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THE EFFECT OF ROLLER STICK MYOFASCIAL RELEASE ON LOWER EXTREMITY RANGE OF MOTION AND FUNCTIONAL PERFORMANCE

ALLISON L MONTGOMERY
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Reviewed and approved* by the following:

Sayers John Miller, III
Assistant Professor of Kinesiology
Thesis Supervisor

Giampietro “John” Vairo
Instructor of Kinesiology
Clinical Education Coordinator, Athletic Training
Thesis Reader

Jinger S Gottschall
Associate Professor of Kinesiology
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

THE EFFECT OF ROLLER STICK MYOFASCIAL RELEASE ON LOWER EXTREMITY RANGE OF MOTION AND FUNCTIONAL PERFORMANCE

Montgomery AL, Vairo GL, Miller SJ: Athletic Training and Sports Medicine Research Laboratory, *Department of Kinesiology, The Pennsylvania State University, University Park, PA

Objective: This study examined the effect of the roller stick on lower extremity range of motion and functional performance. It was hypothesized that the roller stick (RS) myofascial release technique would increase range of motion without impairing functional performance. **Design and Settings:** A pretest-posttest experimental design was used to examine the immediate effect of the RS myofascial release technique on hamstrings and quadriceps flexibility compared to a static stretching (SS) control group. Participants were randomly assigned to the RS or SS group. **Participants:** Sixteen male, Division I college football players were enrolled (18.81 ± 0.75 yrs, 1.856 ± 0.061 m, 96.43 ± 17.07 kg). **Measurements:** Hip and knee range of motion (ROM), single-legged vertical jump and single-legged horizontal hop were the dependent variables. Group means and standard deviations were calculated. Two-sample and paired t-tests were performed to determine differences for between-group and within-group comparisons, respectively. $P < 0.05$ denoted statistical significance a priori. **Results:** Statistically significant increases in ROM were found within the RC group for hip flexion ($P = 0.038$) and knee flexion ($P = 0.007$), but no statistically significant changes in jump or hop task were found. The SS group demonstrated a statistically significant greater horizontal hop distance ($P = 0.032$) but no changes in ROM or the vertical jump task were found. No statistically significant differences existed at baseline between groups. **Conclusions:** The RS myofascial release technique was found to significantly increase hamstring and quadriceps flexibility with no associated reduction in functional performance contrary to what has been previously shown for static stretching. Further research involving a greater number of participants may produce more conclusive results concerning functional performance following a RS myofascial release technique. **Word Count:** 278

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 1

Introduction

Athletes at all levels develop aching muscles and in order to provide the best possible care, athletic trainers and other sports medicine staff members must be familiar with the most recent methods for relieving muscle soreness. To treat muscle pain, possible mechanisms and causes must be examined. This muscle pain experienced by athletes may be related to soft tissue dysfunction and may have chronic or acute onset mechanisms that include physical trauma, overuse injuries, structural imbalances, or inflammation.[1] Commonly, fascia (the layers of connective tissue surrounding and binding the soft tissues in the body) is affected by these injury mechanisms.[1,2] Specifically, fascial restrictions may occur as a response to the variety of injury mechanisms as well as disease or inactivity.[2] It is believed that dehydration and loss of elasticity in the fascia causes fibrous adhesions to form between the fascial layers.[2] These fibrous adhesions may alter surrounding joint and muscle mechanics (range of motion, muscle length, neuromuscular hypertonicity, decrease muscular strength and endurance, motor coordination, and decrease soft-tissue extensibility), thus resulting in pain and additional pathology.[1,2] Furthermore, microtears in the muscle tissue and surrounding connective tissue that occur following heavy exercise (especially, eccentric exercise) may result in delayed-onset muscle soreness (DOMS) and cause pain and discomfort. In addition to pain, DOMS typically results in a reduction of function (reduced strength and range of motion) and increased muscle and soft-tissue stiffness.[3] Multiple treatments (for example, cryotherapy, ultrasound, compression, anti-inflammatory drugs, static stretching, and massage) have been investigated for the treatment of DOMS; however, the effectiveness of these treatments is inconclusive.[3] Roller myofascial release has been proposed to reduce the recovery time needed for DOMS; specifically, it is thought that rehydrating the tissues may promote the removal and reabsorption of the adverse substrates into the blood stream and lymph.[4]

Myofascial release techniques are commonly used to address restrictions or adhesions between the layers of fascia.[1,2] Examples of these techniques generally focus on the treatment of trigger points and include the use of a vapo-coolant spray followed by muscle stretch, ischemic compression, heat, and electrical stimulation.[1] Recently, the use of either a foam roller or hand-held roller stick to massage muscles and connective tissue has become popular in the treatment of myofascial restrictions. Individuals utilizing the foam roller typically use their own body mass on a foam roller to exert pressure on the muscle and soft tissues. The roller stick is more commonly hand-held and may be applied by the individual or a clinician. In addition to potentially relieving muscle soreness, self-myofascial release is often used prior to exercise (commonly believed to improve flexibility) as well as after workouts and functional activities as a form of recovery.

The present literature on the effects of roller myofascial release lacks consistency in the type of roller used in the studies (foam or hard plastic). Additionally, the potential physiological mechanisms that occur during or as a result of using the roller stick have not been consistently examined. However, trends showing reduced muscle soreness, improved flexibility, and equal (non-detrimental) or improved functional performance have been expressed by a combination of recent studies examining either foam roller or roller stick myofascial release.[2,4] The roller stick is unique because it is smaller than a foam roller and more precisely controlled by the individual or health care professional, which allows specific soft-tissue areas to be targeted. Unfortunately, little is understood about the acute effects of the roller stick on measurable physical outcomes and assessments.[5]

The roller stick is thought to have similar effects to static stretching with regard to improving range of motion and decreasing muscle soreness. Recently, literature has shown static stretching for greater than 60 seconds to cause a decrease in functional performance while simultaneously increasing range of motion.[6,7,8] Detrimental effects on flexibility or functional performance that may occur with the roller stick myofascial release technique would make this intervention unadvised. The aim of this investigation is to assess the immediate effects of an application of roller stick myofascial technique, as performed on the hamstring and quadriceps muscle groups, on range of motion and functional performance. It is hypothesized that the roller stick myofascial release technique will increase knee joint range of motion without causing a functional performance deficit. Secondly, it is hypothesized that a static stretching technique applied to the knee joint extensors and flexors will increase knee joint range of motion and decrease functional performance.

Overall, research focal to a specific and commonly used type of roller stick will lend towards greater understanding of the functional and physiological consequences of "rolling out" muscles. Ultimately, through extensive literature review and laboratory analysis, the project intends to provide clarity on the effectiveness of the roller stick as well as contribute focus and direction to future research studies on myofascial interventions.

Chapter 2

Methods and Materials

Overview

A randomized two-group pretest-posttest experimental design was used in this study. The independent variable in this study was treatment intervention. Participants underwent either static stretching or roller stick (The Stick, The Stick/RPI of Atlanta, Atlanta, GA, USA) treatment interventions to the hamstrings and quadriceps muscles. Range of motion (as a measure of flexibility), and the functional performance as measured by a single-legged hop and a single-legged vertical jump were assessed as the dependent variables. The static stretching (SS) technique was chosen as the control since it has previously been shown to have a detrimental effect on muscle performance. Participants were recruited from the Penn State University football team at University Park Campus using Institutional Review Board (IRB) approved flyers and a verbal script (Appendix A and C). Participants read and signed an IRB approved informed consent form (Appendix F) prior to data collection. Demographic and anthropometric measures were initially collected and have been summarized in Table 2-1. Height was measured by using a wall-mounted tape measure and mass was measured using a digital scale. Leg dominance was determined by asking the participants which leg was preferable to kick a soccer ball for the greatest accuracy and distance.[9,10]

Participants were then asked to warm-up on a stationary bike (Schwinn AirDyne, Nautilus, Inc, Vancouver, WA, USA) at a low resistance and self-paced moderate speed for five minutes.[8,11-13] Following the warm-up, baseline data was collected; this included each participant's dominant leg quadriceps and hamstrings flexibility via prone passive knee flexion range of motion and supine passive hip flexion respectively, dominant leg performance of a single-legged hop for maximal horizontal distance, and dominant leg performance of a single-legged jump for maximal vertical height. To prevent order effects, the sequence in which participants progressed through the single-legged hop and single-legged vertical jump measurements were randomized via the generation of random permutations using a statistical software package (Minitab 16, Minitab Inc., State College, PA). A 10-minute rest period was provided after baseline data had been collected.[14] Participants then completed a second five minute warm-up on the stationary bike (Schwinn AirDyne, Nautilus, Inc, Vancouver, WA, USA) before receiving either a static stretch (SS) of the dominant leg quadriceps and hamstrings for 60 seconds each or a roller stick (RS), (The Stick, The Stick/RPI of Atlanta, Atlanta, GA, USA), (Appendix D) myofascial release technique for 60 seconds. Following the SS or RS technique, flexibility of the dominant quadriceps and hamstrings were reassessed. The functional measures (single-legged hop for maximal horizontal distance and single-legged jump for maximal vertical height) were then completed for a second time.

Participants

Sixteen male collegiate football players participated in the study. Interested participants completed a screening questionnaire (Appendix B) prior to participation in the study. Eligible participants expressed written informed consent (Appendix F), as per Institutional Review Board (IRB) guidelines. In order to be admitted as a eligible participant, the following inclusion criteria must have been met: physically active men and women 18 – 25 years of age, generally healthy (not overweight and a non-smoker or non-consumer of nicotine products), and at least recreationally active (defined as individuals engaging in physical activity at least three days per week for 30 minutes over the past six months). Exclusion criteria were not based upon sex, race, ethnicity, or sexual identity. Explicitly, the exclusion criteria included: musculoskeletal or neurological injury to the low-back or lower body within the last six months, history of low-back or lower body surgery, concussion, participation in a formal physical rehabilitation program in the last six months, and pregnancy. Means and standard deviations of demographic data and anthropometric measures were calculated (Table 2-1). Means and standard deviations of dependent variables were calculated and two-sample t-tests were performed to assess differences in the means between the SS and RS groups for demographic and anthropometric measures (Table 2-1).

