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Comparative Effect of Ultrasound and Deep Oscillation on the Extensibility of Hamstring Muscles

Martha R. Hinman, PT, EdD

Rachel Lundy, DPT Elyse

Perry, DPT

Kim Robbins, DPT

Lacy Viertel, DPT

Department of Physical Therapy
Hardin-Simmons University
Abilene, Texas

ABSTRACT

Context: Many athletes and non-athletes have tight hamstring muscles that predispose them to injury when they engage in vigorous physical activity. Thermal and mechanical modalities have been used to enhance the effectiveness of muscle stretching, but evidence supporting their benefits is mixed. Deep oscillation is a relatively new modality being used to promote healing of soft tissue injuries; however, the effect of this modality on muscle extensibility is unknown.

Objective: To compare the immediate effect of a single 15-minute treatment of ultrasound (US) and deep oscillation (DO) on the extensibility of hamstring muscles.

Design: Randomized controlled trial

Setting: University research laboratory

Participants: Fifty athletes and non-athletes between the ages of 18 and 39 who demonstrated at least 15 degrees of hamstring tightness bilaterally.

Interventions: Participants were randomly assigned to receive 15 minutes of treatment with US or DO applied to either their right or left hamstring muscle (also randomly assigned).

Main Outcome Measure: Hamstring extensibility measured in both extremities with an inclinometer using a passive straight-leg raise method. Differences were compared within subjects (treated vs. untreated muscles) and between treatment groups (US vs. DO) using a repeated measures analysis of variance.

Results: Changes in hamstring extensibility were significantly greater in treated vs. untreated extremities (3.5 vs. 0.5 degrees; $p < 0.01$). Although the DO treatment generally produced slightly greater improvements than the US treatment, the mean difference was not statistically significant (4.8 vs. 2.4 degrees; p = 0.10).

Conclusions: DO treatments produced slightly greater improvements in hamstring muscle extensibility compared to US. However, changes associated with both modalities were relatively minor and probably not enough to substantially reduce injury risk. Further studies are needed to investigate the combined effect of each modality with stretching exercise vs. exercise alone to determine whether their application is justifiable as part of rehabilitation program for individuals with tight hamstrings.

Clinical Relevance: This study suggests that a single, 15-minute treatment of DO or US may cause slight improvements in the extensibility of healthy hamstring muscles.

KEY WORDS: hamstring flexibility, physical agents, modalities, ultrasound, deep oscillation

INTRODUCTION

The high prevalence of hamstring muscle tightness among individuals of all ages and physical fitness levels is associated with almost one-third of lower extremity injuries.(Ruiz, 2011) Inadequate muscle extensibility (i.e., flexibility) has been identified as a contributing factor to many hamstring injuries (Worrell & Perrin, 1992). Several treatment modalities have been shown to facilitate the stretching of muscle tissue including various forms of heat, massage, and vibration (Knight & Draper, 2008). In the past, these modalities were generally believed to alter the muscle's viscoelastic properties, thus making it easier to lengthen. However, others now theorize that subsequent increases in muscle extensibility are more likely due to modified sensation. In other words, these modalities stimulate the nerves that inhibit the nociceptive (i.e., pain) response associated with muscle stretching. There are conflicting research reports on this topic; however, more evidence seems to support a sensory mechanism for enhancing muscle extensibility, rather than simply a biomechanical response (Weppler & Magnusson, 2010).

Several treatment modalities have been advocated to enhance the efficacy of muscle stretching based upon the physiological mechanisms described above. Thermal modalities have been the most widely investigated; these include moist hot packs (HP), ultrasound (US), short-wave diathermy (SWD), and ice. Funk, Swank, Adams, & Treolo (2001) compared the effect of 30 seconds of static stretching to 20 minutes of HP on hamstring flexibility of male athletes and reported a significantly greater improvement with the application of HP. However, other investigators (Sawyer, Uhl, Mattacola, Johnson, & Yates, 2003) compared changes in hamstring flexibility and muscle temperature among subjects who received HP treatment to one limb and not treatment to the contralateral limb. No significant changes were found in either variable when the treated and untreated limbs were compared. Brodowicz, Welsh, & Wallis (1996) documented improvements in hamstring extensibility whether stretching was preceded with HP, ice packs, or nothing; the greatest gains were reported following the application of ice. Because these superficial thermal modalities are not believed to penetrate more than 1 cm deep (Knight & Draper, 2008), the results of these studies suggest that the sensory stimulation provided by these thermal modalities is the more likely mechanism by which they are able to alter muscle extensibility.

