COMPARISON OF FOAM ROLLING AND ISCHEMIC COMPRESSION IN THE TREATMENT OF HAMSTRING TIGHTNESS

By

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A Thesis Submitted in Partial Fulfillment of
the Requirements of the Degree of Master of Science in Athletic Training
to the office of Graduate and Extended Studies of
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ABSTRACT

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Athletic Training to the office of Graduate Extended Studies of East Stroudsburg University of Pennsylvania

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Title: A Comparison of Foam Rolling and Ischemic Compression in Treating Hamstring Tightness

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Abstract

Both foam rolling (FR), and ischemic compression (IC) have been shown to be effective in treating muscle tightness, but the literature lacks studies comparing them. This study was a crossover design consisting of 11 healthy NCAA Division II and III collegiate basketball players. Subjects underwent, in a randomized order, 3 treatments: 1) 2x90s trials of FR, 2) 3x30-60s of IC and 3) No treatment; with a 1-week period between each treatment. Variables measure pre and post treatment were: active hamstring range of motion (ROM), pain-pressure threshold (PPT), vertical jump height (VJ), and peak power output (PPO). A global rate of change survey (GROC) was given to measure the subject's perceived effect of the treatment. This study found, following each of the three treatments, a significant increase in ROM, VJ, and PPO. The improvement recorded in ROM, VJ and PPO does not appear to be the result of FR or IC.

KEY WORDS: foam rolling, ischemic compression, hamstring, myofascial release

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION LIST

ACh.... ..... Acetylcholine

AChE . ..... Aceytelcholinease

AChR . .....Acetylcholine Receptors

ADL ... .Activities of Daily Living

AKE ... . Active Knee Extension

ANOVA ..... Analysis of Variance

AROM ..... Active Range of Motion

ATP.... ..... Adenine Triphosphate

CGRP . .....Calcitonin Gene-Related Peptide

cm ....Centimeters

CON... .....Control

DOMS .....Delayed On-Set Muscle Soreness

EPP ....Expanded Polypropylene

FR .... Foam Rolling

GROC ..... Global Rate of Change

IC .... Ischemic Compression

in..... .....Inches

kg..... ..... Kilograms

kgf..... ..... Kilograms of Force

kPa/s... ..... Kilo Pascals per Second

lbf..... ..... Pounds of Force

MET... ..... Muscle Energy Technique

MRT... .....Myofascial Release Techniques

MTrP(s).....Myofascial Trigger Point(s)

N ....Newtons

NBA... ..... National Basketball Association

NCAA ..... National Collegiate Athletic Association

NRS ... .Numerical Rating Scale

ozf..... ..... Ounces of Force

PFPS .. .. Patellofemoral Pain Syndrome

PPO.... .....Peak Power Output

PPT ....Pain-Pressure Threshold

PRO ... . Patient-Rated Outcomes

ROM .. .. Hamstring Range of Motion

sd..... .....Standard Deviation

SLR.... ..... Single-Leg Raise

VJ..... ..... Peak Vertical Jump Height

W ....Watts

CHAPTER 1

INTRODUCTION

BACKGROUND TO THE PROBLEM

The hamstring muscles are a commonly strained because these muscles cross multiple joints and are involved in controlling movements at both the hip and the knee joints.[1] An epidemiological study done by the NCAA showed that 1% of recorded injuries in games for male and female basketball players were hamstring strains,[2,3] but in practice hamstring injury rate increased to 4-5%.[2,3] It has been reported that limited flexibility may predispose a person to musculoskeletal injuries.[4-6] There are many techniques that have been developed to help and treat muscular tightness. These techniques can be broken down into two categories: self-release and clinician-release. Both techniques have significant amounts of literature backing their effectiveness,[4,7-17] but there is minimum research directly comparing the efficacy self-release techniques and clinician-release techniques.

STATEMENT OF THE PROBLEM

Numerous studies have investigated the use of self-release techniques[4,9,10,12-14] and clinician-release techniques.[11,15,16,17] In providing high quality care to patients, healthcare

professionals are bound by both time and money. With the breadth of literature supporting both techniques, clinicians need to know if there is a more efficacious choice. Is self –release techniques or clinician-release techniques better at treating muscle tightness?

PURPOSE OF THE STUDY

The purpose of this study was to compare the acute effects of two myofascial release techniques on muscle flexibility, soreness, and performance. The technique used for the self-release was Foam Rolling (FR). The technique used for the clinician-release was Ischemic Compression (IC).A third non-treatment trial was also used as a control condition (CON).

SIGNIFICANCE OF THE STUDY

This study supported the use of myofascial release and provided guidance in determining the efficacy of the techniques in their ability to treat muscle tightness.

RESEARCH DESIGN

This study employed a 2 x 3 repeated measures cross-over design. The study design allowed for the participants to be their own control. The variables measured were active hamstring range of motion (ROM), pain-pressure threshold (PPT), vertical jump (VJ) peak power output (PPO) and global rate of change (GROC).

Data was collected before and immediately after each treatment for ROM, PPT, VJ and PPO. GROC data was collected immediately after the treatment. A repeated measures design was used to assess for changes in the dependent variable under each intervention condition. There was at least a 7-day washout period between each treatment

which allowed ample time for any lingering effects from the previous treatment to have subsided. The same clinician performed all the variable measurement to minimize any difference in measuring.

The data collected was analyzed using a 2x3 ANOVA for ROM, PPT, PPO, and VJ. The data collected from GROC was analyzed using a Kruskal Wallis and Chi squared test.

RESEARCH QUESTION

Is there a difference in treatment effect between pre and post testing for FR, IC, and no treatment (CON) on hamstring ROM, PPT, VJ, PPO and GROC?

NULL HYPOTHESES

For the purposes of statistical analyses, it was hypothesized that:

1. There is no significant difference among FR, IC, and CON in increasing ROM.
2. There is no significant difference among FR, IC, and CON in increasing PPT.
3. There is no significant difference among FR, IC and CON in increasing VJ.
4. There is no significant difference among FR, IC and CON in increasing PPO.
5. There is no significant difference among FR, IC and CON in increasing GROC.

DIRECTIONAL HYPOTHESIS

1. Both FR and IC will be clinically significant in increasing ROM, PPT, PPO, VJ and GROC when compared to get CON.[4,7-17]

LIMITATIONS

The following factors could not be controlled and may have affected the accuracy and generalizability of the data collected in this study.

1. This study utilized a small homogeneous sample of convenience and therefore limiting the external validity of the study.
2. The study relied on self-reporting of potential confounding factors such as abstaining from the use of over-the-counter or prescription pain relieving medications.
3. The subjects in this study were concurrently engaged in in-season basketball activities. This potentially put them at greater risk for injury or the introduction of confounding factors associated with competitive play.
4. Participants were not screened prior to acceptance into the study for MTrPs. Thus the presence of MTrPs was not guaranteed and the results could be skewed because of the absence of MTrPs.
5. Data collected for this study was completed at two different facilities with two different clinicians delivering the interventions. Although specific treatment protocols were provided and practiced by both clinicians there is the potential that the interventions delivered at both sites were not equal.
6. The pelvis and spine were not stabilized during AKE thus limiting the accuracy and reliability of the measurements.
7. Body weight values used for calculating PPO were obtained from the subjects' pre-participation sports screening collected prior to the study thus reducing the accuracy of this calculation.

DELIMITATIONS

This study was delimited to the following participants and conditions:

1. NCAA Division II and III Men's and Women's Basketball student-athletes at 2 colleges in northeastern Pennsylvania
2. Subjects had to be free of lower extremity injuries during and for 6 months prior to the start of the study.
3. Subjects reporting a history of psychiatric, cardiovascular, endocrine, neurological or metabolic disorders were excluded.
4. Subjects in the study were instructed to refrain from consuming, alcohol, nicotine, analgesics or pain relievers 48 hours prior to testing as these substances can alter pain perception and physical performance.

ASSUMPTIONS

Several assumptions guided this study:

1. Subjects would tell the truth about their health history.
2. Subjects refrained from consuming alcohol, analgesics, pain relievers or other illicit drugs.
3. Subjects communicated truthfully about levels of pain, stretch or improvements.
4. Subjects were consistent in their answers no matter the treatment received.
5. Subjects put forth maximal effort in treatments and in measurements.
6. Subjects did not have any additional treatment affecting hamstring flexibility, tightness or function beyond what is typically done as part of their in-season training program.

DEFINITION OF TERMS

Myofascial Release: Manual therapy technique that helps to reduce restrictive barriers or fibrous adhesions seen between layers of fascial tissue.[12]

Ischemic Compression: Application of sustained pressure on a myofascial trigger point with the intent of decreasing muscle tenderness and tension.[18]

Trigger Point: "A focus of hyperirritability in a tissue that, when compressed, is locally tender and, if sufficiently hypersensitive, gives rise to referred pain and tenderness, and sometimes to referred autonomic phenomena and distortion of proprioception."[18]

Algometer: An instrument that measures the application of pressure and evoking of pain to the skin and underlying tissues in N.[19]

Foam Rolling: The use of body weight on a foam roller to create pressure on the opposing body tissue.[20]

Vertical Jump: the vertical distance between the highest vane tapped during the standing vertical reach and the vane tapped at the highest point of the jump.[10]

Peak Power Output: the maximum amount of force produced by a participant during a vertical jump[10]

Global Rate of Change: A 3-question survey used to quantify a patient's improvement or deterioration over time, to determine the effect of an intervention. GROC scales ask that a person assess his or her current health status, recall that status prior to treatment, and then select from a list of rating one that most accurately reflects the change in symptom. GROC scale used for this study was a standard 15-point scale.[21]

Pain Pressure Threshold: The lowest amount of pressure needed to elicit pain using an algometer measuring in the units of N.[19]

Active Knee Extension: the upward movement of the lower leg from 90 degrees of knee flexion to full knee extension at 180 degrees. This is measured by a goniometer, starting from a position of 90 degrees of knee flexion and 90 degrees of hip flexion while lying supine until slight discomfort is felt with the hip position unchanged and the foot relaxed.[4]

Active Range of Motion: The extent of movement (usually expressed in degrees) of an anatomical segment at a joint. The movement should be caused only by voluntary effort to move the body part being tested.[18]

Injury: not being able to participate in training or competition for at least 7 days.[4]

Active varsity player: participant holds a spot on the team's current varsity roster.

EXPECTED FINDINGS

- It is expected that there will be a significant difference in ROM with FR when compared to CON.[4,9,12-14]
- It is expected that there will be a significant difference in PPT with FR when compared to CON.[16]
- It is expected that there will be a significant difference in VJ with FR when compared to CON.[13]
- It is expected that there will be a significant difference in PPO with FR when compared to CON.[16]

- It is expected that there will be a significant difference in GROC with FR when compared to CON.[13]
- It is expected that there will be a significant difference in ROM with IC when compared to CON.[7,15,17]
- It is expected that there will be a significant difference in PPT with IC when compared to CON.[7,11,17]
- It is expected that there will be a significant difference in GROC with IC when compared to CON.[17]

CHAPTER 2

REVIEW OF LITERATURE

INTRODUCTION

This study specifically focused on muscle tightness of the hamstrings in basketball players. Other studies have examined hamstring tightness[10,14] in soccer players[4-6] but few studies have looked at the impact of hamstring tightness on basketball players, even though the prevalence of hamstring injuries has been documented by both the NCAA[2,3] and the NBA.[22,23] In the NCAA, hamstring injuries for men and women were 1% of all injuries in games and 4-5% of all the injuries recorded in practice.[2,3] In the NBA, hamstring injuries accounted for 3.3% of all recorded injuries.[23] Because of the data found in the NCAA and NBA, hamstring injuries are shown to be a problem. Muscle tightness, sprinting, and the eccentric contraction of the hamstrings during deacceleration while running can make it more vulnerable to muscle straings.[23]

Hamstring flexibility has been shown to be a factor in the onset of hamstring injuries in athletics.[4-6] Hamstring flexibility is defined, for this study, as the ability of the hamstring to lengthen allowing for the knee, hip and back to move through their range of

motion. Hamstring flexibility can be influenced by joint capsule and soft tissue restrictions.[24,25]

Thomas Myers in his Anatomy Trains[24,25] book identify several myofascial or connective tissue lines throughout the body. The hamstrings are a part of the straight back fascial line (SBL). The SBL is a line of fascia shown by Meyers et al[24,25] to run from the plantar fascia to the cranium. The SBL runs through the Achilles tendon, gastrocnemius, hamstrings, sacrotuberous ligament (STL) and erector spinae which connects to the cranium. The hamstrings and STL connect at the ischial tuberosity. Since the hamstrings are a part of the SBL, if the hamstrings are tight it affects the mechanics of other joints and muscles.[24-26]

A study by Cruz-Monetecinos et al[26] showed the amount of pelvic motion allowed affected the amount of force transferred between the gastrocnemius and the hamstrings. If the hamstrings do not allow for adequate pelvic motion it affects force distribution and the biomechanics of the body[26] this can lead to an increased chance of overuse injuries, muscle strains and ligament sprains.[6]

Hamstring tightness can influence the biomechanics of the body as well as performance. In collegiate basketball, players need to have the ability to sprint, explosively cut and jump without hindrance from muscle tightness. If hamstring tightness does not allow for the ability to perform the movements properly a decrease in performance is likely to occur.[27] Wilson et al[27] provided evidence that a decrease in the active tightness of a muscle will increase the force production during a vertical jump.

