

# The Carry-Over Effects of Diathermy and Stretching in Developing Hamstring Flexibility

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**Objective:** To compare the effects of low-load, short-duration stretching with or without high-intensity, pulsed short-wave diathermy on hamstring flexibility.

**Design and Setting:** We used a single-blind, repeated-measures design (pretest and posttest for all treatments) that included a placebo. The 3 independent variables were treatment mode, pretest and posttest measurements, and day. Treatment mode had 3 levels: diathermy and stretching, stretching alone, and control. The dependent variable was range of motion. Subjects were randomly assigned to the diathermy and stretching, stretching-only, or control group. Subjects were treated and tested each day (at approximately the same time) for 5 days, with a follow-up test administered 72 hours later. Hamstring flexibility was tested using a sit-and-reach box before and after each treatment. Diathermy and stretching subjects received a 15-minute diathermy treatment on the right hamstring at a setting of 7000 pulses per second, with an average pulse width of 95  $\mu$ sec. Stretching-only subjects received a 15-minute sham diathermy treatment. Both diathermy and stretching and stretching-only subjects then performed three 30-second

stretches (short duration) before being retested. Control subjects lay prone for 15 minutes before being retested.

**Subjects:** Thirty-seven healthy college students (11 men, 26 women, age = 20.46  $\pm$  1.74 years) volunteered.

**Measurements:** Hamstring flexibility was measured using a sit-and-reach box before and after each treatment.

**Results:** The average increases in hamstring flexibility over the 5 treatment days for the diathermy and stretching, stretching-only, and control groups were 6.06 cm (19.6%), 5.27 cm (19.7%), and 3.38 cm (10.4%), respectively. Three days later (after no treatment), the values for the diathermy and stretching, stretching-only, and control groups were 8.27 cm (26.7%), 6.83 cm (25.3%), and 4.15 cm (14.2%), respectively. No significant differences in hamstring flexibility were noted among the groups.

**Conclusions:** Diathermy and short-duration stretching were no more effective than short-duration stretching alone at increasing hamstring flexibility. The effects of diathermy with longer stretching times need to be researched.

**Key Words:** heat, stretch, injury treatment

Heat and stretching are often used by clinicians to increase flexibility and restore lost range of motion.<sup>1-9</sup> Vigorous heating (>4°C over core temperature) increases collagen tissue extensibility and decreases tissue viscosity<sup>10-13</sup> and tension.<sup>11</sup> High-intensity, pulsed short-wave diathermy can produce vigorous heating over large areas<sup>14</sup> and, in so doing, induce muscle relaxation,<sup>15</sup> decrease muscle spasm,<sup>13</sup> and decrease joint stiffness.<sup>13</sup>

Both isometric contraction (muscle contraction against a stable force that is followed by relaxation) and passive stretching increase joint range of motion.<sup>1</sup> Passive stretching, however, appears to be the safest and best stretching method<sup>2</sup> because prestretch isometric contractions may promote lingering facilitation of the contracted muscles<sup>16</sup> and thus produce more tension and a greater risk of injury.<sup>2</sup>

In animal studies, researchers discovered that stretching a tendon while it was being heated increased tendon length more

than stretching alone.<sup>11</sup> Low-load, long-duration stretching performed once the tissues reached significantly elevated temperatures, however, resulted in the greatest increases in residual tissue length<sup>12</sup> and produced the least amount of damage<sup>17</sup> when compared with tissues stretched at lower temperatures with higher loads.<sup>12,17</sup>

Two groups of investigators<sup>3,4</sup> reported that deep heat (ultrasound) and low-load, long-duration stretching of human triceps surae muscle (dorsiflexion) resulted in small, short-term increases (1.2° to 3°) in flexibility. Their conclusions, however, are debatable due to the methods used: (1) the area treated with ultrasound was so large that deep heating probably did not occur,<sup>3</sup> (2) there was no control for the stretching used,<sup>4</sup> and (3) the muscle studied was not necessarily tight, possibly possessing a significant range for improvement in flexibility.<sup>3,4</sup>

Once muscle has been vigorously heated with high-intensity, pulsed short-wave diathermy, the intramuscular temper-

ature remains vigorously heated for approximately 5 minutes.<sup>14</sup> We believe that stretching should be performed immediately after the diathermy treatment in order to effectively increase tissue extensibility.

