The Long Term Effects of Short-Wave Diathermy and Long-Duration Static Stretch on Hamstring Flexibility

Daniel Joseph Graham

Brigham Young University - Provo

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THE LONG TERM EFFECTS OF SHORT-WAVE DIATHERMY
AND LONG-DURATION STATIC STRETCH ON
HAMSTRING FLEXIBILITY

by

Daniel J. Graham

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Exercise Sciences
Brigham Young University
December 2004
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of a thesis submitted by

Daniel J. Graham

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date        David O. Draper, Chair

Date        J. Brent Feland

Date        Dennis L. Eggett
As chair of the candidate’s graduate committee, I have read the thesis of Daniel J. Graham in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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THE LONG TERM EFFECTS OF SHORT-WAVE DIATHERMY AND LONG-DURATION STATIC STRETCH ON HAMSTRING FLEXIBILITY

Daniel J. Graham
Department of Exercise Sciences
Master of Science

Objective: To compare changes in hamstring flexibility from treatments of pulsed short-wave diathermy and prolonged stretch versus sham diathermy and prolonged stretch and control and to observe how long those changes last.

Background: Heat and stretch techniques have been touted for years. To date, the effect of short-wave diathermy and hamstring stretching has not been thoroughly studied. Because diathermy heats a large area and penetrates deep into the muscle, use of this device prior to or during hamstring stretching may increase flexibility and these gains may last longer.

Study Design: A randomized, counterbalanced 3x2x6 repeated measures design. The 3 independent variables were day, pretest/posttest, and treatment mode. Treatment mode
had 3 levels: diathermy and stretch, sham diathermy and stretch, and control. The dependent variable was the change in knee extension range of motion (ROM).

**Methods and Measures:** Thirty college-age students with tight hamstrings (inability to achieve >160° knee extension at 90° hip flexion) participated. Subjects were assigned to 1 of 3 groups, (diathermy and stretch; sham diathermy and stretch; control). Range of motion was recorded before and after each treatment every other day for 2 weeks. Additional ROM measures were taken on days 15, 22, 29, and 36. A straight-leg raise stretch was performed using a mechanical apparatus. Subjects in the diathermy and stretch group received 10 minutes of diathermy (distal hamstrings), 5 minutes of diathermy and stretch, followed by 5 minutes of stretching only. Subjects in the sham diathermy and stretch group followed the same protocol, except the diathermy unit was turned off. Subjects in the control group lay on the table for 20 minutes. Data were analyzed using an ANOVA, an ANCOVA, and post hoc t-tests.

**Results:** Least Squares (LS) Mean (± Pooled SE) increases in knee extension after 6 treatments were: 11.3 ± 1.2° for the diathermy and stretch group; 10.0 ± 1.2° for the sham diathermy and stretch group; and 3.2 ± 1.2° for the control group. At Day 15, 3 days after the last treatment, the diathermy and stretch group lost 6.9 ± 0.8°; the sham diathermy and stretch group lost 6.6 ± 0.8°; and the control group changed 1.6 ± 0.8°. At Day 22 the diathermy and stretch group had lost 7.4 ± 0.8°; the sham diathermy and stretch group lost 6.8 ± 0.8°; and the control group changed 1.7 ± 0.8° from the last treatment. At Day 29 the diathermy and stretch group had lost 8.2 ± 0.9°; the sham diathermy and stretch group lost 7.1 ± 0.9°; and the control group changed 1.7 ± 0.8°.
from the last treatment. At Day 36 the diathermy and stretch group had lost $8.3 \pm 0.8^\circ$; the sham diathermy and stretch group lost $7.4 \pm 0.8^\circ$; and the control group changed $2.1 \pm 0.8^\circ$ from the last treatment.

**Conclusion:** These results indicate that hamstring flexibility can be improved when long-duration or prolonged stretching is used and that those improvements will slowly diminish over several weeks. Clinicians should consider the use of long-duration stretch to help patients with tight hamstrings increase flexibility and maintain those gains over time.
ACKNOWLEDGEMENTS

I would first of like to thank my committee for their expertise and guidance through this study. I would also like to thank them for their patience. Special thanks go to those who gave of their time to serve as either a subject or assistant. I would like to thank my wife for her love, patience, support, and also for setting the example. Thank you sweetie. Lastly I want to thank my kids for serving as the motivation to finish.
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The Long Term Effects of Short-wave Diathermy and Long-Duration Static Stretch on Hamstring Flexibility

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This study was approved by the Human Subjects Committee at Brigham Young University
Abstract

Objective: To compare changes in hamstring flexibility from treatments of pulsed short-wave diathermy and prolonged stretch versus sham diathermy and prolonged stretch and control and to observe how long those changes last.

Background: Heat and stretch techniques have been touted for years. To date the effect of short-wave diathermy and hamstring stretching has not been thoroughly studied. Because diathermy heats a large area and penetrates deep into the muscle, use of this device prior to or during hamstring stretching may increase flexibility and these gains may last longer.

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diathermy and stretch group followed the same protocol, except the diathermy unit was turned off. Subjects in the control group lay on the table for 20 minutes. Data were analyzed using an ANOVA, an ANCOVA, and post hoc t-tests.

**Results:** Least Squares Mean (± Pooled SE) increases in knee extension after 6 treatments were: 11.3 ± 1.2° for the diathermy and stretch group; 10.0 ± 1.2° for the sham diathermy and stretch group; and 3.2 ± 1.2° for the control group. At Day 15, 3 days after the last treatment, the diathermy and stretch group lost 6.9 ± 0.8°; the sham diathermy and stretch group lost 6.6 ± 0.8°; and the control group changed 1.6 ± 0.8°. At Day 22 the diathermy and stretch group had lost 7.4 ± 0.8°; the sham diathermy and stretch group lost 6.8 ± 0.8°; and the control group changed 1.7 ± 0.8° from the last treatment. At Day 29 the diathermy and stretch group had lost 8.2 ± 0.9°; the sham diathermy and stretch group lost 7.1 ± 0.9°; and the control group changed 1.7 ± 0.8° from the last treatment. At Day 36 the diathermy and stretch group had lost 8.3 ± 0.8°; the sham diathermy and stretch group lost 7.4 ± 0.8°; and the control group changed 2.1 ± 0.8° from the last treatment.

**Conclusion:** These results indicate that hamstring flexibility can be improved when long-duration or prolonged stretching is used, and that those improvements will slowly diminish over several weeks. Clinicians should consider the use of long-duration stretch to help patients with tight hamstrings increase flexibility and maintain those gains over time.
Introduction

Many researchers have studied different stretching techniques to determine which one is the most effective at increasing joint range of motion (ROM). Types of stretching most often reported are static stretch, proprioceptive neuromuscular facilitation (PNF), and ballistic stretch.\textsuperscript{1-6} Other researchers have compared the use of adjunct modalities such as whirlpools and moist heat packs,\textsuperscript{7} ultrasound,\textsuperscript{8,9} and diathermy\textsuperscript{10-12} with a stretching protocol.

In a recently published study from our laboratory,\textsuperscript{11} scientists performed research to determine whether or not pulsed short-wave diathermy (PSWD) application applied prior to and during stretching had any impact on hamstring flexibility. The results showed that a diathermy/stretch protocol was far superior than stretching alone in bringing about hamstring flexibility. However, this study had some limitations pointed out to us from reviewers.

