More specifically, there are inconsistencies in the application of foam rolling techniques when dealing with parameters such as duration, undulation frequency and pressure exertion. Unfortunately, without clear therapeutic protocols and inconsistent research, individuals must gain insight from the effectiveness of massage and apply it to foam rolling techniques.

Physiological Effects of Massage

Varying types of massage have shown to increase blood flow, provide neuromuscular inhibition and promote muscle regrowth (Weerapong et. al., 2005; Golberg et. al., 1992; Morelli et. al., 1990; Miller et. al., 2017; Butterfield et. al., 2008). In addition, massage also has effects the inflammatory process which may facilitate early recovery and pain relief (Crane et. al., 2012; Waters-Banker et. al., 2014). Weerapong et. al. (2005) gathered numerous articles related to the effects of massage. While many authors agree that massage could increase arterial blood flow, most studies were inconclusive due to design limitations. An increase in blood circulation was noted in several articles, but did not obtain any statistical significance (Weerapong et. al., 2005).

Muscle is made up of an intricate cellular matrix called cytoskeleton. This cytoskeleton structure contains mechanosensitive structures and when activated change the signal transduction within and between cells (Waters-Banker et. al., 2014). Through mechanotransduction, the transformation of a mechanical stimulus into a chemical signal, the effects of inflammation can be effected (Waters-Banker et. al., 2014). Butterfield et. al. (2008) examined the different effects of massage on the inflammatory process. The application of a 30-minute massage over 4 consecutive days on damaged rabbit muscle reduced cellular infiltration and tissue necrosis. The researchers found the treated muscles returned mechanical function quicker and histologically looked similar to non-exercised healthy muscle. These findings were compared to that of a non-massaged muscle (Butterfield et. al., 2008). Crane et. al. (2012) found massage attenuates the inflammatory process after exercise-induced muscle damage was performed. They used two separate muscle biopsies at 10-minutes and 2.5 hours' post-massage and found a decrease in different cellular markers related to inflammation. Miller et. al. (2017) researched the effectiveness of massage on enhancing muscle regrowth after atrophy of rat gastrocnemius muscles. The authors found a combination reloading and massage enhanced the cross-sectional area of the muscle through an increase in protein synthesis. A pilot study also showed as a delay in massage increases, the effectiveness to reduce secondary hypoxic injury decreases (Waters-Banker et. al., 2014).

In addition to blood flow and inflammation, varying pressures of massage application have led to an increase in neuromuscular inhibition. Goldberg et. al. (1992) used two different pressure intensities of massage to investigate the effects on Hoffman reflex (H-reflex). The H-reflex measures the changes neuromuscular excitability (Weerapong et. al. 2005). Their findings found a higher pressure provided a greater inhibitory response related to H-reflex. Morelli et. al. (1990) found similar results when studying the H-reflex of the triceps surae muscle group. The biggest difference found was the H-reflex decreased during massage, but returned immediately to baseline once the massage was complete. Even though H-reflex returned to baseline, the results provide useful information which may relate to SMR and muscle inhibition.

Physiological Effects of Foam Rolling

Some foam rolling studies have shown similarities with massage when dealing with muscle inhibition and the contractile properties of muscle, as well as arterial blood flow (MacDonald et. al., 2013a; Okamoto et. al., 2013; Hotfiel et. al., 2016). MacDonald et. al. (2013a) studied the effects of foam rolling as a recovery tool from an intense bout of exercise. One of the measured outcomes in this study was maximum voluntary contraction (MVC). The MVC of treatment and control group were compared after one session of foam rolling. The treatment group maintained muscle activation where the control group had decrements. It is important to note the ability to maintain the muscle contraction may be due to a decrease in muscle soreness noted with the treatment group (MacDonald et. al., 2013a). Okamoto et. al. (2013) researched the effects of SMR on pulse wave velocity(PWV) and nitric oxide(NO) concentration in the blood. These factors relate to arterial stiffness and vascular endothelial function. The authors found a 1-minute bout of foam rolling on each muscle group caused a significant decrease in PWV (1202 to 1073 cm*s) and an increase in NO concentration (20.4 to 34.4 umol*L) when compared to the control groups. This is evidence that foam rolling may have a positive effect on arterial function (Okamoto et. al., 2013). Similarly, Hotfiel et. al. (2016) examined the effects of foam rolling on arterial tissue perfusion using spectral and power Doppler ultrasound. Baseline values were collected prior to foam rolling. The subjects were instructed to foam roll for three sets of 45 seconds with Doppler values collected immediately after intervention and 30 minutes' post intervention. The authors found an increase in blood for directly after and 30 minutes' post intervention when compared to resting baseline measures (Hotfiel et. al., 2016).

Physical Effects of Massage

Although there is some debate on its efficacy, massage therapy is one of the most common treatment modalities for combating soft-tissue injuries (Curran et. al., 2008). The suggested benefits of massage, such as reducing soreness and promoting healing, may be a useful modality to enhance performance and prevent injury for athletes who use their muscle vigorously (Weerapong et. al., 2005).

