EFFECT OF DEEP HEATING AND FOAM ROLLING VS. STATIC STRETCHING OF THE GASTROCNEMIUS AND SOLEUS COMPLEX IN IMPROVING ACTIVE ANKLE DORSIFLEXION RANGE OF MOTION

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ABSTRACT

Ericson MK, Kennedy AR, Rosentreter KK, Turnquist T, Braun S. Effect of Deep Heating and Foam Rolling vs. Static Stretching of the Gastrocnemius and Soleus Complex in Improving Active Ankle Dorsiflexion Range of Motion. Journal of Undergraduate Kinesiology Research; 10(1): 64-78. Purpose: There are many means of intervention when it comes to improving range of motion (ROM) of a joint. There is no consensus as to which treatment is the most beneficial for increasing dorsiflexion of the ankle. The purpose of this study was to determine which treatment protocol involving static stretching, deep heating, and/or foam rolling would provide greater improvements in ankle dorsiflexion range of motion. Methods: The deep squat component of the Functional Movement Screening (FMS) was used as a screening tool to determine the eligibility of volunteers. Those who scored “2 = proper squat with a board placed underneath heals” on the FMS were included in the study. Eighteen Division III Track and Field athletes (ages 19.94 ± 1.43 years) were eligible to participate and were randomly assigned to three treatment groups [static stretching (SS), static stretching and foam rolling (SS+FR) or ultrasound, foam rolling and static stretching (US+FR+SS)].The study measured left and right active ankle dorsiflexion (degrees) with the knee in the extended and flexed to approximately 90 degrees position. Measurements were taken at baseline, prior to and immediately after each treatment session, and at a final assessment after 3 weeks of a treatment period. Results: The two-way repeated measures analysis of variance (ANOVA), with an alpha of .05, revealed there was no group effect, but a significant time effect on all dependent variables. Paired samples t tests revealed left ankle dorsiflexion with the knee extended at final (M = 19.12; SD = 5.54) was significantly greater than baseline (M = 14.11; SD = 3.76), t(16) = -5.97, p < .001. Left ankle dorsiflexion with the knee flexed at final (M = 27.12; SD = 6.81) was significantly greater than baseline (M = 22.50; SD = 7.08), t(16) = -3.30, p = .005. Right ankle dorsiflexion with the knee extended at final (M = 18.88; SD = 5.70) was significantly greater than baseline (M = 15.12; SD = 4.26), t(16) = -3.15, p = .006. Right ankle dorsiflexion with the knee flexed at final (M = 29.29; SD = 7.82) was significantly greater than baseline (M = 24.47; SD = 6.47), t(16) = -2.70, p = .016. Conclusions: All participants improved bilateral active dorsiflexion ROM from baseline to final, which demonstrated that all three treatment types were similar in their effectiveness. Future research should consider involving individuals who have suffered from lower leg injuries in the past year and of various activity levels to generalize our findings in collegiate Division III Track and Field athletes.

Key Words: Ultrasound, Functional Movement Screen, Inclinometer, Track and Field
INTRODUCTION

The prevalence of lower limb injuries among athletes is extremely high accounting for 50% of all injuries among athletes from different sports (1). Specifically, runners have shown a lower leg injury rate ranging from 19-75% according to various studies (2). Athletes with a calf injury can take as long as 4.5 weeks to regain functionality and 6.7 weeks to return to full sport participation if a tear in the gastrocnemius-soleus complex is present (3). Factors that could increase the risk of injury include decreased flexibility, decreased range of motion, and increased muscle pain (4). Shortness and contractures of muscles, or loss of joint motion, may cause limitations in range of motion (ROM) that restrict the normal action of the muscle (5). Limited dorsiflexion has been associated with increased knee valgus during squatting and greater ground reaction forces when landing from a jump (1). These biomechanical alterations strongly correlate with the possibility of anterior cruciate ligament (ACL) injuries (1). Furthermore, limited dorsiflexion ROM has been identified as a risk factor for knee, ankle, shin, and hamstring injuries such as ankle sprains, medial tibial stress syndrome, and hamstring strains. Therefore, improving dorsiflexion ROM may reduce injury rates in the lower limbs among amateur athletes (1).