Techniques

Range of Motion Assessment: Quadriceps Flexibility

Dominant leg quadriceps flexibility was assessed by measuring passive knee flexion range of motion while the participant lay prone on a treatment table. Specifically, the participant moved as close to the edge of the table as possible such that the non-dominant foot would be able to come into contact with the ground (the whole foot had to be firmly planted on the ground). Flexion of the non-dominant knee was allowed in order to obtain this position as well as achieve a level pelvis. The dominant leg remained on the treatment table. Overall, this position secured the pelvis and prohibited accessory motion while the dominant leg quadriceps muscle group ROM was assessed (Figure 2-1). In accordance with previous studies, the researcher then passively flexed the knee of the dominant leg until the participant reported a stretch sensation and the researcher began to feel resistance.[8,15] During passive flexion of the knee, a handheld Nicholas manual muscle testing (MMT) dynamometer (Lafayette Instrument, Lafayette, IN) was used to determine a quantitative value at which the participant experienced terminal ROM. This value was then recorded and used during the reassessment of quadriceps flexibility, thus ensuring that the researcher consistently applied the same amount of force for each participant. The pressure gauge of the MMT dynamometer was consistently placed six inches above the most inferior aspect of the medial malleolus and on the anterior and most central aspect of the tibia of the dominant leg. The researcher kept her hand perpendicular to the MMT gauge during the measurement procedure (Figure 2-2). A fluid goniometer was attached to the most muscular portion of the calf using a Velcro material (Figure 2-2). The angle reached at the terminal point in the ROM was read on the goniometer and recorded. .

Figure 2-1: Quadriceps Flexibility Assessment Technique and Stretching Position

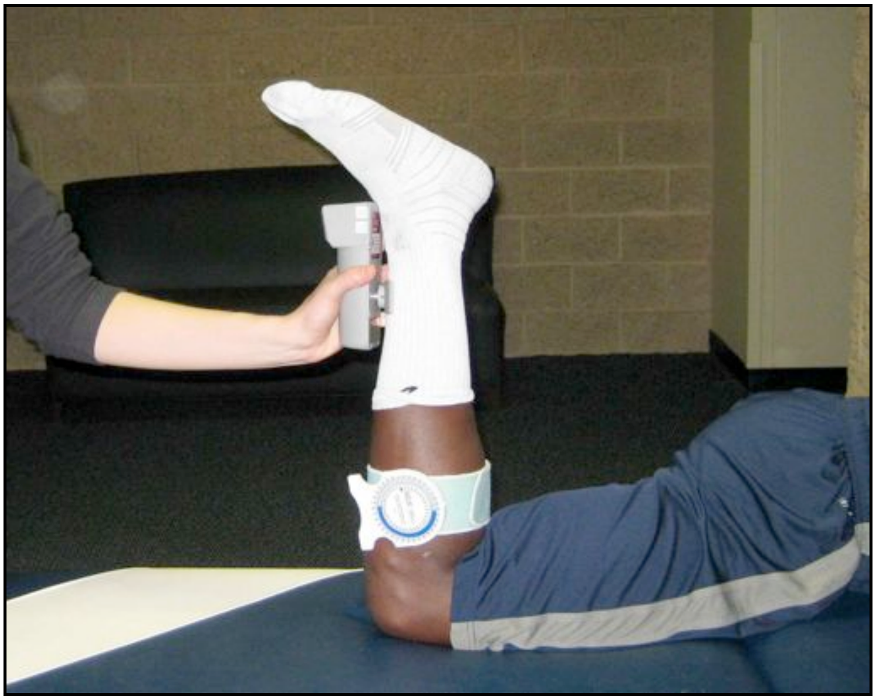


Figure 2-2: MMT Dynamometer Position for the Quadriceps

Range of Motion Assessment: Hamstring Flexibility

Dominant leg hamstring flexibility was assessed by having the participant lay supine on the treatment table. A belt placed across the anterior supine iliac spine was used to secure the pelvis, while a second belt was placed across the distal third of non-dominant thigh just proximal to the knee joint (Figure 2-4). The belts prohibited accessory movement of the pelvis during assessment of the dominant leg hamstring flexibility. Furthermore, the dominant knee was secured in a fully extended position using a straight leg immobilizer (DonJoy Straight Leg Immobilizer, DJO, LLC, Vista, CA) and the dominant ankle was secured at 90º in a firm plastic brace.[16] Once the participant was comfortably in place, the researcher passively flexed the dominant hip. The MMT dynamometer was used to determine a quantitative force value at which the terminal ROM was achieved. Similarly, the pressure gauge of the MMT dynamometer was consistently placed 5 inches above the most inferior aspect of the medial malleolus and on the posterior and most central aspect of the calf of the dominant leg. The researcher kept her hand perpendicular to the MMT device during the measurement procedure (Figure 2-3). A fluid goniometer was attached using a Velcro material along the lateral tibiofemoral joint line (Figure 2-3). The angle reached at the terminal point in the ROM was read on the goniometer and recorded.

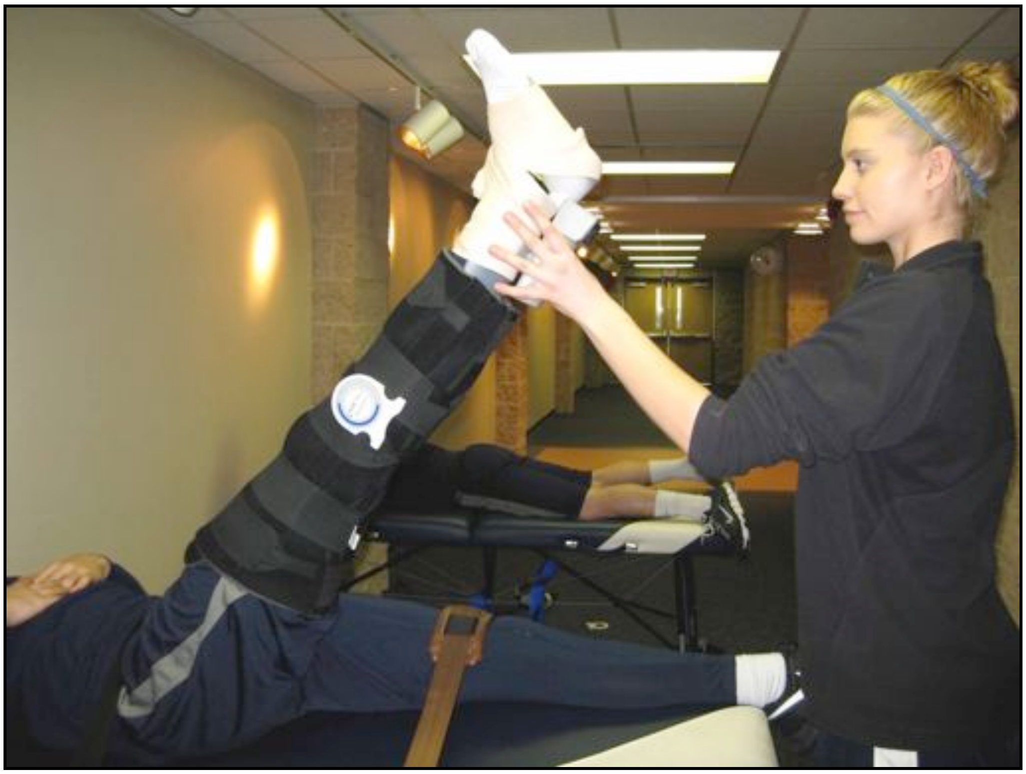


Figure 2-3: Hamstring Position for Flexibility Assessment and Static Stretching

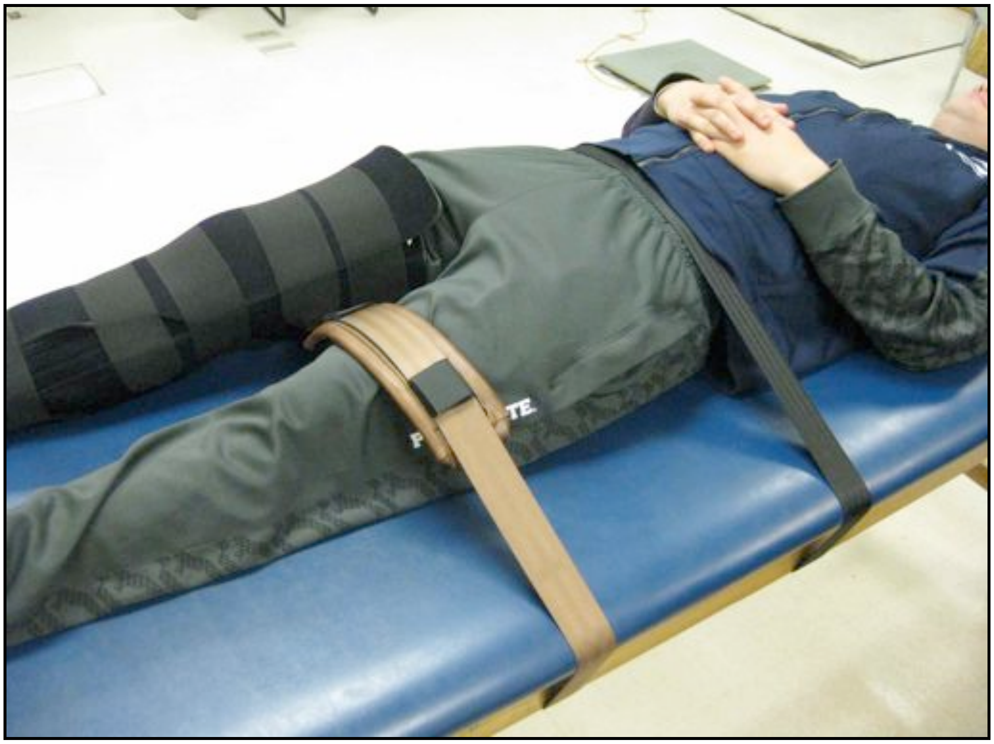


Figure 2-4: Belt Position for Hamstring Flexibility and Stretch

Functional Performance Measure: Single-Legged Vertical Jump

The vertical jump with countermovement was selected as a functional performance measure of lower extremity power.[6,12,15,17] Maximal dominant leg vertical jump height was determined using a Vertec unit (Sports Imports, Columbus, OH). Initially, the standing reach height was determined by having each participant stand directly in front of the Vertec and raise the dominant hand above his or her head, with the arm fully extended; no accessory movement was permitted and the participant kept both heels on the ground (Figure 2-5).[18] Next, the maximal jump height was determined by having each participant perform a single-legged vertical jump with countermovement from a stationary position, as described by Unick et al.[18] While performing the countermovement jump, the participant struck the crossbars on the Vertec with the dominant hand as high as possible.[18] Each participant was allocated three practice trials with thirty seconds of rest in between each trial, followed by a one-minute rest and three measured trials with thirty seconds rest between trials. The time in between each individual trial and the two sets of trials was determined from studies that used 10-15 seconds between individual trials and two minutes between practiced and measured sets.[12,17] The maximal jump height was determined by subtracting standing reach height from the maximal jump height.[18]

