Effects on Lower Extremity Range of Motion After a Single Bout of Proprioceptive Neuromuscular Facilitation with the Addition of Myofascial Release or AquaStretch™

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EFFECTS ON LOWER EXTREMITY RANGE OF MOTION AFTER A SINGLE BOUT OF PROPRIORECEPTIVE NEUROMUSCULAR FACILITATION WITH THE ADDITION OF MYOFASCIAL RELEASE OR AQUASTRETCH™

A Thesis
Submitted to the School of Graduate Studies and Research
in Partial Fulfillment of the Requirements for the Degree
Master of Science

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August 2014
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Little is known regarding the effects of a single stretch on range of motion (ROM) in athletes. This research compares changes in ROM in the hamstring and ankle following a single bout of either proprioceptive neuromuscular facilitation with myofascial release (PNFMR) or AquaStretch™ (A/S). Participants were females who achieved 150 min/week of moderate/vigorous physical activity (PA) (Age = 21.16, SD= ±2.01). Participants received both PNFMR and A/S on two separate occasions. ROM measures were evaluated at baseline and six time points following the stretch. Results indicated PNFMR improved ROM in right (p=.011) and left (p=.007) hamstrings. A/S improved ROM in right (p=.046) and left (p=.002) hamstrings and right (p=.014) and left (p=.002) dorsiflexion. Only A/S improvements lasted to 24h in right dorsiflexion (p=.004) and to 24h (p=.007) and 7d (p=.007) in left dorsiflexion. Significant improvements from a single stretch may assist in the prevention of injuries.
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CHAPTER I
INTRODUCTION

The effects of a single bout of stretching in athletes has been widely evaluated. Little is known, however, regarding the effects of a single stretch session on range of motion. There is limited research evidence that can support the effectiveness of pre-activity stretching (Sexton & Chambers, 2006). Stretching prior to activity is often performed to increase range of motion and prevent injuries. Stretching is also performed following activity to aid in the cool-down process. In athletes, the lower extremity muscles are often prone to tightness or soreness following activity. Soreness of muscles post-activity may be due to adhesions between the bone, soft tissue, and muscle (Ratamess, 2012). Treatments for stiff muscles or deficits in range of motion often include a stretching program before physical activity to aid in the breakdown of adhesions (Ratamess, 2012). Increases in range of motion from a single bout of stretching is important to a warm-up protocol, and may induce lasting effects which can potentially reduce injury risk (Whatman, Knappstein, & Hume, 2006).

Many forms of stretching are commonly used by athletes in warm-up to increase muscular pliability and flexibility. One specific stretch type called proprioceptive neuromuscular facilitation (PNF) is widely used in clinical and athletic settings. There are multiple forms of PNF stretches, but the contract-relax (CR) method will be evaluated in this study. The hamstring stretch usually involves the three hamstring muscles maximally pressing against the stretch, then relaxing into a greater range of motion (Rees, Murphy, Watsford, McLachlan, & Coutts, 2007). PNF stretching is described to “trigger the autogenic inhibition mechanism, creating a subsequent reduction in muscle tension through simulation of the Golgi tendon organs” (Yuktasir & Kaya, 2007, p. 12).
Myofascial release techniques are used to release adhesions of the fascia between bone, tendons, ligaments, and muscles. The technique feels like a deep tissue massage to the participant. The goal is to find trigger points that will release or loosen these adhesions, sometimes with a popping sound, that will potentially result in an immediate gain in flexibility and decreased pain (Luchau, 2011). A foam roller is often used to promote the release of the fascia more easily than finding trigger points. The TheraBand® foam roller is such a device used to promote myofascial release. The company claims that the foam roller supports both superficial and deep tissue mobilization, improves blood flow and circulation, and increases muscle flexibility and range of motion (TheraBand®, 2013).

Additionally, AquaStretch™ is a relatively new form of stretching and myofascial release program. There is little research to support the claims that immediate increases in range of motion and decreased pain are achievable after a single session (Exercise Elements, 2013). The protocol involves stretching while submerged in water or a pool with the use of ankle weights and the release of adhesions in the soft tissue. AquaStretch™ is considered a form of hydrotherapy, thus adding to the technique, the aquatic environment provides additional benefits. Hydrostatic pressure increases blood flow, ease of movement, pain relief, and decreases swelling, which is similar to claims made by TheraBand® foam roller.

**Problem Statement**

To evaluate the use of AquaStretch™ stretching and myofascial release protocol (A/S) and conventional proprioceptive neuromuscular facilitation stretching in
conjunction with a foam roller stimulus (PNFMR) on lower extremity range of motion in female athletes.

**Research Questions**

1. Do A/S and PNFMR protocols induce changes in range of motion in the ankle or hamstring?
2. Which form of stretching, A/S or PNFMR, is better for increasing range of motion in the hamstring after a single exercise session?
3. Which form of stretching, A/S or PNFMR, is better for increasing range of motion in the ankle after a single exercise session?
4. Will either A/S or PNFMR group show lasting effects in terms of increased range of motion in the hamstring or ankle up to 24 hours or after 7 days?
5. Will there be a significant difference between A/S and PNFMR range of motion changes between athletes and recreationally trained females?

**Hypotheses**

1. Both A/S and PNFMR groups will result in a significant increase in hamstring and ankle range of motion.
2. PNFMR will result in a greater increase in hamstring range of motion.
3. A/S will result in a greater increase in ankle range of motion.
4. A/S will show lasting effects in the hamstring and ankle at 24 hours and 7 days post-stretch as compared to PNFMR.
5. Athletes will show a larger initial range of motion increase following A/S and PNFMR as compared to recreationally trained participants.
Definition of Terms

**Actin:** A thin protein filament that acts with myosin filaments to produce muscle action (Kenney, Wilmore, & Costill, 2012).

**AquaStretch™:** A myofascial release and stretching technique performed in water or in a pool. (Eversaul, 2011).

**Dorsiflexion:** Motion at the ankle joint that occurs mostly in the sagittal plane and decreases the angle between the foot and the shin (Armiger, 2010).

**Exercise Elements:** An educational organization focused on teaching professionals in the aquatic fitness and wellness industry how to improve their injury-prevention, rehabilitation and performance training (Exercise Elements, 2013).

**Fascia:** Fibrous or “sheet-like” connective tissue used throughout the body to add structure and support to skin, bones, muscles, and organs (Armiger, 2010).

**Fascicle:** A bundle of individual muscle cells and the nerve cells that supply them (Armiger, 2010).

**Golgi Tendon Organ:** Proprioceptors located at the muscle-tendon junction that conveys information regarding muscle tension to the central nervous system (Ratamess, 2012).

**Goniometer:** A device that measures range of motion, includes a body, a fulcrum, a stabilization arm, and a movement arm, similar to a protractor (Lea & Gerhardt, 1995).

**Hip Flexion:** Motion occurring at the hip joint in the sagittal plane, decreasing the angle between the thigh and the abdomen while keeping an extended knee.

**Kinetic Chain:** Combination of several successively arranged joints constituting a complex motor unit (Steindler, as cited by Gagliardi in American Council on Exercise, 2012).
**Muscle Spindle:** Proprioceptors located within muscle fibers which respond to the magnitude of change in muscle length, rate of change of length, and convey information to the CNS (Ratamess, 2012).

**Myofascial Release:** A protocol performed by manually stretching the fascia and facilitate histological length changes to relieve symptoms of fascial restrictions (Ratamess, 2012).

**Myosin:** One of the proteins that form filaments that produce muscle action (Kenney et al., 2012).

**Plantar flexion:** Motion occurring at the ankle joint, in the sagittal plane, with motion moving in the direction of the bottom of the foot. It increases the angle between the foot and the shin (Armiger, 2010).

**Proprioceptive Neuromuscular Facilitation:** Stretching that incorporates combinations of concentric, eccentric, isometric muscle actions, and passive stretching (Ratamess, 2012).

**Range of Motion (ROM):** The amount of available motion, or arc of motion, that occurs at a specific joint (Lea & Gerhardt, 1995).

**Stretch Reflex:** A monosynaptic reflex where muscle force production is enhanced when the muscle is previously stretched (Ratamess, 2012).

**TheraBand® Foam Roller:** A tool for myofascial release and deep tissue massage, includes a 9.5 inch roller with handles on each end (TheraBand®, 2013).

**Trained:** Participating in a DII sport at Indiana University of Pennsylvania or achieving at least 150 minutes per week of moderate physical activity.
Assumptions

1. The TheraBand® roller massager product works as claimed to increase blood flow and improve range of motion.
2. The AquaStretch™ protocol works as claimed to promote lasting increases in range of motion for up to 7 days.
3. The stretching technique produces similar results for all subjects.
4. The subject pool is a good representation of trained female athletes.
5. All subjects will make the best effort for each stretch measured.

Limitations

1. It is difficult to control for injuries in athletes, and effects of previous or unknown injuries may affect results.
2. Participants are taken from one geographical area in southwestern Pennsylvania.
3. Limited pool facilities are available for A/S sessions.
4. Scheduling of measures in the appropriate timeframe is difficult with college students.