A recently developed tool to assess injury risk is the Functional Movement Screen (FMS) (6). This means of instrumentation can be used to identify functional deficiencies, which can appropriately predict future injuries (7). The FMS is composed of seven tests that help to detect dysfunctional movement patterns. These dysfunctions can be due to having tightness in the gastrocnemius-soleus complex. Other causes of dysfunction can be seen in structural deficiencies, such as a rotated ilium, leg length discrepancies, scoliosis, etc., that causes an individual to not pass the FMS deep squat test.

To combat the dysfunctional movement patterns caused by gastrocnemius-soleus tightness in the lower leg muscles, several treatment methods have been commonly utilized including stretching, foam rolling, and heating (1, 5).

All of the previous research has shown that stretching, foam rolling and heating individually will induce an increase in tissue extensibility (1, 5). No studies have combined the effects of the three nor consistency across other treatment protocols on improving ankle dorsiflexion range of motion. More specifically, there are variations of the heat mechanism to the tissue via moist heat packs, therapeutic ultrasound, and short-wave diathermy when looking at the treatment time and also the treatment parameters of these various applications. For example, diathermy applications varied in times from 5 to 20 minute sessions (4). Ultrasound parameters varied in frequency and time and application site (4). Most studies concluded that ultrasound at 1 MHz had greater effects of heating compared to 3 MHz (4). Treatment duration ranged from a minimum of 5 minutes to a maximum of 8 minutes in the study performed by Nakano et al. (4). To our knowledge, no studies have performed ultrasound treatment on the musculotendinous junction or the Achilles tendon. Stretching parameters from previous studies have varied in length of time such that it ranged from 2 minutes to up to 30 minutes (8). The means of stretching (on a slant board, runners stretch, towel stretch, etc.) varies. No consensus has been made with foam rolling treatment protocols in regards to treatment time ranging from 15-120 seconds, and frequency ranging from 1-3 times a day, 2-3 times a week.

Tightness in the gastrocnemius-soleus complex decreases dorsiflexion ROM at the ankle, which predisposes an individual to injury; however, there is no consensus about which treatment protocol is most effective in decreasing soleus tightness and increasing ankle dorsiflexion. There has not been a study that examined the effectiveness of therapeutic manipulations and modalities to increase the extensibility of the deep posterior lower leg tissues of the superficial compartment to increase active ankle dorsiflexion among collegiate track and field athletes. Therefore, evidence warrants the need to examine the combined or synergistic effect of a deep heating ultrasound treatment, the use of a foam
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roller, and stretching protocol to improving ankle ROM, thus improving the deep squat FMS score among those who are screened.

The primary purpose of the current study, therefore, was to determine which treatment protocol provides better results in regards to improving ankle dorsiflexion ROM among track and field athletes. It was hypothesized that after a 3 week treatment period, athletes who complete the combination of deep heating ultrasound and foam rolling prior to static stretching will have greater improvements in ankle dorsiflexion compared to athletes who were strictly prescribed with foam roll and static stretch individually. The improvements in dorsiflexion will therefore allow an individual to improve the score of an FMS deep squat test.

METHODS

Subjects
The study recruited nine males and eleven female subjects for a total of 20 participants; however, after pre-testing, one was disqualified because they scored a 3 on their FMS deep squat and exceeded normal ranges of motion. After the first two treatment sessions a second participant was disqualified because they would not have been able to complete four out of the five treatment sessions. Nine males and nine females completed the study. Subject demographics are described in Table 1.1. All of our subjects are members of the University of Wisconsin - Eau Claire Track and Field team and volunteered to participate in the study. The events of each individual varies amongst the following: javelin, throwing, various sprints, hurdles, pole vault, triple jump, high jump and multi. The subjects were recruited via email and by individually asking the team members at a mandatory team function. The inclusion criterion was that they be a currently active member of the university’s Track and Field team, have no contraindications for an ultrasound treatment, and had no previous history of lower leg injury within the past month that would compromise the integrity of the study. The FMS deep squat was taped and assessed individually, and as a group of investigators. The videos were reviewed from the front view and side view to then further examine the each subject’s deep squat technique. Refer to “Eligibility Section” for further detail. Upon our individual and group analysis of the subjects, one was excluded. The Institution Review Board approved the study protocol. Prior to baseline testing, all subjects were presented with relevant information on the study, were given a copy of the informed consent, signed an informed consent form stating that their participation was voluntary and all personal information will remain confidential, and completed a pre-assessment questionnaire.

