Shortwave Diathermy and Prolonged Stretching Increase Hamstring Flexibility More Than Prolonged Stretching Alone

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RESEARCH REPORT

Study Design: A randomized, counterbalanced 2×3×5 repeated-measures design.

Objective: To compare changes in hamstring flexibility after treatments of pulsed shortwave diathermy and prolonged stretch, sham diathermy and prolonged stretch, and control.

Background: Heat and stretch techniques have been touted for years. To date, the effect of shortwave diathermy and hamstring stretching has not been 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.

Methods and Measures: Thirty college-age students (mean age, 21.5 years) with tight hamstrings (inability to achieve greater than 160° knee extension at 90° hip flexion) participated. Subjects were assigned to 1 of 3 groups: diathermy and stretch, sham diathermy and stretch, and control). Range of motion was recorded before and after each treatment for 5 days and on day 8. 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) followed by 5 minutes of simultaneous diathermy and stretch, followed by 5 minutes of stretching only. Subjects in the sham-diathermy-and-stretch group followed the same protocol, but with the diathermy unit turned off. Subjects in the control group lay on the table for 20 minutes. Data were analyzed using an ANOVA and post hoc *t* tests.

Results: Mean (± pooled SE) increases in knee extension after 5 days were 15.8° ± 2.2° for the diathermy-and-stretch group, 5.2° ± 2.2° for the sham-diathermy-and-stretch group, and –0.3° ± 2.2° for the control group. Seventy-two hours after the last treatment, the diathermy-and-stretch group lost 1.9° ± 2.2°, the sham-diathermy-and-stretch group lost 3.0° ± 2.2°, and the control group changed –0.4° ± 2.2°.

Conclusion: These results suggest that hamstring flexibility can be greatly improved when shortwave diathermy is used in conjunction with prolonged stretching. *J Orthop Sports Phys Ther 2004;34:13-20.*

Key Words: *heat, muscle, range of motion, thigh*

When a muscle has been in a shortened position or immobilized following injury, shortening occurs and the muscle becomes quite resistant to stretch.[1] Probably the most widely used method for increasing joint range of motion (ROM) is stretching. In some settings, clinicians use a combination of heat and stretch for increasing flexibility and decreasing joint stiffness. A wide variety of heating modalities, including moist heat packs, whirlpools, ultrasound, and diathermy, have traditionally been used in an effort to promote greater increases in flexibility.[4,5,14,18,27,30] Until recently, little research had been conducted on diathermy to determine the proper parameters necessary to increase flexibility, or even if shortwave diathermy used prior to or during stretching could improve flexibility.[8,22]

Peres et al[22] used a combination of pulsed shortwave diathermy (PSWD) and low-load, long-duration calf stretching to increase ankle dorsiflexion ROM. Although this technique improved ROM, it took 14 treatment sessions to be of any significance. However, the

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ankle joint has limited ROM (normal dorsiflexion ROM is 20°)[25] and, as such, may not be the ideal area to test changes in flexibility due to stretching and modality use.

We wondered if pulsed shortwave diathermy and stretching might have a greater effect on a joint with a larger amount of possible ROM. In a previous study,[8] we found little change in hamstring flexibility when shortwave diathermy was used prior to stretching. This study had 2 possible significant limitations. The stretching duration of 3 times 30 seconds may not have been long enough to increase ROM and the method of measuring flexibility via the sit-and-reach test may not have been sensitive enough to isolate hamstring flexibility.

We designed this current study to correct for any possible limitations in the previous study and to readdress the question: Does a regimen of pulsed shortwave diathermy and low-load, long-duration stretch increase hamstring flexibility more than an identical stretching regimen without pulsed shortwave diathermy?

METHODS

Design

The research plan used for this study was a randomized, counterbalanced 3×2×5 repeated-measures design. Measurements were performed prior to and after each treatment session. The design was a single-blind study, the subjects being unaware of the group they were in. There were 3 independent variables: treatment mode, pretreatment-posttreatment measurements, and day (5 levels). Treatment mode had 3 levels, including diathermy and stretch, sham diathermy and stretch, and control. The dependent variable was knee extension ROM with the hip flexed at 90°, the measurement being reflective of hamstring flexibility. An additional ROM measurement was acquired 72 hours after the last treatment session to assess the intermediate term results of the treatment.