To date, no researchers have investigated the effects of using high-intensity, pulsed short-wave diathermy and passive stretching on improving flexibility. Our objective was to determine if this method of heat and stretching would increase hamstring range of motion more than stretching alone in uninjured subjects.

## METHODS

We used a single-blind, 2×3×6 factorial design with repeated measures. The dependent variable was range of motion. The 3 independent variables were treatment mode, pretest and posttest measurements, and day. Treatment mode had 3 levels: diathermy and stretching, stretching alone, and control. Measurements were taken for 6 days.

## Subjects

Thirty-seven healthy, college students (11 men, 26 women, age = 20.46 ± 1.74 years) volunteered to participate. Subjects were excluded from the study if (1) their straight-leg, hip-flexion range of motion was greater than 100°, (2) they had a history of either hamstring or lower back injury, (3) they had metal pins, plates, or screws in the right femur, (4) they were or could possibly be pregnant, or (5) during the study, they reported any discomfort that the researchers deemed to be more than the normal sensation of stretched tissue. The study was approved by the university's institutional review board. All participants signed a consent form after being informed of the risks involved with participation. All participants continued their daily routine without altering their stretching or exercise habits throughout the course of the study.

## Instruments

We used a Magnatherm SSP (International Medical Electronics, Ltd, Kansas City, MO) diathermy unit with an operating frequency of 27.12 MHz. The unit houses dual 200-cm<sup>2</sup> induction drum coil electrodes with 2-cm space plates. The unit was calibrated before the study.

A standard plastic goniometer (Fred Sammons Inc, Bissell Healthcare Corp, Brookfield, IL), marked in 1° increments, was used to initially screen subjects' straight-leg, hip-flexion range of motion. Hamstring range of motion was tested with a Figure Finder Flex-Tester sit-and-reach box (Novel Products Inc, Rockton, IL).

## Procedures

We tested hamstring flexibility before and after each treatment session using a sit-and-reach box equipped with a 5.08-cm (2-in) diameter tube at its base. Subjects sat barefoot with their legs under the ledge of the sit-and-reach box with the right (treatment) leg extended, the heel against the tube, and the left leg slightly bent (Figure 1). The right foot was plantar flexed (but relaxed) over the tube to remove any effect of triceps surae muscle tightness. Subjects then slowly stretched forward as far as the right leg would allow. The distance that the subjects' fingers reached along the sit-and-reach box was recorded. We used the best of 3 trials for statistical analysis.

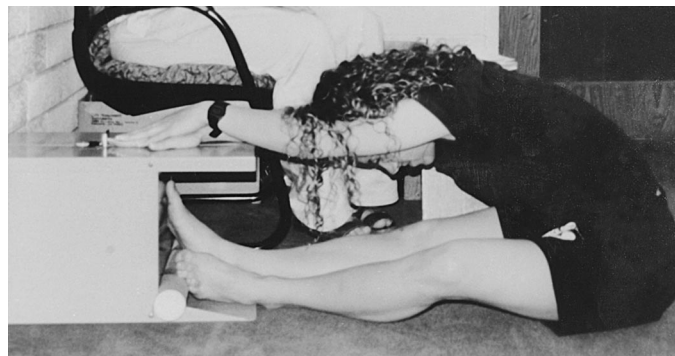


Figure 1. Pretest and posttest measurements as measured by the sit-and-reach box.

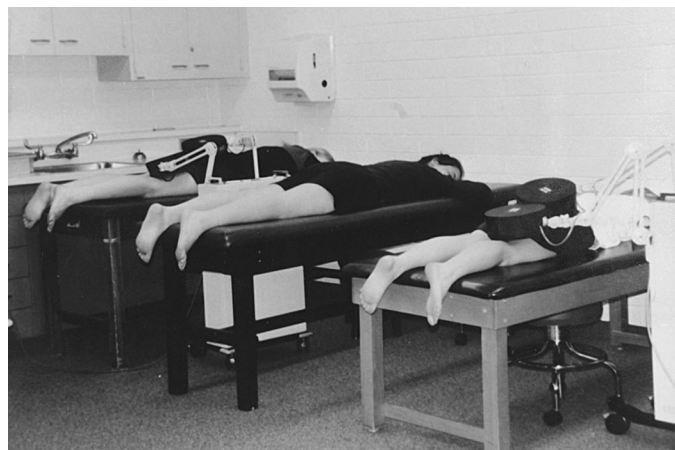


Figure 2. Applied treatments (left to right): stretching only, control, diathermy and stretching.