First, the study was not blinded since the same person who performed the diathermy treatment also measured ROM. This may have introduced tester bias. Second, the study was performed for only one week. Third, post treatment measures were only taken once, and that was 72 hours after the last treatment. Ideally, to measure flexibility retention, ROM should be measured over several weeks until baseline is reached.

The purpose of our study was to determine if the use of PSWD with long duration static stretching produces increased hamstring flexibility that can be retained longer than static stretching alone. To correct for any possible limitations in our previous study:
• The person who measured ROM did not perform the diathermy or sham treatments.
• We increased the study length to two weeks, but changed the treatments to 3 per week instead of 5.
• We obtained post treatment measurements over a 4-week period.

Methods

Design

This study was a double blind, randomized, counterbalanced 3x2x6 repeated measures with 4 follow ups design. The design was a double-blind study; hence neither the subjects nor the researcher measuring ROM was aware of what group subjects were in. Each day of treatment included a pretest and a posttest measurement for ROM. Pretest/posttest measurements, treatment mode, and days were the 3 independent variables. Diathermy and stretch, sham diathermy and stretch, and control made up the 3 levels of treatment. Knee extension ROM/hamstring flexibility was the dependent variable. Eleven total measurements of hamstring flexibility were recorded over the testing period.

Subjects

Brigham Young University’s Institutional Review Board approved this study prior to any data collection. Thirty college-age students (21.5 ± 2.2 yrs.) were used in the study, and recruited mainly from physical education classes at BYU. Prior to testing, each subject was screened to determine if they qualified to participate in the study. Inclusion criteria consisted of tight hamstrings (unable to achieve greater than 160° of knee
extension with 90° of hip flexion). Exclusion criteria included one or more of the following: (1) lower back or hamstring injury in the past 3 months; (2) acute hamstring swelling; (3) pregnancy; (4) pins, screws, or metal plates in the right lower extremity; (5) a pacemaker, or (6) pain or discomfort in the leg concluded to be more than normal by the researchers. Each subject was assigned a random number for the duration of the study to replace names in order to maintain subject confidentiality. All subjects signed an informed consent form prior to testing.

**Instruments**

We used a Megapulse® (Accelerated Care Plus, Reno, NV) PSWD machine with a 27.12 MHz operating frequency. This unit contains a 200-cm² induction coil housed in an electrode drum with an air space plate of 2 cm. The unit was calibrated before the study. Hamstring flexibility pre, post, and during the study was measured using an MIE inclinometer (Country Technology, Inc., Gays Mills, WI).

The same stretching apparatus used by Draper,¹¹ and similar to that used by Moore and Hutton,¹³ was used in order to passively stretch each subject. This apparatus made it possible for each subject to maintain a straight-leg-raise stretch for the duration of treatment without exerting effort.

**Procedures**

The testing took place over a six-week time period. During the first two weeks, subjects reported to the lab on either a MWF or a TTHSat schedule to receive treatments. During the last four weeks, subjects reported to the lab on one day per week to assess residual ROM. The subjects were tested about the same time each day (in the same 2-
hour time block). Subjects were required to dress in athletic shorts for easy access to the hamstring muscles. After being measured for hamstring flexibility, each subject was randomly assigned to 1 of 3 groups. The groups were (1) diathermy and stretch, (2) sham diathermy and stretch, and (3) control. The control group received two ROM measurements each day they reported to the lab, however, they did not receive any treatment. Subjects in all groups were instructed to refrain from any outside lower extremity stretching over the course of the study.

**Flexibility Measurement**

All hamstring flexibility measurements were made using the following procedure: Subjects began with a pretreatment measure. They took a supine position on the measurement table and reference marks were placed on the subject with a permanent marker. The landmark employed for measurement of knee extension flexibility was the tibial tuberosity. To insure consistent 90° hip flexion for each measurement session, one mark was placed on the lateral side of the thigh and the other on the rib cage, and lined up with corresponding marks on the table as a reference point. The right leg of each subject was passively put into 90° of hip flexion with the knee flexed and the left leg flat on the table. Proper hip and thigh placement were maintained through use of a cross bar attached to the table. The researcher passively extended the right knee to the point of mild discomfort and then measured knee extension with the inclinometer (Figure 1). Individual Day 1, pretreatment measures functioned as the baseline measurement for each subject.

**Treatment**
Subjects in Group 1 were treated using the following protocol: Immediately following the premeasurement, the subject walked to an adjacent room and assumed a prone position on a treatment table for the diathermy treatment. The diathermy drum was placed over the distal musculotendinous junction just superior to the popliteal space of the knee (Figure 2). Group 1 subjects had a 15-minute diathermy treatment using the following parameters: 800 bursts per sec; 400 µ sec interburst interval; peak root mean square amplitude of 150 W per burst and an average root mean square output of 48 W per burst. After 10 minutes of diathermy treatment, the subject was moved to the supine position, and their leg was attached to a pulley and weight system (4.54 kg) by applying a rolled up towel around the ankle, which was attached to a cable. The towel rested on the Achilles tendon region on the subjects’ leg (Figure 3). This pulley and weight system placed the hamstrings in a stretch while providing a constant stretch torque. This stretch lasted for 10 minutes. The first 5 minutes of stretch were accompanied by diathermy over the previously discussed treatment area on the hamstrings. Diathermy was then removed for the remaining 5 minutes of stretch.

At the conclusion of the diathermy and stretch period the subjects were removed from the weight and pulley system. The subjects then walked back to the adjacent room, laid down supine on the measurement table and had their knee extension ROM taken once more.

Group 2 subjects followed the same protocol as Group 1 with the exception that the diathermy machine was not turned on. The control group also reported on a regular every-other-day schedule. Control group subjects were measured when reporting to the
research area in the same manner as Groups 1 and 2. After the premeasurement, control group subjects assumed a prone position on the treatment table for 10 minutes and then supine for the remaining 10 minutes. In this way they mimicked the exact position of Groups 1 and 2. Post treatment measures were then made within the same timeframe as Groups 1 and 2.

To insure reliability of ROM measurements, we analyzed the pretreatment ROM data on the control group across the 10 testing sessions. Analysis results (intraclass correlation coefficient [ICC] model 3, 1) indicated an ICC value of 0.90.

**Statistical Analysis**

The statistical design was a 3 x 2 x 6 repeated measures ANOVA with 4 follow up measurements. Independent variables included treatment (3 levels, between subjects factor), pre/post (2 levels, within subjects factor), and day (6 treatment days with 4 follow up measures). A 3 x 10 repeated measures ANOVA was performed on all pretreatment measures along with 4 follow up measures. The dependent variable was knee extension ROM with the hip at 90° of flexion. A one-way ANCOVA of treatment with the pre day 1 measure as a covariate was performed to compare the difference in the ROM at the end of the sixth treatment and Days15, 22, 29, and 36. An additional one-way ANCOVA of treatment with the pre day 1 measure as a covariate was performed to compare the difference in the ROM at the pre day 1 measure and Days 15, 22, 29, and 36. All post hoc analyses were performed using Tukey adjusted t-tests according to SAS software (Alpha =.05)
Results

Least Squares (LS) Mean (± Pooled SE) increases in knee extension ROM after 6 treatments were: diathermy and stretch, 11.3 ± 1.2°; sham diathermy and stretch, 10.0 ± 1.2°; and control, 3.2 ± 1.2°. An ANCOVA showed there was a significant treatment effect (F = 14.09, P = < 0.0001) for the change in ROM from pre Day 1 to the end of the 6th treatment. Post hoc analysis (Tukey) revealed a significant difference between both stretch groups and the control group. The stretch groups were not significantly different from each other. Means and SE can be found in Table 1.