Massage involves methodical pressure, friction and rubbing through various strokes such as effleurage, petrissage, tapotement and friction (McKechnie et. al., 2007). McKechnie et. al. (2007) researched the acute effects of two massage techniques on ankle joint flexibility and power. The authors had three groups, two massage groups consisting of petrissage, tapotement and a control. The authors found both massage groups increased in ankle flexibility by 3.7% and 3.2% respectively. There were no significant differences between the two massage treatment groups or for the concentric calf raise power measurements.

Delayed-onset muscle soreness commonly occurs between 24 and 72 hours when unaccustomed eccentric exercise is performed (Clarkson et. al., 1999). Farr et. al (2002) and Hilbert et. al. (2003) revealed the effectiveness of massage on DOMS, specifically at the 48-hour measurements post-exercise. Farr et. al. (2002) performed a 30-minute effleurage and petrissage massage treatment after treadmill walking. A significant decrease in DOMS was found at the 48-hour mark when compared to the control. These results were similar for Hilbert et. al. (2003). The authors performed 20-minute massage consisting of effleurage, tapotement and petrissage. Lightfoot et. al. (1997) did not find significance when a 10-minute petrissage massage was performed immediately and 24-hours after their DOMS protocol was completed (Lightfoot, Char, McDermont, Goya, 1997). The inconsistent results may deal with the different therapeutic protocols utilized, similar to foam rolling research. Furthermore, Weerapong et. al. (2005) found inconclusive research related to massage and performance. Several studies they reviewed showed performance increases in terms of the body's physiological response rather than performance testing measures. Therefore, the assumed performance increases and recovery is inferred from the increase in blood flow which may allow for quicker delivery of oxygen and help remove waste products after exercise (Weerapong et. al., 2005). Ultimately, the perceived benefits of massage on performance need to be examined further and provide a more detailed focus upon athletic performance measures.

Physical Effects of Foam Rolling

While positive physiological effects of foam rolling have been noted, more advantageous research has been conducted on the physical effects. One major topic related to foam rolling is the concept of increasing ROM. Results have shown, in congruence with static or dynamic stretching, foam rolling has acute effects on ROM but no long-term effects (MacDonald et. al., 2013b; Skarabot et. al., 2015; Mohr et. al., 2014; Cheatham et. al., 2015). MacDonald et. al. (2013b) noted increases in range of motion for both passive and dynamic measures. Skarabot et. al. (2015) noted a larger increase in ROM for the static stretching-foam roll group when compared to static stretching and foam rolling separately. These results were similar to Mohr et. al. (2014) which chose to look at passive hip-flexion ROM when combining static stretching and foam rolling. Through systematic review, Cheatham et. al. (2015) gathered information from 14 articles and concluded different SMR techniques, either foam rolling or a roller massager, have short-term benefits on ROM, with little research on long-term benefits. They noted foam rolling is more effective when combined with static stretching or a dynamic warm-up. Furthermore, there have been increases in ROM without a decrease in force production when performing a bout of foam rolling (MacDonald et. al., 2013a). With similar test measurements as MacDonald et. al. (2013b), the authors compared the maximum voluntary contraction(MVC) and ROM of the treatment and control groups. They found both groups remained at baseline for MVC, but the treatment group increased ROM by 10°.

Considering the success seen with ROM studies, researchers have begun to look at the effectiveness of foam rolling on athletic performance. Some performance increases have been shown using testing measures for power, agility and speed (MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014). MacDonald et. al. (2013b) showed substantial benefits of foam rolling when comparing vertical jump heights of treatment and control groups. While vertical jump is used to measure power, other authors chose to study an array of performance tests to better understand the benefits of foam rolling. Pearcey et. al. (2015) found foam rolling positively affected broad jump and squat repetitions, but had little to no effect on sprint time or change-of-direction. Furthermore, Peacock et. al. (2014) showed increases of statistical significance for vertical jump, standing long jump, pro-agility, sprint speed and 1-RM bench press. The subject groups consisted of a dynamic warm-up and a combination of foam rolling and a dynamic warm-up. These results relate to the additive benefit of SMR, similar to that of static stretching and increases in ROM.

The final assumed benefit of foam rolling which has shown the most success, and seems to mimic the effects of massage, is on muscle recovery and DOMS. In general, muscle soreness peaks within the first 24 to 72 hours after an intense bout of exercise (Clarkson et. al., 1999). With the use of foam rolling, the recovery from DOMS seems to quicken due to the concept of self-induced massage (MacDonald et. al., 2013b; Cheatham et. al., 2015; Pearcey et. al., 2015). MacDonald et. al. (2013b) stated the treatment group had muscle soreness peak at 24 hours, with the control group peaking at 48 hours. This decrease in muscle soreness may be due to the two 60-second bouts of foam rolling on the major muscles of the thigh. Pearcey et. al. (2015) found significant decreases in pressure-pain threshold measurements for the treatment group when compared to the control group. The authors used a pressure algometer to gauge the amount of pain felt during the testing measure. The foam rolling group had less tenderness at the 24 and 48-hour mark when compared to the control group. Cheatham et. al. (2015) a bout of foam rolling ranging from 10 to 20 minutes may significantly reduce an individual's pain caused by DOMS.