Additional research has focused on the effects of deep heating modalities such as US and SWD which can penetrate to tissue depths of 3 to 5 cm. Both modalities heat muscle tissue via conversion; US uses high frequency sound waves to create acoustic vibration deep within the tissue, while SWD delivers electromagnetic radiation that is converted to heat when it encounters tissues with high water content (such as muscle). The heating effect of these modalities has been shown to raise the internal temperature of muscle causing relaxation and greater extensibility when stretched. (Chan, Myrer, Measom, & Draper, 1998; Draper, Castel, & Castel, 1995; Draper et al., 1998). Two studies comparing the effects of moist HP and US on calf and hamstring muscles reported more significant gains in muscle extensibility following the US treatment. (Knight, Rutledge, Cox, Acosta, & Hall, 2001; Lounsberry, 2008) Draper et al. (1998) examined the additive effect of HP prior to the application of US to determine whether there was a benefit to preheating the muscle. Their results study indicated that increased temperature in deep muscles can be reached two to three minutes sooner when tissue was preheated with a HP. Studies investigating the effect of SWD on hamstring stretching have produced mixed findings. One study reported that stretching with or without SWD significantly increased muscle extensibility to a greater extent than treatment with sham SWD or no treatment ; however a similar study reported no significant differences between subjects who received SWD and stretching, stretching alone, or no treatment (Draper, Miner, Knight, & Ricard, 2002).

Because the evidence on the benefits of thermal modalities is still inconclusive, additional researchers have explored the benefits of mechanical stimulation of muscle tissue using various massage techniques, whole-body vibration, and a newer modality known as deep oscillation therapy. Barlow, Clark, Johnson, et al. (2004) reported no differences in the sit-and- reach scores of subjects who received either a week of traditional, 15-minute massage treatments or no treatment to their hamstring muscles. However, Crosman, Chateauvert, and Weisberg (1984) reported significant improvements in hamstring flexibility following a single 9 to 12 minute massage when compared to the opposite, untreated extremity. Hopper et al. (2005) recorded significantly greater improvements in hamstring flexibility among subjects who received a dynamic, soft tissue mobilization procedure compared to subjects who received a "classic" massage or no treatment. More recently, several investigators have examined the effects of whole body vibration (WBV) devices on muscle extensibility. Most of these devices are designed to deliver a high-frequency, low-amplitude vertical oscillation to subjects who are usually in a standing position on the vibrating platform. Several studies have demonstrated improvements in hamstring flexibility and the ability to perform a "splits" maneuver among gymnasts whose stretching protocols were supplemented with vibration delivered via a WBV platform or a handheld vibrator. (Sands, McNeal, Stone, Haff, & Kinser, 2008; Sands, McNeal, Stone, Russell, & Jemni, 2006; Dastmenash, Tillaar, Jacobs, Shafiee, & Shojaedin, 2010; van den Tillar, 2006; Bakhtiary, Fatemi, Khalili, & Ghorbani, 2011)

Deep oscillation (DO) is a relatively new treatment modality consisting of a low-intensity, electrical current applied at varying frequencies to help reduce swelling and promote tissue repair. When applied manually, an intermittent electrostatic field builds up between the hands of the operator and the subject's tissues which creates a penetrating vibratory action which breaks up excess fluid or adhesions deep within the tissue. As the deep oscillation moves the fluid, it may also alter internal tissue temperatures or stimulate nerve endings that help relieve pain and improve soft tissue extensibility; however, deep oscillation is not considered to be a thermal modality. Research conducted on individuals with lymphedema and athletes with ankle sprains have demonstrated the positive effect that deep oscillation has on reducing edema

(Allyev, 2009; Jahr, Schoppe, & Reisshauer, 2008). Because no adverse effects or discomfort have been reported with this treatment, patient compliance tends to be high and results are usually positive. However, no evidence is available related to the effect that DO may have on the extensibility of muscle tissue.

Thus, the purposes of our study were to: (1) compare changes in hamstring muscle extensibility between treated and untreated extremities, and (2) compare the amount of change between muscles treated with US vs. DO. Given that DO produces a deep vibratory effect that may be similar to that produced by US, we hypothesized that the two modalities would produce a similar, positive effect on muscle extensibility when compared to the untreated extremities.