Table 1.1 Descriptive data of the subjects.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (Years)</th>
<th>Height (Inches)</th>
<th>Weight (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 males</td>
<td>19.94 ± 1.43</td>
<td>68.9 ± 4.37</td>
<td>176.12 ± 51.08</td>
</tr>
<tr>
<td>9 females</td>
<td></td>
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</table>

Eligibility Screening
Eligibility screening was conducted to ensure that the potential subjects were qualified to participate in the study. All subjects were given a questionnaire to complete. The information gained from the questionnaire included injuries in the last year, if any of those injuries required surgery or a rehabilitation program, any contraindications for ultrasound that the subject may have (e.g., open wounds, infections, fracture, etc.), and times available to complete the study.

The FMS deep squat test was used to see how dorsiflexion of the ankle affects the deep squat in regards to the closed kinetic chain. The deep squat was recorded on two iPads that were placed to show the front and side views. An iPad app called Ubersense Coach Video Analysis by Ubersense Inc.
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was used to document the motion of the deep squat. The subjects were verbally instructed to perform an overhead deep squat twice on the ground and then twice with their heels on a board. The two researchers that were running the FMS testing portion completed initial scoring. The researchers scored the squat on a scale of 1-3 following the guidelines determined by the FMS scoring criteria (Table 1.2). If the participant scored a one or two on the ground, the subject was asked to repeat the deep squat with his or her heels on a board. While analyzing participant’s form with Ubersense, a subscale was used when participants performed their deep squat on the ground. The subscale looked to see what errors the subject made in order to not meet the FMS score of 3: upper torso parallel with the tibia or is vertical, femur below horizontal, knees over feet, and dowel over feet. The amount of errors that the subject presented would be recorded with a score out of four; 0 being no errors noted (0/4) and 4 being all errors were noted (4/4). It was also noted during post scoring that if the subject’s femur was closer to horizontal or below, indicating that there was decreased tightness in the soleus compared to the participant’s pre-data collection video. A “Yes” (Y) means improvements were seen and “No” (N) means that there were no improvements in regards to the femur becoming closer to below horizontal or the individual going deeper in their squat. More in-depth analysis was conducted with all three researchers based on the 1-3 scoring scale. The purpose of the FMS score is to observe if the subject’s squat technique has changed due to treating soleus tightness. The three researchers also noted if the subject was able to squat lower with the heels on the board versus on the ground.

Following the FMS testing, initial values of left and right ankle dorsiflexion ROM were recorded in two positions. The first position had the subject sit in a comfortable position on a treatment table with the knee fully extended. The second position had the subject sit at the end of the table with the knees naturally placed in approximately a 90 degree angle. Two trials of each position were recorded. These measurements were taken as a baseline ROM to have on record for if the subject were to be accepted to participate in the study. After in-depth review of the data, subjects were notified by email if they qualified for the study.

Table 1.2 FMS Scoring Criteria: Deep Squat.