Another factor that can influence performance but is also influenced by hamstring tightness is pain. The pain may manifest itself in the hamstrings or in other areas of the body such as the low back or knees.[6,28-31] A study done by Esola et al[28] showed that participants with low back pain had decreased hip motion but increased lumbar motion. It has been postulated that a decrease in hip motion caused by hamstring tightness increases the stress put on the lumbar spine leading to an increase in pain and potential injury.[28,29] Another study looking at the effects of hamstring tightness on patella femoral pain syndrome (PFPS) showed a strong correlation between the presence of PFPS and hamstring tightness.[30] Giving evidence that hamstring tightness may predispose an individual to developing PFPS.[30] A different study conducted by Henderson et al[6] focused on the prevalence of hamstring injuries in English Premier League Soccer players and their correlation to multiple factors. A correlation between hamstring injury and tightness was found.[6] The study showed that for every degree loss of active hip flexion increased the odds of hamstring injury by 1.29[6]. Another factor that has been shown to affect hamstring tightness and pain are MTrPs.

PRESENTATION OF SYMPTOMATOLOGY

MTrPs are thought to be caused by either a chronic overuse injury or by nociceptive input.[33-35] Some factors which can influence the formation of MTrPs are type of stresses and the external environment the muscle is in. MTrPs have been commonly found in individuals who do have to sustain postures for long periods of time and/or repeatedly perform maximal or submaximal concentric and/or eccentric exercises.[33,34,36]

It is theorized the sustaining or repeating a movement or exercise affects the interstitial environment and function of the cell.

Several factors, in the local cellular environment, are thought to contribute to the development of MTrPs. Theory being, is that muscle exertion at too high of level or sustained for too long can result in local hypoxemia causing a cascade of reactions. The reactions are theorized to look similar to this: a muscle's demand for oxygen exceeds its immediate availability[37], triggering anaerobic glycolysis which produces an inadequate amount of ATP and lactic acid (LA) as a byproduct[33,38]. The decreased supply of ATP causes the muscle to spasm[34,39], increasing the metabolic crisis and production of LA[33,38].

The body can remove LA from the local environment[33], but if the rate of production is greater than rate of removal it accumulates in the tissue resulting in a lowering of pH.[33,40,41] A lower interstitial pH can increase muscle tenderness by decreasing the nociceptor threshold[33]. The nociceptor threshold is decreased in two ways: an increased production of calcitonin gene-related peptide (CGRP) and an increased regulation of aceytelcholinease (AChE)[33]. CGRP is a compound that elevates two things: the release of acetylcholine (ACh) and the production of acetylcholine receptors (AChR)[33]. Meaning there is a greater ability for ACh to bind and produce a nociceptive message resulting in a perceived area of tenderness[42].

AChE is an enzyme that helps to moderate nociceptor substances, specifically ACh[33]. With an increased regulation of AChE there is an increased efficiency for ACh to produce a nociceptive message, resulting in a perceived area of tenderness[33]. The result

within the muscle is two-fold: an area of palpable tightness and increased muscle tenderness.

MYOFASCIA

Fascia surrounds every part of our body. There are multiple layers of fascia that surround a muscle. Fascia consists of connective tissue cells and fibers surrounded by a gelatinous ground substance.[43] This ground substance which surrounds the fascial cells and fibers is made of water, hyaluronic acid and other glycosaminoglycans which allows these elements to easily slide and slide across one another enabling free and unrestricted movement.[43,44] However, trauma, inflammation and/or disease can alter fascial tissue and the molecular composition of the ground substance reducing its viscosity and restricting movement. Scar tissue or extra connective tissue is laid down following the injury forming adhesions between the skin and muscle. It is theorized, the adhesions restrict normal function and movement of the fascial layers, skin and muscle.[45] The adhesion could possibly cause local dehydration, ischemia, pain, loss of ROM, decreased performance or MTrP.[45] Soft tissue mobilization techniques such as FR and IC have been theorized to produce a variety of effects to the muscle and fascial tissues. These effects can be generally divided into the mechanical and neurophysiological models.

The mechanical models theorize that the material properties of fascia are affected by the pressure exerted through FR and IC which in turn alters the viscoelastic properties of the fascia.[12] Many theories have been proposed as to the mechanisms which cause this change in property: thixotropy, piezoelectricity, plastic deformation. [40,43,46-48]

Mechanically compressing the tissue either via a FR or IC is likely to engage the thixotropic property of fascia resulting in greater ease of movement. [49] This is achieved because fascia is colloidal in nature and when energy through compression is applied to the tissue the fascia becomes more viscous thus allowing for a greater ease of movement.[43,50]

Both FR and IC can potentially cause a piezoelectric effect within the tissues because the mechanical force applied during treatment. A mechanical change in muscle whether by changing length or deformation is theorized to modify the pizioelectric effect of the body.[43,51] Whether this change in charge is enough to significantly alter tissue physiology and yield some benefit is still unknown.[43,51]

Another mechanical mechanism that is theorized to occur is plastic deformation of the fascia. Plastic deformation is a low-grade sustained deformation force to collagen rich tissues which in turn yields changes to the stress-strain cycle.[43] The stress-strain cycle is a model to explain how increasing the stress (load) on the muscle increases the strain (deformation) of the muscle. As the stress is sustained the muscle loses its original shape and in response will tighten up to protect the muscle. For the muscle to return to its original shape outside forces need to be applied; (i.e. FR or IC) these will cause the muscle to relax and soften.[48]

Along with the mechanical effects, compression of a MTrP has shown to have neurophysiological effects as well. Some of the effects that have been studied are the alteration of nociceptor thresholds via pain gating, possible alteration of the interstitial chemistry and reprogramming of the nervous system. Studies by Aguilera et al[7] and Shah

et al[17] showed, following treatments of compression on MTrPs, the nociceptor or pain-pressure threshold was increased. With a greater threshold for pain muscles may move more freely without the inhibition of pain.

Following compression on a MTrP a study by Morsaka et al[52] found the interstitial environment had changed. Increased amounts of lactate and glucose were documented in the area following the treatment. The increased availability of glucose is likely from an increase in blood flow to the area, providing an increase in substrate availability to muscle.[40,46,52] With the increase in nutrients to the area muscles can function properly resulting in less tension in the area. The decrease in muscle tension, subsequently decreases the tension on the nerves allowing for an uninhibited flow of neural signals.

Compression at a MTrP has also been shown to increase parasympathetic nervous activity.[53] An increase in parasympathetic nervous activity is theorized to block the release of ACh.[54] A more regulated release of ACh, is theorized to increase the nociceptor threshold of the muscle, allowing for proper muscle function.[40,46,55]

THIXOTROPY

Thixotropy of fascia is defined as a change in energy in the fascia which causes a change of properties for a solid state to a more fluid state.[12,43] This is achieved through the friction caused by the posterior thigh moving on top of the roam roller. It is theorized, due to the deformation of the fascia that MTrPs will be relived.[12]

TREATMENT INTERVENTIONS

Direct soft tissue mobilization techniques such as, petrissage (kneading), compression, and gliding, have been used by clinicians to treat symptoms of muscle tightness since ancient times.[26] The type of direct soft tissue mobilization presented in this review will focus on myofascial release techniques (MRT). MRT is a soft tissue mobilization technique that uses moderate to deep pressure delivered manually by a clinician or self-administered using a device such as a foam roller. MRT attempt to reduce restrictive barriers and adhesions within fascial tissue.[43] Some of the physiological properties MRT utilizes are friction, ischemia and thixotropy. The application of these properties causes mechanical and physiological changes to the muscle which help resolve MTrPs. The different MRT can be broken down into two categories, self-release and clinician-release.

Studies by MacDonald et al[12] and Mohr et al[14] showed self-MRT's effectiveness in decreasing muscle tenderness. These findings were supported by Bradbury et al.[9] Using a machine operated roller stick, Bradbury et al[9] was also able to decrease muscle stiffness while increasing neuromuscular recruitment. Gulick et al[56] using self-IC by a Backnobber II tool and was able to decrease muscle stiffness and tenderness of the neck musculature. Studies by McDonald et al[12] and Pearcey et al[16] provided evidence MRT was able to decrease muscle tightness and tenderness while improving performance during a vertical jump. Two of the most commonly used MRT to decrease muscle tightness and tenderness while improving muscle performance are FR, a self-release technique, and IC, a clinician-release technique.

MECHANISM OF INTERVENTION

FOAM ROLLING

FR is defined as small movements on a dense foam roller that starts at the proximal end of the hamstring and works distal or vise-versa.[57] While these motions are being performed, direct pressure is applied on the soft-tissue. The pressure creates friction and a thixotropic effect of the soft tissue.[43,49,50] The thixotropic effect causes a change in the viscosity of the fascia.[57,58] This physiological change of the fascia increases the extensibility of the fascia through the breaking MTrPs and improving muscle tightness, tenderness and performance.[7,12,15-17]

MacDonald 2013 et al[12] examined the use of FR as a recovery tool for the lower extremity. During randomized control trial 20 different male subjects completed an intense lower body exercise protocol to elicit delayed-onset muscle soreness during 5 separate sessions which were separated by a minimum of 24 hours. After each session the subjects either received either no foam rolling or a 20-minute foam rolling intervention. The participants in the FR group foam rolled: immediately, 24 hours post-exercise, 48 hours post exercise, and 72 hours post exercise. The result of this study found that FR reduced muscle soreness at all the time measurements, improved ROM, and vertical jump height when compared to the control condition.

Pearcey et al[16] examined the effects of FR on muscle recovery in the quadriceps. During this cross-over design study 8 subjects completed an intense exercise protocol to elicit delayed-onset muscle soreness during 2 separate sessions scheduled approximately 4 weeks apart. After each session they either received no foam rolling or a 20-minute

foam rolling intervention, which was performed immediately, 24, 48 hours post-exercise. The result of this study found that FR improved muscle soreness and lessened the detrimental effect of DOMS on sprint times, power, and dynamic strength-endurance compared to the control condition.

MacDonald et al[13] examined the effects of FR on muscle performance of the quadriceps. During a within-subject design, 11 healthy male subjects underwent 4 different trials with 24-48 hours in between each trial. The trials included: 1) Control measuring ROM, 2) Control measuring knee extensor force, 3) FR measuring ROM, and 4) FR measuring knee extensor force. Results from the study showed a positive correlation between FR and knee extension and a negative correlation between force production and ROM prior to FR which was resolved following FR.

Krause et al[20] created a study design which will look the effect of FR on passive tissue tightness on the quadriceps. The study will employ a crossover design with 16 participants which will undergo 3 different treatments: 1) FR to the quadriceps, 2) passive static stretch to the quadricep, 3) No intervention. No conclusions were included with the article since the study was still in the recruiting phase.

The literature had many different protocols for the application of FR. This study chose to utilize the protocol laid out by Krause et al[20] with modifications of extending the treatment time from 60 seconds to 90 seconds by MacDonald et al[13] to keep treatment times between interventions similar.

ISCHEMIC COMPRESSION

IC is defined by Travell et al[18] as the "application of progressively stronger pressure on a trigger point for eliminating the trigger point's tenderness and hyperirritability". IC breaks the cycle of the MTrPs by theoretically changing the biochemical concentration of inflammatory mediators, neuropeptides, cytokines, and catecholamines of the environment.[39,52] The release of the pressure is thought to causes a reactive hyperemia of the area.[34,44] The change of chemistry and resulting hyperemia brings in the oxygen and nutrients needed to create ATP and stop the flow of ACh. [34,44] With the MTrPs resolved muscle tightness and/or tenderness would decrease and in theory performance would improve.[7,8,15,17,61]

A study by Aguileria et al[7] examined the effect of IC and ultrasound for the treatment of MTrPs in the trapezius muscle. During the randomized control trial 66 healthy individuals were randomly assigned to one of three treatments: IC, ultrasound, and sham ultrasound. Results from the study showed a decrease in basal electrical activity and MTrP sensitivity in both of the therapeutic modality groups and an increase in cervical AROM for the IC treatment group.

A study by Shah et al[17] examined the effect of IC and muscle energy technique (MET) on MTrPs in the upper trapezius muscle. 30 participants, with non-specific neck pain, were randomly divided into two groups, IC and MET, and received treatment every day for a week. Results from the study showed a significant improvement in all three of the outcome measures (PPT, VAS, cervical AROM), for both groups. When comparing between groups the IC treatment group had a significant improvement in PPT compared

to the MET treatment group. The MET treatment group had a significant improvement in cervical AROM when compared to the IC treatment group.

A study by Nambi et al[15] examined the effect of IC and MET on MTrPs in the upper trapezius muscle. During a quasi-experiment 30 participants with palpable MTrPs in their upper trapezius were randomly divided into two treatment groups, IC and MET, and received treatment three times a week for four weeks. Results from the study showed a statistically significant improvement in both groups for cervical range of motion.

A study by Berggreen et al[8] examined the effects of MTrP massage on MTrPs in the muscles of the head, neck and shoulders. During the randomized control trial 29 females with chronic tension-type headaches were randomly assigned to two groups, the MTrP massage group or control group. The MTrP massage group received treatment one time a week for ten weeks. Results from the study showed a significant improvement in morning pain and the number of trigger points in the MTrP massage treatment group compared to the control group. None of the previous studies on IC concentrated on lower extremity performance so it is unknown how IC will affect the VJ performance.

This study compared FR and IC. These two techniques were chosen due to their low cost, large availability of previous literature, no specialized training needed to perform the treatments and high rate of use within sports medicine facilities. The methods which will be used to evaluate each techniques effectiveness is ROM, PPT, PPO, VJ and GROC. Based on the literature, it can be assumed that FR and IC will have a positive effect on areas of assessment. The researcher in the reviewing the literature did not find a

study comparing these two techniques so it is unknown whether one of the techniques will be more effective than the other at reducing hamstring tightness.

INTERVENTION OPTIONS

The outside interventions applied to the MTrPs are IC and FR. These two interventions will be assessed by effects on the hamstrings change of ROM, PPT, PPO and GROC and the patient's results in performing a VJ.

ASSESSING TREATMENT EFFECTIVENESS

The collection of patient-reported, clinician-reported outcomes, and functional performance outcomes are typically used to assess treatment effects and judge efficacy. A wide range clinical outcome measures have been used in the literature to assess the effectiveness of various myofascial release techniques. For this research investigation flexibility, pressure sensitivity, jump performance, power production and subjects' perception of change were the outcome variables used to compare the effects of the FR and IC interventions.