Application Parameters of Foam Rolling

Even though there have been positive results related to ROM, athletic performance and muscle recovery, there is a need for more research. There was an array of foam rolling protocols related to specific muscles, duration, undulation frequency and pressure. Ultimately, the application parameters related to foam rolling need further investigation to solidify a proper treatment method and protocol.

Protocols range from specific muscle groups such as: hamstrings, quadriceps, triceps surae, or as general as full body foam rolling (MacDonald et. al., 2013a; Skarabot et. al., 2015; Mohr et. al., 2014; MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014; Bushell et. al., 2015; Courture et. al., 2015; Okamoto et. al., 2013; Sullivan et. al., 2013). The full body protocols were primarily used during athletic performance testing research, but included two articles dealing with the effects on arterial stiffness and circulation (Okamoto et. al., 2013; Hotfiel et. al., 2016).

The parameter which received most focus and control was duration. The duration parameters for any bout of foam rolling ranged from 1-3 sets of 30 seconds to 1 minute

(MacDonald et. al., 2013a; Skarabot et. al., 2015; Mohr et. al., 2014; MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014; Bushell et. al., 2015; Courture et. al., 2015; Okamoto et. al., 2013; Sullivan et. al., 2013; Hotfiel et. al. 2016). One study focused on the effectiveness of two different durations, but found no significant results between the two groups when compared to baseline measures (Courture et. al., 2015). Sullivan et. al. (2013) used a roller massager in conjunction with 4 different durations. The durations consisted of 1 set of 5 seconds, 1 set of 10 seconds, 2 sets of 5 seconds and 2 sets of 10 seconds. The authors found a trend showing the 10 second duration, regardless of sets, had a larger increase in ROM.

Most research studies did not specify a control for undulation frequency within their protocols (MacDonald et. al., 2013b; Skarabot et. al., 2015; Bushell et. al., 2015). In some studies, the amount of time spent between distal and proximal anatomical landmarks were controlled; ranging from 1 second to 6 seconds (Mohr et. al., 2014; MacDonald et. al., 2013a; Peacock et. al., 2014; Okamoto et. al., 2013; Sullivan et. al., 2013; Hotfiel et. al., 2016). Two studies controlled the rhythm using a metronome with 40-50 rolls per minute (Pearcey et. al., 2015; Courture et. al., 2015).

Finally, and most importantly, the parameter which has little to no research, in relation to foam rolling, is pressure exertion. One article researched the comparison of pressure exertion by two different types of foam rollers (Curran et. al., 2008). Curran et. al. (2008) provided specific information regarding surface area coverage, levels of pressure exertion and the non-effect of body weight during foam rolling. While this article is important, the researchers did not examine how the different exerted pressures may affect the muscle from a functional or performance standpoint. Another article used a force plate as a measurement of pressure-pain-threshold for subjects (MacDonald et. al., 2013b). They found the subjects returned to baseline pressures quicker, showing the effectiveness of foam rolling on reducing muscle soreness and the ability to exert more pressure. Sullivan et. al. (2013) found results when using a roller massager at a constant pressure of 13kg. They found increases in ROM by 4.3% without muscle impairments measured by MVC. These are the only studies using foam rollers rollers and attempting to quantify any sort of pressure exertion. Similarly, in one massage study 4.5N of pressure was used on rat gastrocnemius muscles (Miller et. al., 2017). The authors showed an increase in muscle regrowth by increasing protein synthesis. In addition, massage has shown different pressure intensities can decrease muscle excitability, leading to less muscular tension (Golberg et. al., 1992).

With little emphasis on the parameters related to foam rolling, it is crucial an optimal therapeutic protocol is developed, researched and replicated to further foam rolling as an effective treatment modality. Pressure exertion during foam rolling and its effects on ROM and muscle recovery needs further investigation and may provide the most insight on its effectiveness. Since foam rolling involves self-induced soft tissue manipulation, the concepts and effects of massage can be applied and assumed from a physical and physiological standpoint. The research on the manipulation of soft tissue is consistent for massage, but the extent of the manipulation remains unknown for foam rolling. Furthermore, massage has shown the effects of pressure on neuromuscular inhibition, increases in muscle regrowth, positive effects on inflammation and circulation and decreases in the effects of DOMS (Weerapong et. al., 2005; Golberg et. al., 1992; Morelli et. al., 1990; Miller et. al., 2017; Waters-Banker et. al., 2014; Crane et. al., 2012). These notable differences related soft tissue manipulation applied during massage may provide the same effects when dealing with foam rolling if a consensus can be reached on treatment protocols and pressure exertion.