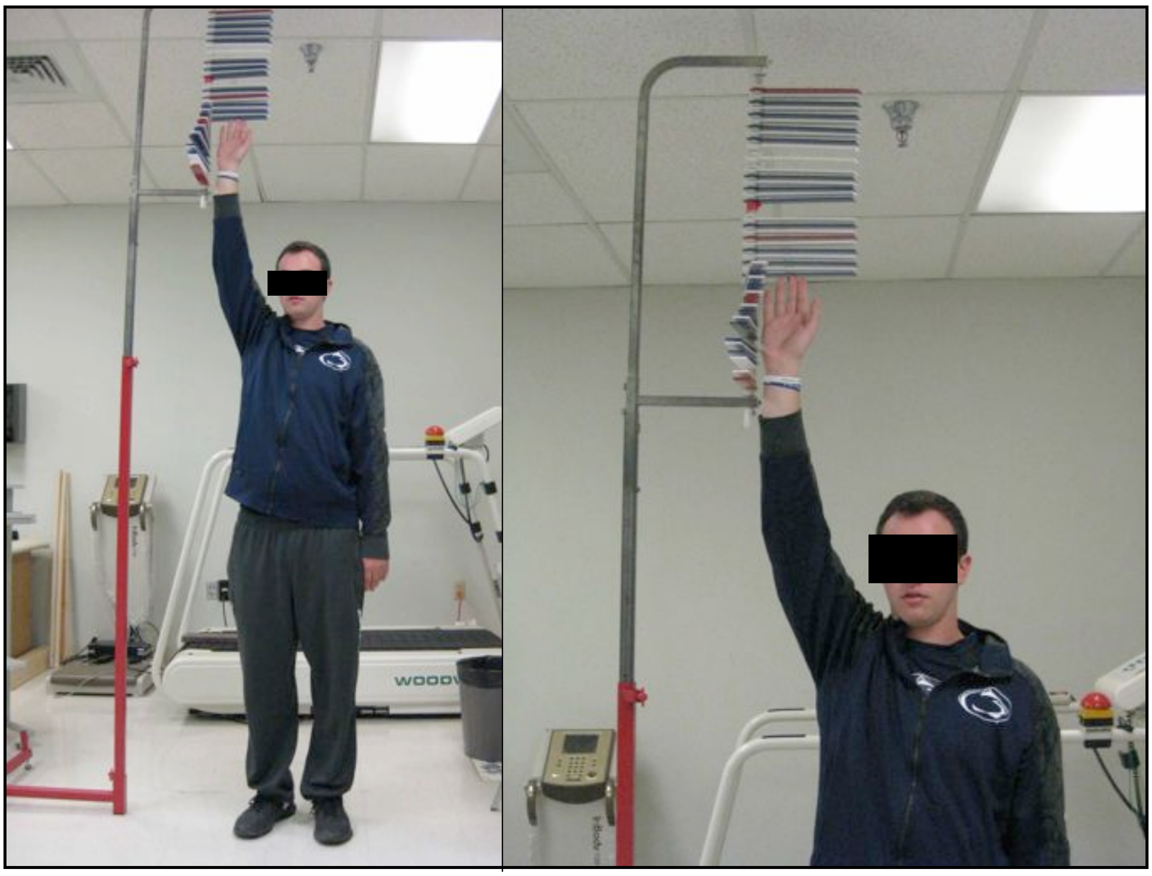


Figure 2-5: Vertical Jump Position (Standing Height)

Functional Performance Measure: Single-Legged Horizontal Hop

Maximal dominant leg horizontal hop distance was determined using a tape measure fixed to the ground. Each participant began by standing with the heel of his or her dominant leg at 0 cm (Figure 2-6). The participant then completed a countermovement hop from a stationary position as far forward as possible. Importantly, the participant had to land without stumbling or taking additional steps. Similar to the vertical jump, each participant was allocated three practice trials with thirty seconds of rest in between each trial, followed by a minute rest. The same timing scheme was used for the measured trials. Measurements were taken from the 0 cm mark to the heel of the foot at the landing point.

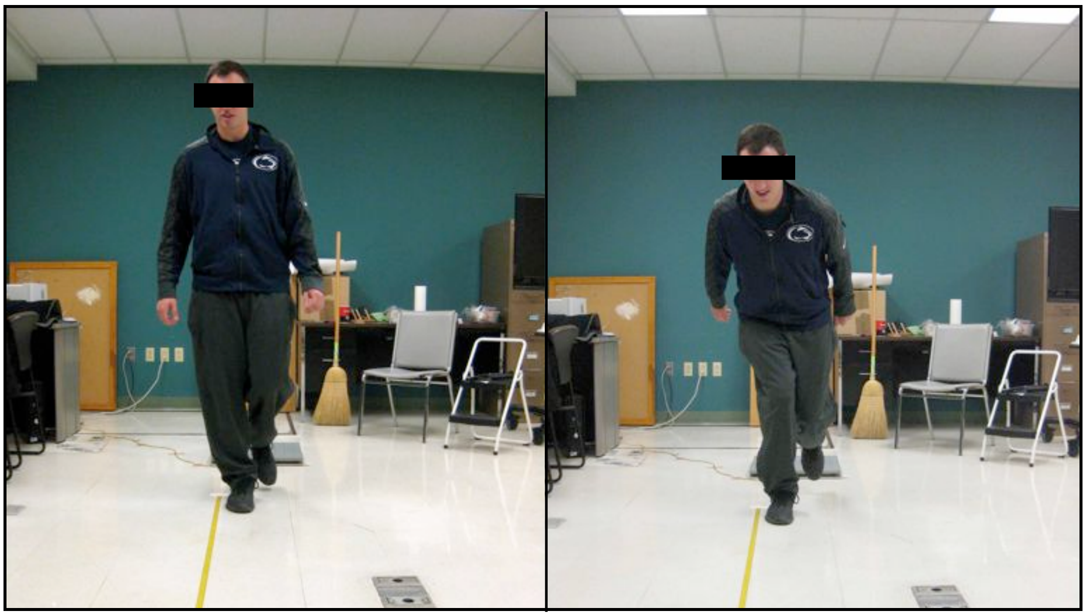


Figure 2-6: Single-legged Hop Position

Static Stretching Technique (SS)

The dominant leg hamstrings were statically stretched for 60 seconds in the same position as ROM measurement for the hamstrings (Figure 2-3). Similarly, the dominant leg quadriceps muscle group was statically stretched for 60 seconds in the same position as ROM measurement for the quadriceps (Figure 2-1). Participants were passively stretched by combining the participant’s initial stretch sensation (defined as less than point of discomfort) and the point at which the research met resistance from the muscle.[12,15,16] Sixty seconds of SS was chosen based upon previous studies that found both an increase in ROM and a detrimental functional performance effect following 30 to 90 seconds of SS.[6,7,12,15,16,19] One bout of SS was selected because it has been shown that the biomechanical effect of viscoelastic deformation may not be influenced by subsequent stretches.[20,21]

Roller Stick Myofascial Release Technique (RS)

The roller stick technique utilizes a hand-held device that is 24 inches long with a semi-flexible center rod that is encapsulated by freely rotating firm plastic beads that roll over the muscle (The Stick, The Stick/RPI of Atlanta, Atlanta, GA, USA), (Appendix D). This technique requires that the researcher grip the roller stick on both ends and press with a moderate amount of pressure on the muscle for 60 seconds; the duration of the roller stick technique was determined partly to maintain consistency between the duration of the two techniques. Secondly, this technique was administered in this manner because this was the average time executed by individuals frequently utilizing the roller stick in athletic training rooms on the University Park campus and because it was found that 60 second bouts were assessed in antecedent studies.[2,4] Furthermore, the myofascial release technique was applied by rolling the stick superiorly and inferiorly along the entire length of the muscle, performing approximately one complete roll (superior aspect to inferior aspect of muscle, then back to superior aspect) per second.[5] As much of the muscle as possible (while remaining parallel to the muscle fibers) was rolled. Specifically, the quadriceps muscle group was rolled from where the rectus femoris tendon arises at the anterior inferior iliac spine (AIIS) to the suprapatellar tendon (just proximal to the base of the patella), (Figure 2-7). The hamstrings were rolled from where the common origin (tendon) of the hamstring muscle group arises at the ischial tuberosity to the posteriomedial and posteriolateral aspects of the tibiofemoral joint line (Figure 2-8).