FLEXIBILITY-ACTIVE KNEE EXTENSION

Hamstring flexibility was assessed using AKE. AKE has been found to be a valid and reliable method of assessing hamstring with intra-tester ICCs values ranging from .79-.94.[59,60] The AKE test was selected over the straight leg raise (SLR) because it is considered easier to control because it only involves motion at one joint rather than two and is an active measure rather than passive giving a better functional assessment.[58] FR has been found in multiple studies to increase the ROM of the muscle it which it is being applied.[4,9,12-14] No previous studies were found assessing IC effect on hamstring

tightness. Most studies used to test IC's ability to affect ROM have been in the upper trapezius and neck.[15,17,61] These studies have produced promising results in being able to increase ROM.[7,15,17,61] Since this study is using the hamstrings as the body part of focus it is unknown whether FR or IC will have a greater effect on increasing the ROM of the hamstrings.

PRESSURE SENSITIVITY- PAIN-PRESSURE THRESHOLD

Point tenderness or pressure sensitivity during digital palpation is a common complaint in muscle pathologies especially MTrPs. An algometer is an instrument that can be used to measure the amount of force applied to a localized area. PPT is defined as the lowest amount of pressure needed to elicit pain.[19] Previous research has used the PPT as measure for evaluating and quantifying myofascial pain and assessing changes in muscle tenderness over time.[19,62] As MTrPs resolve, PPT has been shown to increase.[16] Studies have supported the use of algometers as a reliable way to test PPT and have reported ICC values between .70-.97.[19,62-66] FR had minimal studies using PPT as a measure but in the small pool of literature there was support for FR abilities to increase PPT.[16] PPT was a common measure in the literature to test the effect of IC. Multiple sources have shown statistical significance of IC's ability to positively affect PPT.[7,11,17] From the literature, IC was found to have a greater breadth of support in its ability to increase PPT, but it all was focused on the upper trapezius.[7,11,17] It is unknown which intervention is better increasing PPT in the hamstrings.

JUMP PERFORMANCE- VERTICAL JUMP AND PEAK POWER OUTPUT

Performance measurements were utilized to test the effects of the myofascial treatments on power output and simulate the demands common within basketball. VJ and PPO were chosen because they utilize the hamstrings and are similar to motions performed in basketball.

VERTICAL JUMP

VJ is a commonly used measure of athletic performance to provide a global assessment of lower extremity muscular power and coordination. VJ is defined as the vertical distance between the highest point reached when standing with arm fully raised and highest point of the jump.[10] There are several testing methods identified in the literature: drop jump, run-and-jump and, what was used in this study, countermovement jump.

Rodriguez-Rosell et al[67] investigated the reliability and validity of 4 different vertical jump test in 186 male soccer and basketball players. They found that all vertical jump tests studied were reliable measures with ICC values ranging from .969-.998. In this study they also found a strong correlation between vertical jump tests and sprint and strength performance.

PEAK POWER OUTPUT

PPO was defined as the maximum amount of force produced by the individual when performing a vertical jump. PPO is calculated by using a participant's peak VJ, height and weight. This information was inserted into the Johnson and Bahamonde[68] formula for power output. Balmar et al[69] investigated the reliability and validity if peak

power predicts performance power. They found that PPO affords a valid and reliable measure for performance with ICC values of 0.99. Previous studies on FR have mixed results on the effectiveness in FR positively effecting PPO.[16] It is unknown how IC will affect PPO due to a lack of literature using PPO as a variable in IC studies.

GLOBAL RATE OF CHANGE SCALES

The GROC is a patient reported outcomes measure designed to gather information on the subjects' perception of any changes that occur over time in response to an intervention. GROC scales are commonly used both in research and in actual clinical practice to determine treatment efficacy and provide patients with a formal mechanism to provide qualitative feedback to the clinician regarding symptom improvement or deterioration. Kamper et al[21] did an appraisal of the common GROC scale used in patient care. They found that although there is significant variability in design and scoring, most GROC scales can provide clinically relevant and reliable information. Key factors that affect the reliability and face validity of these measure is the question wording, the size of the rating scale (7 vs. 15 pts), and how much time elapsed between the administration of the treatment or the scale. Questions needed to be specific to the injury that is of interest, specific to the construct of interest and anchored by a specific time point to use as a reference in which to compare their current condition.[21] When questions are worded correctly, the GROC has been shown to be a reliable measure of patient-reported change.[21] Literature supports those who perform FR experience a therapeutic effect which positively affects their GROC score. The literature supports those who undergo IC experience a therapeutic effect which positively effects their reported GROC score.[13,17]

Since there is no literature directly comparing FR and IC it is unknown whether there will be a statistical difference between them. In the review of literature there was a study which looked at the psychological and emotional effect of touch.[70] The study found through the touch of a hand massage individuals cortisol levels decreased.[70] Individual's levels of relaxation and safety were increased based on responses on two different PRO scales.[70] As positive as the findings are from this study they need to be taken with caution since there was no control and the study applied a different type of massage for different purposes. Both FR and IC have support for their ability to increase GROC but since there is no research that has compared the two techniques it is unknown whether FR or IC will have a statistically significant increase when compared to the other.

CONCLUSIONS

From the review of literature, it was shown that both IC and FR have a positive effect on decreasing muscle tightness, tenderness and/or improving performance while resolving MTrPs. [4,7,9,11-17,61] The treatment of MTrPs has been shown to increase the ROM[4,7,9,12-15,17,61], PPT[7,11,16,17], VJ,[13] PPO[16] and GROC[13,17] of the muscle and soft tissue when compared to the control. This study is important because it compares FR and IC to a control as well as to each other. This design will help give support to each of the techniques. The design also allows for a comparison to help guide clinicians whether FR or IC is more effective in treating hamstring tightness. This is important because not only does this help with effectiveness but also helps guide clinicians to how to best allocate time and resources when they are treating patients.

CHAPTER 3

METHODS

PURPOSE OF THE STUDY

The purpose of this study was to compare two MRT and their ability to decrease muscle stiffness and tenderness and improve performance. The techniques can be broken down into two groups: self-release techniques and clinician-release techniques. Although several studies have evaluated the effectiveness of both types of release techniques, studies directly comparing two treatment approaches are limited. This study looks to compare a self-release technique, FR, to a clinician-release technique, IC and the effectiveness of each in treating hamstring tightness, flexibility, perceived pain and function, and power output.

RESEARCH DESIGN

The study employed many measures to strengthening the integrity of the study. The measures taken to improve the integrity of the study included: adopting a randomized crossover design, blinding the assessor to the treatment given, a random order for the administration of the treatments, and a one-week washout period between each treatment. Each participant received each treatment once in a randomized order. The

treatments were: FR, IC and CON. Receiving each treatment once reduced any training effects which are accumulated through multiple treatment of one technique.

TARGET POPULATION AND PARTICIPANT SELECTION

The target population for this study was active varsity collegiate basketball players. The reason for choosing collegiate basketball players was because it is a sport in which men and women participate and is popular sport for both genders in the United States. Basketball athletes were also chosen because they provided a good sample of jump trained individuals whose sporting event requires both dynamic and explosive strength. The collegiate basketball teams provided a convenience sample who were trained and relatively consistent in their jumping. Lastly, collegiate basketball players were chosen because they have not been well represented in previous MRT studies. [4-6]

PARTICIPANTS

Participants for this study were recruited from two university men's and women's collegiate basketball programs in northeastern PA. The inclusion criteria were that they were healthy, active team members between the ages of 18-30 years. Participants with current or recent history of lower extremity injury were excluded from the study. This was done to avoid potential aggravation of the injury and reduce possible influence of these conditions on the repeated performance measures. An injury was defined as not being able to participate in training or competition for at least 7 days. People with a history of psychiatric, cardiovascular, endocrine, neurological or metabolic disorders that could increase the risk of adverse responses to deep tissue mobilization, or injury during physical assessment were also excluded. Participants in the study were instructed to

refrain from consuming, alcohol, nicotine, analgesics or pain relievers 48 hours prior to testing as these substances can alter pain perception and physical performance.

PROCEDURES

Prior to the first treatment, participants were with an informed consent form. The principle investigator (PI) provided an overview of the study and was available to answer participant's question. Once consent was obtained, subjects completed a health-history questionnaire which was reviewed, and eligibility determined. The measurements were taken using the subject's dominant leg. Dominant leg was defined as the leg that the subject would use to kick a soccer ball. The pre-test measurements were taken by the blinded principle investigator in a set order, in a separate area from the treatments. The order was VJ, ROM, PPT, PPO was later calculated using recorded data. After completing the pre-test measurements participants went to the intervention area and were randomly assigned, by two experienced clinicians (CV, CS), to one of three treatments by randomly shuffling, face down a deck of 3 playing cards. Each of the three cards were correlated with one of the three treatments:FR, IC or CON. For this study there were 6 possible trial sequences. After each subsequent treatment the card chosen was not replaced in the deck. This ensured that each participant received all three treatments. CS and CV delivered/supervised all treatment trials. Following the completion of the designated treatment, the participants returned to the measurement area for post-test measurements. The order for post-test measurements was: GROC, VJ, ROM, PPT, PPO.

A period of at least 7 days served as a wash-out phase between the three experimental testing sessions which were done over a consecutive 3-week period[8]

MEASUREMENTS

ACTIVE KNEE EXTENSION

The AKE followed the protocol used by Norris et al[71], except instead of using the right leg, we used the subject's dominant leg. (Figure 3.1) The protocol consisted of the principal investigator marking the center of the knee joint axis over the lateral joint line of the dominant leg. Two lines were then drawn from this point: one, joining the axis point to the center of the greater trochanter of the femur, and a second, joining the axis point to the apex of the lateral malleolus. The lines were removed with alcohol after the post testing and redrawn at the commencement of each testing session.

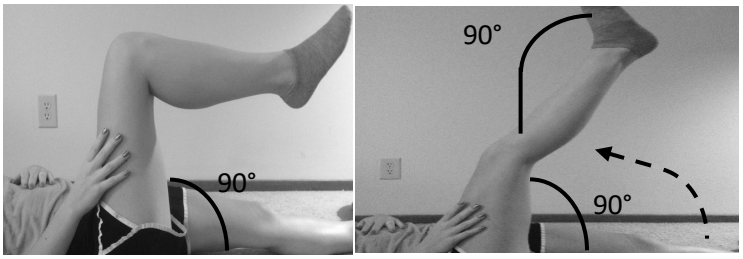
The subjects' reference zero was when they were supine on a bench and they had their hip and knee flexed to 90°. The subject monitored the position of their femur with their dominant hand and were instructed not to allow the femur to move away from the hand at any point during the test. The participant then was instructed to slowly extend their dominant leg as far as possible, keeping their foot relaxed and not allowing their thigh to move away from their hand. Participants then held this position for 5 seconds prior to the measurement being taken. Each participant performed a single repetition of the movement to familiarize themselves with the action. Once the participant was comfortable with the movement, it was repeated and measured three times. The angle of knee extension was measured using a JAMAR 12.5" (32cm) EZ Read goniometer (Performance Health, Trenton, NJ) and the angle fell between 0 and 90 degrees. Therefore, a participant with 50 degrees of AKE initially would have moved their leg 50

degrees towards a straight leg. An improvement, post-treatment, would be any movement greater than 50 degrees.

The center of the goniometer was positioned over the axis point previously marked on the lateral joint line, and the goniometer arms were positioned along the lines marked on the femur and fibula. The goniometer measurements were taken, recorded, and averaged. The calculated average score was then used for analysis.

FIGURE 3.1

ACTIVE KNEE EXTENSION



PAIN-PRESSURE THRESHOLD

PPT was used to assess muscle tenderness and was defined as the minimal amount of pressure that causes pain.[19] The subjects' PPT was measured using a Wagner FPX 50 (Wagner Instruments, Greenwich, CT) handheld digital algometer with a 1-cm^2 flat rubber tip. This device has a firm pistol grip handle and displays a 5-digit force reading in selectable units: lbf, kgf, N and ozf. The unit of measure for force in this study was newtons (N). To perform the measurement consistently the PI, prior to commencing the study, practiced applying 9.8 N/s consistently for 5 seconds. The PI counted 1-one thousand, 2-one thousand…5-one thousand then checked the algometer reading to see if

the reading was close to 49 N. This was repeated until a measurement of 49 N was consistently preformed.

The algometer was consistently placed midway between the ischial tuberosity and fibular head because there was no guarantee of a MTrP being present in the hamstrings. (Figure 3.2) The midway point was found by having the subject positioned prone on the table with the knees extended. A tape measure was used to measure the distance between the ischial tuberosity and head of the fibula and the halfway point in between those two landmarks was used for the placement site of the tip of the algometer. This location was selected because of observations made by Travel and Simons[18]. Travel and Simons theorized this is to be common region for trigger points in the hamstring due to the musculotendinous junction of the biceps femoris.[18]

Participants were instructed to say "yes" at the instant they felt pain rather than pressure. Force was gradually applied at a constant rate of approximately 9.8 N/s until the participant indicated pain was present. The PPT measure was taken 3 times with a 30-second interval between measurements. The applied force readings were recorded in N and the 3 trials averaged for analyses.