Chapter 3

METHODOLOGY

Research Design

This research study design was used to measure the effects of two foam rolling pressures on muscle soreness and range of motion (ROM). The effectiveness of the two pressures were measured using a Visual Analog Scale (VAS) (Mattacola, Perrin, Gansneder, Allen, Mickey, 1997) for muscle soreness and a weight-bearing lunge for ankle ROM (Skarabot et. al., 2015; Konor, Morton, Eckerson, Grindstaff, 2012). All subjects performed a five-minute stationary bike (Kieser M3, 2nd Generation Plus, Fresno, CA) warm-up at a preset resistance. Baseline measurements were recorded. The participants performed the delayed onset muscle soreness protocol (DOMS) consisting of 2 sets of concentric/eccentric calf raises until failure (Selkow et. al., 2015; Tedger, Zimmerman, Meller, Geisslinger, 2002). The calf raises were controlled using a metronome (Metronome app by MarketWall.com; Apple Inc., Cupertino, CA) with subjects performing a contraction every five seconds with a rest interval of five minutes between sets. Once the DOMS protocol was finished, the subjects performed the necessary treatment based upon their randomized group. Each subject completed 3 sets of 30 seconds of foam rolling with a rest interval of 30 seconds (MacDonald et. al., 2013a; Skarabot et. al., 2015; Mohr et. al., 2014; MacDonald et. al., 2013b; Pearcey et. al., 2015; Peacock et. al., 2014; Bushell et. al., 2015; Courture et. al., 2015; Okamoto et. al., 2013; Sullivan et. al., 2013; Hotfiel et. al., 2016). After each group finished their treatment intervention, VAS scores and ROM measurements were collected. Subjects returned 24 and 48 hours post-DOMS to recollect VAS scores and ROM measurements.

Subjects/Participants

Thirteen healthy female subjects from a university Division I soccer program volunteered to participate in the study. All subjects were of high level fitness and participated in the study during their spring offseason session. Subjects were informed and instructed of the treatment and measurement procedures. Subjects signed informed consent and completed a medical health questionnaire related to general health and lower extremity injuries approved by the Sacramento State University Internal Review Board (IRB). One subject was removed due to injuries of the lower leg found on the health questionnaire.

Procedures/Measurements

Baseline measurements consisted of height and weight (Table 1), muscle soreness (VAS), ankle ROM and force measurements of the lower leg (Table 2). Using a force plate (AccuPower System, AMTI Force Plate, Serial No. 0394, Model No. ACP, Watertown, MA), baseline force measurements were collected to provide a baseline response in relation to light and deep pressure (MacDonald et. al., 2013b). Paired T-tests were used to further analyze the force plate data to gather information regarding both foam rolling techniques for pressure exertion and percentage of body weight respectively. The data showed significance ($p=.0001$) for the percentage of body weight. This value reveals there was a significant difference between the foam rolling techniques when the exerted pressures were calculated according specific body weights of the subjects. The deep pressure technique provided 155% more pressure when compared to the light pressure technique.

Table 1.

Subject Characteristics

Subjects	Age (yrs.)	Height (in.)	Weight (lbs.)
N= 12	20.25± 2.83	66.15± 4.6	146.95± 53.28

*Means ± Standard Deviations

Table 2.

Baseline Force Plate Measurements with Body Weight Percentages

Subjects	Single-Leg Force (N)	% of Body Weight	Double-Leg Force (N)	% of Body Weight
1A	41.0796	7.4	123.4196	22.4
1B	37.9448	5.6	124.555	18.2
1C	53.9895	8.7	156.6467	25.1
2A	81.8016	12.8	154.8198	24.2
2B	44.2942	7.2	122.6264	19.9
2C	35.0082	6.6	134.2022	25.3
3A	83.8695	12.4	153.8266	22.8
3B	68.7652	10.6	79.8243	12.3
3C	90.7735	13.4	227.2068	33.6
4A	33.0732	3.8	233.647	26.9
4B	49.885	8.5	74.1222	12.6
4C	92.0455	12.1	295.6897	38.8
Averages	98.3769	9.9	117.7160	23.5*

Table 2. Statistical significance compared to single leg.

DOMS Protocol

A five-minute warm-up on the stationary bike was performed before the DOMS intervention. Specific parameters related to the bike warm-up were controlled to decrease variability muscle temperature between subjects. Resistance was set at gear ten, cadence remained at 50 revolutions per minute (RPM). Seat height was adjusted per individual for comfort. Subjects were placed on an exercise step, approximately four inches off the ground allowing for increased intensity and depth during the calf raise. Upon instruction, the subjects began calf raises. Each calf raise maintained a ratio of one raise per five seconds. By controlling the speed, it allowed for an eccentric focus during the calf raise muscle contraction. Subjects completed two sets until failure (Selkow et. al., 2015; Tedger et. al., 2002). A rest interval of five minutes was completed between the two sets.

Foam Rolling Intervention

The foam rolling application parameters were controlled to increase validity and reliability. Subjects completed three sets of 30 seconds, with 30 seconds of rest between each set. The undulation frequency was controlled using a metronome set at 60 rolls per minute. The type of foam roller used was PVC pipe cut to a length of 40 centimeters with a 10-centimeter diameter. A hollow PVC pipe foam roller was chosen based on research related to pressure exertion and surface area coverage (Curran et. al., 2008). The two foam rolling techniques were based upon everyday foam rolling usage (Figure 1) (Skarabot et. al., 2015) and the different applied pressures found during force plate data collection (Table 2). The difference between light and deep pressure was the positioning of the opposite limb during the foam rolling intervention. The light pressure technique has a three-point stance with the lower extremity place on the foam roller, also known as a single-leg position. The deep pressure technique has a two-point stance with the lower extremities overlapping on the foam roller, also known as double-leg position. The two body positions elicit different pressures applied on the underlying soft-tissue (Table 2).