Subjects lay prone on a treatment table with their feet off the end of the table for 15 minutes (Figure 2). One of 3 treatments was then applied. Subjects in the diathermy and stretching group had their hamstrings dried with a towel to remove any sweat that might have accumulated on the area. The diathermy drums were placed over the belly of the hamstrings and the posterior aspect of the distal hamstrings and musculotendinous junction at the knee. We applied diathermy at a setting of 7000 pulses per second with an average pulse width of 95  $\mu$ sec. At the completion of the treatment, we turned off the diathermy unit.

The procedure for the stretching group was identical to that of the diathermy and stretching group; however, this diathermy unit caused no heating of the tissues. Before the study, we unhooked the power output leading to the diathermy drums. The lights turned on, but no heat entered the tissues, thus creating a sham diathermy treatment. Subjects in the control group simply lay prone on the treatment table (with the feet off the end of the table) for 15 minutes before being tested (Figure 2).

Immediately after the heat treatment, the diathermy and stretching and stretching-alone subjects performed three 30-second stretches. Subjects stood on the left foot (toe turned out laterally approximately 25° from midline) in front of a table 0.762 m (2.5 ft) high (Figure 3). The distance between the left foot and the table was measured by a tape measure fixed to the floor to ensure that all of the stretches were performed identically. The subject placed the right leg on the



**Figure 3.** Stretching the right hamstrings by moving the fingers along a fixed tape measure. Note right foot is plantar flexed 7.62 cm (3 in) behind a 10.16-cm (4-in) ledge, and left foot is turned out laterally 25° from midline.

table with the heel fixed 7.62 cm (3 in) behind a 10.16-cm (4-in) ledge, so that the foot would remain in a relaxed but plantar-flexed position (to eliminate any effect of triceps surae muscle tightness) (Figure 3). To stretch the hamstrings, the subject leaned forward over the right leg and extended the fingers as far as possible along a tape measure that was fixed to the table. The subject was instructed to continue the stretch for the allotted time, working the fingers farther along the tape measure while exhaling. The distance attained during each 30-second stretch was recorded.

The tape measure fixed to the table provided an objective measurement of the subject's stretches and ensured that the subject was working to increase the stretch. It also helped determine if the subject was overstretching (ie, the subject was tighter on a subsequent day).

The first two 30-second stretches were followed by a 15-second rest, during which the subject lowered the right leg and stood erect. After the third 30-second stretch, hamstring flexibility was tested again using the sit-and-reach box.

### Statistical Analysis

We used a 2×3×6 repeated measures (pretest and posttest for all treatments) analysis of variance to identify differences in range of motion among groups (diathermy and stretching, stretching only, control), differences in range of motion among

**Table 1. Sit-and-Reach Measurements (Mean ± SD in cm)**

Day*	Group		
	Diathermy and Stretching	Stretching Only	Control
1			
Pretest	31.1 ± 6.4	26.9 ± 9.0	28.9 ± 7.7
Posttest	35.3 ± 6.0	30.0 ± 8.3	30.0 ± 8.5
2			
Pretest	33.1 ± 5.9	28.4 ± 8.1	29.9 ± 7.3
Posttest	36.7 ± 5.8	31.8 ± 8.2	30.8 ± 6.5
3			
Pretest	34.6 ± 5.8	29.8 ± 7.9	29.9 ± 7.0
Posttest	38.5 ± 5.4	33.1 ± 7.5	31.6 ± 7.0
4			
Pretest	35.9 ± 5.3	30.9 ± 8.4	31.7 ± 6.8
Posttest	39.1 ± 4.9	34.2 ± 7.9	33.0 ± 6.4
5			
Pretest	37.1 ± 5.4	32.2 ± 7.6	31.8 ± 6.3
Posttest	40.3 ± 5.2	35.1 ± 7.2	33.0 ± 6.2
8			
Pretest	39.3 ± 5.6	33.8 ± 7.1	33.0 ± 6.4