FIGURE 3.2

PAIN-PRESSURE THRESHOLD

VERTICAL JUMP

The subject's VJ was measured following the protocol used by Healey et al.[10] The protocol used a Vertec (Perform Better, West Warwick, RI) to measure the height jumped. The vane stack was raised to a height which the, participants could not jump higher or lower than the set of vanes. "Without a preparatory or stutter step, the participants was instructed to perform a countermovement jump by quickly flexing the knees and hips, moving the trunk forward and downward and swinging the arms backward. During the jump, the dominant arm reached upward, whereas the nondominant arm moved downward relative to the body. At the highest point in the jump, the subjects tapped the highest possible vane with the fingers of the dominant hand. (Figure 3.3) The score was vertical distance between the height of the highest vane tapped during the standing vertical reach and the vane tapped at the highest point of the

jump. The best of 3 trials with 3-minute rest period was recorded to the nearest 0.5 inch."[10]

FIGURE 3.3

VERTICAL JUMP

PEAK POWER OUTPUT

The subject's PPO was calculated using the formula developed by Johnson and Bahamonde[68]. To calculate PPO the participant's height in cm, weight in kg and VJ in cm was needed. The results the formula produced were recorded and stored in an Excel document to the nearest .01W.

GLOBAL RATE OF CHANGE SCALE

A 15-point GROC scale that ranged from -7 to +7. The scale descriptors used were similar to the ones used by Jaeschke et al[72]. Zero on the scale represented no

change, positive numbers indicated improvement and negative numbers indicated deterioration. Subject were asked to rate any perceived changes in the treated muscle's tightness, performance and pain. immediately post treatment. Question formatting and administration recommendations described by Kamper et al.[21] were also used in designing this instrument. Several researchers have used a change in a 15-point GROC score of greater than 3 to indicate a clinically meaningful change.[73-75]

INSTRUMENTS

Algometer: In this study, a Wagner FPX 50 (Wagner Instruments, Greenwich, CT) handheld digital algometer with a 1-cm^2 flat rubber tip was used to assess pressure pain threshold. This device has a firm pistol grip handle and displays a 5-digit force reading in selectable units: lbf, kgf, N and ozf.

Goniometer: In this study, a JAMAR 12.5" (32cm) EZ Read goniometer with a scale which reads 0 to 180 degrees and 0 to 360 degrees in 1-degree increments was used to record range of motion.

Vertec: In this study, a Vertec (Perform Better, West Warwick, RI) a stand mounted measurement device that telescopes upward and has colored vanes that are spaced 1/2" inch apart that rotate was used to measure vertical jump.

GROC questionnaire: In this study, a three question 15-point GROC scale was used to measure the subjective post treatment change for a participant. This survey has been previously used by Jaeschke et al[72]. and assesses subjectively a person's degree of muscle pain, tightness and fatigue prior and after a treatment.

INTERVENTION

Subjects were randomly assigned and underwent one of three treatments: FR, IC and CON. Two different athletic medicine facilities with two different treating clinicians were used to conduct the study. The environments for both athletic medicine facilities were busy with people going in and out with variable noise volumes. Each of the treatments took approximately 5 minutes in length and had different levels of supervision depending on the treatment. Following each treatment, post treatment measurements commenced as soon as the participant exited the treatment area and entered the measurement area. The distance needed to travel for both facilities was similar, being no more than 100 feet.

FOAM ROLLING

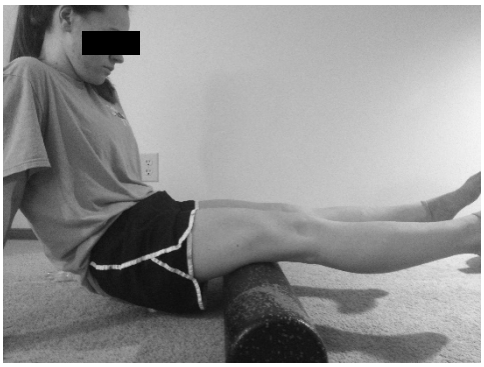
Subjects were randomly assigned and underwent one of three treatments, FR, IC and CON. Subjects assigned to FR were instructed on how to properly perform the intervention but were not supervised. Participants followed the protocol designed by Krause et al.[20], but the treatment time was increased from 60s to 90s based on findings by MacDonald et al[12] and was performed on the hamstring instead of the quadriceps. The FR intervention was performed in the supine position with support given by the arms. (Figure 3.4) The participants were instructed to place their body weight on a closed-cell EPP foam roller with a length of 36" and a diameter of 6" (TheraBand, Akron, OH).

Using a participant's own body weight pressure was applied to the tissue of the posterior thigh, subjects performed a rolling motion from the proximal aspect of the posterior thigh (ischial tuberosity) to the posterior knee (popliteal fold). Once the foam

roller reaches the posterior knee, participants were instructed to return to the starting position and continue the sequence for the remainder of the 90s. The rolling frequency was standardized using a metronome set at 60 beats per minute (bpm). Participants were instructed to roll at a velocity of two metronome beats (thus 2s) for each rolling direction, resulting in 22.5 complete rolling cycles in 90s. Intensity of pressure was controlled subjectively by using a Numerical Rating Scale (NRS), participants were instructed not to exceed a rating of 7/10 (0 representing no discomfort and 10 representing maximal discomfort) during the intervention. After a 30s break in a relaxed supine position, participants performed a second bout. Subjects were observed to make sure they were properly performing the FR treatment.

FIGURE 3.4

FOAM ROLLING



ISCHEMIC COMPRESSION

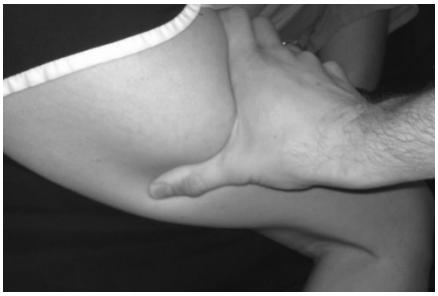
Ischemic Compression is manual therapy technique whose purpose is to reduce muscle and MTrP tenderness and hyperirritability and can be defined as the "application of progressively stronger pressure on a TrP".[18] The identification of TrPs followed the guidelines laid out in the *Trigger Point Manual*.[18,76] Participants laid prone on the

treatment table with their dominant leg hanging off the edge of the treatment table modestly exposed, putting the hamstrings on stretch. (Figure 3.5) Massage cream was applied to the entire length of the hamstrings. The clinician then started at the ischial tuberosity and applied petrissage to the full length of the hamstring muscles. The clinician worked their way down each hamstring muscle until a corded muscle or pea-like structure was palpated. Cross-friction or circulating massage was then applied to the muscle fibers. If the cross-friction or circulating movement produced symptoms of pain (referred pain, twitch response, or localized pain) the area was identified as a TrP and IC was applied.

Ischemic compression followed a treatment protocol based on a description laid out by Travel et al[18,76] and tested by Berggreen et al[8] with modifications by Nambi et al.[15] The treating clinician pressed their thumb directly into the MTrP to produce pain that was controlled subjectively with a target NRS rating of 7/10 (0 representing no discomfort and 10 representing maximal discomfort) during the intervention. The applied pressure was sustained until pain was resolved or 90 seconds elapsed. The procedure was repeated up to three times depending on if MTrPs were present. Following, three applications or each of the three hamstrings being scanned, four strokes of effleurage massage were applied to the hamstring muscle. Then the hamstring was placed on passive stretch for 30 seconds to range the muscle. The total treatment time was approximately 5 minutes in length.

FIGURE 3.5

ISCHEMIC COMPRESSION



CONTROL

The methodology of the control treatment followed the protocol as laid out in a study by Mohr et al.[14] Participants, during the control treatment, were instructed to lie down supine on the treatment table for 5 minutes.

DATA ANALYSIS

Statistical analysis was completed using IBM SPSS Statistics version 24.0 software (Armonk, NY). Descriptive statistics were calculated for all data collected. This study used a repeated measures 2x3 analysis of variance (ANOVA) determine within-subjects factors for Time (Pre, Post-intervention) and between-subjects for Trials (FR, IC, CON), and Kruskal Wallis in combination with a Chi Square test was used for the GROC to assess the difference between the trial conditions (FR, IC CON).

CHAPTER 4

RESULTS

This study was designed to determine the acute effects of two myofascial release techniques, FR and IC, on AKE, PPT, VJ, PPO and GROC. This chapter is a presentation of the data in the following sections: a) participation demographics, b) comparison among time and trial condition on hamstring ROM during AKE, c) comparison among time and trial condition on hamstring PPT, d) comparison among time and trial condition on maximum height reached during a VJ, e) comparison among time and trial condition on PPO during VJ, and f) comparison of among trial conditions on GROC scale scores.

PARTICIPATION DEMOGRAPHICS

A summary of the demographics of the study participants is presented in Table 4.1. A total of 13 subjects volunteered but only 11 completed the study. One was deemed ineligible to participate due to an acute knee injury and one participant dropped out for unspecified reasons. Of the 11 subjects who completed the study, 4 were males (mean age=19.5±1 year; height=174±9.9cm; weight=100±6.7kg) and 7 were females (mean age=19.6±.69years; height=168.8±7.9cm; weight=66.1±3.3kg). Participants in study were active basketball players from two schools competing in the NCAA Division II

(N=6) and a Division III (N=5) levels. No males participated in the study from the NCAA Division II level due to scheduling conflicts and postseason participation.

TABLE 4.1

DEMOGRAPHICS

	Overall	Male	Female
Gender	--	4	7
Age(years)	19.7±.8	19.5±1	19.8±0.7
Height(cm)	173.9±10.4	184.4±0.5	167.9±8.0
Mass(kg)	78.5±17.7	100.0±6.7	66.2±3.6
Division II	6	0	6
Division III	5	4	1

COMPARISON AMONG TIME AND MYOFASCIAL RELEASE TECHNIQUES ON ACTIVE KNEE EXTENSION

A summary of the different pretreatment and posttreatment myofascial release techniques means, and standard deviations of AKE is presented in Table 4.2 and Figure 4.1. To test whether pretreatment means (FR:62.00, IC:55.71, CON:65.45) were significantly different than posttreatment means (FR:63.89, IC:62.65, CON:64.68), a one-way ANOVA with repeated measures was performed. Table 4.3 illustrates the sum of squares, degrees of freedom and the F-ratio over time (pretreatment, posttreatment) for active knee extension. There was a significant difference in mean AKE over time ($F=6.17$, $p=.032$). The $p=.032$ suggests that the intervention or the time elapsed is connected to the change in the mean values. A one-way ANOVA with repeated measures showed an effect for condition on knee-joint ROM ($P<.05$).Post hoc analyses however showed that the changes seen in AKE from pretesting to post-testing for the FR and IC condition were not statically different from those seen in during the control condition.

TABLE 4.2

SUMMARY OF MEAN ACTIVE KNEE EXTENSION PRODUCED BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

(N=11)

Myofascial Release Technique	Control[a]	Foam Rolling[a]	Ischemic Compression[a]
Pretreatment Mean	65.4545	62.0000	55.7121
Pretreatment sd	13.7196	13.2642	16.0430
Posttreatment Mean	64.6818	63.8939	62.6515
Posttreatment sd	12.7912	12.0850	14.5782

[a]Measurements in degrees

FIGURE 4.1

MEAN ACTIVE KNEE EXTENSION BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

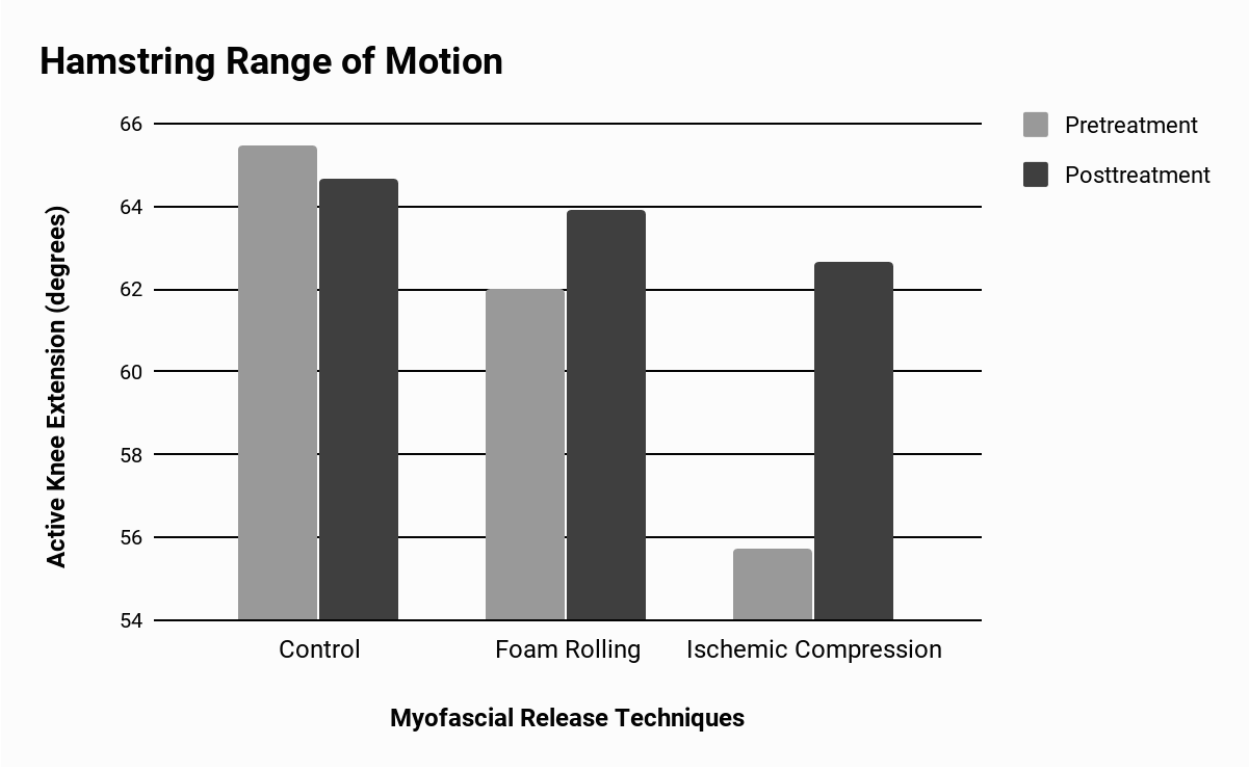


TABLE 4.3

ONE-WAY ANOVA WITH REPEATED MEASURES OF TIME FOR ACTIVE KNEE EXTENSION

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time	1	119.118	119.118	6.16`7	0.032
Error	10	193.169	19.317		
Total	11	312.435			

TABLE 4.4

MEAN DIFFERENCES WITHIN SUBJECTS MEASURES OF TIME ON ACTIVE KNEE EXTENSION

(N=11)

Time	Pretreatment	Posttreatment
Means	(61.056[a])	(63.742[a])
Pretreatment (61.056[a])	-------	-2.687[a,b]
Posttreatment (63.742[a])	2.687[a,b]	-------

[a]Measurement differences are in degrees
[b]Significant at the 0.05 level

To test whether mean between-group differences between three trials (FR, IC, CON) were significant, a one-way ANOVA with repeated measures was performed and found there were no statistical differences (p=.434) in mean AKE among the three trials (FR, IC, CON). Table 4.5 illustrates the sum of squares, degrees of freedom and F-ratio among trial conditions (FR, IC, CON).