Significance

AquaStretch™ is rarely being used clinically or in athletes. There is very little research to compare AquaStretch™ to already established forms of stretching and myofascial release techniques. If significant improvements are made in range of motion in the AquaStretch™ group, the new technique may become as important to an athlete’s weekly routine as static stretching. Previous research on AquaStretch™ has shown an
increase in range of motion at the knee in subjects with prior knee surgery, but has not been compared to other types of stretching. Range of motion is important in injury prevention for both athletes and non-athletes. A study done by Whatman, Knappstein, and Hume investigated the effects on range of motion at the hamstring after a single stretch session. The immediate post-stretch range of motion increases were recorded as clinically useful (greater than 2.7 degree increase). However, they found that there was little evidence to show that the increases lasted longer than five minutes. George Eversaul, the founder of AquaStretch™, claims that results can last up to 7 days. If this is proven to be correct, it will be much more useful than traditional stretching techniques. Improvements in range of motion that can be sustained are helpful to athletes who are recovering from injury and aid in returning to play.

**Delimitations**

1. Only females will participate in the study.
2. The pool water temperature is maintained between 85-87° F.
3. The pool air temperature is maintained between 80-83° F.
CHAPTER II
REVIEW OF LITERATURE

Flexibility is a major domain of health and is important to general fitness (Yuktasir & Kaya, 2007). It is easily measured in the field using a goniometer. In athletes, improved flexibility can lead to prevention of skeletal injuries and improved athletic performance. Athletes with prior injuries may encounter limited or painful range of motion, but with flexibility training, these negative effects can be moderated. Specifically, hamstring and ankle flexibility are very important to athletes in protecting against injury of muscles, ligaments, or tendons. Limited range of motion due to shortness or tightness of the hamstrings are quite common, and can cause other problems (Shadmehr, Hadian, Naiemi, & Jalaie, 2009). Lower body flexibility impairments can travel up the kinetic chain and cause more problems than limited range of motion. The following review of literature is organized by subsections of types of stretching, proprioceptive neuromuscular facilitation, myofascial release, AquaStretch™, and aquatic therapy.

**Purpose of Stretching**

Static or dynamic stretching is often part of a routine that athletes follow before and after practices or competition. The purpose of stretching is to warm-up or cool down the muscles to prevent injury and increase ease of movement. A combination of warm-up and stretching can temporarily increase tissue temperature and elasticity of connective tissue which in turn allows for longer muscle lengths (Safran, Seaber, & Garrett as cited in Armiger, 2010). Despite the wide use of warm-up to temporarily increase pliability of soft tissue, only limited research is available to support the benefits of pre-activity
stretching. The benefit is based on increases in range of motion and the decrease in muscle-tendon unit (MTU) stiffness (Kubo, Kamehisa, Kawakami, & Fukunaga, 2000; Whatman et al., 2006). The MTU also contains proprioceptors called Golgi tendon organs (GTOs). These GTOs relay primary information regarding muscle tension and length. (Ratamess, 2011). When a certain threshold of tension is reached, GTOs activity increases, and causes agonist muscle relaxation and antagonist excitation to act as a defense mechanism to prevent damage to the muscle or tendon. (Ratamess, 2011). Training is often associated with GTO sensitivity reduction, allowing neural adaptations to take place (Ratamess, 2011). As compared to GTOs, muscle spindles are associated with the stretch reflex and can enhance performance. The central nervous system sends information to the muscle spindle about length, or joint angle, and then the spindle initiates the stretch reflex, which in turn increases force production (Ratamess, 2011).

Kubo et al (2000) examined the effects of stretching on the MTU in vivo. This study involved seven healthy, active men, with a mean age of 25.3 (SD = ±1.4) years. Torque, plantar flexion and elongation in the tendons were measured using a dynamometer pre and post static stretch intervention. The stretch involved holding the subject in dorsiflexion for ten minutes. The researchers used ultrasound to monitor changes in the length of the tendon. Length change of the tendon as well as stiffness (N/mm) was significant after stretching, although no p-value was provided.

Static stretching is the most common, and simple, form of stretching. It often involves holding a joint in a position of moderate tension for at least 15-20 seconds (Ratamess, 2012; Wallmann, Christensen, Perry, & Hoover, 2012). The practical benefits of a single bout of static stretching were studied in the hamstring by Whatman, et
al. (2006). The researchers used a Kincom dynamometer to measure pre-stretch and post-stretch range of motion, following the lasting effects up to 20 minutes. The stretching protocol was four sets of static hamstring stretching for 20 seconds each. The initial range of motion immediately post-stretch had a -.5° difference in the mean change of passive stiffness compared to the control (p=.04). The researchers calculated that the smallest clinically useful range of motion increase was greater than 2.7°. There was no clear evidence that clinically significant increases in peak knee angle lasted longer than 20 minutes (Whatman et al., 2006).

A review of literature conducted by Behm and Chaouachi (2010) investigated the effects of static stretching on performance measures. Comparing 109 studies, these researchers found that 10 of the studies investigated reported approximately a 0.5% decrease in jump performance in trained athletes, and 15 studies found around a 3% decrease in jump performance in untrained athletes due to the static stretching. When investigating force production, 31 studies found greater than 5% decrease in trained athletes and 53 studies found greater than 5% decrease in untrained athletes due to static stretching (Behm, 2010). These deficits due to static stretching have been widely researched and are generally agreed on by experts. Other types of stretching have also been investigated regarding the ability to increase range of motion without inhibiting performance.

Dynamic, or active, stretching involves functional movement through the joint’s entire range of motion (Ratamess, 2012). This type of stretching is often used as a sport-specific warm up prior to competition. It allows multiple muscle groups to be stretched at the same time, improving the efficiency of flexibility increases (Ratamess, 2012).
Benefits of dynamic stretching include a large control over the stretching force, lowering the injury risk (Armiger, 2010). Despite the reduced risk of injury, there is also a lack of stretching force in some instances (Armiger, 2010). Fourteen healthy men were tested for passive muscle stiffness prior to and following a two minute dynamic stretching protocol using a dynamometer (Herda et al., 2013). Following the short dynamic stretching exercise, researchers showed a decrease in passive muscle stiffness that was statistically significant (p<.05) (Herda, 2013). Dynamic stretching also aids the warm-up process by increasing heart rate and blood flow, whereas static stretching does not achieve these benefits.

**Proprioceptive Neuromuscular Facilitation**

Proprioceptive neuromuscular facilitation (PNF) is often regarded as the most effective form of stretching to immediately increase range of motion (Sanavi, Zafari, & Firouzi, 2012). PNF is often used in the clinical setting to increase range of motion by using passive stretching to allow the stretch receptors of the muscles to adapt to the stretched muscle length (Carter, Kinzey, Chitwood, & Cole, 2000). The muscle is then contracted, which activates the Golgi tendon organs and causes the fast-twitch muscle fibers to fatigue, lowering the stretch reflex (Carter et al, 2000). The stretch reflex is initiated by muscle spindles, which respond to the length of muscles and send this information to the central nervous system (Ratamess, 2012). This lowered effect of the stretch reflex allows a deeper passive stretch and in turn, increased range of motion.

Sanavi et al. evaluated the effects of PNF on flexibility of the hamstring in male subjects during a six week training program. The training group demonstrated significant improvement in range of motion between the pre-test (32.5°, SD = ±10.54) and post-test
(39.8°, SD = ±8.03) (Sanavi et al., 2012). In the ankle, a 4 week PNF stretching program in 20 active women showed increase dorsiflexion range of motion in both lower limbs. The experimental group increased range of motion of about 7.8% at the end of the study, with p<.001 (Rees et al, 2007). These researchers also found that stretch tolerance force was increased from weeks 1-4 from 100 N to about 325 N (Rees et al, 2007). Etnyre and Abraham (1986) tested 12 university age males with a PNF intervention on the ankle. The researchers used a pedal to provoke the stretch on the soleus. The difference in the ROM using CRAC (contract-relax-antagonist-contract) PNF method from baseline was a 3.63° gain, with p=.0002. They compared static stretching to two types of PNF and found that all increased range of motion, but none were identified to be the most effective. In a separate study by Yuktasir and Kaya (2007), 28 healthy males were identified between 18 and 26 years old. The PNF group had pre-stretch measurements taken a day before the stretch and post-stretch measurements taken a day after. A goniometer was used to take knee joint range of motion measurements. The stretching protocol involved stretching four times per week for a six week period. Range of motion increases were observed in both the static stretch and PNF groups. The PNF group result was range of motion was increased (\( \bar{x} = 19.22°, p=.001 \)).

The training programs involving PNF often find significant increases in range of motion at many joints following recurrent stretching (Rees et al., 2007; Ryan et al., 2010; Sanavi et al., 2012; Yuktasir & Kaya, 2009). It is clear a stretching regimen of 4-6 weeks significantly increases range of motion using the PNF method of stretching.

The main goal of this study is to measure immediate effects from PNF. O’Hora, Cartwright, Wade, Hough, and Shum (2011) implemented the contract-relax (CR) PNF
technique on the hamstring on six males and nine females. These researchers found that immediate post-stretch measurements showed an increase in range of motion of approximately 11.8° which was shown to be statistically significant (p<.05). Similarly in the hamstring, Ford and McChesney (2007) used the contract-relax-antagonist-contract (CRAC) method of PNF. The CRAC technique is similar to CR, with the addition of the antagonist muscle group contraction following the relax stage. The researchers recorded range of motion measurements using an inclinometer at 0, 3, 7, 12, 18, and 25 minutes post-stretch. As compared to the control, static stretch, and active control groups, the PNF treatment group showed consistent increases in range of motion from baseline through the 25th minute. The immediate increase in range of motion from baseline was 4.9° (SD = ±9.6) and continued to improve to a 7.9° (SD = ±7.1) increase over baseline. A study has been done to evaluate hip ROM in 30 healthy individuals (Ryan, Rossi, & Lopez, 2010). The researchers specifically used the CRAC technique to measure postural stability and range of motion. Similar to other studies, Ryan et al. (2010) instructed the subjects to create an isometric contraction of the target muscle for 7 seconds. Results show increased postural stability due to increased range of motion following the PNF stretch (Ryan et al., 2010). The increased stability could assist in preventing injuries to the lower extremities.

