

ABSTRACT

THE EFFECTS OF STATIC VERSUS DYNAMIC MYOFASCIAL DECOMPRESSION ON HAMSTRING FLEXIBILITY IN A COLLEGE-AGED POPULATION: A PILOT STUDY

Objective: To determine the effectiveness of static and dynamic myofascial decompression(MFD) on hamstring flexibility in a healthy college-age population.

Methods: 29 participants (mean age 25.9 ± 4.5) were randomly assigned to a static or dynamic MFD application group. Hamstring flexibility was measured with the Active Knee Extension (AKE) test pre and post intervention in addition to two immediate follow up days. The Global Rate of Change (GROC) scale was used to assess subjective response to treatment. To document ecchymosis resulting from the intervention, photographs were taken throughout all three test days.

Results: A statistically significant increase was shown in both intervention groups in pre-test, post-test, day 2, and day 3 measures ($p=0.00$). No statistical significance was found between static and dynamic MFD interventions ($p=0.891$). Visual analysis with photographs revealed a significantly smaller degree of ecchymosis from the dynamic technique. GROC results show all participants had clinically significant increases in perceived hamstring flexibility post intervention.

Conclusion: Both static and dynamic MFD is safe and effective at improving hamstring flexibility with no negative perceived effects. A dynamic application can improvement flexibility with less ecchymosis compared to a static application. These findings offer clinicians additional effective techniques at improving hamstring flexibility.

Jude Xie
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DECOMPRESSION ON HAMSTRING FLEXIBILITY IN A
COLLEGE-AGED POPULATION: A PILOT STUDY

by
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TABLE OF CONTENTS

	Page
LIST OF TABLES	vii
LIST OF FIGURES	viii
BACKGROUND	1
Flexibility	1
Hamstring Injuries.....	1
Limitations in Flexibility	2
Common Myofascial Treatments.....	4
Myofascial Decompression.....	6
Purpose.....	8
METHODS.....	10
Subjects	10
Procedure.....	10
Intervention	12
Instrumentation	13
RESULTS.....	16
Hamstring Flexibility	16
Ecchymosis Observations	16
Global Rate of Change (GROC).....	17
DISCUSSION.....	18
Comparison of Interventions.....	22
Ecchymosis	24
Limitations	26
Clinical Implications	26

Future Research.....	27
Conclusion.....	27
REFERENCES	29
TABLES	36
FIGURES	39

LIST OF TABLES

	Page
Table 1. Participant Demographics	37
Table 2. Static MFD Hamstring Flexibility Changes.....	37
Table 3. Dynamic MDF Hamstring Flexibility Changes	37
Table 4. Comparison of Static and Dynamic Hamstring Flexibility Changes	38
Table 5. Visual Analysis of Ecchymosis.....	38

LIST OF FIGURES

	Page
Figure 1: Myofascial Decompression Tools	40
Figure 2: Global Rate of Change (GROC) Scale	40
Figure 3: Hamstring Flexibility Results	40
Figure 4: Static MFD Ecchymosis Photographs	41
Figure 5: Dynamic MFD Ecchymosis Photographs.....	44

BACKGROUND

Flexibility

Flexibility is vital to one's overall fitness for maintenance of functional range of motion (ROM) and to provide significant musculoskeletal health benefits.^{1, 2} It is defined as the absolute range of movement in a joint or series of joints attainable actively or passively with the use of external force.³ Research suggests proper flexibility may help decrease the risk of injury and improve performance among the athletic population.^{4, 5} In regards to the general population, adequate flexibility is important in one's ability to maintain proper posture, enable joints to move freely, and decrease inefficient movements which may help lower the risk of low back and joint pain.⁶ The American College of Sports Medicine (ACSM) recommends exercise programs for all populations and emphasizes proper stretching for all the major joints with a focus on areas commonly affected by a decrease in range of motion, such as the trunk, the neck and the hips. Often, individuals with tight hamstrings have limited lumbar range of motion (ROM) and a posteriorly fixed pelvis that can only compensate for imbalance by decreasing lumbar lordosis.⁷ These "lumbar compensators" are prone to overcorrection and postural imbalances that may lead to biomechanical impairments.⁷ Thus, it is particularly important to maintain flexibility in the lower back and posterior thighs, since limited hamstring flexibility is associated with increased incidences of low back pain and lower extremity injuries.^{6, 8, 9}

Hamstring Injuries

Risk for hamstring injury to occur is exacerbated by the presence of poor hamstring length.¹⁰ Among lower extremity injuries, hamstring injuries are described as the third most common orthopedic problem and often have long

recovery time.¹¹ Researchers have suggested that neuromuscular inhibition following the event can disrupt the rehabilitative process and lead to maladaptation of the structure and function of hamstring musculature.¹² Additional pain from muscle stiffness following such injuries can limit an individual's return to their prior level of function, however, research indicates the maintenance of flexible muscle tissue may help eliminate the pain.^{13,14} Therefore it is imperative that rehabilitation techniques be able to address the lack of adequate muscle length in order to decrease hamstring injury rates and avoid potential imbalances that may lead to improper biomechanics.

Limitations in Flexibility

There are numerous reasons as to why people have limited flexibility. Predisposing factors such as age, gender, genetics, ambient level of muscle tensions, and elasticity of connective tissues have a major impact on an individual's overall flexibility.¹⁵⁻¹⁷ Among these factors, both the limitations from connective tissues and level of muscle tension and can be addressed by a physical therapist by targeting the fascia through various techniques.

Review of Fascia

Fascia is defined as a fibrous sheet or band of connective tissue underneath the skin that connects, stabilizes, surrounds, and separates muscles in addition to other internal organs.¹⁸ When fascia covers bones, it forms the periosteum, around tendons – the paratendon, and around vessels and nerves – the neurovascular sheath.¹⁹ This compartmental characteristic protects underlying structures and aids in the body's skeletal-muscle pump system. When muscle contracts against fascia, blood and lymph is pushed out of muscles and directed towards the heart through unidirectional valves; this is known as the myofascial system and is particularly

important in the lower limbs to encourage venous return.²⁰ Furthermore, when fascia cover joints, it strengthens the capsules and ligaments.¹⁹ It can also aid to dissipate stress concentration along the enthuses, the connective tissue between tendon or ligament and bone.²⁰ During movements, fascial fibers orient in patterns parallel to the direction of pull and function to promote both independent and synergistic muscle movement.^{18,20} This aspect of fascia is all the more important since fasciae is continuous throughout the limbs, creating an anatomical continuity between different muscles used in the same direction of movement.^{19,21-23} Thus it is necessary to recognize the fascial link in the coordination of muscular activity in the body.