Subjects

Thirty college-age subjects (mean age, 21.5 years) were included in this study (male, n = 19; female, n = 11). Prior to the recruitment of volunteers, Institutional Review Board approval was provided by the Human Subjects Committee at Brigham Young University. Before the commencement of testing, subjects were screened to see if they qualified. To participate, subjects needed to have tight hamstrings (the inability to achieve greater than 160° of knee extension with the hip at 90° of flexion). Exclusion criteria included pregnancy, previous lower back or hamstring injury, visual acute swelling of the hamstring, use of a pacemaker, or discomfort during data collection as judged by the researchers to be greater than normal. To maintain subject confidentiality, each subject was randomly assigned a number for the duration of the study and names were not used.

The subjects were required to read and sign an informed consent form that described the risks, benefits, and procedures of the study, along with their right to discontinue involvement in the study. Each subject was also asked to arrive in attire that allowed for unhindered access to the hamstring muscle group.

Each subject was measured for hamstring flexibility then randomly assigned to 1 of 3 groups: (1) diathermy and stretch, (2) sham diathermy and stretch, and (3) control. The control group participated in 2 measurements per day without any treatment. All subjects were asked to refrain from any outside stretching and/or exercise regimen for the duration of the study.

Instruments

The diathermy unit was a Megapulse machine (Accelerated Care Plus, Sparks, NV) with an operating frequency of 27.12 MHz. The unit houses a 200-cm^2 induction coil with an air space plate of 2 cm. The unit was calibrated prior to the study. A standard plastic goniometer (Fred Sammons, Inc., Brookfield, IL) was used to measure hamstring flexibility pretreatment, posttreatment, and during the study. A crossbar made of PVC pipe positioned perpendicular to the treatment table was used to position and maintain the hip at 90° of flexion. A timer was used to time the diathermy treatment and the stretching sessions.

A stretching apparatus similar to that used by Moore and Hutton[20] was employed to provide a passive stretch to each subject (Figure 1). This allowed the subject to maintain a standardized stretching force in a relaxed position for the duration of the treatment time.

Procedures

The testing occurred over a 1-week period, with each subject in groups 1 and 2 receiving 1 treatment a day for 5 consecutive days. The subjects were tested at approximately the same time each day, within the same 2-hour period. All of the subjects also had their ROM measured 72 hours after the last treatment to measure the lasting effect of the diathermy and static-stretch regimen.

To measure hamstring flexibility, the subject assumed a supine position where the right lower extremity was positioned into 90° of hip flexion with the knee flexed. A crossbar was used to maintain

FIGURE 1. Stretching apparatus used to stretch the hamstrings. Stretching is performed via a 4.55-kg weight-and-pulley system attached to a cuff around the ankle. A foam splint is used to keep the knee in extension and the opposite leg is strapped to the table.

FIGURE 2. Measuring knee extension range of motion representative of hamstring flexibility.

proper placement of the hip and thigh. Subsequently, we strapped the left lower extremity down to the table to control any accessory movements. The subject then actively extended the right knee as far as possible (no verbal encouragement was given by the researchers). We used the goniometer to measure and record hamstring flexibility (ie, knee extension ROM) at this time (Figure 2). The greater trochanter, lateral epicondyle of the femur, and lateral malleollus were used as landmarks for the measurement and marked with a permanent marker (visible through the duration of the study) to assure consistent measurement. Each day, 1 ROM measurement was taken before the treatment and 1 ROM measurement was taken immediately after the treatment.

After the pretreatment ROM measurement, we applied a SAM splint (Seaberg Company, Inc., South Beach, OR) on the anterior aspect of the knee in an effort to keep the knee in as much extension as possible during treatment. Subjects in the diathermy-and-stretch group assumed a prone position on the table. We placed the diathermy drum over the distal posterior thigh, just superior to the popliteal aspect of the knee. The subjects received a 15-minute diathermy treatment at the following parameters: 800 bursts per second, 400-microsecond burst duration, 800-microsecond 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 (Figure 3). At the 10-minute mark of the diathermy treatment, the subject returned to the supine position and the right leg was attached to a pulley-and-weight system (4.55 kg) by applying a cuff around the ankle that was attached to a cable. This put the hamstrings on stretch, while providing a constant stretch torque. The stretch was maintained for 10 minutes. The diathermy drum was reapplied to the posterior thigh for the first 5 minutes of the stretch (Figure 4). At the conclusion of the 10-minute stretch, the SAM splint and cable weights were removed from the subject, and the ROM measurement was repeated.