<table>
<thead>
<tr>
<th></th>
<th>Criteria</th>
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</thead>
<tbody>
<tr>
<td>3</td>
<td>• Upper torso parallel with tibia or is vertical</td>
</tr>
<tr>
<td></td>
<td>• Femur below horizontal</td>
</tr>
<tr>
<td></td>
<td>• Knees over feet</td>
</tr>
<tr>
<td></td>
<td>• Dowel over feet (no lumbar flexion noted)</td>
</tr>
<tr>
<td>2</td>
<td>• Same criteria for a score of 3, but heels are elevated</td>
</tr>
<tr>
<td>1</td>
<td>• Tibia and upper torso not parallel</td>
</tr>
<tr>
<td></td>
<td>• Femur not below horizontal</td>
</tr>
<tr>
<td></td>
<td>• Knees not over feet</td>
</tr>
<tr>
<td></td>
<td>• Lumbar flexion noted (dowel not over feet)</td>
</tr>
</tbody>
</table>


Instrumentation

Range of Motion. Active ankle dorsiflexion was measured by means of an iPad application (app) used as an inclinometer. The current standard iOS 8 operating system has an inclinometer app. The app will use the internal accelerometer’s three linear axes to measure the pull of gravity (9). When the application is placed against a solid surface, the inclinometer compares the angle with the internal gyroscope, which is a mechanism used for space orientation, and then displays the angle using the software interface (9). There is not a lot of previous research to base the inquisitions of validity on, but authors have cited previously using an application on the iPhone to measure cervical range of motion. They tested the intra-rater reliability and inter-rater reliability of the app and compared it to a gold-
standard cervical range of motion (CROM) goniometer. They found that there is a high intra-rater reliability and poorer inter-reliability among multiple examiners. When comparing the application to the gold standard, there was a good to moderate validity (ICC = 0.43) between the two (9).

**Ultrasound.** The study used ultrasound as the way to administer heat to the tissues versus short-wave diathermy and moist heat packs. Diathermy has the greatest effect of increasing tissue temperature and also has the greatest tissue penetration depth; however, it and moist heat packs require longer treatment time compared to ultrasound. Short-wave diathermy also has more contraindications and precautions compared to ultrasound and moist heat packs, which could play a role in finding enough subjects. Ultrasound delivered at 1 MHz has significant tissue heating properties at a depth of 1.2-2.5 cm (10). Administering ultrasound at 1 MHz compared to 3 MHz allowed the tissue of the deep soleus as well as the superficial gastrocnemius to receive the desired deep heating effects, such as increase tissue temperature, blood flow, and elasticity of the tissue. The time of administration of ultrasound varies from 5-7 minutes. However, seven minutes has shown to be the most effective for increasing ankle dorsiflexion ROM and therefore, most beneficial for this study (5).

**Foam Roller.** A foam roller was used as another technique to help with muscle tightness. Foam rolling can extend the tissues and improve ROM by loosening and breaking apart scar tissue and cross fibers that occur in the fascia (11). By breaking up these adhesions, the fascia can return to its normal alignment and help improve ROM (11). Other than increasing ROM, foam rolling increases flexibility, performance, and muscular function; this is the result of self-massage and self-myofascial release that is occurring when the pressure of the foam roll is over the affected area (11). Overall, there is little research about justifying the effectiveness of foam rolling, but success has been recorded (11). For instance, Grieve, Barnett, Cognill, and Cramp (2013) tested the effectiveness of myofascial trigger point treatment involving foam rolling and a home-stretching program for individuals experiencing sub-acute or chronic calf pain. It showed there was a 5-10 degree increase in ankle dorsiflexion of the soleus over 6 weeks (12). Another study reported that trigger point release with self-stretching improved pressure pain thresholds, or the minimal amount of pressure needed when the feeling of pressure turns into pain, when compared to stretching alone (13). A 36” CANDO foam roller was one that is commonly used within the University of Wisconsin- Eau Claire’s athletic training room among Track and Field athletes. Varying densities of available foam rollers and adjusting them to the subjects was not an issue because only one foam roller was used for the study. The subjects had some knowledge of the amount of pressure that they would experience. However, for consistency among participants, instructions of foam rolling technique were given during the first treatment session.

**Static Stretching.** Due to the fact that stretching is a commonly known aid in the athletic population, all our subjects underwent a stretching protocol, specifically static stretching. The reasoning behind this is because it has a less potential for trauma compared to ballistic, and proprioceptive neuromuscular facilitation (PNF) requires the most expertise and the assistance of a partner or therapist in order to administer (14).