An ANCOVA showed there was a significant treatment effect for the change in ROM between the post day 6 treatment and Day 15 (F = 14.42, P < 0.0001), Day 22 (F = 15.72, P < 0.0001), Day 29 (F = 15.69, P < 0.0001), Day 36 (F = 16.30, P < 0.0001) post-measurements. Post hoc analysis (Tukey) revealed a significant difference between the diathermy and stretch and sham diathermy versus control at Days 15, 22, 29, and 36. Post hoc analysis (Tukey) for all post treatment measures revealed no significant differences between both stretching groups. Least Squared means and SE can be found in Table 1.

An ANCOVA showed there was no significant treatment effect for the change in ROM between pre day 1 and Day 15 (F = 3.15, P = 0.059), Day 22 (F = 2.16, P = 0.14), Day 29 (F = 1.21, P = 0.31), and Day 36 (F = 1.41, P = 0.26) post-measurements. Least Squared means and SE can be found in Table 1.

There was no significant difference (F = 0.40, P = 0.67) between pre day 1 means of all 3 groups (Table 1). This showed that each group was starting at about the same point in flexibility. Results of the 3 x 10 ANOVA revealed a significant effect for day (F
= 4.73, P <0.0001) with ROM increasing on progressive days. Pretreatment and follow up measures showed no significant difference between the groups. Although the 2 stretch groups separated from the control group, it was not a significant difference on a day-by-day basis. No significant differences were found between the diathermy and stretch group and the stretch only group (Figure 4). At week 4 there was no significant difference (F = 1.41, P = 0.26) between the means of the 3 groups (Table 1). This showed that after 4 weeks all groups were at approximately the same level of flexibility.

An ANCOVA of daily gain on each treatment day (post-pre) showed there was a significant difference between the groups in the increases from pre to post treatment. The F values for these tests ranged from 4.01 (P = 0.03) on Day 1 to 18.80 (P < 0.0001) on the final treatment day. Post hoc analysis (Tukey) showed that in each case the two stretch groups were different from the control group but not from each other.

**Discussion**

In this study, the control group reported a mean change in ROM of 3.2 ± 1.2°. Low load, long duration stretching significantly increased ROM after each treatment, regardless of whether PSWD or sham PSWD was used. There was, however, no significant difference in ROM increases between the two treatment groups. These results differ from our earlier study, where the diathermy/stretch group increased their ROM more than the sham diathermy/stretch group. This result could be attributed to the following method differences used in this study:

- Double blinding
- Decreased frequency of treatment
• Several post treatment measurements
• Different measurement technique

**Double Blinding**

In our first study, the same researcher who applied the diathermy/stretch or sham diathermy/stretch treatments also measured ROM. This study was double blinded in order to remove any possible bias from the researchers. Research assistants performed the diathermy or sham treatments in the modality lab and then a separate person measured range of motion in an adjoining room. Subjects were also unaware if they were receiving the diathermy treatment or the sham diathermy treatment. This is possible because we used a pulsed setting that generated 48 watts. At this setting, we have reported average temperature increases of 4º C in 15 minutes, yet subjects are barely able to notice heat on the skin’s surface.¹⁴

**Study Length**

In this study, treatments occurred every other day for two weeks; whereas in our previous study, treatments occurred daily for one week. The daily stretching in our previous study might explain the higher overall increases in ROM. Subjects, who stretch daily, possibly have greater increases in ROM than those who stretch every other day. Research has shown that stretching 5 times per week produces greater gains in ROM than 3 times per week.¹⁵ In our opinion this might especially hold true for our subjects (college students) who spend several hours a day sitting in class and/or at the computer, which leads to tight hamstrings.
In a clinical setting it is unlikely that a clinician will see a patient everyday. To better reflect the clinical setting, we performed treatments every other day for 2 weeks, providing a day off between each treatment.

**Post-treatment measurements**

In our previous study, we obtained only one post treatment measurement due mainly to time constraints on the researcher and the subjects near the end of a school semester. At Day 8, subjects in the sham diathermy/stretch group lost 58% of their gained ROM, whereas subjects in the diathermy/stretch group lost only 12% of their gained ROM. This shows a trend toward the diathermy group maintaining their ROM longer, yet we still didn’t know how long this ROM would last.

In this study, we measured ROM once a week for the 4 weeks following the last treatment. Post hoc analysis revealed significant differences between the treatment groups and the control group in rate of loss of flexibility, meaning the treatment groups lost ROM at a faster rate than the control group (Table 1). These results were consistent with our first study in that flexibility diminished over time. This demonstrates the need for continual stretching to maintain the ROM that was gained following a stretching regimen.

**Different Measuring Tool**

In our first study\(^{11}\) we used a standard plastic goniometer to record flexibility measurements; whereas, in this study we used an inclinometer. Previous research has shown a good to excellent tester reliability when using the inclinometer with little-to-no
difference in measurement accuracy when compared to the goniometer.\textsuperscript{16,17} This reliability combined with the ease of use led us to use the inclinometer.

**Stretching and Measuring Methods**

Why did we use the knee extension measurement and not the sit and reach test? Many researchers argue that the sit and reach test does not account for spinal and pelvic movement, making it not sensitive enough to isolate flexibility in the hamstrings. Use of the active or passive knee extension test, which we employed, is highly recommended from other researchers.\textsuperscript{1, 2, 18-21}

Why did we stretch subjects for 10 minutes? Research has demonstrated that low-load, long duration (greater than 1 minute) stretching invites permanent, plastic deformation of soft tissue structures.\textsuperscript{20} High-force, short-duration stretching may only produce short-term elastic deformation. There is also a greater risk for injury using a high-load, short-duration stretch. A low-force, slower stretch exhibits less structural weakening than a high-force stretch and produces the same amount of tissue elongation.\textsuperscript{20,22-25} Greater time is required for low-force stretching to produce an equal amount of elongation as high-force stretches. When tensile stress is removed the proportion of lengthened tissue that remains is higher in the low-load, long duration method.\textsuperscript{20}

**Limitations**

Some limitations were noted for this study. In our previous study\textsuperscript{11} we performed both treatment and measurement in the same room. In this study, we used one room to measure ROM and an adjacent room for treatment. At the conclusion of treatment,
subjects had to get up and walk to the adjacent room prior to the post measurement of ROM. Although it was a short distance and a short period of time between treatment and measurement, this may have had a small effect on the flexibility gains that were made. In the future it may be beneficial to try to perform both activities in the same space but still maintain the double-blind nature of the study.

Another limitation of this study was the use of different research assistants in the application of the stretching and diathermy. The lead researcher recorded all ROM measurements but, due to the length of the study (6 weeks), 3 different assistants were used to apply the treatment protocol. Each assistant was instructed properly in the application of the treatment protocol. In the future we recommend that one person performs all treatments and one person performs all ROM measurements. This will make the study more consistent.