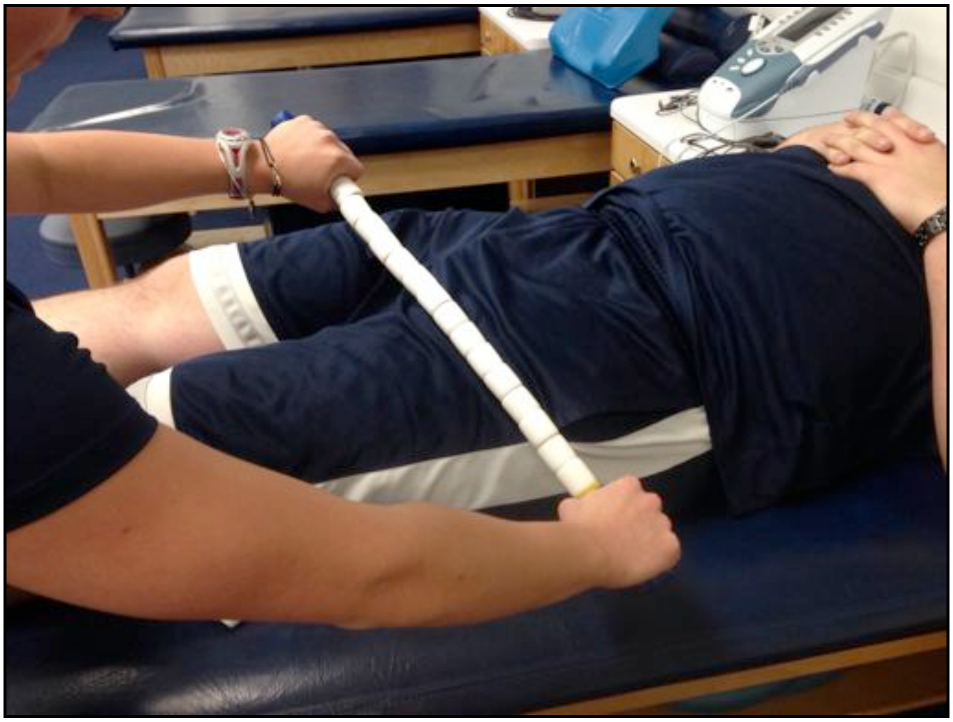


Figure 2-7: Roller Stick Technique of the Quadriceps Muscle Group

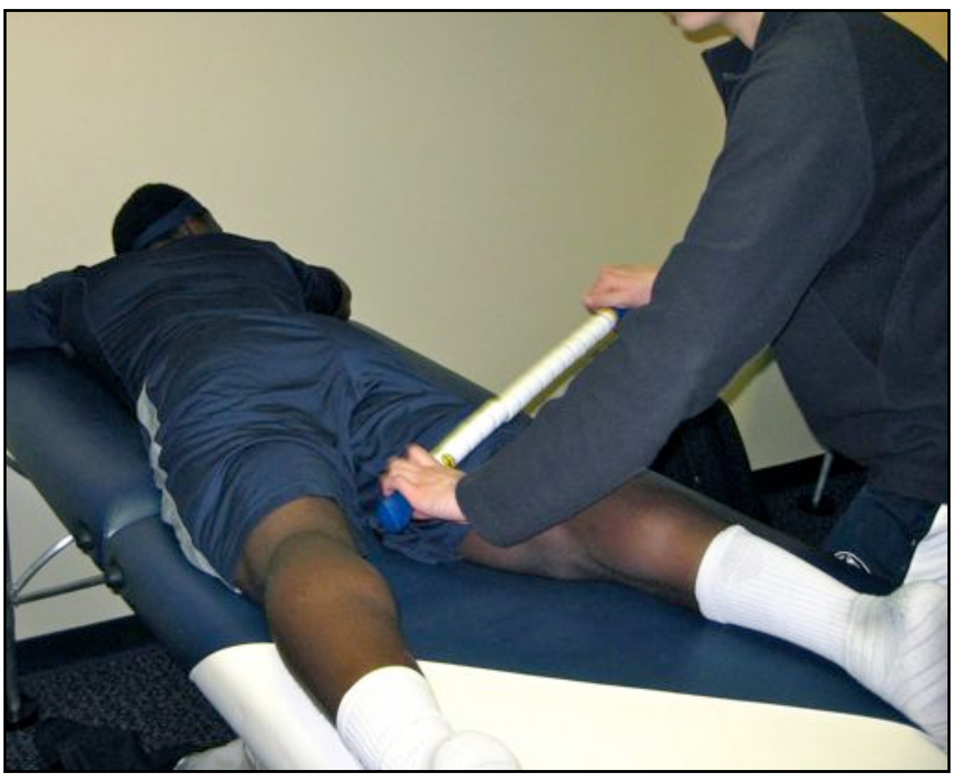


Figure 2-8: Roller Stick Technique of the Hamstring Muscle Group

Statistical Analysis

Means and standard deviations of dependent variables were calculated. Paired t-tests were calculated to assess within group pretest-posttest differences in the means of the dependent variables. Two-sample t-tests were performed to assess between group pretest-posttest differences. Change scores were calculated by subtracting the pretest values from the posttest values for ROM, single-leg horizontal jump, and single-leg vertical jump. Statistical calculations were done using the MiniTab software program (Minitab 16, Minitab Inc., State College, PA).

Table 2-1: Summary and Two-sample T-test for Participant Demographics and Anthropometrics

	M ± S.D.*	**95% Confidence Interval for difference** **(Lower bound, Upper bound)**	***p-value***
Number of Participants (n)	16		
Sex (male)	16		
Age (years)	18.81 ± 0.75 yrs		
Height (m)	1.856 ± 0.0611 m		
Mass (kg)	96.43 ± 17.07 kg		
Difference in Age (yrs)			
SS Control Group (n=8)	18.875 ± 0.641 yrs	(-0.718, 0.968)	0.752
RS Measured Group (n=8)	18.750 ± 0.886 yrs		
Difference in Height (m)			
SS Control Group (n=8)	1.8542 ± 0.0591 m	(-0.0714, 0.0652)	0.922
RS Measured Group (n=8)	1.8574 ± 0.0671 m		
Difference in Weight (kg)			
SS Control Group (n=8)	95.2 ± 21.3 kg	(-21.83, 16.95)	0.787
RS Measured Group (n=8)	97.6 ± 13.0 kg		

*Values are Mean ± Standard Deviation; SS = static stretching; RS = roller stick; yrs = years; m = meters; kg = kilograms

Chapter 3

Results

Within Group Comparisons

No statistically significant increases in passive hip or knee flexion ROM were found within the SS group; however, statistically significant greater hip and knee flexion ROM occurred in the RS group (Table 3-1).

Table 3-1: Paired T-tests for Within Subject Pretest and Posttest Measurements for Flexibility

	M ± S.D.		**95% Confidence Interval for difference** (Lower bound, Upper bound)	***p-value***
	Pre-Technique	**Post-Technique**		
SS Technique (n=8)				
Hip flexion ROM	61.83 ± 6.52º	65.75 ± 7.55º	(-9.86, 2.03)	0.163
Knee flexion ROM	96.54 ± 11.99º	102.38 ± 13.09º	(-14.61, 2.94)	0.160
RS Technique (n=8)				
Hip flexion ROM	65.04 ± 9.59º	70.71 ± 8.67º	(-10.91, -0.43)	0.038 *
Knee flexion ROM	89.33 ± 19.82º	96.38 ± 16.56º	(-11.44, -2.65)	0.007 *

Values are mean ± standard deviation; SS = Static stretching; RS = roller stick myofascial release
* $p < 0.05$ denotes statistical significance

A statistically significant increase in the single-legged hop distance was found after application of the SS technique (Table 3-2). In addition, a trend towards significantly increased single-legged hop distance following the use of the RS was found.

Table 3-2: Paired T-tests for Within Subject Pretest and Posttest Measurements for Single-Legged Hop

	M ± S.D.		**95% Confidence Interval for difference** (Lower bound, Upper bound)	***p-value***
	Pre-Technique	**Post-Technique**		
SS Technique (n=8)				
Horizontal Hop	2.179 ± 0.370 m	2.285 ± 0.290 m	(-0.2000, -0.0123)	0.032 *
RS Technique (n=8)				
Horizontal Hop	2.181 ± 0.219 m	2.215 ± 0.202 m	(-0.0720, 0.0054)	0.081

Values are mean ± standard deviation; SS = Static stretching; RS = roller stick myofascial release; m = meters; * $p < 0.05$ denotes statistical significance

Lastly, no statistically significant differences in vertical jump height were found for either the SS group or the RS group (Table 3-3).

Table 3-3: Paired T-tests for Within Subjects Pretest and Posttest Measurements for Single-Legged Vertical Jump

	M ± S.D.		**95% Confidence Interval for difference** (Lower bound, Upper bound)	***p-value***
	Pre-Technique	**Post-Technique**		
SS Technique (n=8)				
Vertical jump	0.4260 ± 0.0933 m	0.4340 ± 0.1036 m	(-0.0367, 0.0206)	0.528
RS Technique (n=8)				
Vertical jump	0.4122 ± 0.0533 m	0.3836 ± 0.0826 m	(-0.0481, 0.1052)	0.407

Values are mean ± standard deviation; SS = Static stretching; RS = roller stick myofascial release
* $p < 0.05$ denotes statistical significance

Between Group Comparisons

There were no statistically significant differences in average change scores for any of the measured variables between the SS and RS groups (Tables 3-4, 3-5, and 3-6).

Table 3-4: Two-sample T-test Comparing the Change in Means of ROM for SS and RS Techniques

	M ± S.D.	**95% Confidence Interval for difference** (Lower bound, Upper bound)	***p-value***
Passive Hip Flexion (degrees)			
Mean Difference SS Group (n=8)	3.92 ± 7.11º	(-8.99, 5.49)	0.610
Mean Difference RS Group (n=8)	5.67 ± 6.27º		
Passive Knee Flexion (degrees)			
Mean Difference SS Group (n=8)	5.8 ± 10.5º	(-10.46, 8.04)	0.777
Mean Difference RS Group (n=8)	7.04 ± 5.26º		

Values are mean ± standard deviation; SS = Static stretching; RS = roller stick myofascial release

Table 3-5: Two-sample T-test Comparing the Change in Means of Single-legged Hop Distance for SS and RS Techniques

	M ± S.D.	**95% Confidence Interval for difference** (Lower bound, Upper bound)	***p-value***
Distance (m)			
Mean Difference SS Group (n=8)	0.106 ± 0.112 m	(-0.024, 0.17)	0.124
Mean Difference RS Group (n=8)	0.033 ± 0.046 m		

Values are mean ± standard deviation; SS = Static stretching; RS = roller stick myofascial release

Table 3-6: Two-sample T-test Comparing the Change in Means of Vertical Jump Height for SS and RS Techniques

	M ± S.D.	**95% Confidence Interval for difference** (Lower bound, Upper bound)	***p-value***
Height (m)			
Mean Difference SS Group (n=8)	0.008 ± 0.034 m	(-0.043, 0.116)	0.321
Mean Difference RS Group (n=8)	-0.029 ± 0.092 m		

Values are mean ± standard deviation; SS = Static stretching; RS = roller stick myofascial release

Chapter 4

Discussion

Consistent with the first hypothesis, the roller stick myofascial release technique was found to increase knee joint range of motion. No functional performance deficit was found after execution of the single-legged hop in the roller stick group; moreover, a slight increase in jump distance was observed (not statistically significant), which is consistent with current research findings.[2,4,5] Although not statistically significant, a decrease in functional performance of the vertical jump was noted. This is inconsistent with the current literature that shows no change in functional performance or an increase in performance following the use of a roller (foam or stick) as a form myofascial release.[2,4,5]