**Procedures**
The study was held over a three-week period. Subjects either received treatment on Monday and Thursday or Tuesday and Friday. In order to see the longevity of the treatment on elongating tissue extensibility in the gastrocnemius - soleus complex, at least a 72-hour recovery period between treatments was required. The study had three treatment groups: static stretching (SS), foam rolling and static stretching (FR+SS), and ultrasound, foam rolling and stretching (US+FR+SS).

ROM was measured via the iPad application. All the research conductors were trained on how to properly use the inclinometer application. For the baseline testing, one conductor took the assessment to minimize inter-rater error. Once subjects were assigned to a treatment group, the same conductor
worked with and measured ROM of their subjects, as well as at the final assessment. The same procedure that was conducted in measuring ROM at baseline was used throughout the entirety of the data collection period. In order to have a valid study, assessments for ROM of ankle dorsiflexion in all participants was measured without the case and lined up with the third metatarsal and bisecting the calcaneus.

All subjects were competent in how to stretch and foam roll. To ensure complete competence, a brief teaching session was held on the same day prior to the first treatment session. Pre-treatment ROM measurements were taken on both ankles, and then the subject went through an entire treatment protocol on the left leg, recorded post-treatment ROM measurements, and then repeated the same treatment protocol and post-treatment ROM measurements on the right leg.

**Static Stretching.** A protocol similar to the one mentioned in the article written by Halperin et al. (2014) was used (1). A perceived pain scale from zero to ten, with zero representing no pain and ten representing the maximum tolerance was created as a tool for the subjects to use while performing the stretch (Figure 1.1). For the entire duration of the stretching period, participants were asked to keep their stretching at a discomfort level of five out of ten, which represents a nagging, uncomfortable, troublesome sensation. The protocol included four 30-second stretch periods with a 30-second rest period between stretches. The stretching periods consisted of two positions: knee slightly flexed and the knee fully extended. With the knee slightly flexed, that eliminated the use of the gastrocnemius and the stretch was focused on the soleus. The entire gastrocnemius and soleus complex was stretched with the knee in full extension. Stretching was administered by the use of a slant board because it was easily accessible, at a predetermined angle that stayed consistent, and explaining how to use it to perform a stretch was easy. With this protocol, there would be a decreased chance of error and skewed results in our findings.

**Foam Roller + Static Stretching.** The foam rolling group foam rolled once for 90 seconds twice a week for three weeks. Having the foam rolling treatment done 2 times a week will coincide with how often ultrasound should be used. Once a day will be acceptable due to the availability of the participants as well as the study conductors. The subjects used longer strokes until they felt a trigger point (pain that was greater than 5/10), maintained that position until pain was relieved or returned to a five out of
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10, and finally continued with the long stroke pattern until another trigger point was felt. At the conclusion of the foaming treatment, subjects in this group would then partake in the aforementioned stretching protocol.

**Ultrasound + Foam Roller + Static Stretching.** The final group that consists of all three interventions used the following protocol: ultrasound, foam rolling, and static stretching. Deep heating will warm-up the tissues, promote blood flow to the area, and begin to loosen up muscle adhesions. The protocol for ultrasound was administered by a qualified investigator at a frequency of 1 MHz, continuous, 1.5 W/cm² for 7 minutes focusing on the musculotendinous junction. Most studies available focused on applying ultrasound on the muscle itself, instead of its insertion point at the Achilles tendon. Ultrasound also has an effect on collagen rich tissue (15). Increased tissue temperatures during ultrasound treatment can decrease the viscosity of collagen fibers while increasing the elasticity of the deep tissues surrounding the joint that most often restrict ROM (15, 16). When foam rolling, adhesions and scar tissue found in the fascia and muscle will be broken up. After foam rolling, stretching can be done to help increase muscle extensibility since the adhesions and scar tissue are now broken up, allowing a greater stretch and increase of the patient’s ROM (11).