Figure 1. Foam Rolling Positioning Techniques. Picture on the Left shows the Single-leg or Light pressure foam rolling technique. Picture on the Right shows the Double-leg or Deep pressure foam rolling technique.

Muscle Soreness Measurement

A Visual Analog Scale (VAS) was used to gather information related to muscle soreness (Mattacola et. al., 1997). Data was collected at each session with the VAS scores completed by the subject post-ROM measurements. Subjects were provided a VAS sheet and were instructed to place an 'X' directly on the line to measure their soreness (see Appendix C). Scores were collected by measuring from the beginning of the line to the 'X' placed by each subject. Scores were measured in millimeters (mm).

Range of Motion Measurements

A valid test for ankle ROM is a weight-bearing lunge (Skarabot et. al., 2015; Konor et. al., 2012). The weight-bearing lunge was performed in a standing position with the heel in contact with the ground, the knee in line with the second toe, and the great toe 10 cm away from the wall. Balance was maintained by allowing contact with the wall using two fingers from each hand. Participants were asked to lunge forward, directing their knee toward the wall until their knee contacted the wall. If contact was made without a heel lift, the subjects foot was progressively moved away from the wall until maximum ROM was attained. The distance between the great toe and wall was recorded in centimeters (cm). The distance was converted into a ROM degrees using the findings from Konor et. al. (2012) comparing the reliability of measures for ankle dorsiflexion. One centimeter is equivalent to 3.6° of ROM (Konor et. al., 2012). Data was collected at each session.

Statistical Analysis

A Latin-Square randomization design was used to form four groups. This design allows for blocking factors which reduce variability between subjects due performing two treatments on one subject. A Latin-Square design further creates a balance for learned effects with each subject. Mean values for VAS and ROM were analyzed using a Two-Way Repeated Measures Analysis of Variance (ANOVA). A two-way ANOVA was used to compare the interaction effect between foam rolling treatments and time of recovery. Main effect differences were further examined using Paired T-tests. Paired T-tests were selected to compare treatment techniques on recovery and a small sample size. When examining the interaction and main effects a Bonferroni adjustment (p value=(.5x4=.0125) was used for repeated use of Paired t-tests on single data sets. All data were analyzed using SPSS Statistics, release 2013 (IBM Corp, Armonk, NY).

Chapter 4

RESULTS

The purpose of the study was to examine the effects of different pressures during foam rolling on the recovery from delayed onset muscle soreness (DOMS). The force plate data showed a significant difference (p=.0001) for the percentages of body weight for each technique providing an emphasis on each technique providing the intended pressures. The specific measures used to assess the effectiveness of the foam rolling treatment were range of motion (ROM) using a weight-bearing lunge and muscle soreness gathered via a Visual Analog Scale (VAS).

ROM Results

For ROM measurements, a significant interaction effect of time and treatment occurred (p=.001). Paired T-tests were used to further analyze the data to determine at which hour-mark significance was found. Analysis revealed a significant difference (p=.006) when comparing light pressure to deep pressure at the 48-hour mark. Mean value for light pressure at 48-hours was 1.3 centimeters larger, which correlates to an increase of approximately 4.6°. Light pressure foam rolling ROM values did not show significant increases at any other data collection marks (see Table 3). Figure 2 shows the comparisons of means for ROM at each data collection mark.

Table 3.

ROM Measurements (cm)

Treatments	Baseline	0-hour	24-hour	48-hour
1 (SL- Light)	7.958± 2.7835	8.417± 2.6785	8.667± 2.6486	9.208± 2.9654*
2 (DL- Deep)	7.100± 3.2643	7.800± 3.4897	7.650± 3.5438	7.900± 3.3977

Table 3. Significant differences between treatment and time at 48-hour mark.