Throughout the body, fascia varies in thickness based on location and both interpenetrates and surrounds the muscles, bones, nerves, and blood vessels of the body.^{19,20,24} Superficial fascia is the layer of areolar or adipose connective tissue immediately under the skin and function to promote appropriate mobility and to protect underlying structures. Below this layer is the deep fascia which is composed of denser fibrous sheets and bands that provide greater structural support and further promote synergistic muscle movements.²⁰⁻²³ Both fascial layers are continuous with one another and are composed of collagen, elastic fibers, and ground substance.^{20,25}

Collagen, Elastin, and Ground Substance

Collagen and elastin aid in promoting the sliding and stretching of various layers and surrounding structures.²⁶ These two proteins are surrounded by an extracellular matrix called ground substance that is rich in proteoglycans such as hyaluronic acid (HA), that function to decrease friction between muscle fibers and improve mobility. The increased presence of HA in the ground substance allows

the collagen fibers to slide with little friction when movement occurs, providing relative independence of each muscle from the surrounded environment.²⁷

Myofascial release is thought to alter ground substance and encourage appropriate gliding between fibers.²⁵

Myofascial Restrictions

Fascial restrictions are one possible cause of limited flexibility and often form in response to inactivity, injury, inflammation, or disease. As a result, fascial tissue may lose elasticity and become dehydrated.²⁸ With a decrease in fascial elasticity and dehydration, fascia can bind around the affected areas, causing a fibrous adhesion to form. Such fibrous adhesions have been shown to be painful, decrease overall soft tissue extensibility, and prevent normal muscle mechanics with restrictions to joint range of motion and muscle length. Furthermore, fibrous adhesions can lead to neuromuscular hypertonicity along with decreased strength, endurance, and motor coordination.^{29, 30, 15} As a result, a continuous strain pattern may emerge from compensations of joints that may pull the body out of alignment and increase an individual's risk of injury.^{28,31}

Common Myofascial Treatments

Stretching

There are various methods used to improve hamstring flexibility but stretching is most commonly used.^{32,33,34} Within stretching are several subgroups such as ballistic stretching, dynamic stretching, and static stretching. Ballistic stretching involves a rhythmic bouncing motion that utilizes the momentum of a swinging leg to lengthen the muscle. Although this has been shown to be effective in increasing hamstring range of motion, this technique can cause excessively high

tension to one's tissue in a short period of time which can increase rates of strain or rupture of the tissue.³⁴ In contrast, dynamic stretching is a slow controlled lengthening of the hamstring throughout the full ROM which may help lengthen muscles based on the principles of reciprocal inhibitions.³⁵ Lastly, static stretching is performed by taking the hamstring through the full range of motion until the end and holding it at that point for a specific amount of time. When comparing static and dynamic stretching, Bandy et al found that a 6 week static stretching program is more effective than dynamic stretching at improving hamstring length.³⁴

Among these types of stretches, static stretching is most commonly used. Static stretching has been demonstrated to be effectively in all forms of athletic activity to improve range of motion (ROM), flexibility, and prevent injury.^{36,37} However, the literature suggests that when static stretching is used as a warm up, a decrease in muscle power and resistance was evident.¹ These possible side effect may be important among an athletic population where strength is necessary but literature suggests a temporary decrease in strength may not be important in the general public population.³⁷

Myofascial Release

Recently practitioners have begun to utilize soft tissue approaches such as the Graston Technique® or other myofascial release techniques to improve flexibility. Unlike with static stretching, research has shown these methods demonstrate no significant effect on muscle strength.^{6,38,39} Clinicians utilizing this technique target the myofascia, a connective tissue surrounding muscles, which can restrict range of motion, decrease strength, and decrease endurance if it is inactive, injured, or inflamed.^{38,39,28} Clinicians have also found myofascial release techniques useful in physical therapy for alleviating muscle stiffness, decreasing

pain, and improving range of motion.^{29,40} These results are accomplished by using a compressive force either through manual pressure from a clinician's hands or from the use of tools to release adhesions within the fascia between bone, tendons, ligaments, and muscles to address underlying impairments of pain and muscle stiffness.^{6,29,41,42,43}

Myofascial Decompression

In traditional Chinese medicine (TCM), cupping therapy has been used to treat a wide variety of conditions including pain, headaches, and immune disorders.⁴⁴ Cups are placed along specific meridian points with a vacuum seal that draw up soft tissue into the cup. This eastern medicine technique is believed to correct the flow of Qi (energy) imbalances from illness and injuries to address resulting ailments.⁴⁵ In western medicine, cupping therapy techniques and tools are used to assess and correct movement-based impairments by including elements of active movements combined with neuromuscular re-education techniques through the manipulation of the body's myofascial properties. This technique has collectively become known as myofascial decompression (MFD).

The cups used in MFD can be made from a variety of materials such as glass, silicone, or plastic. Cups are applied directly to the skin while a vacuum draws in soft tissue with negative pressure.⁴⁶ This vacuum can result from the pressure gradient created with the passing of a flame inside the cup, with manual pressure, or with a handheld pneumatic pump.⁴⁵⁻⁴⁷ It is this negative, decompressive pressure that separates MFD from other soft tissue techniques.

As soft tissue is subjected to the mechanical stresses within the cup, the forces are propagated through the layers of connective tissue underneath.⁴⁶ In response to the negative pressure, an increase in blood flow and microcirculation

within the local area can occur due to the increased vasodilation of blood vessels and the escape of fluids from superficial capillaries.⁴⁶ The result is an overall increase of temperature within the tissue, leading to a reduction of hyaluronic acid viscosity.⁴⁸ This effect can decrease adhesive properties within and between structures and allow for improved fascial gliding and mobility.¹⁹ As clinicians continue to explore various methods to manipulate fascia, MFD offers an alternative approach to addressing musculoskeletal impairments by utilizing a decompressive effect.

In addition to improvements in fascial and muscular gliding, MFD may result in neurological changes that affect muscle tension. Fascia is permeated with various mechanoreceptors that span throughout tendons, ligaments, and joint capsules. These mechanoreceptors include ruffini bodies, pacini corpuscles, and interstitial muscle receptors that respond to changes in pressure. The nature of decompression in MFD may lead to pressure changes within the tissue that stimulates such receptors; the result is a tonus change in the involved skeletal muscle tissue motor units.⁴⁰

Previous research reports MFD can target both superficial and deep fascial tissue and is effective at increasing both hamstring length and strength in elite athletes with hamstring pathologies.⁴³ However, this study fails to differentiate and compare the effects of static and dynamic MFD. A static approach involves placing the cups along the muscle belly and applying negative pressure to draw in the connective tissue underneath. This action will apply a tensile load that can stretch the soft tissue underneath and increase blood flow to the area.^{43,46,49} With prolonged application, localized blood pooling can lead to the formation of ecchymosis, a discoloration of the skin resulting from extravasation, a leaking of fluids, of blood vessels.⁴⁶ A dynamic approach involves the same application with

the addition of a lubricant that allows the cup to be slid across the muscle belly, while maintaining the negative pressure. Since the decompressive forces are applied over a larger area, bruising is typically minimal.⁴⁶

As with many new techniques for rehabilitation, medical authorities are divided over the treatment's effectiveness with additional concerns mounting in regards to skin discoloration post-treatments. As such, studies such as LaCross et al. sought to provide quantifiable measurements in a study that examined the effects of MFD on hamstring flexibility.⁴³ Researchers used the Active Knee Extension (AKE) test to measure changes in hamstring flexibility since the outcome measure was determined to be the gold standard of hamstring flexibility measurements.⁵⁰ Although this study failed to assess the amount of ecchymosis present post-MFD treatment, researched utilized the Global Rate of Change (GROC) scale to quantify participants' subjective self-perceived improvement or regression after the intervention. Results revealed positive improvements in hamstring flexibility and GROC scores, in which researchers concluded MFD is an effective and safe treatment. As more clinicians utilize MFD in a clinical setting, further research regarding its effectiveness are warranted.