Improvements in ankle ROM were then compared with baseline, pre and post intervention, and final assessment ROM measurements. All measurements were then compared amongst one another to better identify the best protocol for decreasing soleus tightness. The use of the FMS test was utilized in the final assessment to see visual improvements in squat depth from the increased ROM.

**Statistical Analyses**

The design of this study is a case study, pre-test post-test randomized-group design. Sampling of our population was done with convenience. Email and in-person approach was used to gain volunteers. The study consisted of two independent variables (i.e. ankle dorsiflexion ROM with knee extended, and ankle dorsiflexion ROM with knee flexed) and three experimental groups (i.e. SS, FR+SS, and US+FR+SS). Two-way repeated measures ANOVA was used for statistical analysis. Analyses were run using baseline, post session 3, and final ROM assessments to compare improvements amongst treatment sessions. The significant value level was set at .05. The software that was utilized was SPSS version 19.0.

**RESULTS**

Using an alpha of .05, the two-way repeated measures ANOVA indicated time (baseline, post session 3, final) was a significant predictor of left ankle dorsiflexion with knee extended. However, group (SS, SS+FR, US+FR+SS) was not a significant predictor of left ankle dorsiflexion with knee extended (Figure 2.1), left ankle dorsiflexion with knee flexed (Figure 2.2), right ankle dorsiflexion with knee extended (Figure 2.3), right ankle dorsiflexion with knee flexed (Figure 2.4). In addition, no significant interaction effect was examined. See Table 2.1 for complete two-way repeated measures ANOVA analysis. Paired samples T-test was then conducted after finding significance within the two-way repeated measures ANOVA time effect. Paired samples T-test indicated the left and right ankle dorsiflexion with the knee extended and with the knee flexed for post session 3 was significantly greater than the baseline. Paired samples T-test indicated the left and right ankle dorsiflexion with the knee extended for final was significantly greater than post session 3. Paired samples T-test indicated the left and right ankle dorsiflexion with the knee flexed for final was significantly less than post session 3. Paired samples T-test indicated the left and right ankle dorsiflexion with the knee extended and flexed for final was significantly greater than baseline. See Table 2.2 for complete paired samples T-test analysis.
**Figure 2.1.** Average left ankle DF ROM with knee extended for individual treatment groups.

Note: BL= baseline; a= pre-treatment; b= post-treatment; F= final measurement

**Figure 2.2.** Average left ankle DF ROM with knee flexed for individual treatment groups.

Note: BL= baseline; a= pre-treatment; b= post-treatment; F= final measurement
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Figure 2.3. Average right ankle DF ROM with knee extended for individual treatment groups.

Note: BL= baseline; a= pre-treatment; b= post-treatment; F= final

Figure 2.4. Average right ankle DF ROM with knee flexed for individual treatment groups.

Note: BL= baseline; a= pre-treatment; b= post-treatment; F= final measurement
Table 2.1. Results of two-way repeated measures analysis of variance

<table>
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<tr>
<th></th>
<th>Baseline</th>
<th>Post-session 3</th>
<th>Final</th>
<th>(t_1)</th>
<th>(p_1)</th>
<th>(t_2)</th>
<th>(p_2)</th>
<th>(t_3)</th>
<th>(p_3)</th>
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<tr>
<td>Left ankle DF (knee extended)</td>
<td>14.11 ± 3.76</td>
<td>18.22 ± 6.34</td>
<td>19.12 ± 5.54</td>
<td>-4.41</td>
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<td>.021</td>
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<td>Left ankle DF (knee flexed)</td>
<td>22.50 ± 7.08</td>
<td>30.44 ± 8.98</td>
<td>27.12 ± 6.81</td>
<td>-4.43</td>
<td>&lt;.001</td>
<td>4.34</td>
<td>.001</td>
<td>-3.30</td>
<td>.005</td>
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<td>Right ankle DF (knee extended)</td>
<td>15.00 ± 4.12</td>
<td>18.39 ± 6.46</td>
<td>18.88 ± 5.70</td>
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<td>-1.20</td>
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<td>.006</td>
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<tr>
<td>Right ankle DF (knee flexed)</td>
<td>24.83 ± 6.47</td>
<td>32.39 ± 6.90</td>
<td>29.29 ± 7.82</td>
<td>-3.77</td>
<td>.002</td>
<td>2.46</td>
<td>.025</td>
<td>-2.70</td>
<td>.016</td>
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Note: DF = dorsiflexion; Group Effect= SS, FR+SS, US+FR+SS