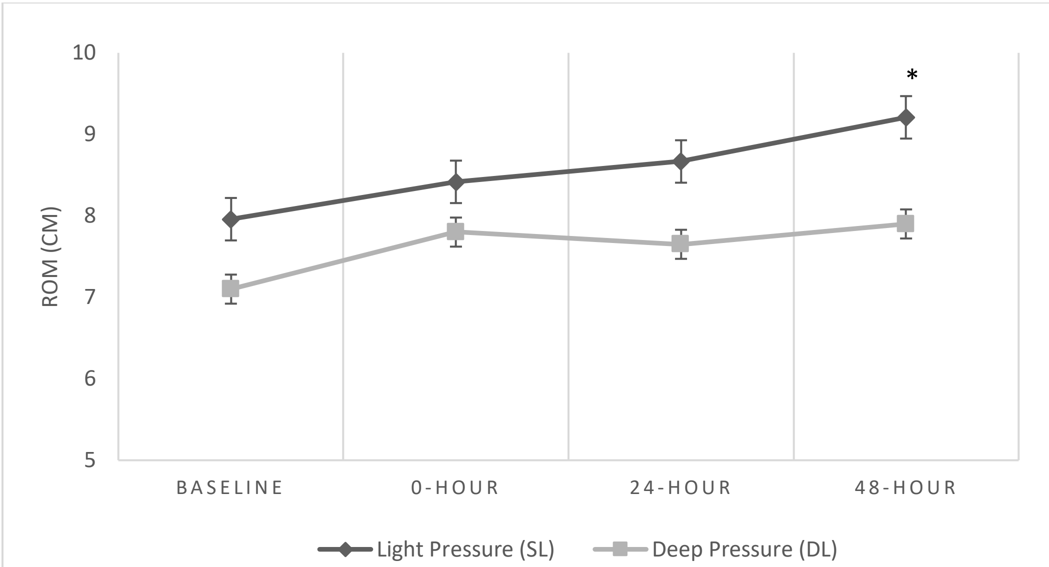

Figure 2. ROM Means Comparison. ROM measurements shown at each data collection mark. Light pressure (SL) is defined as the Single-leg foam rolling technique. Deep pressure (DL) is defined as the Double-leg foam rolling technique. According to Konor et. al. (2012), when performing a weight-bearing lunge, 1cm=3.6°. All significant values are noted by *, seen at the 48-hour mark. Light pressure is approximately 1.3 cm. larger, equating to an increase of 4.6° in ankle dorsiflexion. Reported significance is the due to the interaction effect when comparing treatments versus time.

VAS Results

Two-way ANOVA results show no significant interaction effect for time and treatment for the VAS scores (p=.965). Main effect for treatment approached significance (p=.254) but did not reach a confidence interval of $p < .05$. Although significance was not reached, the data trend showed a 23% decrease in soreness of the light pressure technique which can be expected to occur 75% of the time. Main effect for time reached a significant value (p=.001). Paired t-tests were used to analyze for time, absent of treatment. For time, from baseline VAS scores to 0-hour mark following the DOMS protocol significant increase was noted (p=.0002). This significance shows soreness was induced post-DOMS protocol. VAS scores remained elevated at 24-hours. Significance was found (p=.0001) when comparing VAS scores from 24-hour to 48-hour with VAS scores returning to baseline levels at 48-hours. This signifies peak soreness occurred at the 24-hour mark for both foam rolling techniques, advocating for foam rolling, of any pressure, to increase the time of recovery of muscle soreness. The means and standard deviations for VAS can be seen in Table 4. Figure 3 shows main effect of time for VAS at each data collection mark.

Table 4.

VAS Scores (mm)

Treatments	Baseline	0-hour	24-hour	48-hour
1 (SL-Light)	6.583± 7.9711	20.833± 15.5962	17.417± 15.1145	7.000± 7.1858
2 (DL- Deep)	10.917± 11.9275	24.083± 16.3954	19.417± 16.9032	9.417± 9.0298

Table 4. VAS scores with means and standard deviations shown at data collection marks.

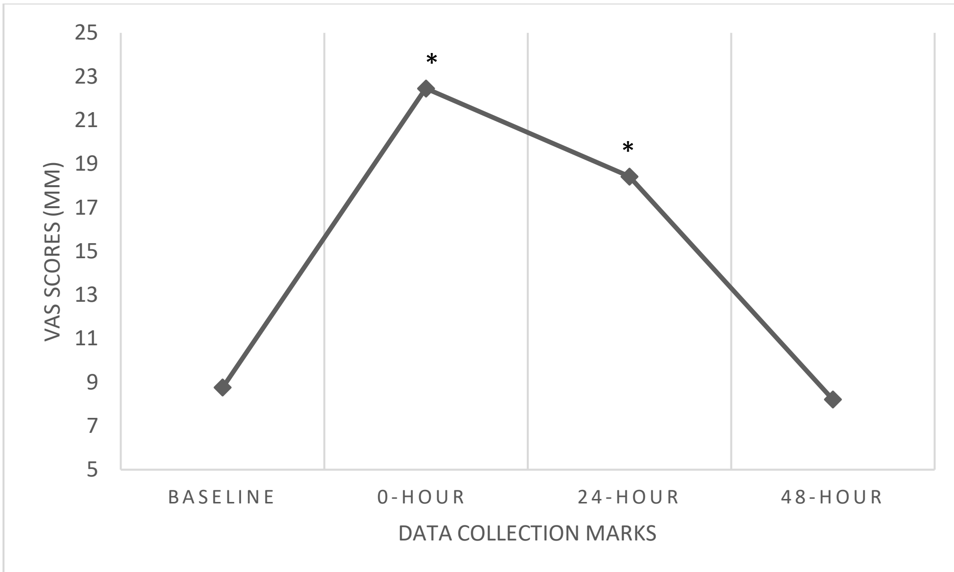

Figure 3. VAS Scores with Main Effect of Time. VAS scores shown at each data collection mark. Graph shows time as the main effect, with no comparison of foam rolling techniques. Lower mean values related to VAS scores are associated with less soreness. Significance was found when comparing baseline values to 0-hour (p=.0002) and from 24-hour to 48-hour (p=.0001). No significance was found from 0-hour to 24-hour or comparing values of baseline to 48-hour. All significant values are noted by *.

Chapter 5

DISCUSSION

Among the athletic world, self-myofascial release (SMR) in the form of foam rolling continues to be a trending topic when discussing methods of recovery. The pressure exerted during foam rolling can be considered a self-induced massage because the body pressure resembles the pressure exerted on the muscles through manual manipulation by a massage therapist (Pearcey et. al., 2015). This study attempted to assess the effectiveness of light and deep pressures on the recovery of ROM and muscle soreness measurements when performing a single bout of foam rolling. Although similarities exist between massage and foam rolling, valid and reliable research lacks regarding specific parameters of foam rolling techniques.