In reference to the second part of the hypothesis, 60 seconds of static stretching (SS) applied to the knee joint extensors and flexors increased range of motion (ROM); however, instead of decreasing functional performance the SS technique significantly increased single-legged hop distance. A slight improvement (not statistically significant) was also noted between the pre-technique and post-technique SS group for vertical jump height. Both functional performance findings for the SS group are inconsistent with the current evidence suggesting that SS decreases functional performance.[6,7,12,15,16,19]

Range of Motion

An increase in muscle extensibility (flexibility) is defined as an increase in end-range joint angles (goniometric values).[20] Since statistically significant greater hip and knee flexion ROM was observed in the RS group from pretest to posttest conditions, it might be inferred from the present study that the roller stick (RS) myofascial release technique acutely improved participant hamstring and quadriceps flexibility. This finding is in accordance with previous studies.[2,4,5] One of the prevailing theories as to how this increase in ROM occurs involves changes to the fascia's thixotropic properties (the condition of being fluid-like).[2] Essentially, when mechanical stress (pressure, as in the case of RS myofascial release) is applied and heat is generated, the fascia takes on a more gel-like consistency.[2] This more relaxed state may allow for greater lengthening capabilities of the muscle and connective tissue; thereby increasing ROM and improving flexibility.[2,5] Furthermore, it was found in the present study that 60 seconds of SS showed an increase in ROM, but this increase was not found to be statistically significant. This may be explained by the viscoelastic property of muscle tissue such that as a tensile force is applied to the muscle, it lengthens, but then returns back to normal length one the force is removed.[20] It has also been speculated that the pressure generated by contact of the RS with the muscle tissue overloads the cutaneous receptors, which may reduce the sensation of stretch endpoint, thereby increasing stretch tolerance and allowing for greater ROM (similar to massage techniques).[2]

Functional Performance

Results for functional performance were less conclusive than the flexibility measures. Single-legged hop distance was found to improve with the use of the RS myofascial release technique, but these findings were not statistically significant. The single-leg vertical jump height was found to decrease with the use of the RS myofascial release technique, although not significantly. Possible explanations may relate to the neurophysiological responses experienced by muscles during massage treatments. Specifically, Weerapong et al[3] reported that petrissage and Swedish massage (effleurage, petrissage, and tapotement) were found to decrease isokinetic muscle strength and have no effect on sprint performance, respectively. Massage is believed to reduce spinal reflex excitability (as measured as a decrease in Hoffman-reflex amplitude), and the inhibitory nature of this effect may originate with stimulation of mechanoreceptors deep within the muscle or other underlying tissues.[3,22,23] Therefore, RS myofascial may follow a similar mechanism as massage in reducing the Hoffman-reflex (H-reflex), which may lead to a decrease in functional performance. This is supported by a study in which subjects where found to have decrements in evoked muscle contractile properties (peak twitch force, electromechanical delay, rate of force development, and half relaxation time) 24, 48, and 72 hours following the use of a foam roller, which may suggest direct damage to the muscle fibers.[4] Contrastingly, the study found small improvements in voluntary functional performance 24, 48, and 72 hours following foam rolling; it was argued that since evoked contractile properties were diminished, the foam roller may improve communication between the afferent fibers of the connective tissues instead of the muscles.[4] Additionally, the study found that foam roller subjects simultaneously reported less pain, which may suggest that the foam roller influenced recovery of the connective tissue more than the muscle tissue.[4]

As for the SS group, single-legged hop distance was found to significantly increase. The SS group was found to have the greatest percent increase in functional performance. Additionally, the single-leg vertical jump height for the SS group increased; however this was only slightly and the findings were not statistically significant. These findings suggest that the 60 second bout of SS was not detrimental to functional performance. This is supported by a few studies showing that SS did not have a significant effect on vertical jump performance.[10,12,18] Additionally, the present findings may be explained by age, fitness level, volume and intensity of the stretching protocol, and time in between stretching and testing.[12] Specifically, young, collegiate athletes may respond differently to the stretching protocol employed in the present study than older or less active individuals. Furthermore, if the intensity and duration of the stretching protocol were increased, the results may have shown a detrimental effect on functional performance in SS group. For example, Behm et al[15] reported that SS greater than 90 seconds produced greater maximal vertical jump height impairment than SS for less than 90 seconds.

Limitations

One of the limiting factors in the current study was the sample size (n=16). While this number is consistent with similar studies examining roller myofascial release techniques, it did not provide sufficient data to clearly identify specific results and trends based on the roller stick technique alone and in comparison to the SS technique. Additionally, the sample size was focused to collegiate male athletes, which limits the overall generaliziblity of the study. Future research should be executed using larger and more demographically diverse sample sizes, as this may reveal stronger statistical relationships or identify new ones. In addition, there is not a guarantee that the participants provided maximal effort on the functional performance tasks. This would further limit the statistical power of the results provided in the present study.

Another limitation is a lack of knowledge on physiological pathways involved with RS myofascial release. For example, MacDonald et al[4] examined the effect of foam rolling on ROM and attributed the results to that of a general myofascial release (decreasing inflammation, potentially reducing muscle adhesions between layers of fascia, and reducing muscle soreness), effects that may be due in part to the promotion of blood flow and movement of interstitial fluid back into circulation. However, the physiological processes that would potentially support this notion have not been closely examined; therefore, it is difficult to conclude whether these effects are occurring as a direct result from use of a RS. While the present study examined roller stick myofascial release in relation to static stretching, it has also been suggested that roller myofascial release may follow massage mechanisms more closely.[5] Two specific types of massage were identified to have shown an increase in ROM, petrissage and tapotement; however, the connection between these types of massage and the roller stick technique remain unspecified.[5]

Furthermore, many different types of roller stick are available for utilization as a myofascial release technique. The present study examined only one type of RS, which limits the results to being applicable for only that specific RS. It was found in a study by Curran et al[1] that different materials (hard or soft) as well as contact surface area may influence the pressure exerted on the tissue by the myofascial roller; specifically, it was reported that a harder material with a reduced contact area may provide more benefit as a roller myofascial release technique than a soft material with a greater contact area. It may be inferred from these findings that hand-held roller sticks made from different materials would elicit varying effects on the tissues.

Lastly, the duration and force of the SS may have been a limiting factor in the present study. Specifically, in a review article by Behm et al[15], it is suggested that SS greater than 90 seconds consistently results in functional impairments, while SS less than 90 seconds yields greater variability in functional performance.

Implications for Clinical Practice

The increase in ROM demonstrates an improvement in flexibility that is applicable to sports medicine professionals treating athletes as well as other health professionals attending to active individuals. Specifically, the RS myofascial technique can be utilized to enhance an individual's flexibility. The RS may also break up fascial adhesions, which may lead to improved muscle length and soft-tissue extensibility. On the other hand, the RS did not show a significant improvement in either functional performance measures. Therefore, it may be advised that the RS should not be used immediately prior to functional activities.

Potential benefits of using the RS may also include decreased pain and reduced neuromuscular hypertonicity; however, these mechanisms would need to be explicitly researched before definitive conclusions can be made. Specifically, a decrease in neuromuscular hypertonicity would reduce irregular joint compression (due to an overly tight muscle or muscle group) and the discomfort associated with the resultant atypical joint forces. Furthermore, decreasing muscle hypertonicity would reduce improper movement patterns that may have been occurring as a result of increased tension in a muscle and the subsequent abnormal joint mechanics. Similar to the neurological responses of massage, the effects of RS myofascial release may override or stimulate specific neurophysiologic pathways and processes. These processes may have a greater overall effect on the changes observed after a RS treatment than mechanical changes. Further studies would need to be conducted comparing the response of the nervous system to physical changes in the soft-tissue following a RS treatment.

Finally, the manufacturer of the specific type of RS examined in the present study (The Stick, The Stick/RPI of Atlanta, Atlanta, GA, USA) primarily promotes the RS as a treatment for tight and sore muscles as well as trigger points. Specifically, the manufacturer website claims that the RS relieves tight muscles, increases strength, flexibility, and endurance, enhances muscle recovery, prevents injury, assists in rehabilitation, and serves as trigger point therapy for the whole body.[24] However, the exact physiological processes (such as improved circulation, increased blood, and improved nutrient delivery) for these claims have not been closely examined. In addition, the RS may be useful during recovery from exercise, as it has been suggested to increase blood flow and enhance nutrient delivery to the muscle and connective tissue.[4,24] While these benefits may occur following the use of the RS, future research should examine the physiological processes behind the aforementioned claims in greater detail.

Conclusion

The results indicate that flexibility of the hamstrings and quadriceps were both significantly improved with use of the specific roller stick examined in this study. A trend towards increased single-legged hop distance (as an expression of functional performance) was also noted, but insufficient data prevents the establishment of a definitive statistical significance.

While the vertical jump height was found to decrease with the roller stick group, this, too, was not a statistically significant result. Therefore, research with increased participant numbers should be a primary focus for future studies examining the effect of roller stick myofascial release technique.

Appendix A

Recruitment Flyer

PENNSTATE

Athletic Training Research Laboratory

Research Volunteers Needed

Are you interested in learning more about the effects rolling out has on flexibility and functional performance?

If so, you may be interested in participating in our research study at Penn State.

Measurements: Functional performance and range of motion assessments after a myofascial release or static stretching technique

Purpose: Examine the effect of a specific myofascial release technique on functional performance and flexibility

Two one-hour sessions at the Lasch Football Building, University Park, PA

Requirements:
- Men and women ages 18 – 25 years old
- Good general health
- Physically active
- Non-smoker or consumer of nicotine products
- Not overweight

Allison Montgomery and Dr S John Miller
Departments of Kinesiology, Orthopaedics and Rehabilitation

For more information, contact
Allison Montgomery at
alm5739@psu.edu or (814) 574-6078
or
Dr S John Miller at
sjm221@psu.edu or 814-865-6782

Appendix B

Participant Screening Questionnaire

PENNSTATE

1855

Title of Project: The Effect of Roller Stick Myofascial Release on Range of Motion and Performance

Principal Investigator: Allison L. Montgomery

Project Coordinator: Sayers John Miller, PhD, PT, ATC

Co-Investigator: Giampietro "John" Vairo, PhD, ATC

Screening Checklist: Healthy Young Adults (18-25 years old)

Participant Identification Number:____

As a general health screen, you must be able to answer 'YES' to the following questions.