The shoulder was used to study PNF and soft tissue mobilization effects on external rotation and overhead reach in 20 patients with decreased shoulder range of motion (Godges et al., 2003). These researchers used the PNF technique to increase range of motion while also mobilizing soft tissue. This is also known as myofascial release. Pre-intervention measurements were taken immediately prior to the stretch and
myofascial release. The increase in external rotation range of motion was significant (p<.005) at 16.4°(SD = ±5.5°), as compared to the control who only increased 0.9°(SD= ±1.5°,p=.35) (Godges et al., 2003). The myofascial release inclusion may have had an effect on increasing range of motion other than the PNF stretching.

Range of motion measures at the hip, knee, and even shoulder were all significantly increased as a result of both the long term stretching program as well as single stretch sessions. A review done by McGuine and Keene (2003) concludes that PNF cannot specifically be correlated to a decrease in injury. However, these researchers found that balance programs, similar to the Ryan et al. (2010) study, that implement PNF as a stability tool can “significantly reduce the risk of re-injury in both male and female athletes” (McGuine & Keene, 2003, p. 6). PNF alone is often not enough to account for all causes of limited joint movement. A PNF stretching session can be combined with a deep tissue massage or myofascial release modality to account for muscular, as well as myofascial, limitations to ROM.

Myofascial Release

The literature is divided on the mechanism of action for myofascial release (Curran, Fiore, & Crisco, 2008). The basic release involves identifying a “knot” or significant amount of fascial adhesions of the lower extremity. Over time, fascia loses its pliability due to participation in sport or trauma, and is a source of tension throughout the body (Barnes, 1997). Limitations in range of motion is often due to fascial adhesions. A massage-like protocol is applied to the adhesion and is expected to release the attachment of bone, muscle, tendon, or ligament. Fascia is a fibrous connective tissue located throughout the skin, bones, muscles, and organs (Armiger, 2010). Several fascicles within
the muscle are wrapped in fascia, called the perimysium, with addition to the epimysium fascia covering the entire muscle (Armiger, 2010). When the actin-myosin filaments slide past one another in the lengthening stage, the primary limit to continued stretch is the connective tissue surrounding the muscle (Armiger, 2010). Barnes (1997, p. 235) reports that “shortening the muscular component of the myofascial fascicle can limit its functional length – reducing its strength, contractile potential, and deceleration capacity.” These negative side effects of muscular inflexibility can be aided by deep tissue massage.

Deep tissue massage is often utilized by athletes to limit post-exercise pain. Chris Kagen (2011, p. 49-50) reported that, “Deep tissue massage moves slowly, uses moderate to deep pressure, and has intention into deep tissues, including fascia.” There is no specific protocol that describes deep tissue massage for all practitioners (Kagen, 2011). Deep tissue massage can elicit similar changes in fascial adhesions in the same way as myofascial release protocols. A study conducted by Yang, Chen, Hsieh, and Lin examined the effects on range of motion of a four week massage therapy protocol on the shoulder. The participants were 52 males and females from a hospital-based outpatient orthopaedic facility who had posterior shoulder tightness. The massage group received an 18 minute massage twice per week for four weeks. The ROM was measured using a goniometer, and the researchers found that there was significant increase in overall glenohumeral ROM as compared to the control. There was also a significant decrease in muscle tightness of all three posterior shoulder muscles (Yang, 2012). Methods other than deep tissue massage are often used to produce these same results.

In order to successfully eliminate fascia adhesions, Luchau (2011) describes the soft fist, gastrocnemius/soleus, and plantar fascia techniques, similar to deep tissue
massage. These three techniques use the hands to soften connective tissue and myofascial adhesions. The plantar foot has many layers of muscle, tendons, and ligaments which cross the ankle joint. Shortness of any of these can subsequently limit dorsiflexion through the gastrocnemius and soleus (Luchau, 2011). The increase in range of motion can be measured, and felt by the participant, immediately. A study by Grieve et al, (2011) investigated the role of trigger point release on dorsiflexion at the ankle in 20 healthy physiotherapy students from the University of the West of England. All ten participants in the intervention (myofascial release group) were female. Initial ankle dorsiflexion range of motion was measured prior to the trigger point release. The researchers looked for specific trigger points along the soleus muscle and released the adhesions using increasing pressure with the hands pressing on the trigger point (Grieve et al, 2011). The range of motion increase following the myofascial release was 3.3° as compared to the control group who lost 0.2° of dorsiflexion. It is clear that acute effects of the release of trigger points are able to be observed immediately post intervention (Grieve et al, 2011).

Foam rollers are a device used to mimic the action of myofascial release that can easily be used by anyone (Sullivan, Silvey, Button, & Behm, 2013). In a study by Sullivan, a foam roller was used to test the range of motion on the hamstring of 17 subjects. All subjects were considered active (physical activity 3 times per week) and were on average 22 years old. These researchers used the TheraBand® roller massager to induce myofascial release. The roller massager was placed in a custom rack that kept consistent force on the hamstring throughout the use. From pre to post measurements, there was a 4.3% increase in range of motion of the hamstring (p=.0001). Ten seconds of
roller massager use on the hamstring was more effective than five seconds (Sullivan et al., 2013).

A similar study was conducted by MacDonald et al. (2013) with eleven trained male college students. The intervention in this study involved the participants using a foam roller to promote myofascial release on their right quadriceps for two, one minute bouts. One minute separated each foam roller usage. The researchers recorded pre-intervention range of motion and recorded again at two and ten minutes post roller use. The mean increase in range of motion two minutes post intervention was 10.6° (SD=±6.7°, p<0.001). At ten minutes post intervention, the mean change was still at 8.8° (SD=±5.5°, p<0.001). There was a significant difference (p<0.001) between the control and foam roller groups. This increase in range of motion due to foam rolling is similar to other results from researchers who use other forms of soft tissue manipulation (MacDonald et al., 2013). Foam rolling and myofascial release using the hands both elicit significant changes in range of motion that can be seen immediately post release. Another method often used in exercise and therapy to improve ROM is the use of aquatic therapy.

**Aquatic Therapy**

Aquatic therapy is often utilized by elderly populations who are prone to falls, have orthopedic conditions, or health limitations and complications. In recent years, the use of the aquatic medium has expanded beyond geriatrics to use in pediatrics and athletes (Paquette, 2013). The buoyancy and hydrostatic effects of water are able to aid all populations in many regards, including movement and blood flow. Denning, E. Bressel, Dolny, M. Bressel and Seely, (2012) cite that aquatic activity can increase ease of movement, and decrease swelling and pain relief (as cited in Hinman, Heywood, &
In a review of literature, Denning et al. (2012) found that pain significantly decreased both in water and on land during exercise, however there were no differences between groups. The Aquatic Exercise Association (AEA) Professional Manual (2010) provides a list of effects on the body that occur during or upon water immersion. This list includes increases in circulation and decreased heart rate at both rest and exercise. This is due to the hydrostatic effects of the water. The water also provides a reduction in swelling in the limbs and a reduction in hydrostatic weight, decompressing the spine (AEA, 2010).

Stretching in the aquatic environment is aided by the temperature, viscosity, and buoyancy of the water. Stretches can be slowed down and exaggerated into larger ranges of motion. The Arthritis Foundation offers an aquatic program that claims to reduce muscular and joint pain while stretching in the pool (Arthritis Foundation, 2013). This type of population can benefit greatly from the hydrotherapy tendencies. The application of immersion to decrease pain and allow for comfortable stretching can also apply to athletes. A study done by Kalpakcioglu, Candir, Bernateck, Gutenbrunner, and Fischer (2008) investigated the differences in electromyography (EMG) measurements on the brachioradialis muscle between land and in water. Electromyography tests the health of the muscle and the nerves that innervate it (Kalpakcioglu et al, 2008). In thermo-neutral water immersion, the resting amplitudes were significantly higher (p=.014) than on land. This suggests that muscle activity and efficiency of neuromuscular communication is enhanced in thermo-neutral water immersion.

A program called the Aquatic Therapy Early Intervention aimed to improve rehabilitation of injuries in athletes (Clark, Marish, & Ezaki, 2011). This program allows
early motion to injured joints and used the properties of water to aid in range of motion. The buoyancy effects allow athletes to remove braces, boots, or slings and improve range of motion without causing further injury (Clark et al., 2011). The velocity of movement in water is significantly slowed, allowing for greater resistance and pull throughout the entire arc of available motion. Aquatic properties significantly aid in rehabilitation of injury, however in healthy athletes, these properties are also helpful in continuing to improve range of motion in all immersed joints. Manual stretching and myofascial release in addition to the positive aspects of the aquatic environment are combined in the use of AquaStretch™.