The same protocol was followed for the subjects in the sham-diathermy-and-stretch group, except that this group received a 15-minute sham diathermy treatment along with the 10-minute stretch. Subjects in these 2 groups were blinded as to what group they were in, and only the examiner knew which subjects received sham diathermy and actual diathermy. This was possible because the diathermy was pulsed at a rate that provided little sensation of surface heat.

The subjects in the control group also reported to the lab for a total of 6 times. The first 5 sessions included 2 flexibility measurements. The first measurement occurred when the subject arrived. The subject then relaxed in a supine position on the treatment table for a period of 20 minutes, and then had the second flexibility measurement taken. All subjects also returned 72 hours later for a follow-up measurement.

FIGURE 3. Applying diathermy.

FIGURE 4. Applying diathermy while stretching.

To establish reliability of ROM measurements across sessions, we analyzed the pretreatment ROM data collected on the 10 subjects in the control group across the 6 testing sessions. Results of the analysis (intraclass correlation coefficient [ICC] model 3,1) indicated an ICC value of 0.99.

Statistical Analysis

A 3×2×5 mixed-design ANOVA was performed. Independent variables included treatment (3 levels, between-subjects factor), pretreatment-posttreatment (2 levels, within-subjects factor), and day (5 levels, within-subjects factor). The dependent variable was knee extension ROM with the hip at 90° of flexion. An additional 1-way ANCOVA of treatment, with the measurement after day 5 as a covariate, was performed to compare the difference in the ROM at the end of the fifth treatment and 72 hours later. All post hoc analyses were performed using Tukey adjusted *t* tests according to SAS software (α = .05)

RESULTS

Mean (± pooled SE) increases in knee extension ROM after 5 days were: diathermy and stretch (15.8° ± 2.2°), sham diathermy and stretch (5.2° ± 2.2°), and control (−0.3° ± 2.2°) (Table 1). At 72 hours, as compared to the measurement taken after the last treatment session, the diathermy-and-stretch group lost 1.9° ± 2.2°, the sham-diathermy-and-stretch group lost 3.0° ± 2.2°, and the control group changed –0.4° ± 2.2° (Table 1). There was no difference between groups (F = 1.74, P = .1955) for the change in ROM from the end of the fifth treatment and 72 hours later.

Results of the 3×2×5 ANOVA revealed a significant effect for day (F = 20.31, $P<.0001$) with ROM increasing on progressive days. The analysis also showed a significant day-by-treatment interaction (F = 21.72, $P<.001$). Post hoc analysis showed that the ROM values were not significantly different between any of the groups on days 1 and 2. However, the ROM for the diathermy-and-stretch group was significantly greater than for the sham-diathermy-and-stretch group and the control group on days 3, 4, and 5. No significant differences were found between the sham-diathermy-and-stretch group and the control group (Table 2 and Figure 5).

Daily posttreatment ROM was significantly greater than pretreatment ROM (F = 127.29, $P<.0001$). A significant interaction was found between treatment and pretreatment-posttreatment factors (F = 25.64, $P<.0001$). Post hoc analysis showed that both stretch

TABLE 1. Means ± SD in degrees for knee extension range of motion (180°, full knee extension) (n = 10 in each group).

Day	Diathermy and Stretch	Sham Diathermy and Stretch	Control
1			
Pretreatment	148.7 ± 7.6	149.5 ± 7.7	152.6 ± 7.9
Posttreatment	156.8 ± 7.2	155.0 ± 6.4	152.9 ± 8.1
2			
Pretreatment	151.0 ± 6.8	152.1 ± 7.4	152.0 ± 7.3
Posttreatment	157.4 ± 7.0	157.6 ± 7.2	152.5 ± 7.3
3			
Pretreatment	157.4 ± 6.9	150.9 ± 6.5	151.8 ± 7.6
Posttreatment	161.6 ± 7.2	154.5 ± 7.2	151.9 ± 9.0
4			
Pretreatment	159.4 ± 6.0	150.8 ± 5.6	152.4 ± 6.9
Posttreatment	163.4 ± 6.1	156.5 ± 5.4	153.1 ± 7.9
5			
Pretreatment	161.5 ± 6.5	151.9 ± 5.8	152.0 ± 7.3
Posttreatment	164.5 ± 6.2	154.7 ± 7.4	152.3 ± 8.5
8*			
Pretreatment	162.6 ± 7.3	151.7 ± 6.7	151.6 ± 7.1

* Day 8, 72 hours after last (day 5) treatment.