Significant results have been noted related to range of motion (ROM), athletic performance and muscle recovery, but there has been a lack of focus and control on the application parameters related to foam rolling. Previously, most research was focused on the physical effects of foam rolling with results showing acute effects on ROM but no long-term effects (MacDonald et. al., 2013; Skarabot et. al., 2015; Mohr et. al., 2014; Cheatham et. al., 2015). The success of these studies correlates to the current research since the light pressure technique was replicated from Skarabot et. al., (2015). Additionally, this study found similar results in relation to acute effects of ROM at 48-hours post-muscle damage and foam rolling treatment. The data indicated a significant interaction effect ($P = .006$) at the 48-hour mark comparing treatment and time. The mean value was 1.3 centimeters larger, correlating to a 4.6° increase in ankle dorsiflexion. The data did not indicate any significance for the deep pressure foam rolling technique. Additionally, foam rolling has shown increases in athletic performance in relation to power, speed, agility (MacDonald et. al., 2013; Pearcey et. al., 2015; Peacock et. al., 2014) and seems to quicken the recovery from delayed onset muscle soreness (DOMS) (MacDonald et. al., 2013b; Cheatham et. al., 2015; Pearcey et. al., 2015). This investigation did not suggest any significant interaction effect between treatment and time in relation to muscle soreness. However, main effects of treatment and time did pose some significant data for VAS scores. Treatment at the main affect approached significance (p=.254). This trend shows a 23% decrease in soreness of the light pressure technique which can be expected to occur 75% of the time. Time as a main effect found significance (p=.001). VAS score means were analyzed using a paired t-test which examined each data collection mark. The findings found significant values comparing means of baseline to 0-hour (p=.0002) and from 24-hour to 48-hour (p=.0001). These findings suggest the DOMS protocol was successful due to the significant value found between baseline and 0-hour. Similarly, MacDonald et. al. (2013b) found significant decrease in peak soreness stating the treatment group had muscle soreness peak at 24 hours, with the control group peaking at 48 hours. Furthermore, Farr et. al (2002) and Hilbert et. al. (2003) revealed the effectiveness of massage on DOMS, specifically at the 48-hour measurements post-exercise revealing less soreness when compared to the control.

Prior to this study, there has been one article which researched the comparison of pressure exertion by two different types of foam rollers (Curran et. al., 2008). However, the researchers did not look at how the different exerted pressures may affect the muscle from a functional or performance standpoint. In theory, with massage research guiding the way, more extensive or deeper pressure when performing foam rolling should provide better results, in turn a quicker recovery to baseline performance measures like ROM and muscle soreness (Weerapong et. al., 2005). This study was able to provide a significant value in relation to the two different foam rolling techniques used (Figure 1). The force plate data was significant ($p=.0001$) when measuring the percentage of body weight between the techniques. This suggests the foam rolling techniques were successful in creating different pressures. The only interaction effect which reach significance was ROM ($p=.006$). The light pressure technique had 4.6° increase in ROM when compared to deep pressure. Due to the significance noted between the foam rolling techniques, the deep pressure technique may have provided too much pressure and discomfort, preventing the inflammatory process from occurring.

A few key points may provide insight for future investigations related to pressure exertion and foam rolling. Foam rolling lacks research related to the physiological measures of muscle, specifically circulation and inflammation. Techniques used during massage such as: effleurage, petrissage or tapoment, provide deep pressure and muscle tension throughout the treatment (Farr et. al., 2002; Hilbert et. al., 2003) This mechanotransduction produced by massage causes a transformation of a mechanical stimulus into a chemical signal where the effects of inflammation can be effected (Waters-Banker et. al., 2014). Two studies related to foam rolling and arterial function found foam rolling can decrease arterial stiffness and increase blood for up to 30 minutes after a session of foam rolling (Okamoto et. al. 2013; Hotfiel et. al. 2016). Before conclusions can be made regarding pressure exertion and blood flow, neither article provided a value for the pressure exerted on the foam roller to elicit their significant results. Furthermore, research has shown how muscle stretching and contractions affect blood flow within a muscle. The effects of stretching a muscle compress blood vessels diminishing return, while a muscle contraction increases blood flow (Causey, Cowin, Weinbaum, 2012). Another point to note is the gender of the subjects used for this study. Gender may play a role in muscle soreness and ROM, preventing proper conclusions being made regarding performance measures (Tsolakis, C. & Bogdanis, G., 2012). Although the foam rolling parameters may be a factor within this study, previous research has shown women tend to be more flexible (Tsolakis et. al., 2012). Tsolakis et. al. (2012) examined warm-up protocols on flexibility and explosive measures between men and women. The authors found men had more explosive power while women had greater ROM at all time points (Tsolakis et. al., 2012). This may provide insight regarding the lack of increases found for ROM throughout the data collection process. These key points related to blood flow, the inflammatory process and gender relate to the current investigation by suggesting the deep pressure technique, with female-only subjects, may have prevented a significant interaction effect of recovery from the DOMS protocol.