**AquaStretch™**

AquaStretch™ is a relatively new myofascial release and stretching program that takes place in the pool. This technique requires the participant to help determine where adhesions may be located, and freeze in a position so the facilitator can release the tension. The founder of AquaStretch™ states, “AquaStretch™ theoretically breaks down fascial adhesions that inhibit flexibility or may cause nerve impingements, muscle tension, or soreness, vascular insufficiencies, hormonal imbalances, and pain” (Eversaul, 2009). Little research has been conducted to determine the efficiency of AquaStretch™ or the comparison to other forms of stretching. Adhesions commonly occur due to overuse, underuse, or use too early following injury. In the case of athletes, it is common for this population to return to play following an injury before their body is healed which can lead to decreased range of motion. Overuse is also a common issue among this population. AquaStretch™ claims to reduce these adhesions that occur due to returning to play too soon or are derived from overuse (Eversaul, 2009). The final claim that will be
tested is the idea that AquaStretch™ results are “immediate and relatively permanent” (Eversaul, 2009).

A study conducted on the AquaStretch™ effects on total knee arthroplasty patients was completed by Raja Devinder Kochar (2011). This study investigated the effects of combining AquaStretch™ with traditional physical therapy and comparing the outcomes to only participating in physical therapy. The sample size was 23, but only 7 were in the AquaStretch™ + physical therapy intervention group. The resulting increases in range of motion between the two groups showed the additional AquaStretch™ sessions increased range of motion more than solely physical therapy, but increases between groups were not statistically significant (Kochar, 2011).

An experimental study by Sherlock and Eversaul (2013) tested lower extremity range of motion following a single bout of AquaStretch™ in 35 healthy participants. The participants were taken through a 20-30 minute AquaStretch™ protocol by a certified facilitator. Pre-intervention range of motion measurements were taken immediately prior to entering the pool. The same measurements were taken immediately following the stretch session and compared (Sherlock & Eversaul, 2013). The ankle range of motion was significantly increased in both left dorsiflexion (p=.0006) and right plantar flexion (p=.0023). Hip extension was also significantly increased in both left and right hips (p=.0057 and p=.0226, respectively). These findings suggest that immediate increases in lower extremity range of motion may be observed after a single 20-30 minute AquaStretch™ session (Sherlock & Eversaul, 2013). The additional benefits of the aquatic environment can aid in the effectiveness of exercise or stretching protocols.
CHAPTER III

METHODS

The purpose of this study was to investigate the effects of two stretching and myofascial release techniques in healthy, college age, female, division II athletes or students meeting 150 minutes of moderate physical activity per week. The study used a randomized quasi-experimental design and compare data for pre and post stretch measures between stretch type. The AquaStretch™ protocol was administered by the primary investigator, who has received certification to perform AquaStretch™ from Exercise Elements. The PNFMR group was also only stretched by the primary investigator to ensure consistency.

Participants

Participants in this study were healthy female athletes or students (age 18-30) participating in 150 minutes per week of moderate physical activity from Indiana University of Pennsylvania. Previous studies have recommended physically active participants when measuring range of motion due to greater chances of significant improvement. The female athletes were in the off-season of their sport and all participants had no previous orthopedic or neuromuscular injuries or conditions that would prevent them from play within the past year. The participants were asked about their demographics as well as previous injuries on the “Athlete General Information Form” (see Appendix B). Estimated sample size was 20 participants. In order to be included in the study the athlete must have attended one orientation session, two baseline ROM measurement sessions, two stretch sessions, and the principal investigator must
have post-stretch measurements up to 24 hours post-stretch for both AquaStretch™ and PNFMR.

**Recruitment**

Athletes and recreationally trained females were recruited by speaking to several Health and Physical Education classes without the instructor present to find potential participants. Health and Physical Education classes tend to contain a high percentage of athletes. All interested participants from the athletic teams as well as the Health and Physical Education classes were invited to an orientation session where the informed consent form (see Appendix A) and athlete general information form (see Appendix B) was explained and was signed.

**General Procedures**

Each participant received one orientation session, two stretch sessions, and post-stretch ROM measures for both stretch protocols. The follow-up measures of range of motion were recorded immediately, ten minutes, twenty minutes, twenty four hours, and seven days post-stretch. On the same day as the seven day post-stretch measure following the first type of stretch, the participant received the second stretch type. The seven day post-stretch measure from the first stretch type was used as the baseline for the second stretch type. Each client was required to return to Zink Hall six times total to complete the data collection. Participants were randomly assigned to the order of stretch type: AquaStretch™ (A/S) or proprioceptive neuromuscular facilitation with the addition of myofascial release (PNFMR). All participants were to participate in both types of stretching. A flow chart describing randomization of groups and order of stretch sessions is attached in Appendix D.
All eligible participants (N=25) arrived at the Human Performance Lab in Zink Hall and received one orientation session regarding the study protocol. All participants were instructed to bring a set of warm clothes (such as a sweatshirt and sweatpants) to wear upon immediate exit of the pool on data collection day while ROM measurements are collected. The orientation session took approximately 20 minutes (ten minutes per stretch type). Participants were then randomized as to which type of stretch they would receive first. Each stretch session lasted around 20 minutes.

On the day of baseline measures, stretch session, and immediate, ten minute, and 20 minute follow-up ROM measures, participants were asked to meet at the Exercise Science Lab in Zink Hall. Baseline range of motion measures in both legs of ankle dorsiflexion, plantar flexion, and straight leg hip flexion, were collected. The “A/S first” group was then asked to move to the Zink pool to complete the A/S protocol. The “PNFMR first” group remained in the lab for stretching. Goniometry measurements for A/S were taken on the pool deck immediately following the end of the stretch session, and participants were asked to put on the clothes they were instructed to bring so the chill of the air would not be a factor to increasing muscle tension. The PNFMR group received PNF on the hamstring and ankle using the CR method, followed with use of the TheraBand® foam roller as described by the manufacturer. As with A/S, both legs were stretched. Range of motion measurements were taken immediately, ten minutes, and twenty minutes post stretch. The primary investigator conducted all A/S and PNFMR stretch sessions. An immobilizer was used to ensure the knee is in full extension for all range of motion measures and during the PNF stretch. One week following the completion of the first stretch type measures, participants returned to have their second
baseline and stretch session completed. The remaining follow-up measures (24 hr post and 7 day post) were also completed in the appropriate timeline.

**Proprioceptive Neuromuscular Facilitation**

The hamstring was stretched using the contract-relax PNF method. The participant was asked to lay supine on a plinth. The principle investigator then ensured the client keeps an extended knee by using an immobilizer, and passively flexed the hip (see Appendix E). When moderate discomfort was felt by the participant, the stretch was held for ten seconds (Photo 1). The participant was then asked to contract the hamstring and gluteal muscles to press against the investigator for six seconds, ensuring to keep both hips firmly against the plinth (Photo 2). Following the six second contract, the participant was instructed to relax the leg while the investigator pressed deeper into the stretch for another six seconds (Photo 3). This method was repeated on the opposite leg.

The ankle had a similar stretch protocol performed for plantar and dorsi flexion. The principle investigator began by stretching the ankle by dorsiflexing the foot until the point of discomfort (Photo 7). This was held for ten seconds. The participant then contracted the gastrocnemius to activate the Achilles tendon and press against the hold of the investigator for six seconds (Photo 8). The participant was then asked to relax the ankle and allow the investigator to deepen the stretch for another six seconds (Photo 9). The same protocol will be used for plantar flexion (Photos 4, 5, 6).

**Myofascial Release with the TheraBand® Foam Roller**

This product was used on the hamstrings, IT band, adductors, gastrocnemius, anterior tibialis, Achilles tendon, soleus, and plantar fascia. The roller was maneuvered down the path of each muscle with consistent pressure throughout. According to the
TheraBand® general instructions sheet, each muscle group should be rolled 30-60 seconds, 1-2 times in a row. These instructions were followed for this study.

**AquaStretch™**

The traditional AquaStretch™ protocol involves foot, ankle, and toe grips, IT band pump, hip roll, hip rock, one leg standing, COPS, lean back, trap tap, and scapula release holds. For this study, only stretches/releases up to and including the COPS position were utilized, due to only the lower extremity range of motion being measured. The photographs of each hold are attached in Appendix F. In addition to the set holds, participants were asked to “play” and “move how you feel you need to move.” This allows the principle investigator to deepen each movement into a longer stretch and locate trigger points. The AquaStretch™ facilitator asked the participant to acknowledge any tight spots or feelings of restriction of movement. The facilitator then applied pressure to the area while the participant actively moves through the range of motion to release the fascia or muscle adhesion. For the one leg standing hold, an ankle weight was placed on one leg to keep the participant on the ground to enhance the stretch. In the COPS hold, ankle weights were placed on both ankles. Each of the other holds required a pool flotation noodle for the participant to lean back on. Each hold lasted around 1-2 minutes depending on how many restrictive spots were located within each leg. The AquaStretch™ protocol is taken from AquaStretch™ Facilitator Pool Guide (2012).
Instrumentation

Athlete General Information Form (Appendix B)

This form documents age, gender, height, weight, sport(s) the athlete participates in at IUP (if any), and any previous injuries to the lower extremity. The Athlete General Information Form is attached.

Data Collection Sheet (Appendix C)

This attachment provides a layout for proper documentation of the following: date of orientation, date of baseline and stretch, ROM measurements for the ankle and hamstring at all time points on both legs. The Data Collection Sheet is attached.