TABLE 2. Knee extension range of motion (mean ± pooled SE) with the hip flexed to 90°. Day-by-treatment interaction (cell means represent average of pretreatment and posttreatment measurements each day).

Group	Day 1	Day 2	Day 3	Day 4	Day 5
Diathermy and stretch	152.8 ± 2.2	154.2 ± 2.2	159.5 ± 2.2*	161.4 ± 2.2*	163.0 ± 2.2*
Sham diathermy and stretch	152.3 ± 2.2	154.9 ± 2.2	152.7 ± 2.2	153.7 ± 2.2	153.3 ± 2.2
Control	152.8 ± 2.2	152.3 ± 2.2	151.9 ± 2.2	152.8 ± 2.2	152.2 ± 2.2

* Significantly greater than sham-diathermy-and-stretch group, and control for the corresponding day ($P<.05$).

TABLE 3. Daily gains in knee extension range of motion following treatment (average of 5 days [mean ± pooled SE]).

	Diathermy and Stretch	Sham Diathermy and Stretch	Control
Pretreatment	155.6 ± 2.1	151.0 ± 2.1	152.2 ± 2.1
Posttreatment	160.7 ± 2.1*	155.7 ± 2.1*	152.5 ± 2.1

* Significantly greater than pretreatment ($P<.05$).

groups increased ROM each day significantly more than the control group, but were not significantly different from each other (Table 3).

DISCUSSION

Stretching with or without diathermy significantly increased ROM after each treatment; however, the cumulative effect of diathermy and stretch over 5 days was significantly greater than sham diathermy and stretch over the same period of time.

The within-day gains in ROM while stretching with diathermy or without diathermy were fairly similar each day. Why then did the diathermy-and-stretch group increase in ROM more than 3 times as much as the sham-diathermy-and-stretch group over the 5-day period? Apparently the sham-diathermy-and-stretch group lost some ROM each 24-hour period before the next treatment, whereas the diathermy-and-stretch group maintained the ROM it gained or didn't lose much ROM during this time. We suspect this is due to plastic elongation that occurred during the time the tissue was heated while it was being stretched.[22,27] As was expected, the ROM of the control group remained quite stable and did not change significantly during the entire experiment.

The results of this study support the premise that when soft tissue is heated and stretched, increased ROM (ie, flexibility) is possible. Although we did not measure tissue temperature during this investigation, our parameters were identical to those of other studies,[7,13] during which we measured deep-tissue temperature (3-5 cm deep in the muscle). Muscle temperature at 3 to 5 cm deep has reached temperatures of 40°C to 41°C when pulsed shortwave diathermy has been applied for 15 minutes at 800 bursts per second, 400-microsecond burst duration, and 800-microsecond interburst interval.[7,13] Some authors suggest that for optimal heating to occur, tissue temperature must reach between 40°C and 45°C.[17] From past studies using ultrasound and diathermy, we have found that once the tissue temperature reaches between 39°C and 41°C, the temperature stabilizes.[6,7,9-11,13] We theorize that this is due to increased blood flow cooling the area in an effort to prevent tissue damage that could occur with higher temperatures. In fact, the highest temperature we have measured in human muscle during the application of the heating modality in our lab was 43°C and it was very uncomfortable to the subject being tested.

We found a significant gain of ROM when using pulsed shortwave diathermy (PSWD) in combination with a low-load, long-duration stretch. These findings are consistent with the results published by Peres et al.[22]

There are several similarities in the methods used by Peres et al[22] and this study. In both studies, subjects received a low-load, long-duration static passive stretch, with constant tension being maintained with a weight-pulley system. By using a passive stretch, the ''effort'' variable was eliminated, because we did not have to worry about whether the subjects were actively maintaining the stretch position. Also, flexibility measurements in both studies were taken with a goniometer. However, Peres et al[22] utilized an electronic goniometer, whereas we took measurements with a standard plastic goniometer.

While both studies provided similar findings, our study showed more rapid increases in flexibility. It only required 3 treatments to produce significant differences in hamstring flexibility between the diathermy-and-stretch group and the sham-diathermy-and-stretch group. The Peres et al[22] study took 11 treatments longer than ours to produce significant differences in flexibility between stretch only versus diathermy and stretch. This difference could be attributed to variation within the methods. Peres et al[22] used healthy subjects and did not measure whether or not dorsiflexion ROM was limited prior to the start of the study. In our study, we only accepted subjects with limited hamstring flexibility (no greater than 160° of full knee extension when measured with the hip at 90° of flexion). We feel that our method of prescreening subjects for tight hamstrings lends itself well to treating clinical conditions for which patients present with limited hamstring flexibility.