Purpose

While research demonstrates that MFD has a positive effect on relieving tissue tension in a short period time, the next step involves determining whether static or dynamic MFD is most beneficial.⁴³ Therefore, the purpose of this study is to determine the effectiveness of static and dynamic myofascial decompression (MFD) on hamstring muscle flexibility as determined by an Active Knee Extension (AKE) Test in healthy college aged individuals. The primary hypothesis is there will be a greater statistical improvement in hamstring flexibility after a

single application of dynamic MFD compared to static MFD. Since, the controversial marks resulting from MFD techniques have limited documentation, the secondary purpose is to observe and compare the ecchymosis present pre-and-post intervention between the two MFD techniques. Thus, the secondary hypothesis is there will be less observable ecchymosis resulting from the dynamic technique compared to the static technique. The tertiary purpose is to quantify the perceived subjective change in hamstring flexibility post treatment. As such, the tertiary hypothesis is participants will report a greater statistically improvement in GROC scores post dynamic MFD treatment compared to static MFD. The primary null hypothesis of this study is there will be no significant difference in hamstring flexibility between static and dynamic MFD. In regards to ecchymosis, the secondary null hypothesis is there will be no observable difference in the amount of ecchymosis between static and dynamic techniques. Lastly, the tertiary null hypothesis is there will no statistical difference of GROC scores between the static and dynamic MFD groups.

METHODS

Subjects

Twenty-nine participants (20 males, 9 females; mean SD age, 25.9 ±4.5 years) were recruited on a volunteer basis from the great Fresno and Clovis area. Prior to the start of the study, all participants were randomly assigned to either a static MFD group (n=14, 9 males and 5 females) or a dynamic MFD (n=15, 11 males and 4 females) group via Excels randomization function. Both inclusion and exclusion criteria were assessed with an intake form and a brief history. The inclusion criteria were healthy males and females between the ages of 18 to 40 years old with limited hamstring muscle flexibility as determined by a minimum of 20 degree loss of active knee extension measured with the femur held at 90 degree of hip flexion. In addition, participants must be able to complete two follow up visits on two consecutive days following treatment. Exclusion criteria included participants that have been diagnosed with musculoskeletal impairments affecting the lower extremity in the past six months that may limit participation, have a past history of severe systemic disease (cardiac, renal, respiratory failure), hemorrhagic disease (allergic purpura, hemophilia, leukemia), any form of dermatitis or malignant tumors, or reported pain/numbness/tingling experienced while performing the AKE test. Prior to participation, all subjects were required to read and sign the informed consent and intake form. This study was approved by the Physical Therapy Department's Committee for the Protection of Human Subjects and the Research Guidance Committee.

Procedure

Initial testing and intervention occurred on location in the Physical Therapy and Intercollegiate Athletics building at the California State University Fresno

campus. The initial visit included the completion of consent and past medical history forms as well as initial measurements of bilateral posterior thigh flexibility utilizing the AKE test. These results determined if the participant was eligible to be included in the study. Hamstring strength was also assessed via a handheld dynamometer in the standard prone testing position as described by Daniels and Worthingham.⁵¹ If eligible, participants were randomized to one of two groups, and the intervention of myofascial decompression was applied for 5 minutes to the extremity with the greatest muscle flexibility restriction under the constraints of either static or dynamic MFD. During the intervention, the patient was asked to record their pain scale using the Visual Analog Scale (VAS) after the first 10 seconds of cup application, at 2.5 minutes (halfway), and immediately following removal of cups (5 minutes). All participants were instructed to verbalize their pain and discomfort throughout treatment to ensure the techniques utilized do not exceed their tolerance level. In addition, participants were informed the intervention could be adjusted or terminated following the use of an agreed upon safe-word. Immediately after the intervention was performed, the participants underwent follow up measurements of hamstring muscle flexibility and strength. Participants were also instructed to complete a Global Rating of Change (GROC) scale to assess their perceived change in hamstring flexibility after the intervention. The following two days after intervention, participants were asked to return for repeat hamstring ROM measurements and were instructed to continue their normal daily activities without restrictions. Participants were informed the total time commitment for initial measurements, intervention, and final measurements would be approximately 30 minutes.

Intervention

Intervention consisted of one of two separate treatments depending on group assignment. These interventions were described as either static MFD or dynamic MFD. The same position will be utilized for each intervention. The participant was positioned prone on the treatment table and asked to expose as much of the posterior aspect of their thigh as they feel comfortable; preferably up to at least to the gluteal fold to expose as much of the ischial tuberosity as possible. Participants were encouraged to wear loose fitting shorts to expedite this process, and as privacy in the room could not be ensured, proper draping procedures were in place to ensure patient comfort. If a participant had excessive hair on the treatment area, it was trimmed or shaven to ensure proper suction.

Static MFD

With the participant in a prone position, 3 cups were placed along the hamstrings at positions in accordance to positions commonly used in clinical practice. One cup was applied near the ischial tuberosity below the gluteal fold, one applied to the insertion of biceps femoris (posterior lateral aspect of the knee), and one in between the two in the middle of the muscle belly. A thin layer of Free-Up® soft tissue massage cream was applied to the posterior aspect of the thigh for skin comfort. The cups remained on the thigh for 5 minutes total. Throughout the treatment, the negative pressure force of the cups were adjusted as needed for comfort.

Dynamic MFD

With the participant in a prone position, 2 cups were placed along the hamstrings. A thin layer of Free-Up® soft tissue massage cream was applied to the posterior aspect of the thigh to allow for gliding of the cups. The suction force

of the gliding cups was initially low to allow the participant to become accustomed to the feeling. After which, the negative pressure was increased to enough force to ensure proper suction without causing unnecessary discomfort. The cups remained on the thigh for 5 minutes total. Throughout the treatment, the negative pressure force of the cups was adjusted as needed for comfort.

Instrumentation

Measurement of Muscle Flexibility

All measurements of muscle flexibility testing were taken with a universal 12-inch goniometer. Assessment of hamstring muscle flexibility was determined through the AKE Test. Young et al. has reports the AKE test has the highest validity, is most specific to the hamstrings, and should be considered the gold standard measure for hamstring muscle flexibility.⁵⁰ Hamid et al. has reported excellent intrarater reliability (0.97) of the AKE test for assessing hamstring flexibility in healthy adults.⁵² In addition, prior to the initiation of the study, the sole researcher involved in goniometric measurements of hamstring muscle flexibility was found to have excellent intrarater reliability (0.96). Measurements were performed with the participant positioned supine on an examination table with both knee and hip flexed to 90 degrees. The opposite leg was placed in an extended position resting on the examination table and maintained in this position throughout the test. The participant was then instructed to actively extend their knee through the full available range of motion until a “strong but tolerable stretch” was felt. The stationary arm of the goniometer was aligned along the femur with a reference point at the greater trochanter of the femur. The axis of the goniometer was aligned with the lateral femoral condyle of the knee, and the moving arm was aligned with the lateral malleolus. The measurement was taken

in degrees to represent the active range of motion. From the 90-90 position, a measurement of 0 degrees will represent maximum hamstring tightness and a measurement of 90 degrees will represent no hamstring tightness. A measurement of more than 20 degrees from vertical has been defined as hamstring muscle tightness. Two trials were performed for each leg with the highest scores taken for data analysis only if each measurement was within 5% of one another.