\*Both the diathermy and stretching and the stretching-only groups showed significant changes in range of motion each day within groups but no significant changes between groups.

days, and immediate treatment effects (comparing pretest and posttest measurements). To analyze the chronic, or carry-over, effects, we computed difference scores by subtracting the pre-treatment range-of-motion measurement for day 1 from the measurements for days 2 through 5 and day 8. These change scores were then analyzed for differences among days and treatment groups using a 3×5 repeated-measures analysis of variance. Follow-up tests for significant main effects and interactions were performed using the Tukey procedure. Alpha levels were set at 0.05 for all comparisons.

### RESULTS

The 3 groups began the study with slightly different but not statistically different amounts of hamstring range of motion as measured by the sit-and-reach box (Table 1). There was no difference among treatment groups ( $F_{2,34} = 2.36, P = .11$ ) or interactions for day-by-group ( $F_{8,136} = 1.2, P = .28$ ), day-by-pretest or posttest ( $F_{4,136} = .525, P = .72$ ), or day-by-pretest or posttest-by-group measurements ( $F_{8,136} = .405, P = .92$ ). All of the subjects improved their flexibility over the 6-day test period ( $F_{4,136} = 42.6, P = .001$ ). Immediate effects (pretest and posttest) ( $F_{1,34} = 152.4, P = .001$ ) and pretest or posttest-by-group interactions ( $F_{2,34} = 11.3, P = .001$ ) were significant. Both the diathermy and stretching and stretching-alone groups had significantly greater immediate effects in range of motion than the control group; however, there was no difference between the diathermy and stretching and the stretching-alone groups (Tukey < .05).

There was a carry-over, or chronic, effect for days ( $F_{4,136} = 47.93, P = .001$ ) (Table 2 and Figure 4), but no difference among groups ( $F_{2,34} = 1.51, P = .24$ ) or in day-by-group interaction ( $F_{8,136} = 1.63, P = .12$ ). Days 4 through 6 were different from days 2 and 3, and days 5 and 6 were different from day 4.

### DISCUSSION

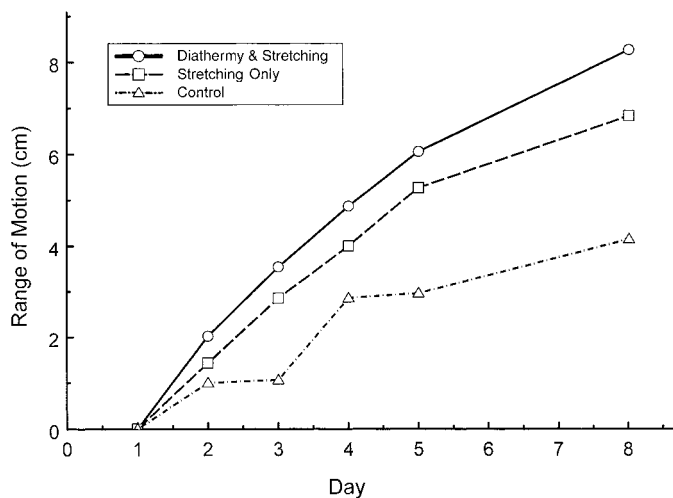
Our results support previous findings that stretching increases flexibility.<sup>1,2,6,7,16</sup> Researchers in 2 studies determined that

**Table 2. Chronic Effects of Stretching (Change in Pretest from Day 1)**

Day	Group					
	Diathermy and Stretching*		Stretching Only*		Control	
	Diff (cm)†	% Change	Diff (cm)†	% Change	Diff (cm)†	% Change
2	2.0 ± 2.5	6.4	1.4 ± 3.3	5.2	1.0 ± 3.3	3.5
3	3.5 ± 3.2	11.3	2.9 ± 4.6	10.8	1.1 ± 2.9	3.8
4	4.9 ± 3.8	15.6	4.0 ± 6.3	14.9	2.9 ± 3.0	10.0
5	6.1 ± 3.6	19.6	5.3 ± 5.5	19.7	3.0 ± 3.4	10.4
8	8.3 ± 3.5	26.7	6.8 ± 5.4	25.3	4.1 ± 3.9	14.2

\*Both the diathermy and stretching and the stretching-only groups showed significant changes in range of motion each day within groups but no significant changes between groups.