Statistical Analysis

All data analysis was conducted using the IBM SPSS Statistics 21 package (SPSS Inc., Chicago, IL). Descriptive statistics were calculated from the demographic information contained on the Athlete General Information Form. Information about the population sample that was analyzed included participant age, height, weight, average minutes of physical activity per week, dominant leg, and baseline ROM measures.

A t-test was used to compare the athlete baseline ROM prior to their first stretch to the recreationally trained participants. This was completed in order to justify the use of statistical analysis on all 18 participants as a single, 18 subject group. A Wilcoxon Rank Sum test was used to compare range of motion increases from baseline to the immediate post-stretch time point between the two stretches. This was used to help answer the research question regarding whether or not either stretch type significantly increased range of motion in the lower extremities.
An analysis using a Friedman Test was used to compare each stretch type and how long each range of motion increase lasted. The Friedman Test was chosen as opposed to an ANOVA due to the assumptions of sample size and sphericity being violated. This conclusion also applies to the previously mentioned non-parametric Wilcoxon Rank Sum test. The data time points included baseline, immediately post-stretch, 10 minutes post, 20 minutes post, 24 hours post, and 7 days post-stretch. Each range of motion measure at each time point were compared to baseline as well as compared to the opposing stretch type.

A post-hoc analysis using the Wilcoxon Rank Sum Test was conducted on the joints that showed significance as well as those that were trending significance from the Friedman test. This measure helped answer the research question as to which, if either, stretch type allowed for lasting increases in range of motion in the ankle and hamstring. Effect sizes were used to determine which stretch type was better in each joint that reached significance in both PNFMR and A/S. The formula used to calculate effect size is \( r = \frac{|z|}{\sqrt{N}} \). This calculation was also used to compare joint increases in ROM from baseline to immediate time points that reached significance in the Wilcoxon Signed Ranks Tests for both PNFMR and A/S.

Means of central tendency were calculated as well as the difference in ROM from baseline to immediate post-stretch for each joint. The changes in ROM were input into an independent samples non-parametric Mann-Whitney test. This test divided the participants between whether or not they were an athlete, and then compared changes in ROM for both stretches as well as in each joint.
CHAPTER IV
RESULTS

As described in Chapter III, descriptive statistics were taken from the Athlete General Information form. Twenty five (N=25) signed up to participate, but eighteen (n=18) participants were included in this study (Age = 21.16, SD= ±2.01; Height = 65.61 in, SD = ±3.05; Weight = 137.39 lb, SD = ±15.73). Eleven (61%) of the participants were athletes on an IUP (Indiana University of Pennsylvania) team, while all remaining participants (n=7) were recreationally trained (attaining >150 min/wk of moderate to vigorous physical activity). The eighteen participants included in this study reported an average of 457.22 minutes per week of physical activity (SD= ±184.29). 88.8% of the eighteen participants were right leg dominant. Demographics of the participants can be found in Table 1.

Table 1

Demographics

<table>
<thead>
<tr>
<th></th>
<th>Age(years)</th>
<th>Height(in)</th>
<th>Weight(lb)</th>
<th>PA(min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>21.17</td>
<td>65.61</td>
<td>137.39</td>
<td>457.22</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.47</td>
<td>0.72</td>
<td>3.71</td>
<td>43.44</td>
</tr>
<tr>
<td>Median</td>
<td>21.00</td>
<td>66.00</td>
<td>135.00</td>
<td>435.00</td>
</tr>
<tr>
<td>Mode</td>
<td>21.00</td>
<td>63.00</td>
<td>155.00</td>
<td>360.00</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.01</td>
<td>3.05</td>
<td>15.73</td>
<td>184.29</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>4.03</td>
<td>9.31</td>
<td>247.43</td>
<td>33962.42</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>1.42</td>
<td>-0.81</td>
<td>-0.61</td>
<td>0.68</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.38</td>
<td>-0.03</td>
<td>0.59</td>
<td>0.84</td>
</tr>
<tr>
<td>Range</td>
<td>9.00</td>
<td>11.00</td>
<td>55.00</td>
<td>720.00</td>
</tr>
<tr>
<td>Minimum</td>
<td>17.00</td>
<td>60.00</td>
<td>115.00</td>
<td>180.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>26.00</td>
<td>71.00</td>
<td>170.00</td>
<td>900.00</td>
</tr>
<tr>
<td>Sum</td>
<td>381.00</td>
<td>1181.00</td>
<td>2473.00</td>
<td>8230.00</td>
</tr>
<tr>
<td>Count</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
</tr>
</tbody>
</table>
Baseline range of motion measures were compared using a t-test between athletes and recreationally trained participants for right hamstring, left hamstring, right dorsiflexion, left dorsiflexion, right plantar flexion, and left plantar flexion. The p-value results are shown in Table 2. There are no significant differences in ROM between the athletes and recreationally trained females in this sample. Therefore, the following statistical analysis was conducted combining both groups as a single, 18 subject sample.

Table 2

<table>
<thead>
<tr>
<th>Baseline ROM p-value</th>
<th>RH</th>
<th>LH</th>
<th>RD</th>
<th>LD</th>
<th>RP</th>
<th>LP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH</td>
<td>0.41</td>
<td>0.4</td>
<td>0.88</td>
<td>0.67</td>
<td>0.64</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Note. Independent t-test comparing baseline ROM values for each joint (RH=Right Hamstring, LH=Left Hamstring, RD=Right Dorsiflexion, LD=Left Dorsiflexion, RP=Right Plantar flexion, LP=Left Plantar flexion)

In order to address hypothesis I, stating that both stretch types (PNFMR and A/S) would increase range of motion as a result of improved flexibility, a Wilcoxon Signed Ranks Test was conducted to determine if ROM was increased from baseline to immediately post-stretch. The results of the test are shown in Table 3 (PNFMR) and Table 4 (A/S). Significant (p < .05) increases in ROM were observed in the PNFMR group only for right and left hamstring, while the A/S group achieved significance in right hamstring, left hamstring, right dorsiflexion, and left dorsiflexion.
Table 3

**PNFMR Baseline to Immediate ROM**

<table>
<thead>
<tr>
<th></th>
<th>PNFMR RH Immediate-Baseline</th>
<th>PNFMR LH Immediate-Baseline</th>
<th>PNFMR RD Immediate-Baseline</th>
<th>PNFMR LD Immediate-Baseline</th>
<th>PNFMR RP Immediate-Baseline</th>
<th>PNFMR LP Immediate-Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>-2.555</td>
<td>-2.705</td>
<td>-1.524</td>
<td>-.086</td>
<td>-1.476</td>
<td>-.740</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.011</td>
<td>.007</td>
<td>.128</td>
<td>.932</td>
<td>.140</td>
<td>.459</td>
</tr>
</tbody>
</table>

*Note.* RH=Right Hamstring, LH=Left Hamstring, RD=Right Dorsiflexion, LD=Left Dorsiflexion, RP=Right Plantar flexion, LP=Left Plantar flexion

*a.* Wilcoxon Signed Ranks Test

*b.* Based on negative ranks.

*c.* Based on positive ranks.

Interestingly, A/S right and left plantar flexion decreased ROM significantly from baseline to immediate time points. This result will be analyzed separately. Hypothesis III states that A/S would be better at increasing ROM in the ankle. The overall result leads to
the conclusion that the hypothesis III is rejected. Hypothesis II states that PNFMR would be better at increasing ROM in the hamstring. Since both stretch types created significant increases in ROM in both the left and right hamstrings, an effect size calculation was conducted to determine which was better in increasing ROM in the hamstring to address hypothesis II.

The effect size was calculated for both right and left hamstring for PNFMR and A/S baseline to immediate ROM measures. The effect size was calculated using the formula $r = \frac{|z|}{\sqrt{N}}$. Using Cohen’s d criteria, it was calculated that PNFMR right hamstring effect size was .42, while A/S right hamstring was .33. This leads to the conclusion that for the right hamstring, PNFMR was better at increasing range of motion immediately post-stretch. The effect size was also calculated for the left hamstring (PNFMR = .45, A/S = .51). This shows that contrary to the right side of the body, A/S was more efficient at increasing ROM in the left hamstring. All effect sizes calculated are large according to Cohen’s (1988) criteria. This means that the differences between groups (baseline to immediate) were large when reported in standard deviation units. No further investigation was necessary for the dorsiflexion and plantar flexion, as only A/S p-values were statistically significant from baseline to immediate post-stretch ROM (p<.05). Therefore, hypothesis II stating that PNFMR would be better at increasing ROM in the hamstring was rejected.

To investigate hypothesis IV, stating that A/S would have lasting effects on ROM up to 24 hours and 7 days post stretch, a Friedman test was performed to determine if there were significant range of motion increases between all time points (baseline,
immediate, 10m, 20m, 24h, 7d). Results of the Friedman tests are shown in Tables 5 (PNFMR) and 6 (A/S).