Myofascial Decompression Instruments

Throughout the study, three 2.5-inch diameter plastic cups from a Kangzhu 24 cupping therapy set, were used to implement the intervention. The tools are shown in **Figure 1**. A plastic handheld pneumatic pump generated the negative pressure within the cups. Prior to cup application, Free-up professional massage cream was spread onto the target area of each participant's skin for improve cup suction and allowed for gliding during the dynamic MFD intervention.

Measurement of Subjective Response

The Global Rating of Change (GROC) scale is a frequently used outcome measure to assess participants subjective self-perceived improvement or regression after a specific intervention.⁵³ In a study by Kamper et al. the GROC was determined to have excellent face validity and test-retest reliability (ICC = 0.9) while the minimally clinically important change (MCIC) was determined to be 2 points on a 11 point scale.⁵³ In this study, to assess subjective response of perceived change in hamstring flexibility after the intervention, all participants were given a GROC to complete after the cups were removed. The scale was designed to quantify a participant's perceived improvement or decline over time to assess the effectiveness of the treatment.⁵⁴ Participants were shown and verbally

asked the following: “with respect to your feeling of hamstring tightness, how would you describe it now compared to before treatment?” The scale presented to participants included a spectrum of 11 possible answers ranging between (-5) “Less Flexible”, (0) “About the Same”, and (+5) “More Flexible.” Refer to **Figure 2** for GROCC scale used.

Photographic Evidence of Ecchymosis

To document and compare possible ecchymosis resulting from the two intervention of MFD, photographs of the posterior thigh were taken immediately pre and post intervention for each group with an iPhone 6s camera. Participants were asked to reveal as much of their posterior thigh as they felt comfortable and were all draped appropriately prior to photograph. Additional photographs were obtained during the two follow up visits on two consecutive days following treatment.

RESULTS

Hamstring Flexibility

All 29 participants within the static MFD group (n=15, 11 males and 4 females) and dynamic MFD group (n=14, 9 males and 5 females) completed the study. The complete demographics table can be found in **Table 1**. Results show a statistically significant increase in both intervention groups when comparing pre-test measures to post-test, day 1, and day 2 measures ($p=0.00$). **Figure 3** illustrates the mean hamstring flexibility gains of all participants. No statistical significance was found between static and dynamic MFD interventions ($p=0.885$). These results suggest that a single application of either static or dynamic MFD can significantly improve hamstring flexibility within this population. Refer to **Table 2, Table 3, and Table 4** for statistical data on hamstring flexibility within and between groups.

Ecchymosis Observations

Of the total 116 photographs obtained during the study, 5 photographs were inaccessible. The remaining 111 photographs effectively document a trend in the amount of ecchymosis produced by each application as well as the speed and degree of reduction during the follow-up days. Ecchymosis was visual assessed through photographs and reveal all of participants experienced ecchymosis immediately post treatment, however, the dynamic application produced a significantly smaller degree of ecchymosis compared to the static application.

By day 2, 50% of participants within the dynamic MFD group had ecchymosis remaining compared to 100% in the dynamic group. By day 3, only 33% within the dynamic group had ecchymosis remaining compared to 79% in the static group. With each passing day, participants in both MFD groups presented

with visible decreases in the degree of ecchymosis however, two participants within the dynamic group exhibited an atypical distribution of ecchymosis. These results suggest a dynamic application causes less ecchymosis than a static application. Refer to **Table 5** for visual analysis of ecchymosis and **Figure 4** and **Figure 5** for the photographs of ecchymosis progression.

Global Rate of Change (GROC)

Results for the static MFD group (mean = 2.64, SD= 1.50) and for the dynamic MFD group (mean= 2.80, SD=1.32) show positive scores in perceived hamstring flexibility post intervention. Both treatment groups yielded results that were above the MCIC threshold of a 2-point difference on the 11-point scale. Thus, all participants reported significant improvements in hamstring flexibility; no perceived negative effects were reported in either groups. In addition, nearly all participants reported increased “warmth” and felt “looser” in their hamstrings with improved ease of movement post treatment. One participant specifically stated "it is much more comfortable to move."

DISCUSSION

The main purpose of this investigation was to determine the effectiveness of static and dynamic myofascial decompression on hamstring flexibility in a healthy college-age population. The secondary purpose was to observe and compare the ecchymosis present post intervention between the two MFD techniques. Lastly, the third purpose is to quantify the perceived subjective change in hamstring flexibility post treatment. The results of this study support the primary null hypothesis and showed both interventions significantly improved hamstring flexibility of all participants, with no statistical difference between static and dynamic MFD techniques. In addition, day 2 and day 3 results show both groups could maintain their gains in hamstring flexibility with a similar small decline after each additional day from post intervention measurements. After the intervention, ecchymosis was present as anticipated, however nearly all participants in the dynamic MFD group experienced a significantly smaller amount of ecchymosis, if any, that dissipated more quickly than those experienced in the static MFD group. These findings support the secondary hypothesis of less ecchymosis resulting from dynamic MFD compared to static MFD. In regards to the third hypothesis, results from the GROC scores supported the tertiary null hypothesis as all participants reported improved perceived hamstring flexibility post intervention with no significant difference between groups.

Since MFD is relatively new to the physical therapy setting, many clinicians are unfamiliar with its techniques and theories. In eastern medicine, practitioners of traditional cup therapy theorizes the use of cups along specific meridian lines can correct the flow of Qi (energy) imbalances from illness and injuries to address resulting ailments.⁴⁵ In contrast, MFD techniques utilizes the

same tools as traditional cup therapy, but also incorporates functional movements with a western medical theory focused on the assessment and correction of movement inefficiencies through the manipulation of the body's myofascial properties. In this pilot study, to isolate the effects due to the negative pressure cups alone, no functional movements were incorporated. Thus, all changes in range of motion can be attributed solely to the intervention. This study is also the first to assess changes of hamstring flexibility post-MFD intervention over a period of time.

Previous research from Tham et al offers a biomechanical explanation to describe the behavior of the skin and underlying soft tissue layers when subjected to cupping therapy. Researchers in this study used a multi-layered axi-symmetric finite-element model to analyze the mechanical response of the soft tissue when cupped. This numeric simulation model was then compared to the experimentally measured skin deflection profile of 1 subject under the cup vacuum load for 5 seconds. The parametric studies included the effects of vacuum pressure and the size and shape of the cup. Results showed that under the vacuum pressure of the cups, all soft tissue enclosed, including the underlying muscle layer, are in tension with the maximum tensile stresses greatest at the soft tissue layer inside and adjacent to the rim of the cup. This is comparable to a "tack and stretch" technique as the region directly under the rim of the cup is under compression, while the region inside the cup is decompressed and pulled away from the body.⁴⁹ In addition, three cup sizes with diameters of 35,50, and 65mm were compared. The results showed the soft tissue tension was at the maximum for the largest cup and minimum for the smallest cup. Thus the larger the cup used under vacuum, the greater the tissue tension. This study however, only focused on the stress levels from the surface to mid-thickness skin layer and did not analyze deeper effects nor

the soft tissue changes after the cup was removed. As a result, no implications of the cup's effect on muscles can be drawn from this study.