TABLE 4.5

ONE-WAY ANOVA WITH REPEATED MEASURES OF TREATMENT TECHNIQUE FOR ACTIVE KNEE EXTENSION

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Treatment	2	391.051	195.526	.869	0.434
Error	20	4498.328	224.916		
Total	22	4889.379			

To test whether interaction between time and myofascial release technique were significant, a one-way ANOVA with repeated measures was performed. Table 4.6 illustrates the sum of squares, degrees of freedom and the F-ratio for the interaction between time (pretreatment, posttreatment) and myofascial release technique (FR, IC, CON). A significant F-ratio (df=2, Error df=20, F=5.88) was determined for the interaction between time and treatment technique (p=.01). But since no significant differences between the two treatment interventions and the control then whatever change, either positive or negative, that occurred between pre and post testing is not likely the result from the intervention.

TABLE 4.6

ONE-WAY ANOVA WITH REPEATED MEASURES OF INTERACTION BETWEEN TIME AND TREATMENT TECHNIQUE FOR ACTIVE KNEE EXTENSION

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time*Technique	2	168.748	84.374	5.883	0.010
Error	20	286.854	14.343		
Total	22	455.602			

COMPARISON AMONG TIME AND MYOFASCIAL RELEASE TECHNIQUES ON PAIN-PRESSURE THRESHOLD

A summary of the different pretreatment and posttreatment myofascial release techniques means, and standard deviations of PPT is presented in Table 4.7 and Figure 4.2. To test whether pretreatment means (FR:44.52, IC:42.63, CON:43.28) were significantly different than posttreatment means (FR:47.75, IC:52.81, CON:40.16), a one-way ANOVA with repeated measures was performed. Table 4.8 illustrates the sum of squares, degrees of freedom and the F-ratio over time (pretreatment, posttreatment) for pain-pressure threshold readings. The F-ratio over the time of measurement main effect was not significant (df=1, Error df=10, F=3.34, p=.097) which indicates that the time of measurement did not affect PPT of the hamstrings. Though there was no statistically significant results there were trends to show that FR and IC can increase PPT where the CON decreased the PPT.

TABLE 4.7

SUMMARY OF MEAN PAIN-PRESSURE THRESHOLD READINGS PRODUCED BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

(N=11)

Myofascial Release Technique	Control[a]	Foam Rolling[a]	Ischemic Compression[a]
Pretreatment Mean	43.2788	44.5212	42.6303
Pretreatment sd	11.1361	10.6746	9.6690
Posttreatment Mean	40.1576	47.7455	52.8091
Posttreatment sd	7.9805	12.7084	15.1788

[a]Measurements in N

FIGURE 4.2

MEAN PAIN-PRESSURE THRESHOLD READINGS PRODUCED BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

(N=11)

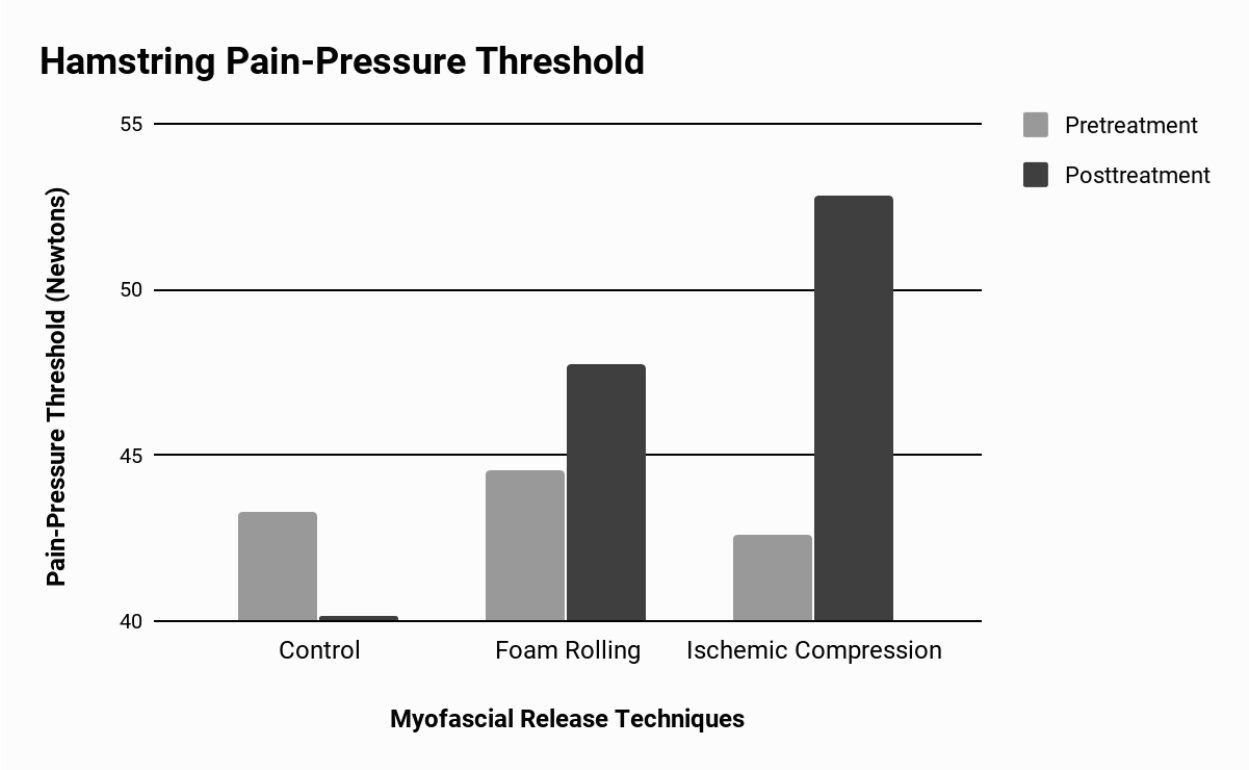


TABLE 4.8

ONE-WAY ANOVA WITH REPEATED MEASURES OF TIME FOR PAIN-PRESSURE THRESHOLD

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time	1	193.812	193.812	3.342	0.097
Error	10	579.863	57.986		
Total	11	773.675			

To test whether mean differences between myofascial release techniques were significant, a one-way ANOVA with repeated measures was performed. Table 4.9 illustrates the sum of squares, degrees of freedom and the F-ratio among myofascial release techniques (FR, IC, CON) for PPT readings. The F-ratio for the between myofascial release techniques main effect was not significant (df=2, Error df=20, F=1.73, p=.203) which indicate that the type of myofascial release technique did not affect PPT.

TABLE 4.9

ONE-WAY ANOVA WITH REPEATED MEASURES OF TREATMENT TECHNIQUE FOR PAIN-PRESSURE THRESHOLD

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Technique	2	425.541	212.770	1.731	0.203
Error	20	2457.914	122.896		
Total	22	2883.455			

To test whether interactions between time and myofascial release technique were significant, a one-way ANOVA with repeated measures was performed. Table 4.10 illustrates the sum of squares, degrees of freedom and the F-ratio among time (pretreatment, posttreatment) and myofascial release technique (FR, IC, CON) for PPT readings. A significant F-ratio (df=2, Error df=20, F=10.34) was determined for the interaction between time and treatment technique (p=.001) but the interaction is not meaningful since the main effects for time and treatment technique were not significant.

TABLE 4.10

ONE-WAY ANOVA WITH REPEATED MEASURES OF INTERACTION BETWEEN TIME AND TREATMENT TECHNIQUE FOR PAIN-PRESSURE THRESHOLD

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time*Treatment	2	486.788	243.394	10.336	0.001
Error	20	470.971	23.549		
Total	22	957.759			

COMPARISON AMONG TIME AND MYOFASCIAL RELEASE TECHNIQUE ON PEAK VERTICAL JUMP HEIGHT

A summary of the different pretreatment and posttreatment myofascial release techniques means, and standard deviations of VJ is presented in Table 4.11 and Figure 4.3. To test whether pretreatment means (FR:16.85, IC:18.15, CON:17.62) were significantly different from posttreatment means (FR:18.45, IC:18.67, CON:17.86), a one-way ANOVA with repeated measures was performed. Table 4.12 illustrates the sum of squares, degrees of freedom and the F-ratio over time (pretreatment, posttreatment) for VJ height. A significant F-ratio (df=1, Error df=10, F=6.85) was determined for the among pretreatment and posttreatment measurements main effect (p=0.026). A pairwise comparison was then performed to determine the differences. Table 4.13 summarizes the mean VJ height differences between pretreatment measurements and posttreatment measurements. The pairwise comparison revealed a significant difference between pretreatment and posttreatment measurements.

TABLE 4.11

SUMMARY OF MEAN PEAK VERTICAL JUMP HEIGHTS PRODUCED BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

(N=11)

Myofascial Release Technique	Control[a]	Foam Rolling[a]	Ischemic Compression[a]
Pretreatment Mean	17.6212	16.8485	18.1515
Pretreatment sd	3.4206	3.3254	3.0336
Posttreatment Mean	17.8636	18.4548	18.6667
Posttreatment sd	3.6193	3.4455	3.0669

[a]Measurements in inches.

FIGURE 4.3

MEAN PEAK VERTICAL JUMP HEIGHTS PRODUCED BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

(N=11)

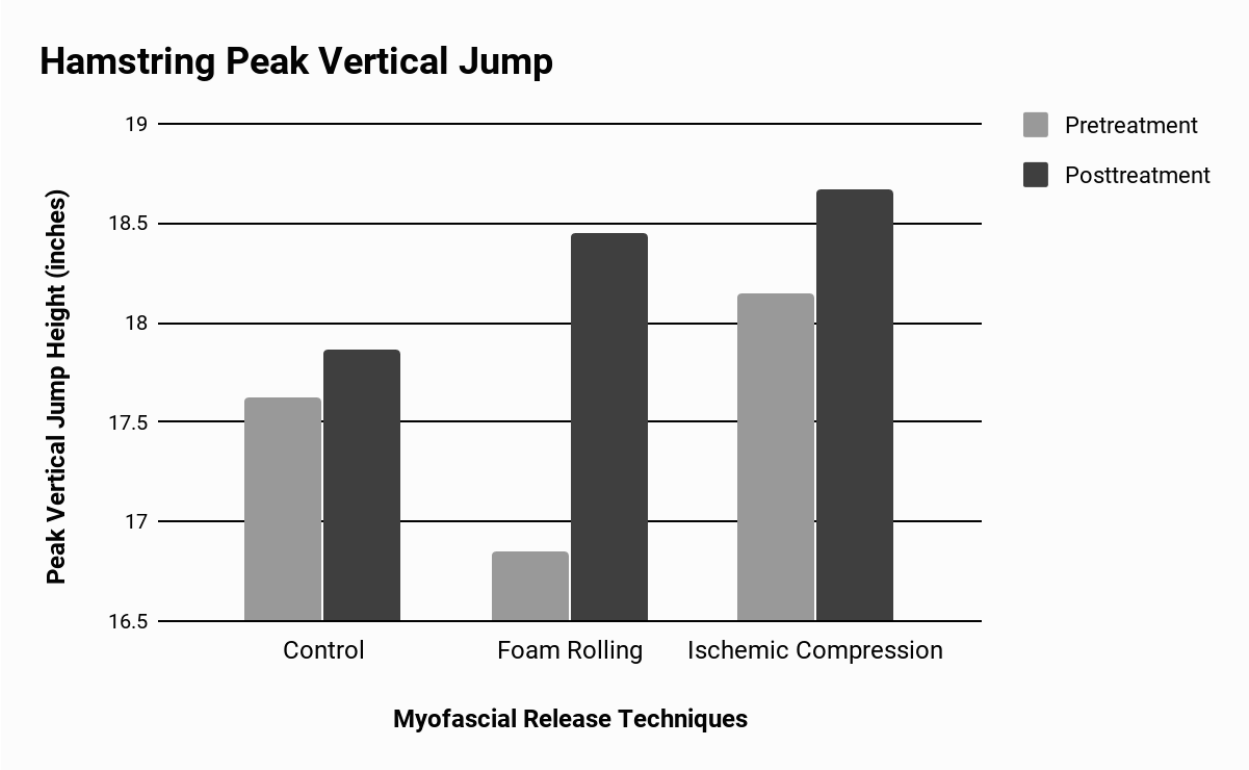


TABLE 4.12

ONE-WAY ANOVA WITH REPEATED MEASURES ON TIME FOR PEAK VERTICAL JUMP HEIGHT

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time	1	10.245	10.245	6.848	0.026
Error	10	14.960	1.496		
Total	11	25.205			

TABLE 4.13

MEAN DIFFERENCES WITHIN SUBJECT MEASURES OF TIME ON PEAK VERTICAL JUMP HEIGHT

(N=11)

Time	Pretreatment	Posttreatment
Means	(17.540[a])	(18.328[a])
Pretreatment (17.540[a])	-------	-.788[a,b]
Posttreatment (18.328[a])	.788[a,b]	-------

[a]Measurement differences are in in
[b]Significant at the 0.05 level

To test whether mean differences between myofascial release techniques were significant, a one-way ANOVA with repeated measures was performed. Table 4.14 illustrates the sum of squares, degrees of freedom and the F-ratio among myofascial release techniques (FR, IC, CON) for VJ height. The F-ratio for the between myofascial release techniques main effect was not significant (df=2, Error df=20, F=0.246, p=0.784) which indicate that the type of myofascial release technique did not affect VJ height.