Table 2.2. Results of paired-samples t tests for each dependent variable

<table>
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<th></th>
<th>(F)</th>
<th>df nominator</th>
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<tr>
<td>Time Effect</td>
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<td>Time Effect</td>
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<td>2.0</td>
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<td>14.0</td>
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<td>4.0</td>
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<td><strong>Right ankle DF (knee extended)</strong></td>
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<tr>
<td>Group Effect</td>
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<td>Interaction Effect</td>
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<td>3.37</td>
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<tr>
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<td>1.54</td>
<td>3.34</td>
<td>23.39</td>
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</table>

Note: DF = dorsiflexion; \(t_1\), \(p_1\) = comparison between post session 3 and baseline; \(t_2\), \(p_2\) = comparison between final and post session 3; \(t_3\), \(p_3\) = comparison between final and baseline

**DISCUSSION**

It was hypothesized that after a 3-week treatment period athletes who complete the combination of deep heating ultrasound and foam rolling prior to static stretching would have greater improvements in ankle dorsiflexion ROM. However, the results showed no significance in treatment group. The improvements in dorsiflexion came from the time factor of applying a treatment to the gastrocnemius-soleus complex. Although not significant to group, three out of 18 individuals (16.7%) did improve their FMS deep squat score from baseline to final.

The study devised a subscale based for the FMS screening (Table 1.2) to show a descriptive analysis of our participants, which allowed for the study to show its improvements from baseline to final. The subscale that was devised evaluated each participant on his or her form. Each participant was then given a score out of 4. In a study done by Kiesel et. al (2009), the use of the deep squat FMS was utilized because it incorporates a balance of mobility and stability (7). From this they hypothesized that failure of the test would indicate dysfunctional movement (7). Their intervention of stretching, trigger
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point treatments, and corrective exercises did increase FMS score from baseline to the final assessment (7). This study did see improvements in participants deep squat FMS. Based on errors in form, 77.8% or 14 out of 18 participants scored the same as they did on their pre-screen, 16.7% or 3 out of 18 improved, or had fewer errors than their pre-screen, and 5.5% or 1 out of 18 declined, or had more errors than their pre-screen. Due to the limitations of the FMS guidelines, it is not able to fully encompass the visual increase in squat depth from baseline to final (Figure 3.1). As seen in Figures 3.1 and 3.2, the individuals pictured do not meet the criteria by FMS guidelines for having the femur below horizontal; but individually comparing all 18 participant’s baselines to their finals, 77.8% or 14 out of 18 were able to squat lower. The increase in squat depth could then be correlated to the increase in dorsiflexion ROM.

The overall degree increase from baseline to final was 4.5 degrees of change. Within each group the percent change from baseline to final were 25% for SS, 33.8% for SS+FR, and 14% for US+FR+SS. The overall percent change from baseline to final was 25%.

![Figure 3.1. FMS deep squat assessment baseline to final](image)

Note: Figure 3.1 used the Ubersense application to approximate degrees of motion. All landmarks (greater trochanter, lateral epicondyle and lateral malleolus) are approximate for each measure.
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Figure 3.2. FMS deep squat assessment baseline to final
Note: Figure 3.2 used the Ubersense application to approximate degrees of motion. All landmarks (greater trochanter, lateral epicondyle and lateral malleolus) are approximate for each measure.

Previous studies have shown improvements in ankle dorsiflexion ROM when using foam rolling as part of a treatment protocol. A 3-week study conducted by Grieve et al. used foam rolling and static stretching along with trigger point release to help increase ROM (12). The study showed that there was an average 4 degree increase in ankle dorsiflexion for both gastrocnemius and soleus muscle (12). This study used the same foam rolling and stretching technique as the one mentioned in the Grieve et al. study; however no specifics in treatment parameters were mentioned. Overall, based on a literary review about foam rolling treatment, there is a lack of evidence available about what is the most effective treatment parameters for foam rolling (11).