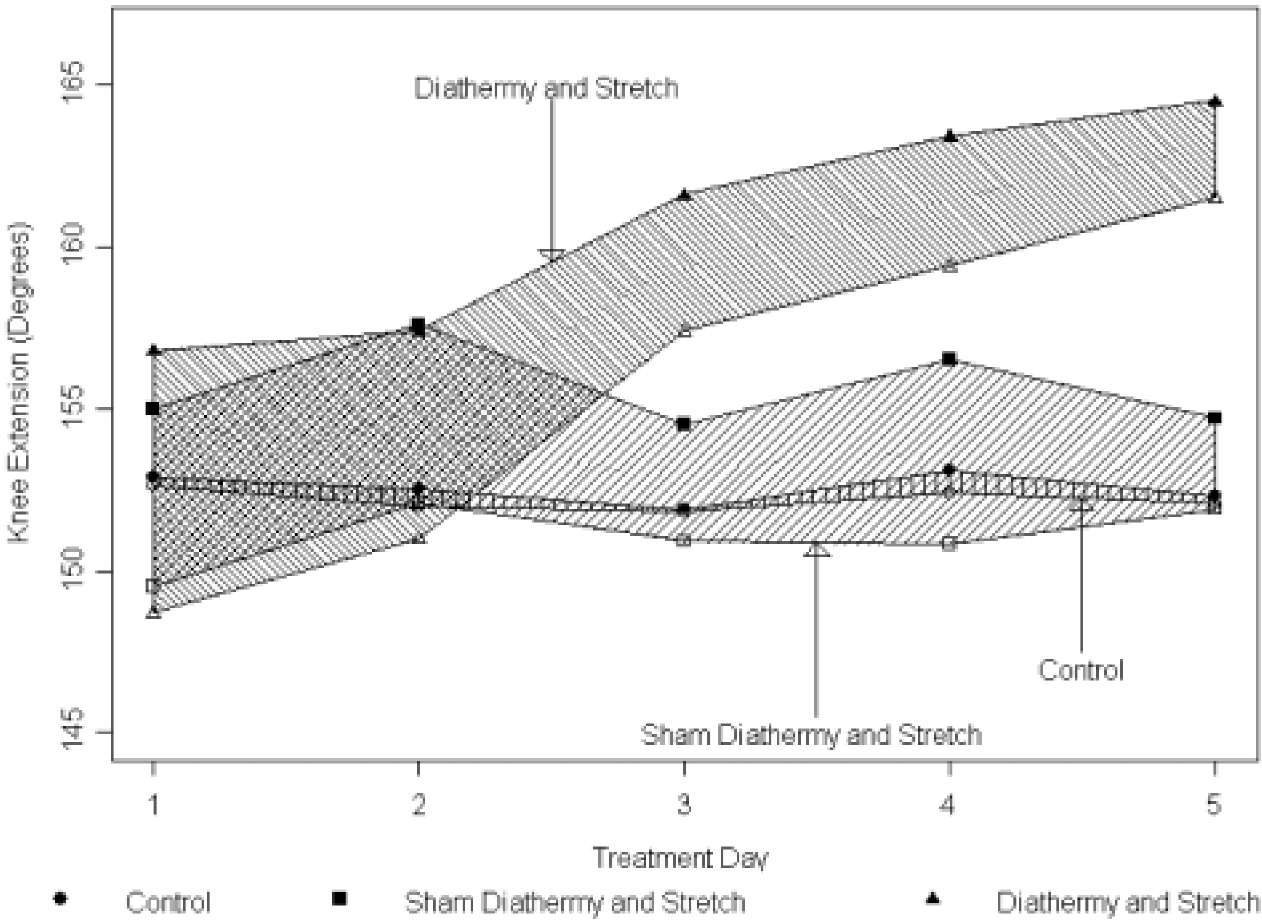

Figure 5: Daily pretreatment (clear symbols) and posttreatment (filled symbols) changes in knee extension range of motion with the hip flexed to 90°.

Learning from Previous Research

In a previously published study that tested the effect of diathermy heat and stretching on hamstring flexibility,[8] researchers reported that short-duration stretching preceded by diathermy resulted in the same amount of change in hamstring flexibility as short-duration stretching without diathermy. The results of this current study were different. We attribute these differences to changes we made in the methods that addressed 4 limitations from the first study.