METHODS

Design

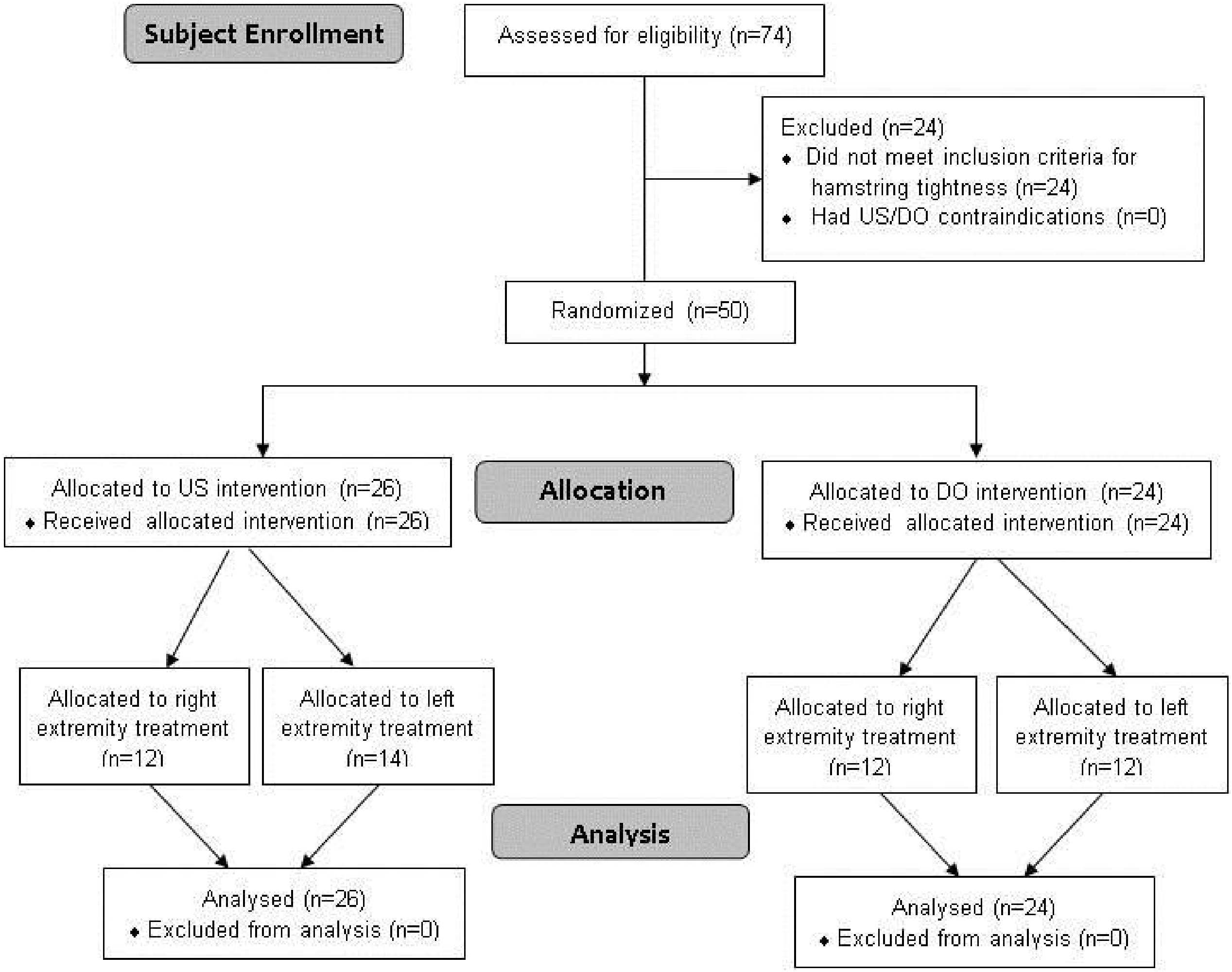
We used a mixed research design (comparison within and between subjects) to test our hypotheses. Our independent variables included the effects of treatment (treated leg vs. untreated leg) and type of treatment (ultrasound vs. deep oscillation) on hamstring muscle extensibility (our dependent variable). After the initial screening measurement of hamstring extensibility, qualified subjects were randomly assigned to receive either US or DO treatment to either their right or left hamstring muscle by drawing from a deck of cards (each suit represented a different treatment-extremity combination). As a result of this randomization, 12 subjects were received US treatment to their right hamstring, 14 received US to their left hamstring, 12 received DO to their right hamstring, and 12 received DO to their left hamstring.

Participants

We recruited college students, both athletes and non-athletes, who were at least 18 years of age and demonstrated at least 15 degrees of hamstring tightness bilaterally as determined by a straight-leg raise (SLR) measurement protocol (Figure 1).