Table 5

**PNFMR Friedman Tests**

<table>
<thead>
<tr>
<th></th>
<th>Chi-Square</th>
<th>Asymp. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH</td>
<td>17.109</td>
<td>0.004</td>
</tr>
<tr>
<td>LH</td>
<td>20.943</td>
<td>0.001</td>
</tr>
<tr>
<td>RD</td>
<td>8.75</td>
<td>0.119</td>
</tr>
<tr>
<td>LD</td>
<td>5.99</td>
<td>0.307</td>
</tr>
<tr>
<td>RP</td>
<td>5.808</td>
<td>0.325</td>
</tr>
<tr>
<td>LP</td>
<td>4.877</td>
<td>0.431</td>
</tr>
</tbody>
</table>

*a n=18

Table 6

**A/S Friedman Tests**

<table>
<thead>
<tr>
<th></th>
<th>Chi-Square</th>
<th>Asymp. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH</td>
<td>5.41</td>
<td>0.368</td>
</tr>
<tr>
<td>LH</td>
<td>17.023</td>
<td>0.004</td>
</tr>
<tr>
<td>RD</td>
<td>8.98</td>
<td>0.11</td>
</tr>
<tr>
<td>LD</td>
<td>19.098</td>
<td>0.002</td>
</tr>
<tr>
<td>RP</td>
<td>10.268</td>
<td>0.068</td>
</tr>
<tr>
<td>LP</td>
<td>8.409</td>
<td>0.135</td>
</tr>
</tbody>
</table>

*a n=18

Significance was achieved in the PNFMR right and left hamstrings, as well as the A/S left hamstring and left dorsiflexion. PNFMR right dorsiflexion, A/S right dorsiflexion, and A/S right plantar flexion were also trending significant. The Friedman test discloses that there is a difference among these time points in the significant joints. However, a post hoc analysis was necessary to determine where, among the time points,
the differences are located. In order to use the Wilcoxon Signed Ranks Test, a Bonferroni adjusted alpha value of .01 must be achieved to control for Type 1 errors.

The first significant Friedman test of the PNFMR right hamstring was analyzed and the Wilcoxon Signed Ranks Test post hoc was performed to determine which time points maintained the improved range of motion from baseline, using the Bonferroni adjusted alpha value. Baseline to ten minute range of motion for PNFMR right hamstring was significant (Z=-2.595, p=.009), and baseline to twenty minute post-stretch range of motion was also significant (Z=2.745, p=.006). The 24h and 7d post measures were not significantly different from baseline. The second significant Friedman test was also analyzed using the post hoc analysis for the PNFMR left hamstring. As with the right hamstring, the baseline to ten minute post was significant (Z=-3.205, p=.001) as well as the baseline to twenty minute (Z=-3.380, p=.001). Again, the 24h and 7d were not statistically significant. Right dorsiflexion for PNFMR showed trending significant results from the Friedman test (p=.119). This joint was further investigated using the post hoc Wilcoxon Signed Ranks test. Results showed that there were no statistically significant range of motion increases at any time point using the Bonferroni adjusted alpha value of .01.

The A/S joints that were statistically significant following the Friedman test were left hamstring (p=.004) and left dorsiflexion (p=.002). Trending significant joints were right dorsiflexion (p=.110) and right plantar flexion (p=.068). The same post-hoc Wilcoxon Signed Ranks Test with the Bonferroni adjusted alpha value of .01 was used to further analyze these joints to locate significant differences from baseline to each time point. The left hamstring reached significance at the 10m (Z=-2.891, p=.004) and 20m
(Z=-2.752, p=.006) post stretch ROM measure. The left dorsiflexion measure reached significance at the 24h (Z=-2.707, p=.007) and 7d (Z=-2.696, p=.007) time points. The two trending significant values from the Friedman test, right dorsiflexion and right plantar flexion, were also further investigated using the Wilcoxon Signed Ranks Test. Right dorsiflexion reached significance at the 7d (Z=-2.906, p=.004) time point. Conversely, right plantar flexion did not reach significance at any time points.

Since left hamstring was the only joint that both PNFMR and A/S both reached significance at the 10m and 20m time points, the effect size was calculated for each to compare between type of stretch. The PNFMR left hamstring effect size for the increase from baseline to the 10m time point is .53. The A/S left hamstring effect size for the increase from baseline to the 10m time point is .48. This means that PNFMR was slightly better at increasing left hamstring ROM from baseline to 10m. The PNFMR left hamstring effect size for the 20m time point was calculated to be .56. The A/S effect size for the 20m time point was .45. Again, PNFMR was slightly better at increasing left hamstring ROM at the twenty minute time points. Research question four regarding whether either stretch would create increases in ROM that lasted up to twenty four hours or seven days can now be answered. The hypothesis that A/S would show lasting increases in ROM can be accepted for both right and left dorsiflexion. No increases from PNFMR lasted until twenty four hours or seven days post stretch.

Hypothesis V stated that athletes would have larger initial increases in ROM than the recreationally trained participants for both stretch types. In order to compare groups, the athletes were analyzed using a Wilcoxon Signed Ranks test separately from the recreationally trained. Table 7 shows the PNFMR gains in ROM with significance values
separately for athletes and recreationally trained. Table 8 shows the A/S changes in ROM separated by group.

Table 7

**PNFMR Athlete & Recreationally Trained**

<table>
<thead>
<tr>
<th>Athlete (Y/N)</th>
<th>PNFMR RH</th>
<th>PNFMR LH</th>
<th>PNFMR RD</th>
<th>PNFMR LD</th>
<th>PNFMR RP</th>
<th>PNFMR LP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate</td>
<td>Immediate</td>
<td>Immediate</td>
<td>Immediate</td>
<td>Immediate</td>
<td>Immediate</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td>Athlete Z</td>
<td>-1.784^b</td>
<td>-1.838^b</td>
<td>-1.688^b</td>
<td>-.179^c</td>
<td>-1.189^b</td>
<td>-.134^c</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.074</td>
<td>.066</td>
<td>.091</td>
<td>.858</td>
<td>.235</td>
<td>.894</td>
</tr>
<tr>
<td>Recreational Trained Z</td>
<td>-1.863^b</td>
<td>-1.947^b</td>
<td>-.256^b</td>
<td>-.420^b</td>
<td>-1.101^b</td>
<td>-1.186^b</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.063</td>
<td>.051</td>
<td>.798</td>
<td>.674</td>
<td>.271</td>
<td>.236</td>
</tr>
</tbody>
</table>

*Note.* RH=Right Hamstring, LH=Left Hamstring, RD=Right Dorsiflexion, LD=Left Dorsiflexion, RP=Right Plantar flexion, LP=Left Plantar flexion

^a^ Wilcoxon Signed Ranks Test

^b^ Based on negative ranks.

^c^ Based on positive ranks.
Table 8

*A/S Athlete & Recreationally Trained*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Athlete</td>
<td>Z</td>
<td>-1.073&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-2.493&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.656&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-2.809&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.073&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Asymp. Sig. (2-tailed)</td>
<td>.283</td>
<td>.013</td>
<td>.098</td>
<td>.005</td>
<td>.283</td>
</tr>
<tr>
<td>Recreationally Trained</td>
<td>Z</td>
<td>-1.787&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.778&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.753&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-.944&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.997&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Asymp. Sig. (2-tailed)</td>
<td>.074</td>
<td>.075</td>
<td>.080</td>
<td>.345</td>
<td>.046</td>
</tr>
</tbody>
</table>

*Note.* RH=Right Hamstring, LH=Left Hamstring, RD=Right Dorsiflexion, LD=Left Dorsiflexion, RP=Right Plantar flexion, LP=Left Plantar flexion

<sup>a</sup> Wilcoxon Signed Ranks Test
<sup>b</sup> Based on negative ranks.
<sup>c</sup> Based on positive ranks.

For the PNFMR stretch, neither athlete nor recreationally trained group reached significance between the baseline and immediate time points in any joint. In comparison, the A/S stretch athlete group reached significance in the left hamstring (p=.013), left dorsiflexion (p=.005), and the recreationally trained group reached significance in right plantar flexion (p=.046), although this joint significantly decreased ROM as shown previously.
In order to better compare the athletes and recreationally trained participants, the change in ROM from baseline to immediate time points was calculated for all participants in all joints for both stretches. The values are located in Table 9 (PNFMR) and Table 10 (A/S).

Table 9

<table>
<thead>
<tr>
<th></th>
<th>PNFMR RH</th>
<th>PNFMR LH</th>
<th>PNFMR RD</th>
<th>PNFMR LD</th>
<th>PNFMR RP</th>
<th>PNFMR LP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.7222</td>
<td>4.8333</td>
<td>1.9444</td>
<td>.5556</td>
<td>.7222</td>
<td>1.8333</td>
</tr>
<tr>
<td>N</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>6.7021</td>
<td>5.6177</td>
<td>4.9523</td>
<td>4.1899</td>
<td>6.0274</td>
<td>7.7781</td>
</tr>
</tbody>
</table>

Table 10

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.3333</td>
<td>7.9444</td>
<td>3.1111</td>
<td>5.7222</td>
<td>-4.0000</td>
<td>-4.7222</td>
</tr>
<tr>
<td>N</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

These values were then input as new variables and an independent two sample Mann-Whitney Test was conducted on each joint and stretch to compare the athlete and recreationally trained ROM differences between baseline and immediate time points. The results are shown in Tables 11-16, separated by joint.
### Table 11

**RH Change in ROM, Athlete vs Recreationally Trained**

<table>
<thead>
<tr>
<th></th>
<th>PNFMR Change RH</th>
<th>A/S Change RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>26.500</td>
<td>24.500</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>92.500</td>
<td>90.500</td>
</tr>
<tr>
<td>Z</td>
<td>-1.095</td>
<td>-1.272</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.273</td>
<td>.203</td>
</tr>
<tr>
<td>Exact Sig. [2* (1-tailed Sig.)]</td>
<td>.285&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.211&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>. Grouping Variable: Athlete (Y/N)

<sup>b</sup>. Not corrected for ties.