TABLE 4.14

ONE-WAY ANOVA WITH REPEATED MEASURES ON TREATMENT TECHNIQUE FOR PEAK VERTICAL JUMP HEIGHT

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Technique	2	7.527	3.763	0.246	0.784
Error	20	305.607	15.280		
Total	22	313.134			

To test whether interactions between time and myofascial release technique were significant, a one-way ANOVA with repeated measures was performed. Table 4.15 illustrates the sum of squares, degrees of freedom and the F-ratio among time (pretreatment, posttreatment) and myofascial release technique (FR, IC, CON) for VJ height. The F-ratio for the interaction among time and treatment technique main effect was not significant (df=2, Error df=20, F=2.41, p=0.116) which indicates that the interaction between time and treatment technique did not affect VJ height.

TABLE 4.15

ONE-WAY ANOVA WITH REPEATED MEASURE ON THE INTERACTION BETWEEN TIME AND TREATMENT TECHNIQUE FOR PEAK VERTICAL JUMP HEIGHT

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time*Treatment	2	5.730	2.865	2.408	0.116
Error	20	23.793	1.190		
Total	22	29.523			

COMPARISON AMONG TIME AND MYOFASCIAL RELEASE TECHNIQUES ON PEAK POWER OUTPUT DURING VERTICAL JUMP

A summary of the different pretreatment and posttreatment myofascial release techniques means, and standard deviations of PPO is presented in Table 4.16 and Figure 4.4. To test whether pretreatment means (FR:3963.13, IC:4386.94, CON:4084.83) were significantly different from posttreatment means(FR:4277.53, IC:4490.55, CON:4141.99), a one-way ANOVA with repeated measures was performed. Table 4.17

illustrates the sum of squares, degrees of freedom and the F-ratio over time (pretreatment, posttreatment) for PPO. A significant F-ratio (df=1, Error df=10, F=7.067) was determined for the between pretreatment and posttreatment measurements main effect (p=.024). A pairwise comparison was then performed to determine the differences. Table 4.18 summarizes the mean PPO differences between pretreatment and posttreatment measurements. The pairwise comparison revealed a significant difference between pretreatment measurements and posttreatment measurements.

TABLE 4.16

SUMMARY OF PEAK POWER OUTPUTS PRODUCED BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

(N=11)

Myofascial Release Technique	Control[a]	Foam Rolling[a]	Ischemic Compression[a]
Pretreatment Mean	4084.8273	3963.1309	4386.9382
Pretreatment sd	1263.7752	1400.7099	1364.7201
Posttreatment Mean	4141.9909	4277.5309	4490.5473
Posttreatment sd	1287.7612	1301.2328	1344.3749

[a]Measurements in W

FIGURE 4.4

MEAN PEAK POWER OUTPUT PRODUCED BEFORE AND AFTER VARYING MYOFASCIAL RELEASE TECHNIQUES

(N=11)

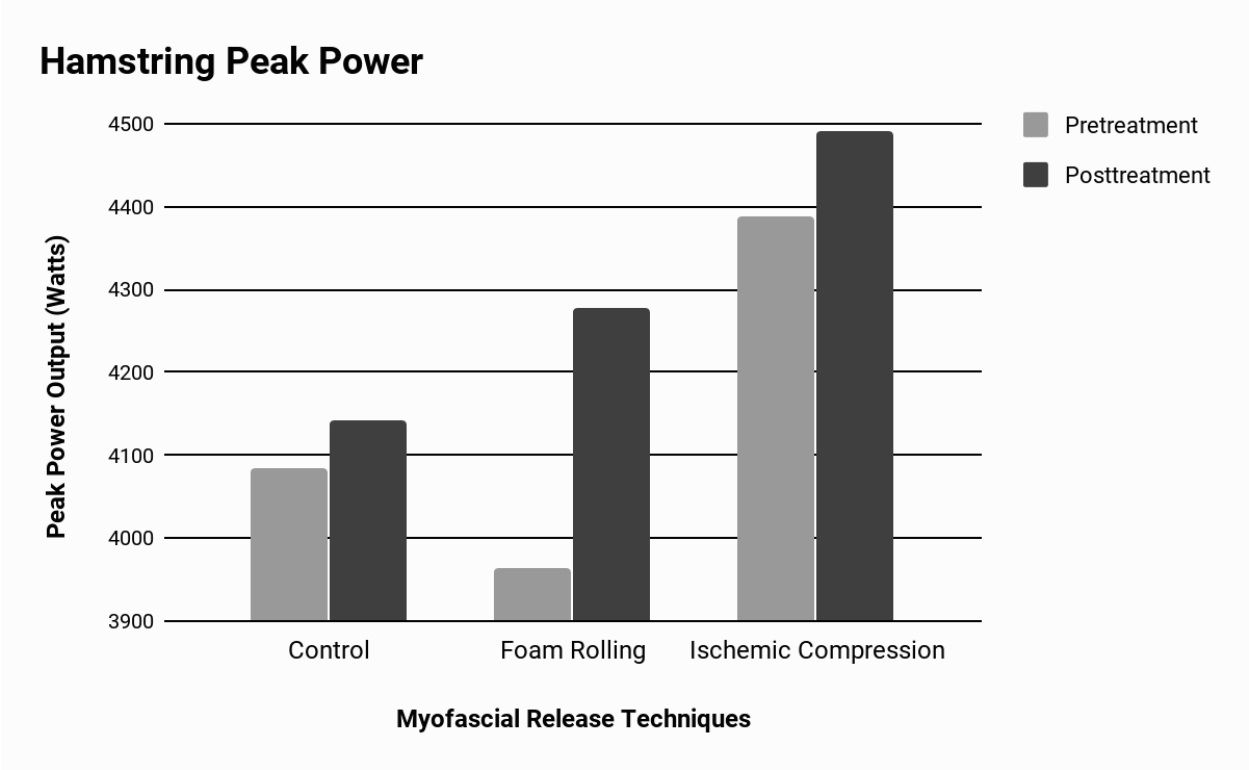


TABLE 4.17

ONE-WAY ANOVA WITH REPEATED MEASURES ON TIME FOR PEAK POWER OUTPUT

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time	1	413946.721	713946.72	7.067	0.024
Error	10	587819.283	58571.928		
Total	11	1001766.004			

TABLE 4.18

MEAN DIFFERENCES WITHIN SUBJECTS MEASURES OF TIME ON PEAK POWER OUTPUTS

(N=11)

Time	Pretreatment	Posttreatment
Means	(4144.965[a])	(4303.356[a])
Pretreatment (4144.965[a])	-------	-158.391[a,b]
Posttreatment (4303.356[a])	158.391[a,b]	-------

[a]Measurement differences are in W
[b]Significant at the 0.05 level

To test whether mean differences between myofascial release techniques were significant, a one-way ANOVA with repeated measures was performed. Table 4.19 illustrates the sum of squares, degrees of freedom and the F-ratio among myofascial release techniques (FR, IC, CON) for PPO. The F-ratio for the between myofascial release techniques main effect was not significant (df=2, Error df=20, F=1.18, p=.329) which indicate that the type of myofascial release technique did not affect PPO.

TABLE 4.19

ONE-WAY ANOVA WITH REPEATED MEASURES ON TREATMENT TECHNIQUE FOR PEAK POWER OUTPUT

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Treatment	2	1520023.798	760011.90	1.177	0.329
Error	20	12914117.35	645705.87		
Total	22	14434141.148			

To test whether interactions between time and myofascial release technique were significant, a one-way ANOVA with repeated measures was performed. Table 4.20 illustrates the sum of squares, degrees of freedom and the F-ratio among time (pretreatment, posttreatment) and myofascial release technique (FR, IC, CON) for PPO. The F-ratio for the interaction among time and treatment technique main effect was not significant (df=2, Error df=20, F=2.15, p=.142) which indicates that the interaction between time and treatment technique did not affect PPO.

TABLE 4.20

ONE-WAY ANOVA WITH REPEATED MEASURES ON THE INTERACTION BETWEEN TIME AND TREATMENT TECHNIQUE FOR PEAK POWER OUTPUT

(N=11)

	Df	Sum of Squares	MS	F	Sig.
Time*Treatment	2	206727.646	103363.82	2.153	0.142
Error	20	960309.591	48015.48		
Total	22	1167037.237			

COMPARISON AMONG MYOFASCIAL RELEASE TECHNIQUES ON GLOBAL RATE OF CHANGE RANK SCORES

A summary of the differing variable means and standard deviations of GROC rank scores is presented in Table 4.21 and Figure 4.5 (FR:3.17, IC:2.17, CON:2.46). A Kruskal Wallis and Chi Squared Tests were conducted on the different myofascial release techniques to compare their effects on each of the variables tested by the GROC and the results are presented in Table 4.22 and 4.23. The results are presented in mean rank scores not in the GROC scale scores. The scores were presented in this way to allow for

the GROC scores to be statistically analyzed. Differences can be seen, in Table 4.22, between treatments for each variable (Pain: FR:14.29, IC:25.32, CON:15.00; Tightness: FR:16.42, IC:25.86, CON:12.38; Fatigue: FR:17.79, IC:24.23, CON:12.50) but due to the type of test and data, significance was unable to be determined between treatments. The Chi-Square test, Table 4.23, revealed statistically significant perceived increases for each of the variables (Pain, Tightness, Fatigue). The Chi-Squared test did not parse out between the variables to determine if there was significant between group differences.

TABLE 4.21

SUMMARY OF MEAN GLOBAL RATE OF CHANGE RANK SCORES FOR DIFFERING VARIABLES

(N=11)

Variables Tested	Muscle Pain	Muscle Tightness	Muscle Fatigue
Mean	2.4571	3.1714	2.1714
Sd	2.2274	2.4792	2.4553

FIGURE 4.5

MEAN GLOBAL RATE OF CHANGE RANK SCORES FOR DIFFERING VARIABLES

(N=11)

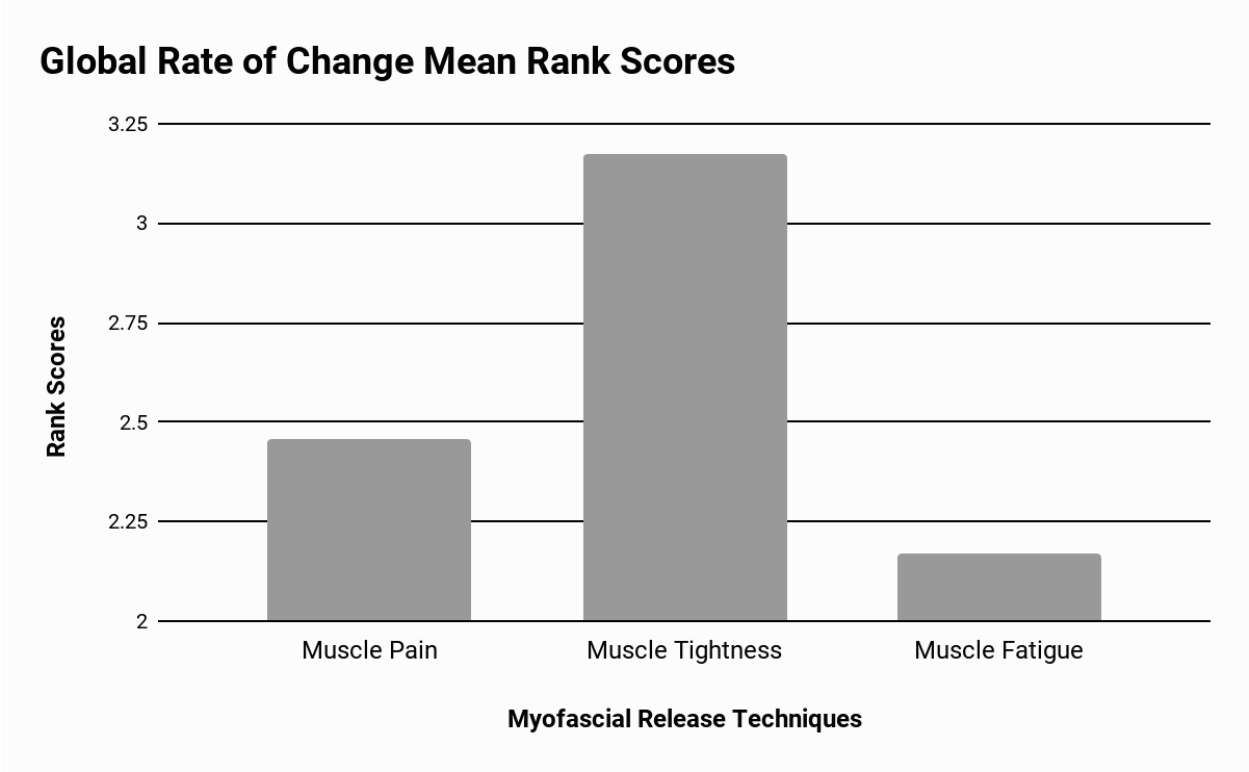


TABLE 4.22

SUMMARY OF MEAN GLOBAL RATE OF CHANGE RANK SCORES FOR PERCEIVED MUSCLE PAIN, TIGHTNESS AND FATIGUE AFTER DIFFERENT MYOFASCIAL RELEASE TECHNIQUES

(N=11)

Myofascial Release Technique	Control	Foam Rolling	Ischemic Compression
Mean Rank Score for Perceived Muscle Pain	15.00	14.29	25.32
Mean Rank Score for Perceived Muscle Tightness	12.38	16.42	25.86
Mean Rank Score for Perceived Muscle Fatigue	12.50	17.79	24.23

TABLE 4.23

SUMMARY OF MEAN GLOBAL RATE OF CHANGE RANK SCORES FOR PERCEIVED MUSCLE PAIN, TIGHTNESS AND FATIGUE AFTER DIFFERENT MYOFASCIAL RELEASE TECHNIQUES

(N=11)

	Muscle Pain	Muscle Tightness	Muscle Fatigue
Chi-Square	8.514	10.820	7.994
Df	2	2	2
Asymp. Sig.	.014	.004	.018

CHAPTER 5

DISSCUSSION AND CONCULSION

INTRODUCTION

The purpose of this study was to compare the effectiveness of foam rolling and ischemic compression and their effectiveness in treating hamstring tightness. The effectiveness of the treatments was measured using ROM and PPT of the hamstrings, VJ and PPO during VJ and GROC. This chapter is presented in the following sections: a) discussion for ROM performance, b) discussion for PPT, c) discussion for VJ height, d) discussion for PPO during VJ, e) discussion of GROC, f)summary, g) findings, h) conclusions and i) recommendations for further study.