1. Are you between 18 to 25 years old? **Yes No**

2. Do you speak English? **Yes No**

3. Do you read at a minimum of an eighth-grade level? **Yes No**

4. Are you generally healthy (not overweight and a non-smoker or non-consumer of nicotine products)? **Yes No**

5. Are you recreationally active (defined as individuals engaging in physical activity at least three days per week for 30 minutes over the past six months)? **Yes No**

As a general health screen, you must be able to answer 'NO' to the following questions.

1. Do you have a history of musculoskeletal or neurological injury to the low-back or lower body within the last six months? **Yes No**

2. Do you have a history of low-back or lower body surgery? **Yes No**

3. Have you sustained a concussion within the past six months? **Yes No**

4. Have you followed a formal physical rehabilitation program in the last six months? **Yes No**

5. Do you have any low-back or lower body pain described as above ‘1’ on a 10-point pain scale? **Yes** **No**

6. Are you diabetic or suffer from peripheral neuropathy? **Yes** **No**

7. Do you currently have any lower body joint swelling? **Yes** **No**

8. Are you pregnant? **Yes** **No**

9. If you are pregnant, are you in the third trimester of your pregnancy? **Yes** **No**

Appendix C

Verbal Script

PENNSTATE
1855

Title of Project:	The Effect of Roller Stick Myofascial Release on Range of Motion and Performance
Principal Investigator:	Allison L. Montgomery
Project Coordinator:	Sayers John Miller, PhD, PT, ATC
Research Support:	Giampietro "John" Vairo, PhD, ATC
Screening Checklist:	Healthy Young Adults (18-25 years old)

Hello, my name is (*Penn State Institutional Review Board-approved investigator*) and I work with the Athletic Training Research Laboratory at Penn State. I am currently looking for research volunteers and was wondering if you would be interested in participating or at least hearing more about this study. I am looking for a group of participants who are 18 to 25 years old, have no history of lower body or low-back injury in the past six months and no related surgeries. Participants in this research study should be in good general health, not overweight and non-smokers. If you are undergoing physical therapy or sports rehabilitation under the supervision of a physical therapist or athletic trainer you will not be eligible to participate. I will be examining how a specific type of myofascial release may affect flexibility and functional performance in healthy young adults. If you are interested in participating, you would be required to come to the Lasch Football Building for a total of two testing sessions lasting approximately one hour each over the course of approximately two weeks. During the testing sessions we will measure the power of your lower extremity by asking you to perform a single-legged hop for maximum vertical and horizontal distance. Secondly, we will be assessing the range of motion of your knee joint to examine flexibility of your hamstrings. During the sessions you will be exposed to either a static stretching technique or a myofascial release technique (the roller stick). As a participant we will be happy to provide you with your specific data results. If you have any questions or need to get in touch with our research group for any reason, please call or e-mail Allison Montgomery at (814) 574-6078 or alm5739@psu.edu. You may also contact Dr. John Miller at 814-865-6782 or sjm221@psu.edu. Thank you.

Appendix D

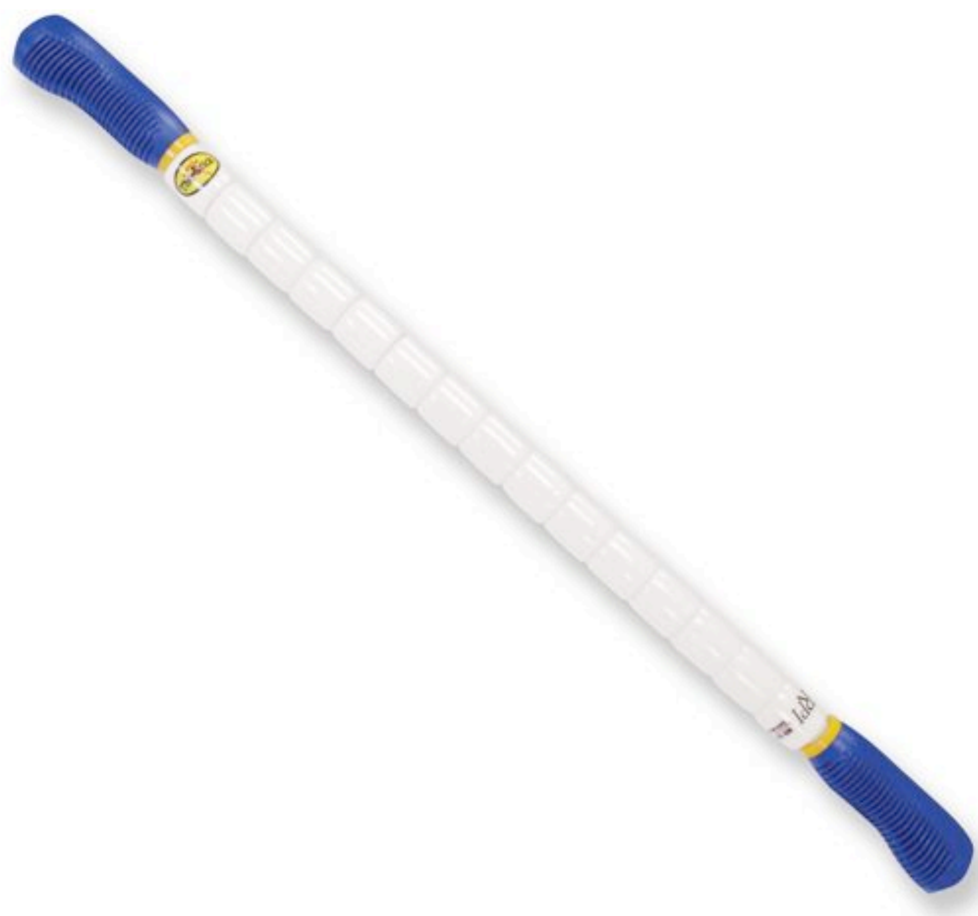
Roller Stick

Image of the myofascial release roller stick, “The Stick”

Manufactured by RPI of Atlanta

Company Address:
The Stick/RPI of Atlanta
120 Interstate North Parkway East
Suite 440
Atlanta, GA 30339-2158

Company website: http://intracell.info/



Appendix E

Data Collection Form

DATA COLLECTION FORM (1)

Participant Number:_____________ Date of Collection:____________________________

Demographic Information:

Gender:______________ (M = male, F = female)

Age (years):__________ Height (inches):___________ Weight (pounds):___________
(m):___________ (kg):___________

Leg Dominance (Leg Tested): R or L

Range of Motion Assessment:

MMT Value: ________ (Hamstring)
________ (Quad)

		Trial 1	**Trial 2**	**Trial 3**
Baseline	Hamstring (Hip Flexion)			
	Quadriceps (Knee Flexion)			
Post-Technique Intervention	Hamstring (Hip Flexion)			
	Quadriceps (Knee Flexion)			

DATA COLLECTION FORM (2)

Participant Number:____________ Date of Collection:__________________________

Leg Dominance (Leg Tested): R or L

Order #____ Single Leg Hop (Horizontal):

	Trial 1	**Trial 2**	**Trial 3**
Baseline			
Post-Technique Intervention			

Order #____ Single Leg Jump (VERTEC):

		Trial 1	**Trial 2**	**Trial 3**
Baseline	**Standing Reach** (Vertec set to 65 in)		**n/a**	**n/a**
	Maximal Jump Height (Vertec set to 75 in)			
Post-Technique Intervention	**Standing Reach** (Vertec set to 65 in)		**n/a**	**n/a**
	Maximal Jump Height (Vertec set to 75 in)			

Appendix F

Informed Consent Form

Informed Consent Form for Biomedical Research
The Pennsylvania State University
Healthy Young Adults (18-25 years old)

ORP OFFICE USE ONLY
DO NOT REMOVE OR MODIFY
IRB# 44397 Doc. #1001
The Pennsylvania State University
Institutional Review Board
Office for Research Protections
Approval Date: 02/05/2014 – J. Mathieu
Expiration Date: 02/04/2015 – J. Mathieu

Title of Project: The Effect of Roller Stick Myofascial Release on Range of Motion and Performance

Principal Investigator: Allison L. Montgomery
Schreyer Honors College Undergraduate Students
Department of Kinesiology
276 Recreation Building, University Park PA 16802
alm5739@psu.edu; 814-574-6078

Advisor: S John Miller, PhD, PT, ATC
Assistant Professor of Kinesiology
Department of Kinesiology
146 Recreation Building, University Park PA 16802
sjm221@psu.edu; 814-865-6782

Co-Investigator: Giampietro “John” L Vairo, PhD, ATC
Instructor of Kinesiology
Department of Kinesiology
146 Recreation Building, University Park PA 16802
glv103@psu.edu; 814-865-2725

1. **Purpose of the study:** The proposed study is designed to provide athletic training and sports medicine practitioners with additional information regarding the effects of a roller stick myofascial technique on flexibility and performance. A total of 30 people between the ages of 18-25 years old will be taking part in this study.

2. **Criteria for inclusion of participants:** You are being invited to participate in this research study because you are healthy, physically active and between the ages of 18-25 years old. You have no history of lower body or back injuries within the last six months and have never undergone surgeries for injuries to these areas. You are also not diagnosed with diabetes, peripheral neuropathy or epilepsy.

3. **Procedures to be followed:** If you chose to participate in this research study, you will be asked to perform the following procedures:

<u>Procedures</u>

A. We will begin the study by measuring your height and weight. We will also ask you what leg you like to kick a ball with.

B. Initially, you will perform a series of base-line data collection tests. These tests will include a measurement of knee joint range of motion using a hand-held goniometer, a single-leg hop test for maximal vertical distance, and a single-leg hop test for maximal horizontal distance. The order in which these data are collected will be randomized for each participant.