### Table 12

**LH Change in ROM, Athlete vs Recreationally Trained**

<table>
<thead>
<tr>
<th></th>
<th>PNFMR Change LH</th>
<th>A/S Change LH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>29.500</td>
<td>35.000</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>95.500</td>
<td>101.000</td>
</tr>
<tr>
<td>Z</td>
<td>-.819</td>
<td>-.318</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.413</td>
<td>.751</td>
</tr>
<tr>
<td>Exact Sig. [2* (1-tailed Sig.)]</td>
<td>.425&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.791&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>. Grouping Variable: Athlete (Y/N)

<sup>b</sup>. Not corrected for ties.
Table 13

*RD Change in ROM, Athlete vs Recreationally Trained*^a^  

<table>
<thead>
<tr>
<th></th>
<th>PNFMR Change RD</th>
<th>A/S Change RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>27.000</td>
<td>32.500</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>55.000</td>
<td>98.500</td>
</tr>
<tr>
<td>Z</td>
<td>-1.048</td>
<td>-.545</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.295</td>
<td>.585</td>
</tr>
<tr>
<td>Exact Sig. [2*(1-tailed Sig.)]</td>
<td>.328^b</td>
<td>.596^b</td>
</tr>
</tbody>
</table>

*a* Grouping Variable: Athlete (Y/N)  

*b* Not corrected for ties.

Table 14

*LD Change in ROM, Athlete vs Recreationally Trained*^a^  

<table>
<thead>
<tr>
<th></th>
<th>PNFMR Change LD</th>
<th>A/S Change LD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>34.000</td>
<td>19.500</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>100.000</td>
<td>47.500</td>
</tr>
<tr>
<td>Z</td>
<td>-.411</td>
<td>-1.728</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.681</td>
<td>.084</td>
</tr>
<tr>
<td>Exact Sig. [2*(1-tailed Sig.)]</td>
<td>.724^b</td>
<td>.085^b</td>
</tr>
</tbody>
</table>

*a* Grouping Variable: Athlete (Y/N)  

*b* Not corrected for ties.
Table 15

*RP Change in ROM, Athlete vs Recreationally Trained*<sup>a</sup>

<table>
<thead>
<tr>
<th></th>
<th>PNFMR Change RP</th>
<th>A/S Change RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>30.000</td>
<td>26.000</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>96.000</td>
<td>54.000</td>
</tr>
<tr>
<td>Z</td>
<td>-.775</td>
<td>-1.138</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.438</td>
<td>.255</td>
</tr>
<tr>
<td>Exact Sig. [2*(1-tailed Sig.)]</td>
<td>&lt;sup&gt;b&lt;/sup&gt;.479</td>
<td>&lt;sup&gt;b&lt;/sup&gt;.285</td>
</tr>
</tbody>
</table>

<sup>a</sup> Grouping Variable: Athlete (Y/N)

<sup>b</sup> Not corrected for ties.

Table 16

*LP Change in ROM, Athlete vs Recreationally Trained*<sup>a</sup>

<table>
<thead>
<tr>
<th></th>
<th>PNFMR Change LP</th>
<th>A/S Change LP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>30.000</td>
<td>38.500</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>96.000</td>
<td>66.500</td>
</tr>
<tr>
<td>Z</td>
<td>-.776</td>
<td>.000</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.438</td>
<td>1.000</td>
</tr>
<tr>
<td>Exact Sig. [2*(1-tailed Sig.)]</td>
<td>&lt;sup&gt;b&lt;/sup&gt;.479</td>
<td>1.000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Grouping Variable: Athlete (Y/N)

<sup>b</sup> Not corrected for ties.

There was no statistical significance between athletes and recreationally trained participants for either stretch at any of the joints that were evaluated. This result leads to the conclusion that the hypothesis that athletes would have a larger increase in ROM following both stretch types can be rejected.
CHAPTER V

DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

Possible changes in range of motion following a single stretch has been not well evaluated in research. It is known, however, that increasing ROM in athletes often reduces the risk for injury and improves performance. The purpose of this study was to further investigate the acute effects of two stretching techniques on range of motion in trained women. One of the stretch techniques, AquaStretch™, is relatively new and has little research to support its benefits. On the other hand, proprioceptive neuromuscular facilitation and myofascial release have both been researched significantly and are known techniques to increase ROM.

Hypothesis I

The first hypothesis stated that both A/S and PNFMR groups will result in a significant increase in hamstring and ankle range of motion. This hypothesis was confirmed in some ways, and rejected in others. The PNFMR stretch resulted in significant increases in ROM in the right and left hamstring. A/S resulted in significant increases in right and left hamstring, and right and left dorsiflexion. The only joint, for either stretch, that decreased range of motion resulted from A/S in the right and left plantar flexion movement. These results should be viewed cautiously, as no other follow up measures showed changes in plantar flexion range of motion from baseline. The immediate measurement using the goniometer for A/S took place on the pool deck as opposed to the plinth, where the rest of the measures took place. This change in angle and limited views of the goniometer for this motion may have altered the results.
Hypothesis II

The second hypothesis suggested that PNFMR would be better than A/S in improving range of motion in the hamstring. Since both stretch techniques improved range of motion significantly in the hamstrings, the effect size calculation was conducted to determine which stretch was better. By very narrow margins, PNFMR was better on the right side, and A/S was better on the left side. This leads to the conclusion that hypothesis two cannot be fully accepted. With a larger sample size, the difference between effect sizes may have been more helpful in determining which stretch was better. These results are comparable to O’Hora et al. (2011). These researchers also found statistically significant increases in ROM following a PNF stretch to the hamstring. No known studies have addressed increases in hamstring ROM following A/S, however Sherlock and Eversaul (2013) found hip extension was significantly improved following a single A/S session in both left and right hips ($p=.0057$ and $p=.0226$, respectively). It is notable that both stretch types did induce significant changes in ROM relatively equally in the hamstring.

Hypothesis III

The third hypothesis proposed that A/S was better than PNFMR in improving range of motion in the ankle movements. In both legs, dorsiflexion ROM was significantly increased following the A/S stretch session. Conversely, ROM of dorsiflexion following PNFMR was not significantly improved. This leads to the conclusion that for dorsiflexion, A/S is better than PNFMR at increasing ROM. This result is consistent with a Grieve et al (2007) who discovered an increase of 3.3° in dorsiflexion ROM following a single myofascial release on the ankle. However, in the
current study, plantar flexion ROM was significantly decreased following the A/S session, and PNFMR ROM was unchanged. As previously stated, this result may not be representative of correct measures. The leg was not completely flat on the ground as with the other measures when taken on the plinth. The ankle had to be slightly lifted (around 5°) to make up for the fact that the heel was raising the leg slightly upon plantar flexion of the ankle. This slight adjustment in angle may have altered results for immediate plantar flexion post stretch resulting from A/S. Evidence shows that in the 10m, 20m, 24h, and 7d time points ROM from baseline was unchanged, and did not decrease from baseline. This may be expected due to structural limitations in the plantar flexion direction (Luchau, 2011). This concludes that there can be a partial confirmation of hypothesis III, stating that A/S would be better at improving ROM in the dorsiflexion motion of the ankle, but not plantar flexion.

Hypothesis IV

Hypothesis IV stated that A/S would show lasting changes in ROM to 24h and 7d post stretch, and PNFMR would not. The Friedman test discovered which joints had significant difference among all time points, but did not disclose where the differences were located. The post-hoc Wilcoxon Signed Ranks test showed that PNFMR right and left hamstring improvements in ROM lasted until the 20m post stretch measure, but not to the 24h time point. This result matches that found by Ford and McChesney (2007), whose increases in ROM following a single bout of PNF lasted up to 25 minutes. The left hamstring for A/S also lasted to the 20m post mark. However, right and left dorsiflexion following A/S had lasting increases in ROM up to seven days post stretch. These results show that improvements in ROM following A/S do have the potential to last up to seven
days following the stretch session. No joint improvements in ROM following PNFMR lasted more than 20 minutes. This result is consistent with Ford and McChesney (2007), who also did not see significant improvements in ROM longer than 25 minutes following the PNF stretch. The hypothesis that A/S would last up to seven days can be accepted.

**Hypothesis V**

The final hypothesis indicated that the athletes would have larger increases in ROM as compared to the recreationally trained women. Mean differences in ROM from baseline to immediate post stretch were calculated for each joint and for each stretch. The differences between athlete ROM increases and recreationally trained ROM were tested using independent t-tests. The results of these tests showed that there were no differences between athletes and recreationally trained participants in their ROM improvements for either A/S or PNFMR. This leads to the rejection of the final hypothesis stating that athletes would show larger improvements in ROM as compared to recreationally trained participants.

**Recommendations**

Future research regarding lasting increases in ROM following a single stretch is necessary. This study would have benefitted from a larger sample size to potentially reveal improvements in ROM that lasted longer following A/S. A more consistent measure of ROM for each stretch time point also would have been beneficial in regards to the A/S plantar flexion measure immediately post stretch. A major finding of this study is that A/S was able to induce changes in ROM as consistently as PNFMR, which is consistent with other research. A/S may be used more frequently following further research in athletes, as lasting improvements may be beneficial.
Research on A/S with a sedentary population may also reveal a more generalized usage of this technique. It is clear that athletic status (athlete vs recreationally trained) does not make a difference in this study, however there was no difference between groups for minutes per week of physical activity. A longitudinal study may be necessary regarding long term effects on pain tolerance, muscle length, and injury rates resulting from chronic stretching in both athletes and non-athletes. Since the left hamstring and left dorsiflexion following A/S both reached significance from the Friedman test as compared to the right leg, further research may reveal tendencies for non-dominant leg to incur more lasting changes in ROM.