In another case-based study conducted at the University of California, San Francisco (UCSF), further insight into the effects of MFD on myofascial structures were derived using magnetic resonance imaging (MRI). In this study, a 29-year-old asymptomatic male with no previous history of shoulder or neck pathologies had one negative pressure cup placed upon his right shoulder above the spine of scapula. Images were taken with a T1-weighted coronal-oblique view of three conditions: the cup in place with no pressure applied, the cup with vacuum pressure, and the cup in place after the vacuum was released. No specific time of vacuum pressure applied were given. Resulting images showed distinct changes through multiple soft tissue layers including the skin, fat, fascia, and muscle trajectories of the upper trapezius and supraspinatus fibers.⁵⁵ Although this study is in the process of publication, these results offer further insights on possible biomechanical structural changes due to a single MFD application.

Evidence of fascial changes after an application of MFD may be a possible explanation of improvements in range of motion. Although there is limited research regarding the effects of MFD on range of motion, LaCross et al conducted a similar study that examined the effectiveness of MFD compared to self-myofascial release (SMR) with a heat pack on hamstring flexibility. The MFD technique used was a comprehensive treatment that included both static and dynamic applications along with active movements and manual stretching. The study was carried out on 17 collegiate athletes (13 males, 4 females: mean age =20.5) with a history of hamstring pathology. A Global Rating of Change (GROC) scale was used after treatment to reflect each participant's perception of treatment effect. The results of the study revealed both techniques yielded significant

improvement in overall hamstring flexibility ($p=0.01$). In addition, GROC scores showed participants in the MFD group rated their overall condition as “moderately better” post intervention compared to the SMR group who rated their overall condition from a “tiny bit better” to a “little bit better.” Researchers concluded that MFD can alter fascial tissue and is effective at increasing hamstring flexibility and strength in elite athletes with hamstring pathologies.⁴³ A major flaw in this study is the MFD application combined multiple techniques and thus improvements in hamstring flexibility cannot be solely attributed to the negative pressure cups used.

Although the GROC is a frequently used outcome measure to assess participants self-perceived improvement or regression after a specific intervention, of the limited studies on MFD and cupping therapy, only LaCross et al. utilized the GROC.^{43,53} Due to the similarity in nature of our study compared with LaCross et al, the GROC scale was also used in this study to assess subjective response to MFD interventions. The open nature of the GROC allowed for simple quantification of subjective results post treatment. Our results were similar to LaCross et al. since all participants experienced positive responses with no perceived negative effects.

Along with reported improvements in perceived hamstring flexibility while completing the GROC, most participants also reported feeling “looser” and increased “warmth” in their hamstrings post treatment. These results and subjective comments may be explained by the findings of Markowski et al. that explored the effects of dry cupping on 17 participants (8 male, 9 females: age range 30-56 years) who suffered from non-specific low back pain.⁵⁶ Researchers in this study revealed cupping therapy for 10 mins in the lumbar region both decreased low back pain, as determined by the visual analog scale, and significantly improved lumbar ROM ($p=0.016$) and hamstring flexibility

($p=0.043$). Findings were attributed to an increased vasodilation of blood vessels and increase in circulation. The result was an overall increase of temperature within the tissue, leading to increased hyaluronic acid fluidity, decreased adhesive properties, and improved fascial gliding and mobility.^{19,48} Furthermore, Petrofsky et al. suggests an increase in tissue temperature is generally correlated to an increase in muscle elasticity.⁵⁷ In addition to demonstrating the effects of negative pressure cups on changes of flexibility across joints, these findings lend further explanations to the results of our study that revealed improvements in hamstring flexibility after a single application.

Comparison of Interventions

Static and Dynamic Stretching

In our study, hamstring ROM gains immediate post-intervention ($\text{avg}_{\text{static}} = 7.14^\circ$; $\text{avg}_{\text{dynamic}} = 6.93^\circ$) are comparable to another study by Bandy et al. that assessed the effects of static and dynamic stretching on hamstring ROM. The study included 58 subjects (age range: 21 to 41) with limited hamstring flexibility defined as a minimum of 30° loss of knee extension during the AKE test. Subjects were split into three groups: a static group that performed one 30 second static stretch for 5 days a week, a dynamic group who performed 6 dynamic stretch and holds (5 seconds) within 30 seconds for 5 days a week, and a control group who did not stretch. After 6 weeks of flexibility training, hamstring muscle flexibility in both stretching groups increased significantly, however, the static stretch group ($\text{avg. gain} = 11.41^\circ$) revealed greater improvements compared to the dynamic group ($\text{avg. gain} = 4.26^\circ$). In contrast to our results, a primary reason Bandy et al. demonstrated a greater improvement in hamstring flexibility with static stretching may be due to the group training for 6 weeks between pre- and post-test

measurements; our study shows similar results after a single MFD application. Furthermore, Bandy et al. did not continue to assess how long subjects maintained their new range of motion.

Self-Myofascial Release (SMR)

Another technique used to treat limited hamstring flexibility is self-myofascial release using a foam roller. Researchers in Roberts et al compared the effects three types of SMR on dermal temperature and hamstring flexibility on 28 healthy participants (14 males, 14 females; avg age = 23 ± 2.0). All groups used the foam rollers for a total of 4 minutes and 30 seconds. Results showed an improvement in hamstring flexibility with all foam rollers post-treatment (mean difference = 5.86° , $p < 0.001$) immediately following and 30 minutes post-treatment (mean difference = 3.98° , $p < 0.001$). In this study, the time constraints of foam rolling were similar to our study that used static or dynamic MFD for 5 minutes. Both showed a significant increase in hamstring flexibility immediately post treatment as well as a small decrease in hamstring ROM gains with repeated measures after a period of time. The difference was the repeated measures in this study were taken 30 minutes post-intervention while our study remeasured after day 1 and another after day 2.

Proprioceptive Neuromuscular Facilitation (PNF)

In MFD, negative pressure cups are generally used in conjunction with active movements or PNF techniques to maximize improvements in mobility. During PNF stretching the patient will contract the muscle being stretched against some form of resistance, the contraction recruits more motor units containing stimulated golgi tendon organs creating a decrease in muscle tension.⁵⁸ In a study

by Puentedura et al, the immediate effects of hamstring stretching using contract-relax PNF and static stretching were analyzed.⁵⁹ A group of 30 participants (17 males, 13 females; mean age 25.7 ± 3.0 , range 22-37) with limited hamstring flexibility, defined as a minimum of 10° loss of knee extension during the AKE test, were randomized into a static stretch group and a PNF group. The non-tested leg was treated as a control and did not received any intervention. Results revealed there was no significant difference when comparing static stretch (avg. gain= 9.1°) and hold-relax PNF (avg. gain= 8.9°), but both were significantly more effective than the control group (avg. gain = 1.5°). Although there was no effort to assess maintenance of flexibility gains over time, these results are comparable to the hamstring gains in our study. Literature also suggests that PNF stretching and dynamic stretching combined is more effective than static stretching alone.⁵⁸ As such, a combination of MFD with PNF may be warranted for future studies since clinical testimonies of experienced MFD practitioners have reported significant improvements in hamstring ROM after incorporating this technique into their treatments.⁵⁵