DISCUSSION FOR RANGE OF MOTION PERFORMANCE

The results of this study found that a single treatment of FR or IC did not yield a significant improvement in HS flexibility (AKE) compared to the control condition. AKE improved from pre and post-testing but no condition (FR, IC, or CON) was significantly better than another. This finding that the FR condition did not significantly improve ROM compared to the control condition is consistent with the finding of several previous studies[14,61,77-79]. Mohr et al.[14] conducted a study comparing the effects of 4 different

treatment conditions on passive hip-flexion ROM: foam rolling (FR), static stretching (SS), foam rolling and static stretching (FR+SS) and control (CON). In the Mohr et al[14] study all conditions studied significantly changed passive hip-flexion, but only the combined FR+SS yielded significantly greater changes in passive hip-flexion ROM compared to the other conditions. In another pretest-posttest study[77] assessing the effect of a single 60 sec FR session on hip flexor and quadriceps muscle flexibility found that FR no significant effect on individual muscle flexibility measures. In this study FR condition did show a small gain in overall flexibility compared to the control, but the authors concluded that was insignificant in terms of improving overall function.[77] Couture et al[78], conducted a small repeated measures study evaluating the effects of a single bout of self-administered FR using 2 protocols (Long= 4x 30 sec and Short=2x 30sec) on passive knee extension ROM. The subjects were measured on 3 consecutive days where the baseline measure was used as the control and the 2 protocols were delivered in a counterbalanced order. Neither of the FR protocol resulted significant changes in passive knee extension ROM compared to baseline.

The present study's finding suggest that a single session of FR may not be sufficient to product significant improvements in ROM. However, this conclusion is not consistent with several previous studies that found that a single bout of FR resulted in improvements in knee ROM.[7,9,12,13] Bradbury-Squires et al [9] conducted a small repeated measures pretest-posttest study comparing both a 20 and 60-second application of FR to the quadriceps muscle to a control condition. In this study both FR protocols elicited a greater improvement in knee flexion than the control condition. Two key differences

between the current study and the Bradbury-Squires et al[9] study were the muscles treated (HS vs. Quads) and the method of delivery for the FR. The HS are a deeper muscle groups and their location in relation to the femur can make it harder to effectively compress them with the foam roller compared to the more superficial quadriceps. Also, in the Bradbury-Squires study[9] the amount of compression pressure used was controlled by the roller device used. In the present study, the amount of pressure used was determined by the individual subject based on perceived discomfort. Because of the location and depth of the HS muscles and the lack of external pressure control it is plausible that some subjects in this study may have used insufficient pressure to adequately mobilize the HS muscles. Aguilera et al[7] conducted a randomized control trail which compared IC to US and its ability to increase ROM, decrease MTrP sensitivity, and decrease electrical output. The current study differs from Aguilera et al[7] by the muscle that was tested and the presence of MTrPs. The current study tested the hamstrings where Aguilera et al tested the upper trapezius. The upper trapezius is a more superficial muscle allowing for greater ease of compression of the muscle possibly resulting in a greater and more noticeable change in ROM. The current study did not require the participants to have MTrPs but the participants in the Aguilera et al[7] study needed to have latent MrTPs. The presence of MTrPs whether active or latent could explain why the current study did not see a significant difference between treatments. Having MTrPs present in theory explains why IC would have a positive effect on it. The muscle is spasm and IC will help then lengthen the muscle returns it to its originally tension and increasing ROM.

MacDonald et al[13] conducted a small randomized controlled trial which looked at the effectiveness of FR versus a control in treating DOMS in the lower extremity. In this study[13], FR was able to decrease the effects of DOMS while improving passive quadricep and hamstring ROM and dynamic hamstring ROM. There were a few key differences between the current study and MacDonald et al.[13] One was the muscles treated, (HS vs HS, Quads, Glutes, ADDs and IT band) another the amount of times FR was applied (1 vs 3), and lastly the condition of the athletes. (not sore vs sore) Receiving multiple treatments may have a compounding effect to improve muscle extensibility and performance which are only seen over the course of time as compared to looking at the acute effects of one FR treatment. Treating multiple muscles may increase the effects of FR since the agonist and the antagonist muscles are both being treated decreasing the restriction to movement throughout the joint. In this study[13], treating just one muscle group may limit the effects that could be produced since muscles are affected by their opposing muscle. Lastly, the improvement in ROM with FR might only occur when there is existing muscle soreness. The subjects in the MacDonald study[13] may have only seen improvements in ROM since they were sore where the subjects in the current study were not sore.

MacDonald et al[12] conducted a randomized control trial comparing the ability of FR to a control in increasing quadricep range of motion. Different from the current study, MacDonald et al[12] found that FR increased ROM compared to a control. Some of the differences between MacDonald et al and the current study that could explain the differing results is the presence of delayed onset muscle soreness (Sore vs. Not Sore) and

the muscle FR (Quadriceps vs Hamstrings). MacDonald et al[12] did testing on the quadriceps which is a more superficial muscle compared to the hamstrings which is a deeper muscle and covered with more adipose tissue. The resulting factor is that current study allowing for the muscle treated to receive a higher dose of treatment. The other difference between the studies is the presence of DOMS. MacDonald et al[12] had the study participants, prior to FR go through a standardized workout routine to induce delayed-onset muscle soreness in the quadriceps. Following the exercise routine, it is possible the participants quadriceps were at a shortened state and due to decrease in muscle length the treatment of FR would have greater effects on the muscle as compared to someone who was not sore, like the participants from the current study.

DISCUSSIONS FOR PAIN-PRESSURE THRESHOLD

The results of this study found that a single treatment of FR or IC did not yield a significant improvement in HS pain-pressure threshold (PPT) compared to the control condition but for both FR and IC a trend of increased PPT was seen posttreatment compared to the CON. For IC on average a 10N increase in PPT was seen. Similar results were found in a study by Ravichandran et al.[61] Ravichandran et al[61] conducted a small single-blind randomized control trial comparing IC with CON (ultrasound). In congruence with the current study trends toward improvement were noted but no statistically significant results were found.

Contrary to this finding, several studies have found FR and IC to be effective in raising PPT[8,16,54,56,80] . Pearcey et al[16] used a repeated-measures within subjects crossover study to assess the effect of FR on subjects suffering from induced DOMS. The key differences

in this study were the number of times FR was applied (0 hours post vs 0, 24, 48 hours post), the muscles FR was applied to (HS vs the entire LE) and then soreness of the subjects (not sore vs sore). Treating a muscle multiple times versus once may result in compounding effects from the treatment that would not be seen in the current study since FR was only applied once. The results from Pearcey et al[16] maybe different because of the muscles treated (HS, Quads, ADD, IT band and Glutes vs HS). Treating a larger area of muscle provides potentially greater chance of eliciting the purported mechanical and pain modulation effects. Another difference between the current study and Pearcey et al[16] is how the PPT was measured. In the study by Pearcey et al[16] participants were weight bearing and PPT was assessed on the quads compared to the current study which assessed the PPT while the participants were non-weight bearing and was assessed on the hamstrings. Being weight bearing naturally causes the quads to be contracted. Having the quads contracted increase the tension of the muscle being treated. The quads do not have as much adipose tissue, as compared to the hamstrings, between the muscle and the surface of the skin allowing for a greater ease to compress the desired muscle tissue. Testing the participant's quads while weight bearing is a significant difference between the studies which may explain the difference between them. Lastly, another reason the current study's results may have been different from Pearcey et al[16] were the subjects in the study conducted by Pearcey et al[16] were already sore prior to FR. The effect of FR may be more pronounced in individuals with DOMS compared to healthy non-painful subjects. Since the current study's subjects were not sore the results seen in the study by Pearcey et al[16] may only have been due to the subjects being sore prior to FR.

Similarly, studies by Gulick et al[56] and Jagad et al[80] conducted single-blind randomized controlled trials comparing IC to a control. Both Gulick et al[56] and Jagad et al[80] found following IC, there was a statistically significant inter and intra group increase in PPT. The key differences between the current study and the studies conducted by Gulick et al[56] and Jagad et al[80] is what was used as sites of treatment (standardized point vs MTrPs), the amount of treatments (1 vs 3/7) and the body part used for treatment (Hamstrings vs Upper Trapezius). A key difference is Gulick et al[56] and Jagad et al[80] used MTrPs as the sites for treatment compared to the current study which used a single standardized point on every participant regardless if that point was sore or not. Using sites that have a decreased pain-pressure threshold as the points which measurements are taken from could show a greater effect from the treatment since the sites were more sensitive to pain prior to the treatment than the sites measured from in the current study. Another difference between the current study and Gulick et al[56] and Jagad et al[80] is the amount of treatments. Gulick et al[56] and Jagad et al[80] performed IC multiple times compared to a single treatment in the current study. Though the current study did not look at the long-term effects of repetitive treatments, having multiple treatments may produce a compounding effect that would not have been seen in this study. Overall differences in the muscles treated, inclusion criteria, and protocol could explain why the results of the current study did not match that of previously conducted studies.

DISCUSSION FOR PEAK VERTICAL JUMP HEIGHT

The results of this study found that a single treatment of FR or IC did not yield a significant improvement in vertical jump (VJ) compared to the control condition. VJ

improved from pre and post-testing but no condition (FR, IC, or CON) was significantly better than another. Similar results were found in a different study.[10] Healy et al[10] conducted a randomized crossover design comparing the effects of a single session of FR to a control of planking. No statistically significant results were found in between treatments, which is consistent with a previous study by Healey et al.[11] but both treatments did induce an increase in PPO. Overall these results suggest that the application of a myofascial release technique, FR or IC, can positively effect VJ.

The present study's findings indicate that a single session of FR does not significantly increase VJ compared to the control treatment. A previous study conducted by MacDonald et al[13] conducted a randomized control trial comparing FR to a control that found contradicting results to the current study.[13] In the MacDonald et al [13] the subjects had identified muscle soreness, the treatment consisted FR multiple muscles, and the exposure time was 3x longer than the current study. These differences may account for the differences in findings. Receiving multiple treatments may have a compounding effect on muscle performance (VJ) which is only seen over the course of time as compared to looking at the acute effects of one FR treatment. Treating multiple muscles may also increase the effects of FR since the agonist and the antagonist muscles are both being treated which may increase proper or more affective in muscle contraction . Lastly, the improvement in VJ with FR might only occur when there is existing muscle soreness. The subjects in the MacDonald study[13] may have only seen improvements in VJ since they were sore where the subjects in the current study were not sore and therefore explains why there is a difference in results between the studies.

DISCUSSION FOR PEAK POWER OUTPUT DURING VERTICAL JUMP

The results of this study found that a single treatment of FR or IC did not yield a significant improvement in peak power output (PPO) compared to the control condition. PPO improved from pre and post-testing but no condition (FR, IC, or CON) was significantly better than another. Similar results were found in a different study.[10] Healy et al[10] conducted a randomized crossover design comparing the effects of a single session of FR to a series of planking exercise on vertical jump height and power, isometric force, and agility test performance. No statistically significant results were found in between treatments, which is consistent with the current study, but both treatments, in each of the studies did induce an increase in PPO. Overall these results suggest that the application of a myofascial release technique, FR or IC, can positively effect PPO.

The present study's findings indicate that a single session of FR does not significantly increase PPO compared to the control treatment. A previous study found contradicting results to the current study.[13] MacDonald et al[13] conducted a randomized control trial comparing FR to a CON. The key differences between the current study and MacDonald et al[13] are: one was the muscles treated, (HS vs HS, Quads, Glutes, ADDs and IT band) two the amount of times FR was applied (1 vs 3), and lastly the condition of the athletes. (not sore vs sore) Receiving multiple treatments may have a compounding effect on muscle performance (PPO) which is only seen over the course of time as compared to looking at the acute effects of one FR treatment. Treating multiple muscles may also increase the effects of FR since the agonist and the antagonist muscles are both being treated which may increase proper or more affective in muscle contraction . Lastly,

the improvement in PPO with FR might only occur when there is existing muscle soreness. The subjects in the MacDonald study[13] may have only seen improvements in PPO since they were sore where the subjects in the current study were not sore and therefore explains why there is a difference in results between the studies.