Figure 1. Straight leg raise (SLR) method of measuring hamstring extensibility.

Previous investigators have found this testing protocol to have good reliability with ICCs ranging from 0.92 to 0.99.(Askling, Nilsson, & Thorstensson, 2010; Boyd, 2012; Piva et al., 2006) Participants were excluded if they did not demonstrate this minimal amount of muscle



tightness or if they had any condition for which either treatment modality was contraindicated such as a cardiac pacemaker, broken skin or sensory loss over the posterior thigh, and/or a history of recent infection, lower extremity blood clots, or metastatic disease. These contraindications were determined via a medical history questionnaire. Of the 74 students recruited, 50 qualified to participate in the study (Figure 2); this number was the estimated sample size needed to provide a statistical power of .80 or higher when testing our hypotheses at the .05 alpha level. Our sample included 28 men and 22 women between the ages of 18 and 39 years. A history of previous lower body injury was reported by 58% of these participants.

Figure 2. CONSORT diagram for randomized controlled trial.

Procedures

Both the US and DO treatments were performed by trained physical therapy students to the assigned hamstring muscle for a period of 15 minutes. The US treatment was delivered in a continuous mode using a handheld transducer connected to an Omnisound 3000™ (Physiotherapy Inc., Topeka, KS) which has a BNR of 3:1. The US parameters included a frequency of 1 MHz and an intensity of 1.0 – 1.5 W/cm^2, depending on subject tolerance. The DO was delivered manually via a Hivamat 200™ device (Physiomed Elekromedizin, AG, Schnaittach, Germany) using a light stroking technique applied with gloved hands (Figure 3).

Figure 3. Deep oscillation treatment using Hivamat 200™.

The electrical current of this device was set to oscillate at a frequency of 150 Hz for the first 10 minutes and at a frequency of 60 Hz for the remaining 5 minutes at an output of 80-100%. Both pieces of equipment had been calibrated during recent safety inspections. Following the 15-minute US or DO treatment, the extensibility of both hamstring muscles was measured again by the same investigator who performed the pre-treatment measurements. This investigator was blinded to which leg was treated as well as the type of treatment received.

Statistical Analyses

A repeated measures, analysis of variance was used to compare pre- and post-treatment hamstring measurements in both extremities within all participants as well as between treatment groups. The main effect of time (pre vs. post) was analyzed along with the interaction effect between time and treatment group (US vs. DO). Descriptive statistics were used to analyze the means, ranges, and variances of hamstring measurements in each treatment group. The standard error of measurement (SEM) for measures of hamstring extensibility was calculated using the standard deviation from the baseline measures for the treated extremities and reliability coefficients (0.92 – 0.98) reported in previous studies. All data were analyzed at the .05 alpha level using PASW 18.0 statistical software.

RESULTS

A significant within-subjects improvement was found in the extensibility of treated muscles ($F = 25.83$, $p < 0.01$, power = 0.99) but not in the contralateral, untreated extremity ($F = 0.57$, $p < 0.45$, power = 0.12). The extensibility of treated muscles increased an average of 3.5

degrees compared to 0.5 degree in the untreated muscles. Based on the standard deviation of our baseline measures (5 degrees) and previously reported reliability coefficients for this test protocol, the standard error of the measurement (SEM) was estimated to be somewhere between 0.5 degree and 1.4 degrees. Thus, the changes found in the treated muscles exceeded the range of measurement error.

When comparing these changes by treatment group (the interaction effect), no significant difference was found between the changes in the treated muscles ($F = 2.84$, $p = 0.10$, power = 0.38), although slightly greater improvements were noted in muscles treated with DO. These muscles averaged an increase of 4.8 degrees of extensibility compared to 2.4 degrees in the muscles treated with US. Nevertheless, the overlapping confidence intervals in Figure 4 reflect a great deal of variance in both of these means.