Ecchymosis

As MFD increasingly expands into the physical therapy setting, the presence of ecchymosis has been highlighted as a main area of concern for clinicians. Although previous research studies on cup therapy have focused on the changes in flexibility, strength, and/or pain, there were no studies identified that chronologically documented the presence of ecchymosis, a common result of an MDF application. Unlike a hematoma or “bruise” resulting from trauma to soft tissue that ruptures blood vessels deep under the skin, ecchymosis is a discoloration of the skin due to leakage of superficial blood vessels.⁴⁶ There are

abundant arteries in subcutaneous tissue layers that form superficial networks close to the skin surface; thus, when soft tissue is subjected the mechanical stresses within the cup, local blood vessels vasodilate and may leak. With prolonged application, the leaked fluids accumulate in the tissue and the skin takes on a deeper red.⁴⁶ Tham et al. determined a higher degree of ecchymosis with negative pressure cups will result when there is increased application time, higher vacuum pressure, and increased cup diameter. Generally, such residual markings fade in 1-10 days.⁵⁶

In our study, the degree of ecchymosis varied due to the nature of both MFD techniques. With static MFD, negative pressure cups were placed in prolonged static positions that allowed blood and fluids to accumulate in tissues directly under the cup and result in distinct circular red marks. This higher concentration of fluids within a small area has been shown in our study to require a longer period until full resolution compared with dynamic MFD. With the dynamic application, the negative pressure cups are glided across the whole treatment area, preventing resulting fluid extravasation from accumulating in one area; the result is minimal to no ecchymosis. Although two participants in the dynamic group experienced abnormal ecchymosis, both were females of small stature. Since the same cup size was applied to all individuals, the cups may have generated a greater tensile force over a larger surface area, and resulted in more ecchymosis. In addition, during every intervention, negative pressure was adjusted to the patient's tolerance level which may explain variations in ecchymosis between individuals in both groups.

Limitations

Due to the nature of this study, it was difficult to blind participants to the treatment since they would know if a vacuum was applied; thus, no sham treatment was possible. There was also lack of a control group to compare the results to a no treatment or traditional treatment groups with techniques more commonly used. Another limitation was that there was no data collection on height and weight which may have affected the resulting ecchymosis given the study utilized cups of the same diameter for all individuals. In addition, there was no control of the participants' activity level post treatment, however, this was necessary to ensure all changes in flexibility can be attributed solely to the intervention. Furthermore, several confounding variables in this study included the presence of bias which may have affected the outcomes since some participants were familiar with the technique and its expected effects. Another factor that may have influenced the degrees of hamstring flexibility gained is the variation in negative pressure generate under the cups and the speed of cup gliding that occurred during dynamic MFD. Lastly, no standard outcome measure for ecchymosis measurements was used and photographic inconsistencies with distance and lighting may have affected some pictures. Despite this flaw, a clear trend in ecchymosis can be extrapolated from photographs shown in **Figure 2** and **Figure 3**.

Clinical Implications

In this study, both static and dynamic MFD interventions have demonstrated its effectiveness in improving hamstring flexibility. Although this study focused on the effects solely from the cups to achieve the resulting hamstring ROM gains, MFD is generally used in conjunction with active movements and/or PNF techniques. Despite the limitations present in this study,

these findings are significant in determining additional viable options for myofascial release. Disadvantages for manual myofascial release include injury to the therapist. A survey by Holder et al revealed the second highest injury for physical therapists were in the upper back, wrist, and hands due to their frequent use of manual therapy.⁶⁰ The use of tools in MFD may help alleviate strain from repeated movements when clinicians treat their patients. Although there are other tools such as Graston® that can be used for myofascial release as well, a set of cupping tools used in MFD are significantly less expensive compared to the latter.

Future Research

To provide more evidence for this technique, future studies should compare MFD, with the incorporation of functional active movements or PNF, to other currently used techniques such as static stretching or PNF alone. A comparison to other instrument assisted soft tissue mobilization (IASTM) may further assess the effectiveness of both techniques at improve range of motion since there is a limited amount of literature for both techniques. Lastly, this study was performed on a single body part in healthy individuals; thus further research on the effects of MFD in other areas of the body and in a population with pathological impairments on flexibility is warranted.

Conclusion

This pilot study has shown both static and dynamic MFD techniques, using negative pressure cups alone, is a safe and effective technique at significantly improving hamstring flexibility after a single application. Furthermore, the gains in flexibility can be maintained without further management for up to two days post treatment. The dynamic technique will also result in a significantly smaller degree of ecchymosis compared to the static technique. Lastly, the global rate of

change scores showed all participants had positive perceived changes in hamstring flexibility with no perceived negative effects. Overall, the findings of this study suggest both static and dynamic MFD techniques are a viable alternative to common hamstring flexibility treatments.

REFERENCES

REFERENCES

1. Behm D CA. A review of the acute effects of static and dynamic stretching on performance. *Eur J Appl Physiol* 2011;111(11):2633-2651
2. Corbin CB NL. Flexibility: a major component of physical fitness. *J Phys Educ Recreat* 1980;51(6):23-60
3. Wright S. *Dancer's Guide to Injuries of the Lower Extremity* New York: Cornwall Books; 1985.
4. Clark MA, Lucett, S.C., & Rodney, J.C. NASM essentials of personal fitness training. *Lippincott Williams & Wilkins*. 2008
5. Earle RW, & Baechle, T.R. NSCA's essentials of personal training. *HumanKinetics*. 2003
6. Clark M, & Lucett, S. *NASM essentials for corrective exercise*. *National Academy of Sports Medicine*. 2007
7. Hosman A J, Kleuver M, Anderson P, Limbeek J, Langeloo D, Veth R, and Slot G. Scheuermann Kyphosis: The Importance of Tight Hamstrings in the Surgical Correction. *Spine*. 2003;28:2252-2259
8. Sainz de Baranda P, Ayala F, Ayala F. Chronic Flexibility Improvement After 12 Week of Stretching Program Utilizing the ACSM Recommendations: Hamstring Flexibility. *Int J of Sports Med*. 2010;31(6):389-396
9. Croisier JL FB, Namurois MH, Vanderthommen M, Crielaard JM. Hamstring muscle strain recurrence and strength performance disorders. *The American Journal of Sports Medicine*. 2002(30):199-203
10. Waterworth S. Hamstring flexibility: Measurement, stretching and injury susceptibility. *ProQuest*. 2013
11. Woods C, Hawkins R, Hulse M, Hodson A. The football association medical research programme: an audit of injuries in professional football – analysis of preseason injuries. *Br J Sports Med*. 2002(36):436-441
12. Opar DA, Opar D, Williams M, Shield A. Hamstring Strain Injuries. *Sports Med*. 2012;42(3):209-226

