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Therapeutic Heat: Effects of Superficial and Deep Heating Modalities on Hamstring Flexibility

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Abstract

Poor muscle flexibility has often been associated with injury. Therapeutic heating modalities are frequently used to increase the extensibility of the muscle. The purpose of this study was to compare immediate changes in hamstring flexibility following the application of superficial (moist heat pack) and deep (1 MHz ultrasound) heating modalities. Twenty-four college aged subjects met the inclusion criteria and volunteered for this study. Subjects reported to the Athletic Training Lab and received either the ultrasound or moist heat pack treatment. Hamstring flexibility was measured pre and post treatment using an active knee extension test with an inclinometer. An average of three measurements was used in the analysis. Subjects who received the ultrasound treatment showed greater immediate gains in hamstring flexibility. Therefore ultrasound would be the recommended treatment for increasing extensibility of the hamstring muscles.

Poor extensibility is a predisposing factor to muscle injury, especially with regard to the hamstring muscle group. According to the National Collegiate Athletic Association Injury Surveillance System (1988-1989 through 2003-2004), upper leg muscle-tendon strains constituted 10% of the practice injuries in men's football and 11% of the game injuries in men's baseball.[1,2] In women's field hockey, 26.9% of the practice injuries consisted of upper leg strains.[3]

Many of these injuries may be avoided by maintaining adequate extensibility of the hamstring muscles. Often, the application of some form of heat prior to stretching is often used to enhance range of motion and extensibility. The two most common modalities used in the athletic training room are moist heat packs (MHP) and ultrasound (US). Moist heat is a superficial heating agent that has the ability to cover a large surface area and has a simple application procedure, often performed by the athletes themselves. Therapeutic ultrasound (US) is a deep heating agent applied by a clinician to a much smaller and localized area.

As health care practitioners, we are taught to use evidence based practices when treating our patients in order to provide the best possible care to our patients and athletes. We should always use the most effective means of treatment and these treatments should have a strong foundation of research to support them. As professionals, we need to move away from administering treatments simply because that is the way it has always been done and make sure that we are providing treatments that have been proven to work.

Researchers have studied the effects of modalities on increasing range of motion and extensibility. Often these studies incorporate a stretching protocol following the application of heat.[4-9] As a result of their design, it is often difficult to determine the effectiveness of the modality alone on enhancing extensibility. Researchers have investigated the use of a MHP alone on increasing extensibility.[5,10-14] Robertson et al [13] applied moist heat to the triceps surae and measured changes in ankle dorsiflexion ROM without stretching. Their study determined that the MHP treatment was not significantly more effective than the control.

Although this is a common treatment in the athletic training room, it is only one option for heating up tissue. As mentioned previously, US is often used as a form of deep heat to enhance muscle extensibility. There appears to limited research comparing the effects of MHP and US application without the aid of stretching on muscle extensibility. A single study was found which directly compared US and MHP treatments. Knight et al [4] investigated the effects of MHP and 1 MHz US treatments on the extensibility of the plantar flexors using a concurrent stretching protocol. Therefore, the purpose of this study was to compare the effects of US and MHP application on tissue extensibility of the hamstring muscle group.

Review of Literature

Ultrasound

Therapeutic ultrasound can serve as either a superficial or a deep heating modality depending on the frequency used. While 3 MHz US provides superficial heating, 1 MHz US heats tissues at depths of 3-5 cm and is considered to be a deep heating agent.[15]

US produces heat through high frequency acoustic vibrations. A benefit of this type of energy transmission is that it is minimally hindered by adipose tissue due to its high water content.[15,16] Adipose tissue can be a crucial obstacle for therapeutic heating agents because of its ability to insulate underlying tissues from external heating agents. Rose et al [17] showed that US was an ideal means of reaching higher tissue temperatures at greater depth because of its ability to heat without affecting superficial structures. The study found that, after the first two minutes following treatment, tissues at 5cm deep cooled more slowly than those at 2.5cm deep. Baker et al [18] found that US was capable of significantly increasing blood flow within muscle where moist heat could not. US heats deep tissues without affecting superficial tissues, therefore any overlying adipose tissue serves to insulate the underlying structures and helps to slow the rate of cooling significantly.

US can be used to target the collagen-rich tendinous units of the hamstring muscles because of its ability to penetrate deeper tissues. Several researchers have demonstrated the beneficial effects of heat on collagenous tissue.[19-21] It has been shown that increasing the temperature of collagen to 40 degrees Celsius will increase the elasticity of the tissue.[13] This increased elasticity allows for an even distribution of force and reduces the stress on localized areas of the tissue. Warren et al [19] found that the application of heat with a low load produced a faster elongation of the tendon than the load without heat. He also found that the tendons treated with heat were able to support greater loads and sustained less tissue damage than those that were not. Strickler et al [22] found that an increase in temperature of 4 degrees for a brief period increased the amount of elongation a tissue could sustain without rupture.