DISCUSSION FOR GLOBAL RATE OF CHANGE

The results of this study indicate the application of myofascial release techniques causes a statistically significant perceived improvement in muscular pain, tightness, and fatigue. The current results agree with previous research which has shown both FR and IC to be effective methods of for treating muscular pain.[8,10,11,13,17,54] The method utilized by the current study to collect the perceived effect of the treatment differs by using a 15-item GROC scale instead of a 10-cm VAS scale. This method was chosen due to the ability to have a discrete answer instead of a continuous answer. Both ways have been shown to effective tools to measure the participant's perceived benefit from a treatment.[8,10,11,13,17,54]

Even though significance was found by the study the degree of significance did not equal or exceed the threshold of minimum meaningful difference of ≥5 ranks set by Stratford et al[81] for a 15-item scale. This agrees with Nambi et al[15] which did not find significant difference in perceived muscular pain following IC. Another randomized crossover study also did not find any significant difference in pain between 20-sec and 60-sec of FR and a CON.[9]

The current study's findings indicate that a single treatment of FR or IC does not significantly change perceived muscle pain, tightness or performance. Previous research

has shown differing results.[7,8,82] A randomized control trial comparing IC, US and a control was conducted by Aguilera et al[7]. The key difference between the current study and Aguilera et al[7] is the muscle treated (HS vs Up Trap). The HS is a deeper muscle compared to the upper trapezius meaning that the same applied pressure may not elicit the same results because the HS is a deeper muscle.

A double-blind randomized trial comparing the effects of FR and neuromuscular stabilization on DOMS.[82] The three key differences between the current study and the study by Moraleda et al[82] is the muscle treated (HS vs Quads), condition of the participants (not sore vs sore) and the presence of a control (CON vs no CON). The HS are a deeper muscle groups and their location in relation to the femur can make it harder to effectively compress them with the foam roller compared to the more superficial quadriceps. The subjects in the study by Moraleda et al[82] may have only seen improvements in perceived pain since they were sore where the subjects in the current study were not sore. Lastly, in the current study used a CON to see if the effects produced by the treatments were from the treatments or from other sources. The study by Moraleda et al[82] did not utilize a CON so the improvements seen may have been due to other factors apart from or in addition to the treatment.

Berggreen et al[8] conducted a randomized control study comparing the effects of IC to a CON. The two key differences between the current study and the study conducted by Berggreen et al[8] are the muscles treated (HS vs Up Trap, Neck and Facial musculature), the condition of the participants (not sore vs sore) and the number of treatments (1 vs 10). The HS is a deeper muscle compared to the upper trapezius

meaning that the same applied pressure may not elicit the same results because the HS is a deeper muscle. The subjects in the study by Berggreen et al[8] may have only seen improvements in perceived pain since they were dealing with chronic pain where the subjects in the current study did not deal with chronic pain. Lastly, receiving multiple treatments may have a compounding effect on perceived pain which is only seen over the course of time as compared to looking at the acute effects of one IC treatment.

SUMMARY

As mentioned earlier it has been reported that both FR, and IC have been shown to effectively treat muscle tightness. However previous research lacked studies comparing the effectiveness of FR to IC. Therefore, the goal of this study was to compare the effectiveness of FR to IC to increase ROM and PPT of the hamstrings, VJ height, PPO and the perceived GROC. Statistical significance was found in all three treatment groups (FR, IC and CON) when comparing pretreatment measurements to posttreatment measurements for AROM, VJ and PPO. There was no between-group significance AROM, PPO or VJ. Statistically significant increases in perceived GROC were found following the application of FR and IC but the increases were not large enough ($\leq$5) for a clinically meaningful increase. The application of FR, and IC did not produce any significant increases in hamstring PPT. The results did find a perceived difference between FR and IC, but no measurable differences were found. These results give support that the application of myofascial release techniques can increase ROM, VJ height and PPO.

FINDINGS

As a result of the current study and analysis of data the following this were found:

1. There was a significant increase in ROM between pretreatment and posttreatment measurements
2. There were no significant differences between FR, IC, and CON in increasing ROM of the hamstrings.
3. There was no significant increases in PPT between pretreatment and posttreatment measurements for FR, IC or the CON
4. There were no significant differences between FR, IC, and CON in increasing PPT.
5. There was a significant increase in VJ height between pretreatment and posttreatment measurements
6. There were no significant differences between FR, IC, and CON in increasing VJ height.
7. There was a significant difference between pretreatment and posttreatment measurements in increasing the PPO of the hamstrings.
8. There were no significant differences between FR, IC, and CON in increasing the PPO of the hamstrings.
9. There was not a meaningful improvement for perceived muscle pain, tightness and fatigue following a treatment of FR, IC or CON.

CONCLUSIONS

Within the scope and limitations of this investigation, it seems reasonable to conclude that:

1. An application of FR or IC on the hamstrings may have a beneficial effect on hamstring ROM.
2. An application of FR or IC on the hamstrings may have a beneficial effect on VJ height.
3. An application of FR or IC on the hamstrings has a beneficial effect on PPO.
4. An application of FR or IC on the hamstrings had no effect on hamstring PPT.
5. An application of FR or IC on the hamstrings overall had no meaningful increase on perceived muscle pain, tightness or fatigue.

RECOMMENDATIONS FOR FUTURE RESEARCH

The following recommendations for further study seem warranted based on the data obtained and questions that arose throughout the course of this study.

1. A study should be performed that uses more sport specific tools to measure performance outcomes after varying myofascial release techniques.
2. A study should be performed that compares the outcomes of varying myofascial release techniques to different levels of competition.

3. A study should be performed comparing the outcomes of varying myofascial release techniques to level of previous exposure to myofascial release techniques.
4. A study should be performed comparing the long-term effects of varying myofascial release techniques.
5. A long-term study should be performed comparing the outcomes of varying myofascial release techniques.

APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL FORMS

East Stroudsburg University of Pennsylvania
200 Prospect Street
East Stroudsburg, PA 18301-2999

East Stroudsburg University Institutional Review Board
Human Research Review
Protocol # **ESU-IRB-021-1718**

Date: **December 18, 2017**
To: **Kelly Harrison and Nathan Sheneberger**
From: **Shala E. Davis, Ph.D., IRB Chair**
Proposal Title: **"Comparison of Foam Rolling and Ischemic Compression in the Treatment of Hamstring"**

Review Requested:	Exempted	Expedited **X**	Full Review
Review Approved:	Exempted	Expedited **X**	Full Review

FULL RESEARCH

____ Your full review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your full review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your full review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit.

EXEMPTED RESEARCH

____ Your exempted review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your exempted review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your exempted review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

EXPEDITED RESEARCH

__**X**__ Your expedited review research proposal has been approved by the University IRB (12months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your expedited review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your expedited review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

Please revise or submit the following:

APPENDIX B

INFORMED CONSENT FORM

INFORMED CONSENT
For a Research Study entitled
A Comparison of Foam Rolling and Ischemic Compression in Improving Hamstring Tightness

You are invited to participate in a research study to evaluate the effects of two manual therapy techniques on hamstring muscle tightness and pain. The study is being conducted by Nathan Sheneberger, at East Stroudsburg University in Athletics Department. You were selected as a possible participant because you are between the ages of 18-30 and are a collegiate basketball player.

What will be involved if you participate? If you decide to participate in this research study, you will be asked to engage 3 brief sessions over a 3-week period. During the initial session, you will receive one of three 5-minute manual therapy treatments delivered to the posterior thigh area. Muscle flexibility, function, pain and survey data will be collected before and immediately following the treatment. Participants will then be scheduled for 2 other sessions approximately a week apart. During each session the muscle flexibility, function, pain and survey data will be recollected. Your total time commitment will be approximately 60-75 minutes over a 3-week period.

Are there any risks or discomforts? The risks associated with participating in this study are possible muscle discomfort and skin redness during the application of the treatment intervention. The interventions utilized in this study are designed to stretch and elongate skin, muscle, and fascial tissues and can be uncomfortable. Some participants may experience mild muscle soreness and possible visible bruising of the skin in the hamstring area. To minimize these risks, we will be using well trained clinicians and a 10-point discomfort scale during the intervention. The clinician delivering manual therapy will be monitoring for any discomfort throughout the treatment session to avoid any discomfort rating beyond a 7 on the discomfort scale.

All participants have the option to discontinue the treatment at any time. Any subjects reporting symptoms inconsistent with mild muscle soreness or localize skin irritation will be immediately referred to the University Health Center or personal physician for follow up. Participants are responsible for any costs associated with medical treatment.

Are there any benefits to yourself or others? Participants will receive an assessment of their hamstring flexibility. This information may be helpful in identifying a potential risk factor in hamstring muscle injuries. Participants will also receive two 5-minute manual therapy treatment of an intervention reported in previous studies to improve hamstring flexibility,

function and pain. We/I cannot promise you that you will receive any or all of the benefits described.

Will you or you receive compensation for participating? There is no compensation for participating in this study.

Are there any costs? There are no direct costs to participants associated with participation in this study.

If you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with East Stroudsburg University, the Athletic Training Department or any of the East Stroudsburg University personnel associated with this study.

Your privacy will be protected. Any information obtained in connection with this study will remain confidential. The information obtained during this study may be used in follow-up research, published in a professional journal, or presented at professional meetings but your name and identify will not be reveal.

If you have questions about this study, please ask them now or
contact Nathan Sheneberger by phone at (320)-405-9824 or e-mail at
nsheneberg@live.esu.edu. A copy of this document will be given to you to keep.

If you have questions about your rights as a research participant, you may contact the East Stroudsburg University Institutional Review Board by phone (570)-422-3336 or e-mail at sdavis@esu.edu.

THIS PROJECT HAS BEEN APPROVED BY THE EAST STROUDSBURG UNIVERSITY OF PENNSYLVANIA INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHERE OR NOT YOU WISH TO PARTICIPATE IN THIS RESARCH STUDY. YOUR SIGNATURE INDICATES YOUR WILLINGNESS TO PARTICIPATE.

_____ _____

Participant Signature Date Investigator obtaining consent Date

_____ _____

Printed Name Printed Name

APPENDIX C

HEALTH SCREENING FORM

Health Screening Form

This study involves the use of myofascial therapy techniques that may include deep pressure and soft tissue stretching. To minimize potential risks of adverse effects from this type of deep tissue work, we are collecting the following information. This information will be kept confidential and used for your protection only. Please be truthful in providing you responses. If you have any questions or concerns regarding the items below or any other health issues you may have, please don't hesitate to ask the investigator while completing this form.

Directions: Please circle either YES or NO for each item below. If you answer YES, please provide a brief explanation in the space provided.

1. Have you had a hamstring injury in the past 6 months? **Explain:**	YES	NO
2. Are you currently undergoing treatment for a lower extremity injury? **Explain:**	YES	NO
3. Do you have any open wounds, increased skin sensitivity, or other skin conditions in the area of the posterior (back) of the thigh and legs? **Explain:**	YES	NO
4. Do you have a history or have been diagnosed with any systemic conditions or diseases	YES	NO

such as: diabetes, fibromyalgia, phlebitis or thrombophlebitis, arteriosclerosis, clotting or bleeding disorders, chronic inflammatory disorder, or autoimmune disorders? **Explain:**		
5. Do you currently have or have you had any neurological conditions/symptoms such as: spinal disc herniation, neuropathy, numbness, tingling, or shooting pain into extremities, or any history of lower back pain that included symptoms that radiated into your arms or legs? **Explain:**	YES	NO
6. Are you currently taking any medications that alter pain perception or have any effect on healing or the normal inflammatory response (e.g. anti-coagulants, NSAIDs, steroids, muscle relaxants, or analgesics (pain relievers))? **Explain:**	YES	NO
7. Do you have any other health conditions or concerns that you feel may expose you to potential risks from deep	YES	NO

tissue mobilization or stretching techniques? **Explain:**		

Interviewer notations:

_____

_____

_____ Participation Status: **Cleared Not Cleared**

Participant's Name (Print): _____Date: _____

Participant's Signature:_____ Date: _____

PI's Signature: _____Date: _____

APPENDIX D

GLOBAL RATE OF CHANGE SCALE SURVEY

Global Rating of Change Scale

Please rate any changes in **pain or discomfort** in the back of the thigh, knee or calf of the limb treated since you began this treatment until now (check only one):

☐ A very great deal worse (-7)	☐ About the same (0)	☐ A very great deal better (7)
☐ A great deal worse (-6)		☐ A great deal better(6)
☐ Quite a bit worse (-5)		☐ Quite a bit better (5)
☐ Moderately worse (-4)		☐ Moderately better (4)
☐ Somewhat worse (-3)		☐ Somewhat better (3)
☐ A little bit worse (-2)		☐ A little bit better (2)
☐ A tiny bit worse (-1)		☐ A tiny bit better (1)

Please rate any changes in **muscle tightness or restriction** in the back of the thigh, knee or calf of the limb treated since you began this treatment until now (check only one):

☐ A very great deal worse (-7)	☐ About the same (0)	☐ A very great deal better (7)
☐ A great deal worse (-6)		☐ A great deal better(6)
☐ Quite a bit worse (-5)		☐ Quite a bit better (5)
☐ Moderately worse (-4)		☐ Moderately better (4)
☐ Somewhat worse (-3)		☐ Somewhat better (3)
☐ A little bit worse (-2)		☐ A little bit better (2)
☐ A tiny bit worse (-1)		☐ A tiny bit better (1)

Please rate any changes in **muscle performance or fatigue** in the back of the thigh, knee or calf of the limb treated since you began this treatment until now (check only one):

☐ A very great deal worse (-7)	☐ About the same (0)	☐ A very great deal better (7)
☐ A great deal worse (-6)		☐ A great deal better(6)
☐ Quite a bit worse (-5)		☐ Quite a bit better (5)

☐ Moderately worse (-4)		☐ Moderately better (4)
☐ Somewhat worse (-3)		☐ Somewhat better (3)
☐ A little bit worse (-2)		☐ A little bit better (2)
☐ A tiny bit worse (-1)		☐ A tiny bit better (1)

Investigator/Clinician Notations:
Subject: _____
Time: _____ Date: _____ Clinician Initials: _____

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