C. After a period of five days, you will then undergo a roller stick myofascial release or static stretching technique. The technique will be performed on the dominant leg quadriceps and hamstring muscle groups. These roller stick myofascial release and static stretching techniques will last 60 seconds each. The static stretching technique utilized will require that you lay on your back and the examiner lift one leg until any movement of the pelvis occurs. This position will be held for 60 seconds. Then, you will be asked to lay on your stomach with one leg off of the treatment table and foot flat on the floor. Your opposite knee will then be bent until movement of the pelvis occurs. This position will be held for 60 seconds. The roller stick technique is a form of myofascial release and will be applied by the researcher. The roller stick technique utilizes a hand-held device that is 24 inches long with a flexible center rod that is encapsulated by freely rotating firm plastic beads that roll over the muscle. This technique requires that the researcher to press with a moderate amount of pressure on the muscle for 60 seconds.

D. You will be asked to perform a flexibility assessment of the hamstrings and quadriceps for both legs, which will be measured with a plastic goniometer. This procedure will dictate that you lay on your back while the examiner lifts your leg until movement of the pelvis occurs. The hip flexion angle will then be measured. We will ask you to perform the assessment a total of three times for each leg, taking a measurement each time. You will be asked to flip a coin to determine which leg will be assessed first. You will then be asked to lay on your stomach with one leg off of the treatment table and foot flat on the floor. Your opposite knee will then be bent until movement of the pelvis occurs. The knee joint flexion angle will then be recorded. We will ask you to perform the assessment a total of three times for each leg, taking a measurement each time. You will be asked to flip a coin to determine which leg will be assessed first.

E. You will be asked to perform a single-leg hop for maximum vertical distance. You will stand next to a measuring device mounted on the wall. Measurements of maximal vertical reach will be recorded. You will then be asked to jump with countermovement as high as possible. That measurement will be taken from the mounted measuring device and recorded. You will repeat this task three times. You will be asked to perform the single-leg vertical hop for both of your legs. You will be asked to flip a coin to determine which leg will be assessed first.

F. You will be asked to perform a single-leg hop for maximum horizontal distance. To begin, you will place your heel at 0 cm on a tape measure that is secured to floor. You will then perform a single-leg jump with countermovement as far forward as possible. You will perform three maximum efforts and the examiner will immediately document the three distances each time. You will be asked to perform a single-leg hop for both of your legs. You will be asked to flip a coin to determine which leg will be assessed first.

G. You will be randomly assigned to one of two participant technique groups, the group that receives the static stretching technique for the hamstring and quadriceps muscles or the group that receives the roller stick myofascial release technique for the hamstring and quadriceps muscles.

H. The order in which you complete the assessment tasks (Procedures D through F) will be randomized for each session.

4. **Discomforts and risks:** The discomforts and risks with participation in this type of research study are minimal. The tests used are within expected ranges for physically active people. During the flexibility assessment, slight discomfort may arise from the stretching of the hamstrings. During the roller stick technique, flushing of skin may occur; however, this should dissipate quickly after the technique has ended. To lessen the chance of injury, you will also be shown how to properly perform every task in the experiment. Possible discomfort may consist of delayed onset muscle soreness 48 to 72 hours following testing. As with any research study, it is possible that unknown harmful effects may happen. However, the chance for injury in this type of research study is minimal and includes muscle strains, ligament sprains and bone fractures. We will take every possible effort to watch for and help prevent against any discomforts and risks. There is a risk of loss of confidentiality if your information or your identity is obtained by someone other than the investigators, but precautions will be taken to prevent this from happening.

5. **Benefits:** There is no direct benefit to you from participating in this research study. The benefits to athletic training and sports medicine practitioners is that it will provide them with additional information regarding the effects of the roller stick as a form of myofascial release.

6. **Duration/time of the procedures and study:** Participants will be asked to report to the Athletic Training Research Laboratory for the experiment two times over the course of two weeks. Each session will last approximately 1 hour and include your flexibility assessment and functional performance assessment with no technique and following a technique. The sessions will be separated by five days. All testing takes place at the Lasch Football Building, University Park, PA.

7. **Statement of confidentiality:** We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may find out about your participation in this research study. For example, the following people/groups may check and copy records about this research.
    - The Office for Human Research Protections in the U. S. Department of Health and Human Services
    - The Institutional Review Board (a committee that reviews and approves research studies) and
    - The Office for Research Protections.

    Efforts will be made to limit the use and sharing of your personal research information to people who have a need to review this information. A list that matches your name with your code number will be kept in a locked file or password-protected file at the Athletic Training Research Laboratory.

    In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

8. **Right to ask questions:** Please call the head of the research study (principal investigator), Allison Montgomery at 814.574.6078 if you:
    - Have questions, complaints or concerns about the research.

- Believe you may have been harmed by being in the research study.

You may also contact the Office for Research Protections at (814) 865-1775, ORProtections@psu.edu if you:

- Have questions regarding your rights as a person in a research study.
- Have concerns or general questions about the research.
- You may also call this number if you cannot reach the research team or wish to talk to someone else about any concerns related to the research.

9. **Voluntary participation:** Your decision to be in this research study is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this research study will not involve penalty or loss of benefits you would receive otherwise. You may be removed from this research study by investigators in the event you cannot complete the testing procedures.

10. **Injury Clause:** In the unlikely event you become injured as a result of your participation in this research study, medical care is available. If you become injured during testing procedures the investigators listed on this informed consent form will provide you with appropriate first aid care and instruct you on proper steps for follow-up care. If you were to experience any unexpected pain or discomfort from participating in this research study after leaving the Lasch Football Building please contact Allison Montgomery immediately at 814-574-6078 or S John Miller at 814-865-6782. If you cannot reach Allison Montgomery or S John Miller please leave them a voicemail and contact your doctor.

    If you are a Penn State student and cannot reach S John Miller or your doctor, please leave them voicemails and contact Penn State University Health Services at:

    Student Health Center
    University Park PA 16802
    814-863-0774

    It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent form for your records.

_______________________________________ _________________

Participant Signature Date

_______________________________________ _________________

Person Obtaining Consent Date

Appendix G

IRB Approval Letter

PENNSTATE

Vice President for Research
Office for Research Protections

The Pennsylvania State University
The 330 Building, Suite 205
University Park, PA 16802-3301

(814) 865-1775
Fax: (814) 863-8699
www.research.psu.edu/orp/

Date: February 5, 2014

From: Jodi L. Mathieu, Research Compliance Specialist

To: Allison Montgomery

Subject: Results of Review of Proposal - Expedited **(IRB #44397)**
Approval Expiration Date: February 4, 2015
"The Effect of Roller Stick Myofascial Release on Range of Motion and Functional Performance"

The Institutional Review Board (IRB) has reviewed and approved your proposal for use of human participants in your research. By accepting this decision, you agree to obtain prior approval from the IRB for any changes to your study. Unanticipated participant events that are encountered during the conduct of this research must be reported in a timely fashion.

Participants must receive a **copy** of the approved informed consent form to keep for their records.

If signed consent is obtained, the principal investigator is expected to maintain the original signed consent forms along with the IRB research records for this research at least three (3) years after termination of IRB approval. For projects that involve protected health information (PHI) and are regulated by HIPAA, records are to be maintained for six (6) years. The principal investigator must determine and adhere to additional requirements established by the FDA and any outside sponsors.

If this study will extend beyond the above noted approval expiration date, the principal investigator must submit a completed Continuing Progress Report to the Office for Research Protections (ORP) to request renewed approval for this research.

On behalf of the IRB and the University, thank you for your efforts to conduct your research in compliance with the federal regulations that have been established for the protection of human participants.

Please Note: The ORP encourages you to subscribe to the ORP listserv for protocol and research-related information. Send a blank email to: L-ORP-Research-L-subscribe-request@lists.psu.edu

cc: Giampietro L. Vairo
Sayers J. Miller, III

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Review of Literature

Introduction

Specific to roller stick myofascial release, the current literature lacks consistency in the experimental design. Specifically, large variation exists between the type of roller stick used and how the roller stick is used. One study by Sullivan et al[1] closely resembles the type of roller stick (RS) used in the present study; the RS was utilized by developing a machine that consistently applied the same amount of pressure while rolling. Additionally, the study examined bouts of rolling that were 5 seconds and 10 seconds in duration, not 60 seconds as was performed in the present study. The device that applied the RS is not as clinically applicable as the handheld RS technique, which the authors identified as a limitation of the study. Furthermore, the authors identified that it is unknown whether prolonged rolling or increased pressure exerted on the muscle by the RS would result in more beneficial results. It was found that a trend towards increased range of motion (ROM) occurred for 10 seconds of rolling duration over 5 seconds of rolling duration (p-value = 0.069).[1] These findings, in addition to clinical observation and experience, set the foundation for the preliminary research for the present study. Therefore, the purpose of the literature review is to synthesize clinically applicable background information for health care professionals in regards to the RS myofascial release technique.

Foam Rolling as Myofascial Release

Hand-held roller sticks have begun to gain popularity alongside the foam roller. Foam rollers are commonly used during self-myofascial release (SMR), a technique where the individual uses his or her bodyweight over the foam roller to apply pressure and exert force on the muscles and connective tissue. It has been claimed that foam rolling may alleviate muscular imbalances, muscle soreness, relieve joint stress, improve neuromuscular efficiency, and improve ROM.[2] It was reported that foam rolling may be an effective method for reducing delayed-onset muscle soreness and associated performance deficiencies.[2] In addition, foam rolling prior to muscular performance has been found to have no detrimental neuromuscular effects while demonstrating an increase in ROM.[1,3] Furthermore, it is speculated that higher density foam rollers have the capacity to increase the pressure exerted on the soft tissue and isolate the contact area between the roller and the tissues, which may provide a more beneficial result than softer, less-dense foam rollers.[4] Provided that the aforementioned studies are the most current evidence regarding myofascial rollers, many of the physiological mechanisms and theories supporting the use of a hand-held RS were based off of foam roller literature.