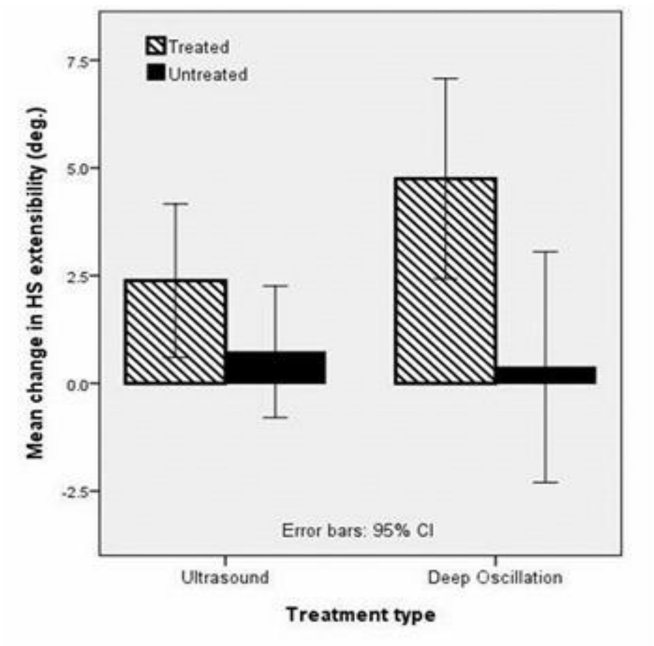


Figure 4. Comparison of gains in hamstring extensibility by treatment group.

When comparing the relative effect sizes for each treatment group the data in Table 1 suggest a moderate effect for muscles treated with US, a large effect for muscles treated with DO, and little or no effect in the untreated muscles.

Treatment Type	Effect Size Index	
	Treated limb	Untreated limb
Ultrasound	0.51	0.11
Deep Oscillation	0.89	0.07

Table 1. Comparison of effect sizes by treatment group.

DISCUSSION

These results supported our hypothesis that muscles treated with US or DO would demonstrate similar levels of improvement compared to untreated muscles. Although we found no statistically significant difference in the extent of improvement, the amount of extensibility gained from the DO treatment was slightly greater than seen in the US group and beyond the estimated measurement error. The SEM we calculated for our study is similar to the one recently reported by Boyd (Boyd, 2012) using the same SLR test protocol; he reported an SEM between 0.5 and 1.2 degrees and a minimal detectable change (MDC) of 1.5 to 3.4 degrees. Thus, only our DO group exceeded this MDC range. However, in a review article on the variability of SLR measurements, Dixon et al (Dixon & Keating, 2000) indicated that test-retest measures really need to exceed 6 degrees to be considered credible. Because no minimal clinically important difference (MCID) has been reported for measures of hamstring tightness, it is difficult to determine whether the changes produced by either the US or DO treatment were clinically meaningful.

As for the proposed physiological mechanisms responsibility for the increase in muscle extensibility, we can only speculate that the deep vibratory stimulation caused by the DO may have had an inhibitory neurosensory influence on subjects' pain thresholds when they repeated the SLR test. As observed by other investigators (Bakhtiary et al., 2011), this response may be regulated by stimulation of the muscle spindles and Golgi tendon organs located deep within the hamstring muscle. However, one limitation of our study was that we made no attempt to clear the proximal lymphatic channels with the DO treatment prior to applying it to the muscle belly. According to our communications with W. Griffith, owner of Physiomed North America (February 2012), the mechanical effects of DO that result in edema reduction and improved tissue mobility can only be expected if the lymph system has been properly opened. Further studies using a more thorough application of DO are needed to support this claim.

Another limitation of this study is the isolated nature of the treatment we performed. When treating individuals who have actual hamstring tightness, it is standard practice for physical therapists or athletic trainers to combine any modality treatment with a stretching exercise program. Thus, additional studies should focus on differences in the combined effect of DO and stretching exercise vs. DO alone. Other logistical limitations that we could not control which may have affected our results included the time of day that participants were treated (some had to come early in the morning and others came in late afternoon following athletic practice) and room temperature which fluctuated from day to day. Both of these factors could have influenced the hamstring measurements to some extent. Finally, the results of this study can only be generalized to relatively healthy young adults who have tight hamstring muscles. Similar results may or may not be expected in other age groups, in other muscle groups, or among individuals with neurological conditions that affect their muscle extensibility.

CONCLUSIONS AND CLINICAL IMPLICATIONS

When used alone, both US and DO appear to produce minor, but significant changes in hamstring extensibility among college-aged athletes and non-athletes. Although not significantly different, the improvements in muscle flexibility associated with the DO treatment surpassed those produced by the US treatment and yielded a greater effect when compared to untreated muscles. Given that DO has fewer contraindications and potential adverse effects than US, it may be the preferred treatment modality when both types of equipment are available. However, most athletic training facilities and physical therapy clinics are more likely to have US units than DO devices. Further evidence is needed to determine whether the benefits of DO, particularly when combined with a stretching exercise program, would justify its relatively higher cost.

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