It was hypothesized that the treatment group that received US+FR+SS would have the greatest increases in dorsiflexion ROM. However, the analysis showed no significant difference in ROM compared to the other treatment groups. The mean increase in dorsiflexion ROM from baseline to final assessment for the US+FR+SS group was 2.5 degrees compared to the FR+SS group which had a mean increase of 6.8 degrees from baseline to final assessment and SS group which had a mean increase of 4.5 degrees from baseline to final assessment. These results are opposite to a study conducted by Knight et al.(5). They also used an US+SS treatment group and a SS treatment group. However, in their study the US + SS group had a mean increase of 6.2 degrees from baseline to final assessment while the SS group had a mean increase of 4.2 degrees from baseline to final assessment (5).

This study was designed to obtain a more thorough understanding of stretching protocols for increasing dorsiflexion ROM and how the use of therapeutic interventions affect these protocols. According to the data, in a treatment lasting 3 weeks, active foam rolling, or ultrasound and foam rolling prior to stretching or stretching alone had no effect on significantly increasing ankle dorsiflexion active ROM. However, even though group had no significant effect, as time went on and treatment interventions continued there was a gradual increase in ROM for each dependent variable (left knee extended, left knee flexed, right knee extended, and right knee flexed).
STRENGTHS AND LIMITATIONS
Strength of the study was that it used a unique design that measured baseline ROM, pre and post ROM’s of five treatments, and a final ROM assessment of all 18 track and field participants. The study incorporated means and standard deviations of baseline ROM, post session 3, and final ROM to determine the significance. Due to the unique design of the study, there is no other study to our knowledge that used a three-group treatment intervention that focused on ROM improvements. This study also used different means of measuring ROM with the use of an inclinometer application instead of the standard goniometer. Another unique aspect of this study is that when performing the ultrasound we focused on the musculotendinous junction instead of the muscle belly (17).

One limitation of this study was that it included a small sample size (n=18). Another limitation is that we had no control over what the participants did outside of the study. Being that they participate in different track and field events, the workouts that they completed varied in intensity from day to day. Some participants even admitted to foam rolling outside of the study as part of their own day-to-day routine. Also, the time frame for the study only allowed for a short treatment period, five sessions over three weeks. Another limitation was that the participants were randomly assigned and not placed evenly throughout the treatment groups. For instance, the FR+SS group ended up with the majority of participant’s event was throwing. These individuals had low dorsiflexion to begin with and are less likely to stretch compared to a participant whose event consisted of sprints or distance running. Therefore, any treatment that they received may be beneficial compared to a participant that already stretches or foam rolls on a regular basis.

CONCLUSIONS
From the results the study can conclude that all participants improved bilateral active dorsiflexion ROM from baseline to final, which demonstrated that all three-treatment types were similar in their effectiveness. The study did not look at injury rate following treatment, but such improvements could be correlated to a decrease in lower leg injuries.

From the FMS subscale that the study created, the pre-screen and post-screen showed that there were overall improvements in 14 of our 18 participant’s squat depth. Although there may not have been improvements in the number of errors with individual form, the overall depth of the squat, for the majority, got deeper. This could indicate that the significance from improved ROM in active ankle dorsiflexion due to the extensibility of the soleus tissue allowed for participants to go deeper in their squat.

Future research
For future studies, to gain a better appreciation for the values observed, a wider range of participants would be recommended. This study only focused on Track and Field athletes at the level of Division III athletics. The results may vary when compared to another division of athletics, recreationally active individuals, or even individuals under the age of 19 and over the age of 22. This study only focused on individuals that had not suffered any lower leg injuries in the past month, it would be interesting to see if similar findings could be obtained to those suffering from an injury, such as an ankle sprain, who also need to improve their dorsiflexion ROM.
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