Conclusions

The results of the PNFMR portion of this study coincide with results of O’Hora et al. (2011) and Ford and McChesney (2007). Both of these groups of researchers found statistically significant increases in ROM from a single bout of PNF. As for myofascial release, Grieve et al (2011) found significant improvements in female participant ROM following a single release. The improvements in ROM in the current study cannot be attributed to either PNF or myofascial release, and the additive effects are unknown. The results showing immediate increases in ROM following a single A/S session also align with results from Sherlock and Eversaul (2013). Their study showed statistically significant increases in ROM in left dorsiflexion, right plantar flexion, and both left and right hip extension. This result of improved ROM in plantar flexion is evidence that the results of the current study may be due to human error.

A larger sample size may have created a larger difference in improvements between the two stretch types. It is important to note that the results of this study how that
A/S does have the potential to induce changes in ROM that last up to seven days. These lasting changes do not typically occur with other types of stretching. Future research on this topic includes incorporating physically active male participants into this sample to make broader conclusions about the results. A/S is often used by athletic trainers or therapists in rehabilitation settings following injuries. Research must be completed on acute injuries such as sprains and strains as well as chronic injuries such as tendonitis, bursitis, or fasciitis. It would also be interesting to conduct a study that involved multiple A/S sessions on athletes long-term to see effects on injury prevention. Overall A/S is in need of more research to better justify the claims of improved ROM, reduced risk of injury, and improved performance.
References


doi:10.3233/BMR-2009-0227


Appendix A

Consent Form

Principal Investigator: Hannah J. Weyrick
Exercise Science Graduate Student – IUP
111-A Zink Hall
1190 Maple Street
Indiana, PA 15705
(724) 910-1079

Co-Investigator: Dr. Madeline Paternostro Bayles
Professor
Indiana University of Pennsylvania
210 Zink Hall
1190 Maple Street
Indiana, PA 15705

You have been invited to participate in this research study. This form will describe all aspects of the study. The purpose of this study is to compare two different stretching techniques to see which is better in terms of improving range of motion, specifically at the hamstring and ankle. You are eligible to participate because you are a healthy female, age 18-30, and have participated on an athletic team at IUP or achieve at least 150 minutes of moderate physical activity per week for at least six months.

In this study, all participants will receive both stretch types. All participants will receive an orientation session to the stretches that will take approximately 20 minutes. Half of the orientation will take place in the Zink pool, and the other half will take place in the Zink Exercise Science lab. Following orientation, participants will be randomized as to which stretch type they will receive first. Within seven days later, they will receive range of motion measurements, and then participate in their first stretch session. The range of motion measures will be on the hip and ankle to determine how far each joint can be stretched. One stretch type called AquaStretch™ will include personalized stretching only on the lower extremity and will require a swimsuit or appropriate waterwear. This session will be followed up with range of motion measurements immediately, 10 minute, and 20 minute intervals, 24 hours later, and 7 days later. The total time for the first day will be around 1 hour. The second stretch type is called proprioceptive neuromuscular facilitation, or PNF. This involves lying on your back while the primary investigator stretches your hamstring and ankle with your assistance. This stretch will also be aided by using a foam roller to help release sore spots between muscle, bone, tendons, and ligaments that occur naturally in the limbs. This PNF stretch will have the same measurements taken as in the AquaStretch group. Following the 7 day follow up measure from the first stretch type, the participants will participate in the second stretch type and following range of motion measures. Both stretching times will be kept as equal as possible. As in any stretching protocol, both techniques may lead to muscle soreness or tenderness for a few hours or days, like if you exercised moderately.
You will be assigned a number for research purposes and your name and information will be kept confidential. Your name will not be released in the research, only results. All information will be locked in a file cabinet in office 111-A in Zink Hall, which only the principle investigator has access. Results may be published in scientific journals but individual participants will not be identified and kept confidential.

Your participation in this study is completely voluntary. At any time, you may wish to withdraw from participation with no adverse consequences. Your decision to remove yourself from the study will in no way affect any standing at IUP, IUP Athletics, or relationship with any of the investigators. Upon request to withdraw, all participant data and information will be destroyed.

If you are willing to participate in this study and think you may qualify, please fill out and sign the attached form and return it via e-mail to H.J.Weyrick@iup.edu or in person to 111-A Zink Hall.

This project has been approved by the Indiana University of Pennsylvania Institutional Review Board for the Protection of Human Subjects. IUP IRB: (724) 357-7730

VOLUNTARY CONSENT FORM

I have read and understand the information on the form and I consent to volunteer to be a subject in this study. I understand that there is no compensation for participating. I understand that all of my data is kept completely confidential and that I have the right to withdraw at any time. I have received an unsigned copy of this informed consent form to keep in my possession. I understand and agree to the conditions of this study as described.

Name: (PLEASE PRINT)

____________________________________________________

Signature: ____________________________ Date: ____________

Phone number or email where you can be reached:

____________________________________________________

____________________________________________________

Best days to reach you: PLEASE CIRCLE ALL THAT APPLY:

MONDAY TUESDAY WEDNESDAY THURSDAY FRIDAY
I certify that I have explained to the above individual the purpose and nature of this study, and potential benefits, and possible risks associated with participating in this research study, have answered any questions that have been raised, and have witnessed the above signature.

________________________  _____________________________
Date                      Investigator’s Signature

This project has been approved by the Indiana University of Pennsylvania Institutional Review Board for the Protection of Human Subjects. IUP IRB: (724) 357-7730
Appendix B

Athlete General Information

Name: ____________________

Number: ________________

E-Mail Address: ________________

Phone Number: ________________

Sport at IUP: ________________

Estimated physical activity (in minutes) per week: ________________

Age: ________________

Height: ________________

Weight: ________________

Dominant Leg: ________________

Injury History:

Do you have, or have you had, any injuries to your lower extremity joints, muscles, bones, tendons or ligaments? Please list conditions, their location and put an ‘X’ on the provided diagram:

Front

Back
Do you have pain in the lower extremity that has been present for longer than 6 months? If yes, please put an ‘X’ on the location of the pain on the diagram below.

Do you currently have any broken bones or soft tissue injury (muscle, ligament or tendon tear)?

YES  NO

If YES, please list the condition and the location of the injury.

Have you had any recent surgeries?

YES  NO

If YES, please list the procedure and its location.

If you have had an injury within the last year, have you been cleared by an athletic trainer or doctor to return to play?

YES  NO

Are there any reasons you should not participate in this activity?  YES  NO
# Appendix C

## Data Collection Sheet

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### FIRST STRETCH SESSION

**Stretch Type:**

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<th>24 hr</th>
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Appendix C (continued)

SECOND STRETCH SESSION
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Appendix D

Participant Flow Chart

Eligible Participants (n=20)

- Ten minute orientation to PNFMR and A/S

Randomized

**PNFMR First**

- Visit 2: Baseline ROM, 20 minute stretch session, immediate post-stretch ROM, ten minute post ROM, 20 minute post ROM

- Visit 3: 24 hour post ROM

- Visit 4: 7 day post ROM, 20 minute A/S stretch session, immediate post-stretch ROM, ten minute post ROM, 20 minute post ROM

- Visit 5: 24 hour post ROM

- Visit 6: 7 day post ROM

**A/S First**

- Visit 2: Baseline ROM, 20 minute stretch session, immediate post-stretch ROM, ten minute post ROM, 20 minute post ROM

- Visit 3: 24 hour post ROM

- Visit 4: 7 day post ROM, 20 minute PNFMR stretch session, immediate post-stretch ROM, ten minute post ROM, 20 minute post ROM

- Visit 5: 24 hour post ROM

- Visit 6: 7 day post ROM
Appendix E

PNFMR Photos

Photo 1: Hamstring held at moderate tension for ten seconds

Photo 2: Participant presses against investigator for six seconds

Photo 3: Participant releases tension and relaxes deeper into stretch
Photo 4: Plantar flexion is held for ten seconds

Photo 5: Participant dorsiflexes against stretch for six seconds

Photo 6: Participant relaxes deeper into stretch for six seconds
Photo 7: Ankle is dorsiflexed for ten seconds

Photo 8: Participant presses against investigator for six seconds

Photo 9: Participant relaxes ankle deeper into stretch for six seconds
Appendix F

A/S Photos


1. Foot Grip
   Top Hand Plantar Flexes Foot & Both Hands Invert Foot

2. Ankle Grip
   Traction & Plantar Flexion
3. Toe Grip
Spread Metatarsals & Traction Toe

4. Ilio-Tibial Band (ITB) Pump
Flex & Extend Knee to Identify Adhesions
Press on Adhesions & Move
5a. Hip Sway & Roll
Lateral Spinal Flexion & Figure 8’s of Pelvis

5b. Hip Rock
Support Legs – Cupped Pressure to Paraspinals with Other Hand
Lift & Lower Pelvis in Rocking Motion.
6. One Leg Standing
Foot Grip with Traction
Hip Fulcrum or Sandwich Grip in Lumbar/Sacroiliac Region

8. COPS – Assume the Position
Downward Pressure on Upper Rim of Ilium