One last limitation of this study was that only passive ROM was recorded. Each subject lay prone on the table and the researcher passively flexed the hip to 90° and then passively extended the lower leg to the point of discomfort where the measurement was recorded. Previous research has concluded that both passive and active knee extension tests are reliable in determining ROM. We suggest recording both passive ROM and active ROM in the future in order to compare the differences between the 2 different test results.
Conclusions

Six sessions of low-load, long duration stretch every other day for 2 weeks increased flexibility in all treatment subjects. Subjects receiving PSWD had a slightly greater increase in flexibility but the result was not significant. All treatment subjects maintained some of the flexibility gains over 4 post treatment measures.
References


Table 1. Least Squares (LS) means ± SD in degrees for knee extension range of motion (180°, full knee extension) (n = 10 in each group)

<table>
<thead>
<tr>
<th>Day</th>
<th>Measurement</th>
<th>Diathermy/Stretch</th>
<th>Sham Diathermy/Stretch</th>
<th>Control</th>
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<td>1</td>
<td>Pretreatment</td>
<td>148.4 ± 1.34</td>
<td>150.1 ± 1.34</td>
<td>149.3 ± 1.34</td>
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<tr>
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<td>155.3 ± 1.25</td>
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<td>3</td>
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<td>Post treatment</td>
<td>160.6 ± 1.17</td>
<td>159.2 ± 1.17</td>
<td>152.5 ± 1.16</td>
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Figure 1.
Measuring Flexibility with an inclinometer.
Figure 2.
Applying Diathermy to the distal hamstrings.
Figure 3.
Hamstring stretching apparatus application.
Figure 4.
LS Mean changes in ROM for pre-treatment measures.
Appendix A

Prospectus
Chapter 1
Introduction

Acute musculoskeletal injuries can lead to a myriad of secondary problems during recovery and rehabilitation. Loss of joint range of motion is one of the most common obstacles to overcome. When a muscle has been in a limited position or immobilized following injury, shortening occurs, and the muscle becomes tight and resistant to stretch (Alter, 1996). Often, treatment protocols aimed at increasing flexibility while simultaneously decreasing joint stiffness include a combination of heat and stretch. Whirlpools and moist heat packs (Taylor et al., 1995), ultrasound (Wessling et al., 1987; Draper et al., 1998), and diathermy (Peres et al., 2002; Draper et al., 2004; Draper et al., 2002) traditionally have been the modalities used in concert with stretching to promote increased flexibility of a joint. At this time, little research has been conducted on the longevity of flexibility obtained from a regimen of diathermy and stretching.

Draper et al. (2002) researched the use of heat (using diathermy) and stretch on hamstring flexibility. Both the stretch only and the heat/stretch groups increased in flexibility, but no method was superior to the other. Draper et al. stated that there were a few limitations in their study that might have affected the outcome. For example, they used a standing leg extended/hip flexion stretch, which according to Sullivan et al. (1992) puts the pelvis in a posterior tilted direction making it inadequate for appropriate hamstring stretching. The back saver sit-and-reach test was used to measure flexibility, which Sullivan also reported to be less effective, because it failed to control pelvic and spinal movements.
Draper et al. (2004) corrected for these limitations by stretching the hamstrings using a posteriorly tilted pelvis and by using a more reliable method for measuring hamstring flexibility. The results showed that a diathermy/stretch protocol was far superior than stretching alone in bringing about hamstring flexibility. However, this study also had some limitations. First, this study was not blinded properly because the same person who performed the treatment also measured range of motion. This may introduce tester bias. Second, some subjects complained that the 15 pounds resistance provided by the stretch was too stressful to hold for 10 minutes, which may not have allowed the muscles to relax as much as possible. Third, the study was only performed for one week. Fourth, post treatment measures were only taken 72 hours after the last treatment. Considering the reported differences in flexibility retention at 72 hours by Castro, the lasting effects of the treatment need to be measured over several weeks to gain a greater insight as to the effects of diathermy and stretch.

**Problem Statement**

The purpose of this study is to determine if the use of pulsed shortwave diathermy with long duration static stretching produces increased hamstring flexibility that can be retained longer than static stretching alone.

**Hypotheses**

1. Use of pulsed shortwave diathermy with long duration static stretch will produce greater increases in hamstring flexibility over time than long duration static stretch alone, or control.
2. There is no difference in hamstring flexibility improvement between the three groups.

**Operational Definitions**

Pulsed shortwave diathermy - a modality that employs an induction technique and high frequency (27.12 MHz) electromagnetic current to produce deep heating (2-5 cm) in the tissues. Pulse duration of 800 µ sec at 400 Hz is the minimum parameters required to produce intense heating.

Hamstring tightness - inability to achieve greater than 160° of knee extension with the thigh at 90° of hip flexion.

Long duration stretch – stretch that lasts longer than 1 minute, for purposes of this study a stretch that will last for 10 minutes.

**Assumptions**

Subjects will not alter their level of activity during the length of the study.

**Delimitations**

The only modality being used is pulsed shortwave diathermy. Results may not be generalized to diathermy treatments using a different frequency or different parameters from those we will be using. Only healthy college-age subjects will be used in the study. Results of the study will represent the subjects used and may not be representative of a different age group or subjects with a known pathology other than hamstring tightness. The results cannot be generalized to stretching or measuring techniques outside of those employed in this study.
Significance of Study

Increased flexibility of the hamstrings is often seen as a preventative measure for injury activity. Hamstring flexibility can reduce low-back pain and result in greater ease of movement. Many hamstring studies have observed that flexibility retention has been for very short periods of time. This study will help determine the effectiveness of diathermy and stretch over an extended time period. The ability to increase and maintain a client’s flexibility for an extended period of time will be a valuable tool for those in sports medicine fields and other health care professions.
Chapter 2

Review of Literature

Table 1 summarizes databases, years, and keywords searched:

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This literature review will be divided into the following subheadings: stretching, flexibility measuring, diathermy, heating effects, and stretch and heat.

Stretching

**Stretching Techniques.** Static stretching, ballistic stretching, and proprioceptive neuromuscular facilitation (PNF) are the most commonly studied stretching techniques. Definitions for these three techniques come from Arnheim & Prentice (Tenth Edition, 2000). Static stretching is done by passively stretching an antagonist muscle by placing it in a maximal stretch and holding it there. Ballistic stretching is an older stretching technique that employs the use of repetitive bouncing motions. This technique includes the danger of going beyond the limits of extensibility in the muscle during the bouncing motions. This can lead to injury and is not a recommended stretching technique.
Proprioceptive neuromuscular facilitation is a technique involving combinations of alternating contractions and stretches. The goal of PNF stretching is facilitation of the agonist muscle. Facilitating the agonist will increase the recruitment of additional motorneurons or increase the excitability of the motorneurons already in use. Agonist facilitation leads to inhibition (a decrease in the excitability) of the antagonist (the stretched muscle). These events result in the relaxation of the inhibited muscle and muscular resistance in the facilitated muscle (Alter, 1996).

**Stretch Duration.** Bandy et al. (1994) studied the duration a static stretch should be maintained in order to maximize the benefits. Subjects with “tight” hamstrings were recruited to participate. Fifty-seven subjects were randomly assigned to one of four groups. The groups were given different modes of stretch and different time durations to hold those stretches. The researchers concluded that 30 seconds of static stretching 5 times a week was just as effective as 60 seconds of static stretching 5 times a week. They concluded that holding a stretch for a duration longer than 30 seconds was not necessary.