13. Malliaropoulos N PS, Papalada A, Papacostas E. The role of stretching in rehabilitation of hamstring injuries: 80 athletes follow-up. *Medicine and Science in Sports and Exercise*. 2004;36(5):756-759
14. Andersen JC. Stretching before and after exercise: effect on muscle soreness and injury risk. *Journal of Athletic Training*. 2005;40(3):218-220
15. Cipriani J, Cipriani D, Terry M, Haines M, Tabibnia A, Lyssanova O. Effect of Stretch Frequency and Sex on the Rate of Gain and Rate of Loss in Muscle Flexibility During a Hamstring-Stretching Program. *Journal of Strength and Conditioning Research*. 2012;26(8):2119-2129
16. Youdas J. The influence of gender and age on hamstring muscle length in healthy adults. *The Journal of Orthopaedic and Sports Physical Therapy*. 2005;35(4):246-252
17. Rivas D. Skeletal muscle metabolic flexibility: contribution of genetics and lifestyle. *National Library of Australia (Trove)*. 2009.
18. Marieb, Elaine, Hoehn, Katja. *Human Anatomy & Physiology*. Pearson Education. 2007.
19. Stecco A, Gesi M, Stecco C, Stern R. Fascial Components of the Myofascial Pain Syndrome. *Current Pain and Headache Reports*. 2013;17(8):1-10
20. Benjamin M. The fascia of the limbs and back - a review. *Journal of Anatomy*. 2009;214(1):1-18
21. Gerrish FH. *A Textbook of Anatomy*. Henry Kimpton. 1899.
22. Bloom W, Fawcett DW. *A Textbook of Histology*. W.B. Saunders. 1975.
23. Gerlach UJ, Lierse W. Functional construction of the superficial and deep fascia system of the lower limb in man. *Acta Anat*. 1990.
24. Guimberteau JC, Guimberteau JC, Delage JP, McGrouther DA. The microvacuolar system: how connective tissue sliding works. *Journal of hand surgery. European volume*. 2010;35(8):614-622
25. Shah S, Bhalara A. Myofascial Release. *Int J. Health Serv*. 2012;2(2):69-77

26. Kawamata S, Ozawa J, Hashimoto M, Kurose T, Shinohara H. Structure of the rat subcutaneous connective tissue in relation to its sliding mechanism. *Archives of Histology and Cytology*. 2003;66(3):273-279
27. McCombe D, Brown T, Slavin J, Morrison WA. The histochemical structure of the deep fascia and its structural response to surgery. *Journal of hand surgery. British volume*. 2001;26(2):89-97
28. Barnes MF. The basic science of myofascial release: morphologic change in connective tissue. *Journal of Bodywork and Movement Therapies*. 1997;1(4):231-238
29. Barnes MF. The basic science of myofascial release: Morphologic change in connective tissue. . *J Bodywork Move Ther* 1997(1):231-238
30. Swann E, Graner SJ. Uses of manual-therapy techniques in pain management. *Athl Ther Today*. 2002(7):14-17
31. Boehme R, Boehme J. *Myofascial release and its application to neuro-developmental treatment*. Boehme Workshops; 1991.
32. Smith CA. The warm-up procedure: to stretch or not to stretch. A brief review. *The Journal of Orthopaedic and Sports Physical Therapy*. 1994;19(1):12-17
33. Borman N, Trudelle Jackson E, Smith S. Effect of stretch positions on hamstring muscle length, lumbar flexion range of motion, and lumbar curvature in healthy adults. *Physiotherapy Theory and Practice*. 2011;27(2):146-154
34. Bandy WD. The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. *The Journal of Orthopaedic and Sports Physical Therapy*. 1998;27(4):295-300
35. Murphy DR. A critical look at static stretching: Are we doing our patients harm? *Chiropractic Sports Med*. 1994:967-970
36. Amiri-Khorasani M, Abu Osman, N.,A., & Yusof, A. Acute effect of static and dynamic stretching on hip dynamic range of motion during instep kicking in professional soccer players. *Journal of Strength & Conditioning Research*.2011;25(6):1647-1652.

37. Whatman C, Knappstein, A., & Hume, P. Acute changes in passive stiffness and range of motion post-stretching. *Physical Therapy in Sport*. 2006;7(195-200)
38. Sullivan K. Roller-massager application to the hamstrings increases sit-and-reach range of motion within five to ten seconds without performance impairments. *International Journal of Sports Physical Therapy*. 2013;8(3):228-236
39. Macdonald Z, MacDonald G, Mullaley ME, et al. An Acute Bout of Self-Myofascial Release Increases Range of Motion Without a Subsequent Decrease in Muscle Activation or Force. *Journal of Strength and Conditioning Research*. 2013;27(3):812-821
40. Schleip R. Fascial plasticity- a new neurobiological explanation: part1. *Journal of Bodywork and Movement Therapies*. 2003;7(1):11-19.10.1016/S1360-8592(02)00067-0
41. Myofascial release: The scientific rationale. Retrieved from <http://myofascialrelease.com/resources/articles.aspx>. 2005.
42. Morton R, Morton RW, Oikawa S, Phillips S, Devries M, Mitchell C. Self-Myofascial Release: No Improvement of Functional Outcomes in “Tight” Hamstrings. *International Journal of Sports Physiology and Performance*. 2016;11(5):658-663
43. LaCross Z. Treatment outcomes of myofascial decompression on hamstring pathology. *ProQuest*. 2014.
44. Ahmadi A, Schwebel D, Rezaei M. The Efficacy of Wet-Cupping in the Treatment of Tension and Migraine Headache. *The American Journal of Chinese Medicine (1979)*. 2008;36(01):37-44
45. Wu Y, Qi. *Journal of the History of Medicine and Allied Sciences*. 2016;71(3):322-344
46. Tham LM, Lee HP, Lu C. Cupping: From a biomechanical perspective. *Journal of Biomechanics*. 2006;39(12):2183-2193
47. Lauche R, Lauche R, Cramer H, et al. Is a series of five dry cupping treatments effective in the treatment of chronic non-specific neck pain? A randomised controlled pilot study. *European Journal of Integrative Medicine*. 2010;2(4):240-241

48. Liu W, Piao S-a, Meng X-w, Wei L-h. Effects of cupping on blood flow under skin of back in healthy human. *World Journal of Acupuncture-Moxibustion*. 2013;23(3):50-52
49. Tham LM, Tham LM, Lee HP, Lu C. Cupping: From a biomechanical perspective. *Journal of Biomechanics*. 2006;39(12):2183-2193
50. Young C. Concurrent validity of four clinical tests used to measure hamstring flexibility. *Journal of Strength and Conditioning Research*. 2008;22(2):583-588
51. Hislop H, Avers D, Brown M. *Daniels and Worthingham's Muscle Testing: Techniques of Manual Examination and Performance Testing*. 2013
52. Hamid M, Ali M, Yusof A. Interrater and intrarater reliability of the active knee extension (AKE) test among healthy adults. *Journal of Physical Therapy Science*. 2013;25(8):957-961
53. Kamper SJ, Maher CG, Mackay G. Global Rating of Change Scales: A Review of Strengths and Weaknesses and Considerations for Design. *The Journal of Manual & Manipulative Therapy*. 2009;17(3):163-170
54. Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertaining the minimal clinically important difference. *Controlled Clinical Trials*. 1989;10(4):407-415
55. DaPrato C. Effects of Soft Tissue Mobilization with Negative Pressure Device on the Shoulder, using MR Imaging. 2016.
56. Markowski A, Sanford S, Pikowski J, Fauvell D, Cimino D, Caplan S. A Pilot Study Analyzing the Effects of Chinese Cupping as an Adjunct Treatment for Patients with Subacute Low Back Pain on Relieving Pain, Improving Range of Motion, and Improving Function. *Journal of Alternative and Complementary Medicine*. 2014;20(2):113-117
57. Petrofsky JS, Laymon M, Lee H. Effect of heat and cold on tendon flexibility and force to flex the human knee. *Medical Science Monitor: International Medical Journal of Experimental and Clinical Research*. 2013;19:661-667
58. Safran MR, Garrett WE, Seaber AV, Glisson RR. The role of warmup in muscular injury prevention. *Am J Sport Med*. 1988;16(2):123-129