The first limitation in this earlier study[8] may have been the use of the sit-and-reach test to measure hamstring length. Past research has shown that the Flexi-Bench (Health Accessories, Seattle, WA) sit-and-reach test has good test-retest reliability ($r = 0.90$) for measuring low back and hamstring flexibility and has compared favorably with goniometer measurements.[15,16,21] Some researchers, however, argue that due to spinal and pelvic movement the sit-and-reach test is not sensitive enough to isolate hamstring flexibility. They recommend using the knee extension test that we used in this study.[2,3,12,26,31]

A second limitation of the Draper et al[8] study was the method of stretching by bending at the waist and reaching for the toes. This technique accentuates lumbar flexion and posterior pelvic rotation. Researchers have shown that keeping the pelvis in anterior rotation in a straight leg raise position actually increases flexibility more than when stretching with the pelvis rotated posteriorly.[26] For this current study we used a passive straight leg raise stretch with the opposite lower extremity fixed to the table, thus maintaining anterior rotation of the pelvis, minimizing excessive lumbar flexion, and isolating the stretch on the hamstrings.

A third limitation of the Draper et al[8] study was that they did not use a randomized block design to assure similar in initial flexibility between groups. We employed a randomized block design in our current study and no group differed in initial hamstring flexibility, thus all groups had an equal chance of increasing knee extension ROM.

The last limitation of the Draper et al[8] study was that the stretch duration was apparently too short (30 seconds, 3 times daily, 5 days). In this second study, we applied a stretch of 10 minutes, 1 time daily for 5 days, and by the third day the subjects in the diathermy-and-stretch group had an increase in their hamstring flexibility that was significantly greater than that of the subjects in the sham-diathermy-and-stretch group. The time required to cause tensile deformation of tissue has been a topic of research for years. Most researchers agree that tissue elongation varies according to the type and duration of the force applied.[28,29] A low-force stretching method requires more time to produce the same amount of elongation as a higher-force stretching method; however, the proportion of tissue lengthening that remains after tensile stress is removed is greater for the low-load, long-duration method.[24] Researchers have found that low-load, long-duration (greater than 1 minute) stretching promotes permanent, plastic deformation of soft tissue structures as opposed to high-force, short-duration stretching that may produce only short-term elastic deformation. Low-load, long-duration stretching may also be safer than high-load, short-duration stretching. For the same amount of tissue elongation, a low-force, slower method of stretching produces less structural weakening than a high-force stretching method.[19,24,28,29]

Qualifications

There are some qualifications to this study. The major qualification is that we haven't answered the question of whether a diathermy and low-load, long-duration stretching regimen would produce lasting increased flexibility in the hamstrings. We did measure ROM 72 hours after the last treatment. Subjects in the diathermy-and-stretch group gained 15.8° of knee extension from the 5 treatments, but 72 hours later, lost 1.9° (12%). At the end of the fifth treatment, subjects in the sham-diathermy-and-stretch group increased knee extension by 5.2°; however, they lost 3° (58%) 72 hours later. Because subjects in both groups lost some ROM during 72 hours of nonstretching, we don't know how many days it would take for both groups to return to their baseline if they didn't continue hamstring stretching. In retrospect, we should have had subjects report back to our lab so that we could remeasure hamstring flexibility on a weekly basis for several weeks.

Another qualification of this study is that it was not double-blind, meaning the investigator measuring ROM also applied the diathermy or sham-diathermy treatments. In future studies, we suggest that 1 investigator apply the diathermy or sham treatment, and when the treatment is over, another investigator come into the room and measure ROM and thus be blinded to who is in which group.

One last qualification of this study was that subjects in the control group did not assume the same position as subjects in the 2 treatment groups. Control subjects lay supine for 20 minutes, whereas the treatment groups were prone for 10 minutes and then supine for 10 minutes. We doubt that this had any effect on the outcome; however, it should be addressed in future studies.

CONCLUSIONS

Five daily sessions of pulsed shortwave diathermy and a low-load, long-duration stretch, increased hamstring flexibility more than identical stretching with sham-diathermy application. This study was performed on subjects who had tight hamstrings. This might have clinical relevance in treating patients with tight hamstrings due to immobilization or inactivity. Regardless, pulsed shortwave diathermy is a valuable tool that can be used effectively with static stretching.

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