Bandy et al. (1997) again looked at duration of stretching and included frequency as another variable. Ninety-three subjects with limited hamstring flexibility were assigned randomly to one of 5 groups. Four of the groups were assigned to stretch 5 days per week for 6 weeks with each group stretching 1 to 3 times per day. The fifth group served as the control group. This study reconfirmed the findings of their previous study, a 30 second static stretch was as effective as 60 seconds. The researchers also reported that there was no significant difference between the groups stretching once per day and those stretching 2 or 3 times per day.
Feland et al. (2001) performed a study examining the effect of duration of stretching of the hamstrings in increasing range of motion in people aged 65 years or older. Sixty-two subjects with tight hamstring muscles were randomly assigned to 1 of 4 groups. The subjects in group 1 performed no stretching and served as a control. The randomly selected right or left limb of subjects in group 2, 3, and 4 was stretched 5 times per week for 6 weeks for 15, 30, and 60 seconds, respectively. Range of motion was measured once a week for 10 weeks to determine the treatment and residual effects. Researchers found that a 60-second stretch produced greater gains in range of motion, which lasted longer than the gains in any other group. These results may differ from studies performed with younger populations because of age-related physiologic changes.

**Static Stretching vs. Other Techniques.** Sullivan et al. (1992) set out to compare static stretching to PNF stretching. They also looked at the significance of the position of the pelvis during the stretching regimen. Randomly assigned subjects formed two groups, a posterior tilted pelvis group and an anterior tilted pelvis group. These subjects were then assigned to either the static stretch or PNF stretch group. Sullivan et al. concluded that pelvic position was more important than the stretch method (static or PNF) employed. Researchers found that an anterior pelvic tilt brought the ischial tuberosity into a superiorly and posterior displaced position. This position put the ischial tuberosity farther from the proximal tibial and fibular insertions of the hamstrings resulting in greater stress on the hamstring muscle and increased muscle elongation. Researchers concluded that anterior pelvic tilt was superior to posterior pelvic tilt in facilitating increased hamstring flexibility.
Bandy et al. (1998) performed a study comparing the effects of static stretch and dynamic range of motion (DROM) training on the flexibility of the hamstring muscles. During DROM, a contraction by the antagonist muscle causes the joint crossed by the agonist (lengthening muscle) to move through the full range of motion at a controlled, slow tempo. Fifty-eight subjects with limited hamstring flexibility (defined as 30 degrees loss of knee extension measured with the femur held at 90 degrees of hip flexion) were randomly assigned to one of three groups. One group performed DROM 5 days a week. The second group performed one 30-second static stretch, 5 days per week. The third group served as a control group and did not stretch. Before and after 6 weeks of training, flexibility of the hamstring muscles was determined in all three groups by measuring knee extension range of motion with the femur maintained in 90 degrees of hip flexion. The results of this study suggest that, although both static stretch and DROM will increase hamstring flexibility, a 30-second static stretch was more effective than DROM for enhancing flexibility. Given the fact that a 30-second static stretch increased range of motion more than two times that of DROM, the use of DROM to increase flexibility of muscle must be questioned.

Spernoga et al. (2001) examined the hold-relax method of stretch. Thirty male subjects with limited hamstring flexibility in the right lower extremity were randomly assigned to 1 of 2 groups: control (no-stretch) or experimental (stretch). All subjects performed 6 warm-up active knee extensions, with the last repetition serving as the pre-stretch measurement. The experimental group received 5 modified (no-rotation) hold-relax stretches, whereas the control group rested quietly supine on a table for 5 minutes.
Posttest measurements were recorded for both groups at 0, 2, 4, 6, 8, 16, and 32 minutes. Results revealed a significant group-by-time interaction, a significant main effect for group, and a significant main effect for time. These results suggest that a sequence of 5 modified hold-relax stretches produced significantly increased hamstring flexibility that lasted 6 minutes after the stretching protocol ended.

A study by Gribble et al. (1999) compared static stretching with the hold and relax method of stretch. Forty-two participants were randomly assigned to either a control, static, or hold-relax training group. Participants were stretched four times a week over a 6-week period, with four 30-second stretches per session using a straight-leg-raise method on the FlexAbility LE1000. Researchers determined that both static and hold-relax techniques significantly improved hamstring flexibility. Participants of both techniques reached a plateau in flexibility improvement between weeks 4 and 5. Thus, static and hold-relax stretching are equally effective in improving hamstring range of motion (ROM) over several weeks time.

*Passive Stretch.* Medeiros et al. (1977) compared the effectiveness of isometric and passive stretch on ROM increases about a joint. The passive stretch group performed 20 passive stretches per day at their threshold forces. The duration of stretches was 3 seconds with a 15 second rest period between. The isometric stretch group performed 20 isometric hip extension contractions at threshold force and matching limb position for 6 seconds with a 15 second rest period between each contraction. Researchers concluded that both passive and isometric stretch methods are effective means of increasing joint ROM.
Moore and Hutton (1980) sought to determine the level of relaxation in a muscle during passive (P), modified contract-relax (CR), and contract-relax with agonist contraction (CRAC) PNF stretching methods using electromyogram (EMG). Twenty-one female gymnasts were recruited as subjects. Each subject was instructed to execute each stretching method in order to produce a hamstring stretch. Three consecutive trials were performed for each stretching method. During testing, each stretch was held for 9 seconds. Prior to the CR and CRAC tests, a 5-second isometric hip-flexor contraction was performed. The researchers concluded that passive stretching exhibited the least amount of tension when compared to the 2 other techniques when measured after the stretch.

Magnusson et al. (1996) studied passive resistance to stretch in human hamstring muscle. Thirty male subjects with varying levels of flexibility were used. “Loose” subjects were those with a hip flexion ROM greater than 90°. Tight subjects exhibited a hip flexion ROM no greater than 70°. “Normal” subjects had hip flexion ROM between 70° and 90°. A goniometer was used to determine these ranges. The arms of the goniometer were on the lateral knee joint line and the trunk of the subject. Researchers determined that looser subjects were more resistant to stretch than tight subjects due their ability to stretch further to begin with.

Halbertsma et al. (1994) examined the effect of passive extensibility and stiffness on subjects determined to have short hamstrings. Fourteen volunteers were selected from a young healthy population with the toe-touch test (finger-ground distance greater than 0 cm), and a straight-leg-raising angle about 80°. According to usual standards the
diagnosis was short hamstrings. One group of 7 subjects was treated for 4 weeks with a daily home exercise program aimed at stretching the hamstrings, whereas the untreated group was used as a control. Instrumental straight-leg-raising was performed in the subjects of both groups. Results showed a slight but significant increase in the extensibility of the hamstrings accompanied with a significant increase of the stretching moment tolerated by the passive hamstring muscles, however, the elasticity remained the same. They concluded that stretching exercises do not make short hamstrings any longer or less stiff, but only influence the stretch tolerance.

Halbertsma et al. (1996) again performed a study looking at the effect of passive extensibility and stiffness on those with “short” hamstrings. Sixteen subjects without any history of neurological and orthopedic disorders were recruited. To select subjects with short hamstrings, the finger-ground distance had to be greater than 0 cm (unable to touch the floor when bending forward) and the manual leg lifting was not to exceed 80°. One group of 10 subjects performed static stretching exercises for 10 minutes interspersed with periods of muscle relaxation, whereas the untreated group of 6 subjects was used as a control. One 10-minute static stretch resulted in a significant increase in passive muscle movement, ROM, and elongation of the hamstrings. There was no significant change in the course of the passive muscle stiffness curve with respect to the pre-stretch stiffness curve. Researchers concluded that one session of static stretching does not influence the course of the passive muscle stiffness curve. The increased ROM, the extensibility of the hamstrings, is a result of the increase in stretch tolerance.
Several conclusions can be drawn from the preceding literature. First, a stretch must last at least 30 seconds in length to be effective in a population with an average age of 26. Second, an anterior rotated pelvis is the most useful position of the hips to perform a stretch. Third, active and passive stretching techniques are both effective in increasing hamstring flexibility. In our study we will use a passive stretch for 10 minutes with the pelvis in an anteriorly rotated position.