A factor that often inhibits significant gains in tissue temperature is the body's natural homeostatic mechanism.[20,23] As the tissue temperature increases, vasodilation occurs, bringing cooler blood into the tissue to help normalize the temperature. Lehmann et al [23] demonstrated the cooling effects of circulation by performing US on animals both pre and post mortem. Upon comparison, post mortem tissue measurements were elevated compared to those taken pre mortem due to the absence of the cooling effect produced by circulation.

It has also been shown that because tendon tissue is less vascularized than muscle tissue, tendons will retain heat for longer periods of time.[24] This lack of vascularity prevents the body from cooling these tissues as efficiently as others because it cannot bring in as much cool blood. Chan et al [24] demonstrated that tendon reaches greater temperatures and heats more quickly than muscle. It was also shown that the tendon was able to maintain vigorous heating for longer periods than muscle.

Application

Because it cannot readily travel through air, US must be applied using a dense coupling medium.[16] Unless an irregularly shaped area requires treatment, most clinicians will use a topically applied coupling gel. Although there are theories that increasing or decreasing the temperature of the conducting gel will alter the effectiveness of the treatment, the research is inconclusive.[25,26]

The treatment area is based on the US unit's effective radiating area (ERA) which represents the portion of the transducer that actually produces the sound wave. The recommended treatment area is no more than three times the ERA.[15,27] Treating an area that is too large will dilute the effects of the treatment and will not allow for adequate tissue temperature increases at desired depths.[10] Research has shown that treating an area four times the ERA can still achieve vigorous heating, but will take significantly longer and be less effective than an area two times the ERA.[24]

The beam nonuniformity ratio (BNR) describes the variance in intensity of the US beam. It is recommended that the transducer head should be moved at a rate of approximately 4cm per second throughout the treatment.[16] If a machine has a BNR of 6:1 or greater, it may be necessary to move the transducer head a little quicker to avoid "hot spots" from forming as a result of peaks in the beam's intensity.

The total duration of the treatment is dependent upon the frequency and intensity being used, as well as the desired amount of heating. Average treatment times range from 5 to 8 minutes. As the intensity is increased, the duration of the treatment should be decreased accordingly. Draper et al [27] found that, with 1 MHz US, treatments using an intensity of 1.5 W/cm^2 reached vigorous heating temperatures 100% faster than those at 1.0 W/cm^2 and 25% slower than those at 2.0 W/cm^2.

Moist Heat Packs

Moist heat packs are a form of superficial heating modality that penetrate to depths of 1-2cm.[11,15] Studies have shown that this modality is capable of improving active joint range of motion.[4,5,12,13,28] An issue of importance with these studies, however, is that almost all used the moist heat treatment in conjunction with a stretching routine. Funk et al [12] found that a 20 minute MHP treatment without a stretch was no more effective than 30 seconds of static stretching without heat.

The effectiveness of superficial heating to increase ROM is attributed more to sensory input than to actual changes in muscle length. Heat acts as an analgesic and may help to alleviate some of the pain associated with stretching, thus allowing for a more significant and beneficial stretch.[15,28] Heat has also been shown to decrease muscle spindle sensitivity.[15] This inhibition results in relaxation of the muscle's stretch reflex which will increase the effectiveness of any stretch applied after treatment. Taylor et al [10] determined that superficial heat was not capable of raising muscle and tendon temperature to a therapeutic level, providing no increases in collagen elasticity.

Hendricson et al [9] also found that the external application of heat does not influence the elasticity of muscles or connective tissue.

It should also be noted that the time required for an MHP treatment is much longer than that of US. The average treatment time for moist heat is between 15 and 20 minutes. Research has shown that treatments should last at least 20 to 25 minutes to achieve significant gains in tissue temperature.[5] After seven to nine minutes of treatment, the body's natural homeostatic defenses begin to take effect which evens out the temperature gradient that was initially created between the moist heat pack and the patient's tissue.[15] In a study examining the effects of moist heat on the hamstrings, Sawyer et al [11] determined that a MHP treatment should last approximately 20 to 25 minutes in order to achieve an appreciable increase in tissue temperature. A study by Abramson et al [28] using wet heat found that peak subcutaneous temperature was not reached until 25 minutes after the initiation of the treatment. When the treatment time is added to the time needed for stretching after the treatment the total time required is close to 30 minutes.

Application

Moist heat packs operate via conduction. Comprised of a silicate gel encased in a canvas cover, these packs are maintained in hydrocollator units. The hydrocollator units keep the MHP's in water that is maintained between 70 and 75 degrees Celsius.[16] Although no coupling medium is needed, they do require insulation. Layers of protective cloth must be placed between the heat pack and the patient to prevent burns from occurring.[15] If the treatment area becomes too hot additional layers of toweling may be added for patient comfort and protection.