Specifically, the preexisting roller studies consistently found that bouts of myofascial release applied with a roller (either SMR with a foam roller or a hand-held RS) significantly increased ROM without causing functional performance deficits.[1-3,5] In one study, it was reported that foam rolling improved performance measures of vertical jump height.[2] It was stated in the aforementioned study that the improvement in functional performance was due to neural responses and amelioration of connective tissue dysfunction instead of benefits made directly to the muscle.[2] Furthermore, it was argued that use of a roller may actually cause damage to the muscle fibers as use of the roller was found to decrease evoked muscle contractile properties 24, 48, and 72 hours post-rolling.[2] However, subjects who underwent foam rolling reported peak pain values 24 hours post foam rolling while the control subjects reported peak pain values at 48 hours post-session.[2] The authors therefore suggested that foam rolling was an effective tool at reducing delayed-onset muscle soreness (DOMS).[2] Furthermore, the authors suggested that the pain and stiffness associated with DOMS may be due primarily to connective tissue damage incurred with eccentric muscle contractions instead of muscle fiber damage.[2] Specifically, cells, substrates, and fluids moving into the interstitial space as a result of inflammation may contribute more to the sensation of pain than the muscle damage; in support of this notion, the authors cited a study performed on horses where the presence of muscle damage was found without the presence of muscle soreness and vice versa.[2] Recently, a study was published using a hand-held RS that found a significant improvement in ROM (approximately 4%) in the ankle joint up to 10 minutes after a RS treatment.[5] This study was also unique in that static stretching (SS) was used in comparison to the RS; it was reported that use of the RS on the plantar flexor muscles led to a significantly greater force production relative to SS (8.2%).[5] Furthermore, it was reported that SS led to a 4% decrease in maximal voluntary contraction (MVC) of the plantar flexors; in contrast, after 10 minutes of rest following the use of the RS an increase in MVC of approximately 4% was observed.[5]

Overall, the results are encouraging for practicing health care professionals, especially since the myofascial roller can be utilized in a variety of settings. However, it will be especially critical to examine possible underlying structures and mechanisms involved with roller myofascial release. Central to this notion of myofascial release is the connective tissue enveloping the muscles and other soft-tissues (fascia). Additional treatments examined in the present literature review involve massage and static stretching.

Fascia

Classified as a dense irregular connective tissue, fascia has been found to be an important component to posture and organization of movement.[6] From a clinical perspective, fascia can become restricted, and these restrictions are caused by adhesions formed during an inflammatory process. Moreover, fascial restriction can manifest with a myriad of symptoms (pain, reduced ROM, decreased muscle length, neuromuscular hypertonicity, and decreased muscle strength, endurance, and motor coordination).[3] It has been proposed that intramuscular connective tissue, specifically the perimysium, may have the ability to contract and thereby influence passive muscle stiffness (passive muscle tone, muscular compliance, passive extensibility, and resting tension), especially within the tonic (postural) musculature.[7] Specifically, these contractile fascial structures possess the ability respond to mechanical stresses, which influences the changes in passive muscle stiffness.[7] Furthermore, tissue stretches induced by manual myofascial release therapies may induce tissue loading that promotes a temporary decrease in water content of the tissues; this phenomenon would allow for a transient reduction in tissue stiffness (perception of increased tissue softness or mobility), followed by an over-hydration of the tissue and increased stiffness.[8] Therefore, it would be important to consider if the amount of tissue loading and duration of rest afterwards would be great enough to illicit the response; however, this notion requires further research *in vivo*, since the proposed theory was formulated based off of studies performed with *in vitro* subject matter.[8]

In summation, fascia, which has also been described as a body-wide tensional network, is comprised of fibroblasts that respond to applied loads.[9] As the term network implies, everything is connected similar to a web or matrix; this includes muscles, organs, and varying types of connective tissues (muscle envelopes, aponeuroses, tendons, and ligaments).[8] Therefore, when certain areas of connective are placed under great strain, the physiological response dictates adaptation to better meet the demands, which ultimately alters the arrangement of the network and how it interacts with the surrounding tissues (structure affects function). Examining how fascia specifically responds to certain treatment techniques (roller myofascial release, for example) will enable future research studies.

Massage

Massages is considered to be a physical manipulation of the muscle and is preformed to manage pain and promote recovery.[10] It is also considered to improve performance (as a result of reduced pain and soreness, enhanced muscle relaxation, and improved blood flow).[10,11] Furthermore, massage may provide a soothing, sedative, and invigorating feeling, which may have a psychological effect of enhance an athlete's confidence about the beneficial processes potentially occurring within the body.[11] Theoretically, massage is thought to reduce the possibility of acute injury (muscle strain or tear as a result of overly tight musculature) or chronic injury (tendinopathies) by rearranging the muscle fibers such that proper alignment takes place.[11] In addition, it has been proposed that an increase in blood flow would result in an increased amount of oxygen and nutrient (protein) delivery to muscle, thereby increasing temperature (warming up) and buffering blood pH (via the removal of waste products). However, evidence is lacking to support these suggestions, and studies examining the effect of massage on circulation have shown that massage does not increase blood flow.[11] A study by Crane et al[10] found that massage reduced the production of the inflammatory cytokines tumor necrosis factor–a (TNF-a) and interleukin-6 (IL-6) and reduced heat shock protein 27 (HSP27) phosphorylation. These combined effects subsequently dissipated cellular stress resulting from muscle fiber damage.[10]

Currently, limited literature exists to suggest that massage performed acutely on an individual will enhance performance.[11] For example, a study examining the effect of precompetition massage on a group of sprinters found that massage did not have an effect on improving sprint performance.[12] It was also found in a study by Wiktorsson-Moller et al[13] that massage decreased isokinetic muscular strength. Additionally, a lack of consistent evidence exists to suggest whether massage increases muscle flexibility (defined as an increase in joint ROM) or not.[11] However, it has been recently shown that massage at the musculotendinous junctions of the plantar flexors and hamstrings significantly increases ROM, while two additional studies showed an increase in ROM of hip joint following massage of the hamstrings.[3] Importantly, the study by Wiktorsson-Möller[13] demonstrated that SS was more effective at increasing ROM than massage.

Lastly, massage is generally used as a recovery aid because it is believed to help overcome fatigue and reduce the amount of time needed for recovery.[11] However, current findings are inconclusive and lacking relevant data to support these claims. Even for the prevention or reduction in the severity of DOMS, massage has not been found to be effective.[11] Furthermore, inconclusive evidence exists as to whether massage is effective at reducing blood lactate levels. For example, one study found massage to be more effective than passive recovery at reducing blood lactate levels but less effective than an active (dynamic) recovery; however, the differences in performance time between the active recovery and massage were not significant, which may indicate that massage had a similar level of effectiveness on reducing blood lactate as the active recovery.[14] A second study found massage to have no effect on muscle metabolites (glycogen and lactate).[10]

Overall, it is not clear whether massage benefits an athlete by improving performance or enhancing recovery. Specifically, evidence regarding the type of massage used, the physiological effects of that massage type, and the methodologies of the experiments are inconsistent. This makes it challenging to draw specific conclusions regarding the effectiveness of massage as it pertains to functional performance and recovery. Massage remains apropos to the present study because RS myofascial release is commonly compared to massage and is thought to elicit some of the same proposed benefits as massage.

Static Stretching

Primarily, static stretching (SS) has been found to increase ROM, but cause functional performance deficits.[15-18] An increase in muscle extensibility may be explained by a decrease in muscle stiffness (demonstrated by an increase in length for a given applied tension or tensile force) or a simple increase in tensile force applied to the muscle, thereby causing it to stretch more.[19] The aforementioned outcomes may occur as a result of the mechanical or neurological properties of muscle tissue; specifically, the viscoelastic property of muscle, plastic deformation, or sensory theory.[19] The viscoelastic property of muscle may be explained by comparing muscle to both a liquid and solid. Muscle behaves viscously (similar to a liquid) and elasticity (by returning to its original position following removal of the tensile force).[18-20] The viscoelastic property is illustrated by SS; for example, when a muscle is held in a stretched position for an extended period of time, the muscle eventually relaxes slightly as the resistance to the stretch decreases (viscoelastic stress relaxation).[19,20] This relaxation allows for the muscle to be stretched to a greater length and suggests that the muscle tendon unit is affected during this phenomena.[3,18] Plastic deformation may be thought of as permanent tissue deformation; essentially, the muscle tissue can be stretched past the point of elasticity, rendering it unable to return the its previous length.[19] The sensory theory explains that an individual's perception of the stretch sensation (pain onset, maximum stretch, or maximum pain tolerance), may begin to occur later during application of the stretch following subsequent bouts of stretching.[19] Therefore, if an individual feels (or tolerates) the stretch sensation later in the stretch, increased ROM and subsequent muscle length can be achieved.

Static stretching, while commonly believed to have prophylactic benefits, has been shown to have no effect on injury prevention. Static stretching has also been shown to decrease muscle performance. Specifically, an article published by Magnusson and Renstrom[18] reported that the effect of SS on injury prevention is inconclusive, while overwhelming evidence exists to suggest that SS will decrease maximal muscle efforts. One mechanism to explain reduced muscle force following a bout of SS is that the stress applied during muscle lengthening may cause damage to the sarcomere and the reduce the ability of the muscle to contract effectively.[3]

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ACADEMIC VITA

Allison L. Montgomery
687 Tanager Drive, State College, PA, 16803
alm5739@psu.edu

<u>Education</u>
The Pennsylvania State University
Bachelor of Science in Athletic Training
Expected Graduation: May 2014

<u>Honors and Awards</u>
Eastern Athletic Trainers' Association
District 2 "Charlie Thompson" Scholarship **January 11, 2014**

Dean's List **Fall 2010, Fall 2011, Fall 2012, Spring 2013, Fall 2013**

<u>Association Memberships/Activities</u>
National Athletic Trainers' Association (NATA), *Member*, **January 2012 - Current**
Eastern Athletic Trainers' Association (EATA), *Member*, **January 2012 - Current**
Pennsylvania Athletic Trainers' Society (PATS), *Member*, **January 2012 - Current**
Athletic Training Student Club, *Public Relations Chair*, **September 2013 – Current**
Women's Leadership Initiative, *Member*, **September 2012 – May 2013**
Athletic Training Student Club, *Vice President*, **August 2012 – July 2013**
Penn State Saxophone Alliance, *Vice President*, **September 2010 – May 2011**

<u>Professional Experience</u>
The Pittsburgh Steelers, *Athletic Training Intern*, **July – August 2013**
EATA Annual Student Quiz Bowl, *Participant*, **January 10, 2014**
* Qualified to represent District 2 at the 2014 NATA Student Quiz Bowl
PATS Annual Student Quiz Bowl, *Participant*, **May 30, 2013**

Penn State University, *Undergraduate Teaching Assistant*, August 2013 – May 2014

<u>Professional Presentations</u>
Pennsylvania Athletic Trainers' Society (PATS); Student Poster, May 30 – June 1, 2013