*Flexibility Measuring*

Traditionally the standard sit-and-reach test has been the benchmark method of measuring hamstring flexibility. Patterson et al. (1996) reported a reliability of \( r=0.99 \) on the back saver sit-and-reach test. Chung and Yuen (1999) determined that traditional, modified, and YMCA sit-and-reach tests were valid in assessing hamstring flexibility. Hui and Yuen (2000) concluded that a modified back saver sit-and-reach test was a reliable measure of hamstring flexibility. Jones et al. (1998) introduced the chair sit-and-reach test, a modification of the traditional sit-and-reach test, as a valid alternative to the traditional method. The inability of the sit-and-reach test to control both pelvic and spinal movements has brought its level of sensitivity into question. Sullivan et al. (1992) came to the conclusion that active knee extension is more sensitive to changes in ROM than the sit-and-reach test.

Gajdosik and Lusin (1983) used an active knee extension measurement in which the subject’s hip was placed, using a pendulum goniometer directly on their leg, at 90° of flexion with the foot plantar flexed. Subject’s knee flexion angle was recorded after they were instructed to slightly flex their knee in order to prevent the myoclonus induced by
knee extension. Webright et al. (1997) was able to avoid the problem of myoclonus by having subjects pause for 1 second at their end range of knee extension. Webright et al. used video in order to record knee flexion angles. Both testing routines are equally reliable.

Bandy et al. (1994, 1997) reported that the most favorable method of measuring hamstring flexibility is to use either the passive or active knee extension technique. This technique is performed by having the subject lie supine and the leg being measured in $90^\circ$ of hip and $90^\circ$ of knee flexion. At this point, the subject either has a tester passively extend the knee, or the subject actively extends the knee to the point of tightness, or until pain is felt in the hamstrings.

The sit-and-reach test or any of its modifications are effective methods at measuring hamstring and low back flexibility. The active knee extension technique has been shown to be a reliable measuring tool as well. We will use the passive knee extension technique, because it tests the hamstrings specifically and the low back muscles are not a factor. It is also a more comfortable technique for long duration stretching.

**Diathermy**

Diathermy converts electromagnetic energy into heat, thus making it a deep heating modality (Cole and Eagleston, 1994). Diathermy research has not been broad in scale. Most research on the effects of diathermy was conducted prior to 1980. Research exploring the beneficial effects of diathermy, as an effective modality in clinical treatment, has been a topic of increased research, recently.
Treatment of sports related injuries and deep heating of superficial muscles and subcutaneous tissues are uses of diathermy (Cole and Eagleston, 1994). Draper et al. (1999) helped determine the parameters of an effective diathermy treatment. A 15-20 minute treatment of PSWD (pulsed short wave diathermy) at a setting of 800Hz, an intensity of 150 watts, and a pulse width of 400 µsec with an interpulse interval 12.5 msec, provides vigorous heating (increases of 4° C over baseline) in muscle 3-5 cm deep. Therapeutic benefits such as decreased pain, decreased muscle spasm, and joint and muscle contracture reduction result from the deep heating of the muscle (Cole & Eagleston, 1994).

There are several other reported benefits through the use of diathermy. Increased blood flow (Abramson et al., 1960), enhanced recovery from ligamentous injury and hematoma, decrease in joint stiffness (Behrens and Michlovitz, 1996; Lehmann et al. 1974), and collagen tissue extensibility (Behrens and Michlovitz, 1996) are some of the benefits reported. Draper et al. (1999) found that use of a stationary pulsed short wave diathermy applicator makes the heat more constant. Also, according to Garrett et al. (2000), diathermy can heat larger body areas in one treatment as compared to ultrasound. The heated area can be as large as the size of the diathermy applicator (200 cm²). They also found heat retention to last longer than with ultrasound.

Heating Effects

Response to the application of heat in muscle and similar connective tissue is equivalent. Therapeutic effects arise through specific tissue temperature increases. Tissue temperature increases of 1°C from a baseline temperature of 37°C lead to increase in
metabolic rate. Tissue temperature increases of 2-3°C produce an increase in blood flow and a decrease in pain, muscle spasm, and inflammation (Draper and Ricard, 1995; Lehmann et al., 1970).

Injury recovery (Brown and Baker, 1987) and reduction of pain and muscle spasm (Lehmann et al., 1974) have been shown to be the result of increased blood flow and increased tissue temperature. Intense heating (> 4°C) has been shown to decrease tissue viscosity and increase tissue extensibility (Lehmann et al., 1970, Lehmann et al., 1974; Warren et al., 1971) and tension (Lehmann et al., 1970).

Sapega et al. (1981) summarized the effects of temperature on connective tissue during tensile deformation into three concepts. First, extensibility of connective tissue increases with the rise of temperature in that tissue. Second, after stretching connective tissue at an increased temperature, maintaining that stretch during cooling of the tissue extends the lasting effects. Third, when connective tissue is stretched within the therapeutic range (102-110°F), structural weakening incurred through the stretch, is diminished in proportion to the temperature. Sapega et al. came to the conclusion that “structural weakening produced by permanent tissue deformation is minimized when prolonged, low-force application is combined with high therapeutic temperatures” and that “plastic or permanent lengthening is most favored by lower force, longer duration stretching at elevated temperatures.” Longer duration stretch was defined as maintaining the stretch during the cooling of the tissue. Lower force was not defined by the researchers.
Stretch and Heat

The combination of stretch and heat is a common method used in the clinical setting. Taylor et al. (1995) stated that therapists often use deep heating modalities in order to improve tissue extensibility, so as to allow for increased effectiveness of stretching regimens. In a study, using ultrasound in combination with a static stretch, Wessling et al. (1987) found that triceps surae extensibility increased when compared to static stretching alone, without the ultrasound.

Draper et al. (2002) looked at the effects of low-load, short duration stretching with or without high-intensity, pulsed shortwave diathermy on hamstring flexibility. Three groups consisting of stretch and diathermy, stretch alone, and control were used. Using a sit-and-reach test, 37 college-age subjects were treated and tested for 5 days with a follow-up test performed 72 hours later. Diathermy and stretch subjects received a 15-minute diathermy treatment on the right hamstring. Stretch-only subjects received a sham 15-minute diathermy treatment. These 2 groups followed their treatment with three 30-second stretches before being retested. The control group lay prone for 15-minutes prior to retesting. They concluded that diathermy and short-duration stretch was no more effective than short-duration stretching alone at increasing hamstring flexibility. There were a few weaknesses in this study that may have altered the results. First, the method of stretching was an active hurdler’s stretch with the pelvis in a posterior tilt. Sullivan et al. (1992) showed that an anterior pelvic tilt is much more effective. Second, stretching periods were 3 x 30 seconds, which may have been too short of a time period to achieve...
lasting gains in flexibility. Third, the duration of treatment in the study was only for one week.

Rubley et al. (2001) followed the same basic research design as Draper et al. (2002) but wanted to determine the long-term effects versus the short-term effects of pulsed shortwave diathermy on hamstring flexibility. Subjects were measured not only 72 hours after the final treatment, but received a weekly flexibility measure for 4 weeks after the cessation of treatment. Researchers found that increases in flexibility remained for 3 weeks after testing.