MHP's are produced in a variety of sized to accommodate various parts of the body. In this study, we used a standard size MHP which measures 10 inches by 12 inches. The standard size pack is commonly used in athletic training rooms and clinics and provides an adequate treatment size for the hamstring muscle group.

Methods

Subjects

Seven male (average age = 21.9 years; height = 179.9 cm; weight = 89.9 kg) and six female (average age = 21.7; height = 164.3 cm; weight = 60.3 kg) volunteered for this study. Each subject had no recent history of injury to the dominant leg. Dominance was defined as the preferred leg to kick a ball. All subjects included in this study were required to have limited hamstring extensibility as determined by an active knee extension (AKE) angle of 170 degrees or less while in 90 degrees of hip flexion.[10,11] Prior to participation, subjects read and signed the informed consent form that had been approved by the University of North Florida's Institutional Review Board.

Protocol

Upon reporting to the Athletic Training lab each subject's height, weight, and age was recorded. The subjects were asked to lie supine on the treatment table and AKE angles were recorded for the dominant leg using a gravity inclinometer attached to the lower leg as seen in Figures 1 and 2. Marks were made on the lateral lower leg using a felt tipped pen to ensure consistent placement of the inclinometer. During the measurement, a cloth strap was placed across the mid thigh of the contralateral limb to prevent any compensatory movement.[13] A crossbar made of polyvinyl chloride pipe was used as a guide to ensure that the hip remained at 90 degrees of flexion during the measurement.[30] Subjects were asked to flex the hip until 90 degrees of flexion was reached (as determined by a standard goniometer) and the crossbar was put in place.

Figure 1: AKE resting position.

Figure 2: AKE testing position.

For each measurement, subjects were asked to flex their hip until their anterior thigh came into contact with the crossbar. They were then asked to extend their lower leg as far as possible while keeping their thigh in contact with the crossbar. This position was held for two to three seconds while the measurement was taken. An average of three recordings was used as the baseline measurement.

Subjects were randomly assigned to receive either the US or the MHP treatment during their first session. Treatment sessions were kept at least one week apart to account for any carryover effect. Three AKE measurements were recorded prior to each treatment session and the average of the three readings was used as the baseline measurement. Immediately following each treatment three AKE measurements were taken and the average of the three readings was recorded as the post-treatment measurement

MHP's were maintained at a temperature between 70 and 75 degrees Celsius using a hydrocollator tank. One standard hot pack cover and one layer of toweling were placed between the MHP and the subject's posterior thigh to protect the skin and superficial structures as seen in Figure 3. MHP's were applied over the musculotendinous junction of the distal hamstrings. Each MHP treatment lasted 20 minutes and additional layers of toweling were added as needed for subject comfort.

Figure 3: Application of moist heat treatment.

Ultrasound treatments were performed using an Omnisound 3000 (Physio Technology Inc, Topeka, KS) unit at a frequency of 1 MHz with an intensity of 1.5 W/cm^2. A water based gel, maintained at room temperature, was used as a conducting medium. A template was placed over the musculotendinous junction of the hamstring muscle group to ensure that the treatment area remained at four times the effective radiating area of the transducer head as seen in Figure 4.[30,31] The principle investigator performed all treatments using the same ultrasound unit which had been recently calibrated. Each US treatment lasted seven minutes. If subjects complained of intense heat or any abnormal sensations, treatment was discontinued.

Figure 4: Application of ultrasound treatment.

Statistical Analysis

A repeated-measures analysis of variance (ANOVA) with 2 within-treatment variables (treatment (MHP and US) and time (pre-treatment and post-treatment)) was performed to determine differences in hamstring extensibility between the two treatment conditions. Differences were considered significant at $p \leq 0.05$.

Results

Descriptive data for extensibility measures are reported in Figure 5. The repeated measures ANOVA revealed no significant difference between the two treatments ($p=.29$) but yielded a significant main effect for time ($p=.02$). Post-treatment measurements showed that US increased extensibility more than the MHP treatment.