With little emphasis on application parameters related to foam rolling, it is crucial a protocol is developed, researched and replicated to further foam rolling as an effective treatment modality. If there are notable differences in relation to effectiveness when using different massage pressures, the results could be similar for foam rolling. These similarities constitute more research related to different exerted pressures on foam rollers and their effectiveness on ROM and muscle soreness recovery. In order to truly show effectiveness and make the results replicable, a protocol related to the application of foam rolling needs to be created.

Conclusion

Light pressure was more effective at 48-hours when measuring ROM and pressure had a minimal effect on VAS scores measuring muscle soreness.

Practical Application

Recovery from exercise is critical for athletes and the physically active. Most people assume foam rolling is an effective method of recovery, when research has yet to develop a replicable and effective protocol. Significance at the 48-hour mark related to ROM was found in this study, similar to previous foam rolling research (MacDonald et. al., 2013b; Skarabot et. al., 2015; Mohr et. al., 2014; Cheatham et. al., 2015). For this current investigation, it’s important to note this significance occurred for the light pressure technique and not the deep pressure technique. No significance was found for either foam rolling technique in relation to DOMS and muscle recovery which failed to repeat previous research (MacDonald et. al., 2013b; Cheatham et. al., 2015; Pearcey et. al., 2015). Furthermore, the deep pressure technique may have delivered too much pressure, creating discomfort and preventing the increases in arterial blood flow which are crucial for muscle recovery from exercise (Okamoto et. al. 2013; Hotfiel et. al. 2016).

Health care professionals cannot confidently provide information on foam rolling parameters to provide the beneficial results. This topic needs further research to prevent practitioners from providing incorrect or inefficient instructions when dealing with foam rolling.

Appendix A

Medical Health Questionnaire

Inclusion in this research study will be based upon your medical information related to general health and past injuries regarding the lower body in relation to this study. It is essential to remain honest and truthful about past and present medical history. The questionnaire will be reviewed and participation will be determined based upon your answers.

Review all questions and circle the appropriate answer

1. Do you know of or have even been diagnosed with a circulatory disorder like Reynauds disease? **YES** **NO**
    a. If Yes, please explain:
    ____
    ____
    ____

2. Have you even been diagnosed with Deep Vein Thrombosis? **YES** **NO**
    a. If Yes, please explain:
    ____
    ____
    ____

3. Have you obtained an ankle or lower leg injury in the last 6 months?**YES** **NO**
    a. If Yes, please specify which body part, side and extent of injury:
    ____
    ____
    ____

4. Have you even received surgery on a lower extremity? **YES** **NO**
    a. If Yes, please specify Year of procedure, body part and extent of surgery:
    ____
    ____
    ____

Please specify any other relevant information regarding your health history related to lower extremity injuries:

____

____

Appendix B

INFORMED CONSENT

Effects of Two Pressure Intensities during Foam Rolling on Delayed-Onset Musle Soreness and Range of Motion

You are invited to participate in a research study which will involve Self-Myofascial release in the form of foam rolling and its effects on muscle soreness and range of motion.
My name is Kevin Lennon and I am a Graduate Student and Athletic Trainer at California State University, Sacramento, Kinesiology and Athletic Department.

Your participation in this project is voluntary. Even after you sign the informed consent document, you may decide to leave the study at any time.

You were selected as a possible participant in this study because of your qualitfications regarding the health questionairre and inclusion criteria.The purpose of this research is to gauge the effectiveness of two different pressure exertions of foam rolling on muscle recovery and range of motion. If you decide to participate, you will be asked to undergo a series of baseline measurements, a delayed-onset muscle soreness(DOMS) protocol and three(3) separate data collection days regarding your specific treatment group. Your participation in this study will last 2(two) weeks, with a total of 4(four) days of participation.

There are some possible risks involved for participants and these are not anticipated to be greater than those risks encountered in daily life. The risks are: discomfort related to muscle soreness, varyied pressure exertion on soft tissue structures related to foam rolling and muscle tenderness measurements, and minor discomfort during range of motion measurements related to the stretch of muscles and fascia. There are some benefits to this research, particularly a possible increase muscle soreness recovery, self-induced massage through foam rolling and the opportunity to gain insight related to self-myofascial release techniques.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Measures to insure your confidentiality are codeable identification numbers related soley to participant, limited subject-to-subject interaction and the research will be conducted by HIPPA compliant individuals. The data obtained will be maintained in a safe, locked location and will be destroyed after a period of three years after the study is completed.

If you have any questions about the research at any time, please call me at 916-278-3563, or Dr. Daryl Parker at 916-278-6902. If you have any questions about your rights as a participant in a research project please call the Office of Research Affairs, California State University, Sacramento, (916) 278-5674, or email irb@csus.edu. In the event of a research-related injury, please contact your regular medical provider and bill through your normal insurance carrier, and then advise us.

Your signature below indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled, and that you are not waiving any legal claims, rights or remedies.

Signature ______________________ Date ______________________

Appendix C

Visual Analog Scale (VAS)

Name: ________________________ Date: ____________________

Place a mark on the line below to indicate your current level of soreness

0 ____ 10

No Soreness | Worst Soreness ever experienced

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