Draper et al. (2004) performed a similar study to Draper et al. (2002), but with a few changes. Castro did not use the sit-and-reach test, but used a passive extension measure of the right hamstrings through use of a goniometer. A straight-leg raise method of stretching using an apparatus similar to that used by Moore and Hutton (1980) was utilized for the stretching period. This stretching method put the subject in an anterior pelvic tilt. Subjects in the diathermy-stretch group received 15 minutes diathermy with 10 minutes passive stretch. Subjects in the stretch-only group received a 15-minute sham diathermy treatment with 10 minutes of passive stretch. The control group lay supine for 15 minutes. Researchers came to the conclusion that a treatment regimen of 15 minutes PSWD and 10 minutes of passive stretch for 5 days increases hamstring flexibility 3 times more than the other groups. They also stated the diathermy and stretch group retained more flexibility 72 hours after testing, than the other groups.

Peres et al. (2002) conducted a study comparing use of PSWD in combination with stretching of the gastrocnemius to stretching with no heat modality.
subjects were divided into 4 groups: control, stretching, stretching and diathermy, and stretching and diathermy with ice applied. Each subject received 14 treatments over a 3-week period, with a follow-up measure 6 days after the last treatment. A digital inclinometer was used to measure ankle dorsiflexion before and after treatments. After 14 days of treatment, the range of motion increase was greater after heat and stretching than after stretching alone. After 6 additional days rest, the heat and stretching ROM increase was greater than that for stretching alone. They concluded that PSWD applied prior to long-duration static stretch is more effective than stretching alone.

Lehmann et al. (1970) determined that heat and stretch in combination with one another caused significant increases in tendon length. This same result could not be found when looking at heat alone, or stretch alone in increasing tendon length. They also concluded that a sustained stretch, with heat, produced greater tendon length increases versus a short-duration stretch with heat. Lehmann et al. were also able to conclude that the greatest length retention occurred when the sustained stretch is prolonged after the heating modality is removed. They suggested that muscle contractures can best be overcome by using heat during stretch, and then continuing to stretch after heat is removed and cooling is underway.

Draper et al. (1998) researched the effects of stretch and heat using ultrasound. They compared ultrasound and passive stretch to passive stretch alone of the triceps surae muscle. They concluded that ultrasound and stretch increased ROM immediately, but in the long-term the gains were not much different than the stretch-only group. They also concluded that a surface area too small in size was heated in order to gain lasting effects.
The ultrasound transducer head had an ERA (effective radiating area) of 4 cm$^2$ and could adequately heat an area 8 cm$^2$. Heating of a large area, such as the hamstring, with ultrasound will be inadequate, and the thermal effects will be minimal. Draper et al. (1999) went further to conclude that ultrasound is not effective in treating large areas. They went on further to determine that tissues retain their heat 60% longer when heated through PSWD as compared to ultrasound. The ability to retain heat longer provides an increased “stretching window” in which benefits from the heating process can be increased.

Lentell et al. (1992) performed a study comparing the effects of superficial heat, cold, and low-load, long-duration stretch on increasing shoulder flexibility. Groups using heat demonstrated rapid and lasting flexibility increases. Groups using cold did not report similar results in long duration stretching routines.

**Summary**

Through our review of literature we were able to determine that use of an anteriorly tilted pelvis during a hamstring stretch provides the best flexibility. Second, we found that passive or active knee extension was the most valid way to correctly measure flexibility of the hamstrings. These 2 findings will be incorporated into our study.

Our review of literature also determined the appropriate parameters for use of pulsed shortwave diathermy. These parameters are: 1) a setting of 800Hz, an intensity of 150 watts, and a pulse width of 400 µsec with an interpulse interval of 12.5 msec for 15 minutes in order to produce vigorous heating; 2) heat should be applied before and during the stretch; 3) the stretch should be prolonged during the cooling phase so as to obtain
plastic or lasting elongation; and 4) a long duration, low load stretch should be used. All of these parameters will be employed in our study.
Design

A double blind, randomized, counterbalanced 2x3x11 repeated measures design will guide this study. The design is a double-blind study; hence neither the subjects nor the researcher measuring ROM will be aware of what group subjects are in. All treatments will include a pretest and a posttest measurement for ROM. Pretest/posttest measurements, treatment mode, and day are the 3 independent variables. Diathermy and 10 pounds resistance, diathermy and 15 pounds resistance, and control will make up the 3 levels of treatment. Knee extension ROM/hamstring flexibility will be the dependent variable. Eleven total measurements of hamstring flexibility will be recorded over the testing period.

Subjects

Brigham Young University’s Institutional Review Board will approve this study prior to any recruitment of subjects. Thirty college-age students will be used in the study, and recruited mainly from physical education classes at BYU. Prior to testing, each subject will be screened to determine if they qualify to participate in the study. Inclusion criteria consist of tight hamstrings (unable to achieve greater than 160° of knee extension with 90° of hip flexion). Exclusion criteria include one or more of the following: (1) lower back or hamstring injury in the past 3 months; (2) acute hamstring swelling; (3) pregnancy; (4) pins, screws, or metal plates in the right lower extremity; (5) a pacemaker, or (6) pain or discomfort in the leg concluded to be more than normal by the researchers.
Each subject will be assigned a random number for the duration of the study and will never be referred to by name in research or publication of this research in order to maintain subject confidentiality.

A one-page informed consent document describing the procedures, benefits, potential risks, and subject’s right to forgo involvement in the study will be distributed to all subjects. Subjects will be required to give informed consent by reading and signing the form before testing. Subjects will also be required to dress in athletic shorts for easy access to the hamstring muscles.

After being measured for hamstring flexibility, each subject will be assigned to one of 3 groups using a stratified, random formula. The groups are: (1) diathermy and stretch with 10 pounds resistance, (2) diathermy sham and stretch, and (3) sham control. The control group will receive two measurements each day but no treatment. Subjects in all groups will refrain from any outside lower extremity stretching over the course of the study.

*Instruments*

We will use a Megapulse® (Accelerated Care Plus, Sparks, NV) pulsed shortwave diathermy machine with a 27.12 MHz operating frequency. This unit contains a 200-cm² induction coil housed in an electrode drum with an air space plate of 2 cm. The unit will be calibrated before the study. Hamstring flexibility pre, post, and during the study will be measured using an MIE inclinometer (Country Technology, Inc., Gays Mills, WI). This same inclinometer will be used to ensure that hip flexion is at 90° during the initial measurement. A crossbar will be placed against the thigh to prevent hip flexion
from going beyond 90°. When the subject’s hip is at 90° a mark will be placed on the thigh, which will correspond to a mark on the table. During each measurement these 2 marks will be aligned in order to make sure that the hip is flexed to 90°. Stretching and diathermy treatment sessions will be timed with a timer built in to the diathermy machine.

The same stretching apparatus used by Draper et al. (2004), and similar to that used by Moore and Hutton (1980), will be used in order to passively stretch each subject. This apparatus will make it possible for each subject to maintain the position of stretch for the duration of treatment without each subject exerting effort.

**Procedures**

The testing will occur over a six-week time period. The subjects will be tested about the same time each day (in the same 2-hour time block). Subjects in Group 1 will be tested Monday, Wednesday, and Friday for 2 straight weeks. Subjects in Group 2 will be tested Tuesday, Thursday, and Saturday for 2 straight weeks. Control group subjects will also be measured on an every other day schedule. All groups will then be measured 72 hours after final treatment in order to obtain a posttest measurement. Subjects will continue to have their ROM measured once each week for 4 weeks after the last treatment in order to assess the lasting effect of the 2 protocols.