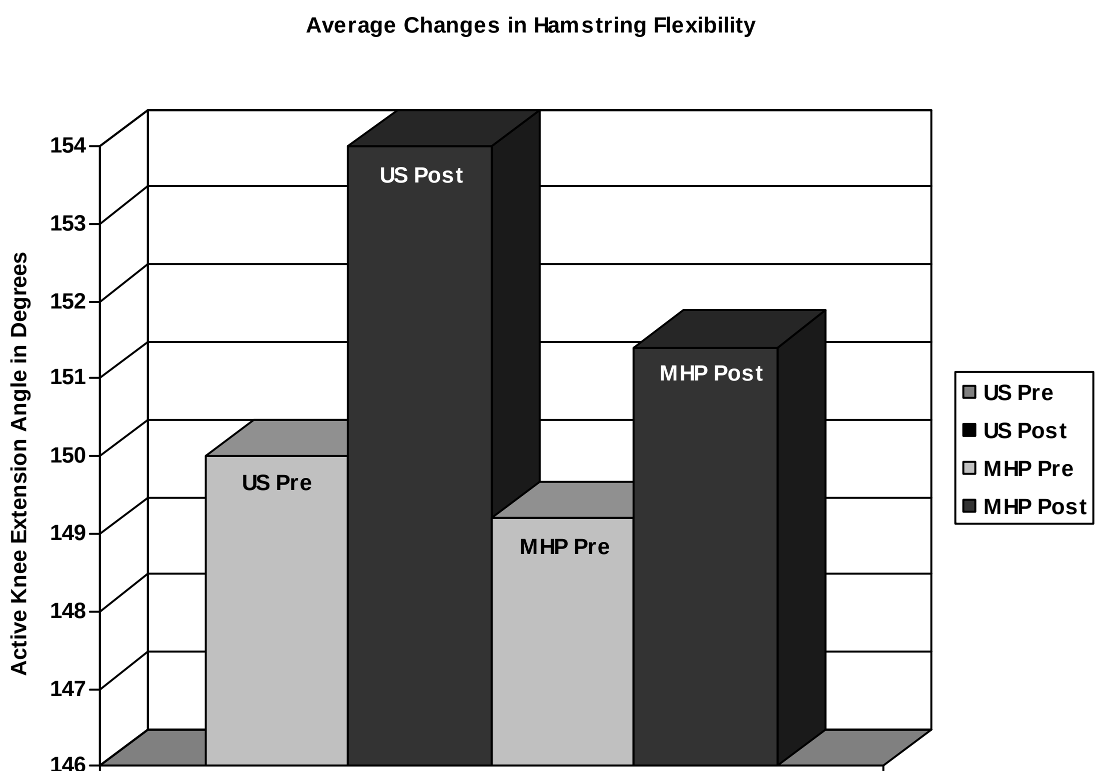

Figure 5: Average pre-treatment and post-treatment AKE measurements.

Discusssion

This study demonstrated that there was no significant difference between US and MHP application in increasing hamstring extensibility (extensibility). Our results were in agreement with Sawyer et al [11], who reported that superficial heat did not significantly increase hamstring extensibility without stretching. Although the muscle groups differed, our results were also similar to those of Knight et al.[4] Comparing US and MHP treatments on the plantar flexors, they found no significant difference between the two treatments when measuring changes in dorsiflexion range of motion after heat application and a stretching routine.

Robertson et al [13] found that the application of heat will increase dorsiflexion range of motion without the aid of a stretch. Contrary to our results, their study found that deep heat produced significantly greater gains than superficial heat. This difference may be explained by their use of short-wave diathermy as the deep heating modality. Short-wave diathermy is capable of treating a larger surface area than US and thus a larger volume of tissue.

Funk et al [12] performed a study comparing MHP treatments without a stretch and a stretching routine alone on hamstring extensibility. They found that MHP treatments resulted in significant increases in hamstring extensibility compared with the stretching routine. Because we found no significant difference between MHP and US treatments, it can be inferred that an US treatment would also be more effective than a stretching routine.

Clinicians must remember that a MHP is a superficial heating modality and 1 MHz US is a deep heating modality. The appropriate treatment should be based on the type of tissue being treated in each patient. Further research should be done to directly compare the effectiveness of 1 MHz US and moist heat on the hamstrings with the addition of a concurrent stretching protocol.

Limitations

A potential limitation of this study was its sample size. Only 13 subjects were used, two of which were unable to complete the US treatment. A larger sample size could have made the results more significant.

Clinical Application

This study shows that US provides greater gains in hamstring extensibility than moist heat without stretching, thus making it the preferred treatment for increasing extensibility. It is also important to note the lack of significant difference between the US and MHP treatments. Many Athletic Training Rooms, particularly in the high school setting, cannot afford US units. The lack of significant difference between these treatments means that Athletic Trainers with limited budgets can still provide effective treatment for their athletes.

Conclusion

There was no significant difference in hamstring extensibility gains between 1 MHz US and an MHP treatment. The US treatment produced greater immediate gains in hamstring extensibility than the MHP treatment. Results indicate that either treatment is an effective means of increasing extensibility of the hamstring muscle group. Although US performed slightly better, institutions that have access only to moist heat can still provide effective and evidence-based treatment to their athletes.

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