59. Puentedura E, Puentedura EJ, Huijbregts P, et al. Immediate effects of quantified hamstring stretching: Hold-relax proprioceptive neuromuscular facilitation versus static stretching. *Physical Therapy in Sport*. 2011;12(3):122-126
60. Holder N. Cause, Prevalence, and Response to Occupational Musculoskeletal Injuries Reported by Physical Therapists and Physical Therapist Assistants. *Physical Therapy*. 1999;79(7):642

TABLES

Table 1: Participant Demographics

Group	Mean Age	Males	Females
Static Group (n=14)	25.5 ± 3.8	9	5
Dynamic Group (n=15)	26.3 ± 5.1	11	4
Total (n=29)	25.9 ± 4.5	20	9

Table 2: Static MFD Hamstring Flexibility Changes

		Mean	SD	Std. Error Mean	95% Confidence Interval of Difference		t	df	Sig. (2-tailed)
						Lower	Upper		
Pair 1	Pre-Post	-7.14	2.41	0.66	-8.54	-5.75	-11.07	13	0.00
Pair 2	Pre-Day2	-4.71	3.02	0.81	-6.46	-2.97	-5.83	13	0.00
Pair 3	Pre-Day3	-4.43	4.80	1.28	-7.20	-1.66	-3.45	13	0.00

Table 3: Dynamic MDF Hamstring Flexibility Changes

		Mean	SD	Std. Error Mean	95% Confidence Interval of Difference		t	df	Sig. (2-tailed)
						Lower	Upper		
Pair 1	Pre-Post	-7.13	2.23	0.58	-8.37	-5.90	-12.38	14	0.00
Pair 2	Pre-Day2	-5.60	3.88	1.00	-7.75	-3.45	-5.83	14	0.00
Pair 3	Pre-Day3	-4.87	3.38	0.87	-6.74	-3.00	-5.58	14	0.00

Table 4: Comparison of Static and Dynamic Hamstring Flexibility Changes

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Pre	Equal variances assumed	0.023	0.880	1.045	26.951
Post	Equal variances assumed	0.898	0.352	1.251	26.491
Day2	Equal variances assumed	0.023	0.881	0.948	26.849
Day3	Equal variances assumed	0.035	0.853	0.920	27

Table 5: Visual Analysis of Ecchymosis

Group	Ecchymosis Remaining (%)			
	Pre	Post	Day 2	Day 3
Static (n=14)	1 missing	100 % (14/14)	100% (13/13) 1 missing	79% (11/14)
Dynamic (n=15)	1 missing	100% (14/14) 1 missing	50% (7/14) 1 missing	33% (5/15)

FIGURES



Figure 1: Myofascial decompression tools

With respect to your feeling of hamstring tightness, how would you describe it now compared to before treatment?

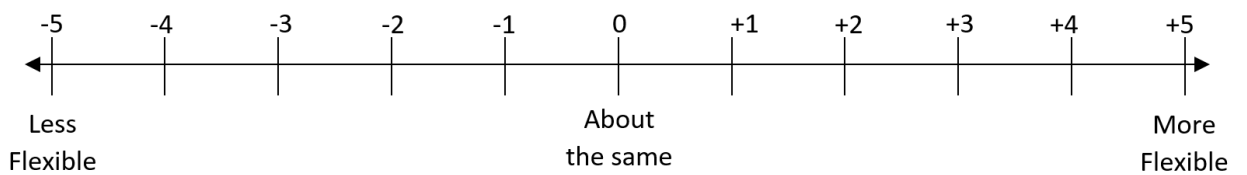


Figure 2: Global rate of change (GROC) scale

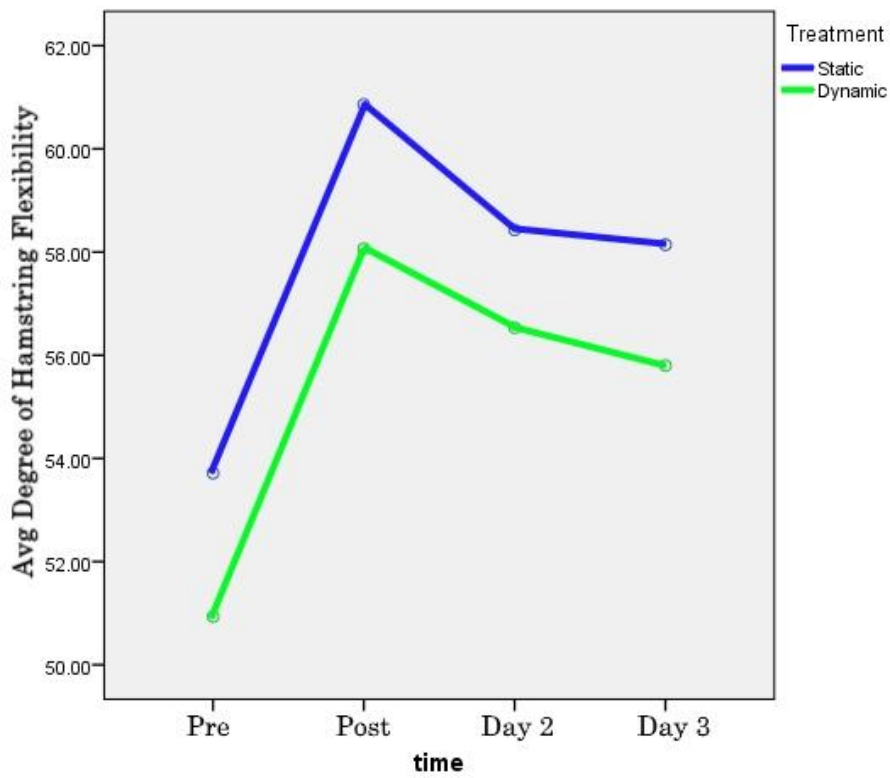





































Figure 3: Hamstring Flexibility Results

Figure 4: Static MFD Ecchymosis Photographs

#	Leg	Before	After	Day 2	Day 3
1	R				
2	R				
3	L				
4	R				

5	L				
6	R				
7	L				
8	R				
9	R				








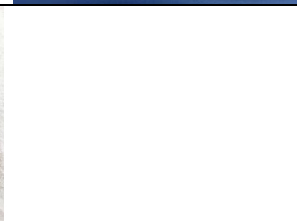
































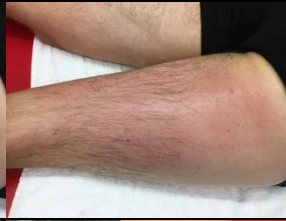













10	R				
11	R				
12	R				
13	R				
14	R				

Figure 5: Dynamic MFD Ecchymosis Photographs

#	Leg	Before	After	Day 2	Day 3
1	L				
2	R				
3	L				
4	L				

5	L				
6	R				
7	R				
8	L				
9	R				

10	R				
11	R				
12	L				
13	L				
14	R				