Group 1 subjects will begin with a pretreatment measure. They will lie supine on the measurement table; the right leg of each subject will be put into 90° of hip flexion with the knee flexed and the left leg flat on the table. Proper hip and thigh placement will be maintained through use of a cross bar. The tester will then passively extend the right
knee to the point of mild discomfort. The flexibility measurement, through the use of the inclinometer, will be recorded at this time. The landmark employed for measurement of flexibility will be the tibial tuberosity. This landmark will be marked with a permanent marker so as to assure accuracy of measurement. Another mark will be placed on the lateral side of the thigh and lined up with a mark on the table as a reference point to insure consistent hip positioning for each measurement session.

Immediately following the premeasurement, the subject will move to the prone position on the treatment table for the diathermy treatment. The diathermy drum will be placed over the distal musculotendinous junction just superior to the popliteal space of the knee. Group 1 subjects will have a 15 minute diathermy treatment using the following parameters: 800 bursts per sec; 400 µ sec interburst interval; a peak root mean square amplitude of 150 W per burst and an average root mean square output of 48 W per burst. After 10 minutes of diathermy treatment, the subject will move to the supine position, and the leg will be attached to a pulley and weight system (4.54 kg) by applying a padded cuff around the ankle, which is attached to a cable. The cuff will rest on the Achilles tendon region on the subject’s leg. Group 1 will have 10 pounds resistance. This pulley and weight system will place the hamstrings in a stretch while providing a constant stretch torque. This stretch will last for 10 minutes. The first 5 minutes of stretch will be accompanied by diathermy over the previously discussed treatment area on the hamstrings. Diathermy will be removed for the remaining 5 minutes of stretch.
At the conclusion of the diathermy and stretch period the subject will be removed from the weight and pulley system. The subject will then move back to the measurement table and have their knee extension ROM taken once more.

Group 2 subjects will follow the same protocol as Group 1 with the exception of not turning the diathermy machine on. The control group will report on a regular every other day schedule. Control group subjects will be measured when reporting to the research area in the same manner as Groups 1 and 2. After the premeasurement, control group subjects will lie prone on the treatment table for 10 minutes and then supine for the remaining 10 minutes. In this way they mimic the exact position of groups 1 and 2. They will then have the second flexibility measurement taken after the rest period.

Analysis

A 2x3x11 repeated measures (pretest and posttest measurements for all treatments) ANOVA will be used to calculate the differences in range of motion/flexibility between groups. A Tukey post hoc test will be used for follow-up tests. The alpha levels will be fixed at 0.05.
References


36. Rubley MD, Brucker JB, Knight KL, Ricard MD, Draper DO. Flexibility retention 3 weeks after a 5-day training regime. *J Sport Rehab.* 2001;10;105-112.


Appendix A-1

Research Consent Form
Research Consent Form

This study will research the effect of using deep heat in conjunction with stated stretching on hamstring flexibility. This study will last for approximately 6 weeks. For the first 14 days, the subjects will participate in 6 treatment sessions, 1 every other day, lasting 25-30 minutes. Following the final treatment, the subjects will receive no treatment for 72 hours, and will then be measured after that period. The subjects will then report once a week for the following 4 weeks for follow-up measurements. These follow-up measurements will last approximately 5 minutes each. Daniel J. Graham, A.T.C., and graduate student in Athletic Training at Brigham Young University will conduct the study. Dr. David Draper, A.T.C., Professor of Graduate Athletic Training in the Physical Education department at Brigham Young University will supervise the study. Research will be conducted in room 123 of the Richards Building of BYU.

Previous studies on heat and stretch have been inconclusive. We want to see if using a uniform method of heating muscle prior to stretch will increase a muscle’s flexibility. We also want to see how long retention of flexibility gains lasts. The machine we will use is called pulsed short-wave diathermy. This device sends electromagnetic waves into the muscle that cause an increased movement in molecules that results in comfortable increases in muscle temperature. You will not feel much heat on your skin since this heats from inside out. This technique has been proven safe and effective and has been used in physical therapy for more than 50 years.

You will be randomly assigned to 1 of 3 groups. Depending on which group you are in you may do one of the following steps. For the first step, you will begin by lying face up on a treatment table. Your right leg, with your knee bent, will be brought up to a right angle at the hip. The researcher will then straighten your leg until you feel slight discomfort. Your knee extension range of motion (ROM) will then be measured. After the measurement, your leg will be brought back down to the table. You will then move to a different treatment area. If you are assigned to group 1 or 2, you will then be asked to lie on your stomach. The diathermy drum will be placed on the back of your leg, just above the knee. For subjects in Group 1, the diathermy machine will be turned on for a treatment time of 15 minutes. Those in Group 2 will not have the machine turned on, however it will appear that the machine is working. After 10 minutes of diathermy, you will be asked to turn over on your back, and your leg will be attached, at the ankle, to a stretching apparatus. This apparatus will pull the leg into a straight-leg-raise stretch, to the point of mild discomfort. This position will be held for the final 5 minutes of diathermy and for 5 minutes after diathermy. At the conclusion of the stretch, you will be disconnected from the stretching apparatus, and then measured again, as above.

Subjects in Group 3 will be measured using the same process as the other groups. The first measure will be taken when you first arrive and then you will be asked to lie on your stomach for 10 minutes. The diathermy drum will be placed on the back of your leg, just above the knee. After 10 minutes you will be asked to roll over onto your back where you will remain for the final 10 minutes. At the conclusion you will be measured once again.
In order to participate in the study, you must exhibit tight hamstrings (the inability to achieve greater than 160° of knee extension at 90° of hip flexion). The following are risks of short-wave diathermy and if you have any of the following you will not be allowed to participate in this study: (1) pregnancy, (2) metal plates, screws, or pins present in the right lower extremity, (3) acute swelling of the hamstring, and (4) a pacemaker. Although not a risk of diathermy use, you will be excluded if you have had a previous lower back or hamstring injury within the past 6 months, or if during the study you experience discomfort that the researchers conclude as more than normal. More than normal discomfort includes shooting pain while in the stretch position, sensitivity to heat from the diathermy machine, and/or significant pain during any point of the treatment.

Participation in this study is voluntary. You may terminate your involvement in the study at any time, without any bias or concern. You may benefit from increased hamstring flexibility because of your participation in the study. Although this is not usually the case, there may be some discomfort experienced during prolonged stretching and diathermy. This discomfort will be no worse than what is normally felt during a stretch, and should only last as long as you are being stretched. You may feel some slight soreness the day after being treated, but it will be mild and should decrease as the study continues. If you feel any more discomfort than this, please tell the researcher.

Confidentiality will be maintained throughout the course of the study by assigning a number to each subject. No individual identifying information will be disclosed. Questions regarding the research can be addressed by Dr. David O. Draper, A.T.C, 120C RB, Brigham Young University, Provo, UT 84602 (telephone: 801-422-2679). Should you have any questions regarding your rights as a participant, contact Dr. Shane Schulties, Chair of the Institutional Review Board, Brigham Young University, Provo, UT 84602 (801-422-3982).

I have read, understood, and received a copy of the above consent, and desire of my own free will and volition to participate in this study and accept the benefits and risks relating to the study.

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Appendix B

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