†Mean ± SD. Diff indicates difference.



**Figure 4. Residual effects (change in range of motion from day 1). Treatments were applied on days 1 through 5.**

one 30-second stretch is effective for increasing hamstring range of motion.<sup>6,7</sup> Subjects in these studies stretched 5 times a week for 6 weeks. In another investigation, subjects performing two 30-second static stretches daily over a 6-week period increased flexibility more than control subjects did. Our subjects who performed three 30-second stretches per day for 5 days also increased in flexibility. Had we also continued our study for 6 weeks, we might have shown even greater increases in flexibility.

Our results do not support previous reports that deep heat and stretching cause greater increases in flexibility than stretching alone in the short term.<sup>3,4</sup> Warren et al<sup>18</sup> noted that the greatest increases in residual tissue length in rat-tail tendons occurred when low-load, long-duration stretching was performed once the tissues had reached significantly elevated temperatures.<sup>12</sup> Tendon properties change under mechanical stress at temperatures greater than 37°C.<sup>19</sup> With increased temperatures, the microstructure of collagen changes such that the stress-relaxation property increases (greater relaxation), which permits deformation when stretched.<sup>19</sup> When collagen is heated, it undergoes a number of thermal transitions. These transitions cause increased extensibility and allow plastic deformations of the tissue when it is stretched.<sup>19,20</sup> These studies,<sup>10-12,18-21</sup> however, were all performed on rat-tail, kanga-

roo-tail, and beef tendon. The general assumption that heat and stretching is more effective than stretching alone at increasing flexibility is based on these animal studies.<sup>10-12,18-21</sup> Controversy exists as to whether or not the conclusions from animal studies can be applied to humans.

Studies by Draper et al<sup>4</sup> and Wessling et al<sup>3</sup> support the results of the animal studies. Deep heat and stretching were more effective than stretching alone in increasing flexibility in the short term. The animal tendon data, therefore, may indeed be applicable to human muscle.

It is possible that our results are different from the Wessling et al,<sup>3</sup> Draper et al,<sup>4</sup> and animal studies because our subject groups varied slightly (although not statistically) in initial flexibility. The most flexible subjects were in the diathermy and stretching group, while the tightest subjects were in the stretching-only group. "Looser" subjects have a greater resistance to stretching than "tighter" subjects.<sup>22</sup> Based on the findings of Magnusson et al,<sup>22</sup> one might expect to find that the looser subjects would not increase in flexibility as much as the tighter subjects. In our study, however, the diathermy and stretching (looser) subjects increased in flexibility by 26.7% over the 8-day test period, while the stretching-only (tighter) subjects increased in flexibility by only 25.3%. Therefore, had initial flexibility among our subject groups been identical, the diathermy and stretching group may have increased in flexibility much more than the stretching-only group. In this case, our results may also lend support to the animal studies.

Men usually are not as flexible as women; thus, it is important to note that even though both sexes were studied, the groups were fairly equal in the ratio of men to women. Four men were in the diathermy and stretching group, 3 in the stretching-only group, and 4 in the control group.

Previous investigators<sup>14,23</sup> reported that a 15-minute diathermy treatment at similar settings increased intramuscular temperature (3 cm deep) 4.58°C ± 0.87°C above baseline and maintained it in the vigorous heating range (4°C above baseline) for 7.65 ± 4.96 minutes.<sup>23</sup> Perhaps there was a difference in heating by the diathermy units. Previous work was done with a Megapulse (Accelerated Care Plus, Sparks, NV); we used a Magnatherm SSP. We chose to use the Magnatherm SSP diathermy unit for 2 reasons. This unit has 2 drums and is thus able to heat a larger surface area. We also had 2 Magnatherm SSP diathermy units available for our use, so we were able to create a sham treatment for the stretching-only subjects by using this machine.

We were surprised that our treatment group results were not different from the control group results. In designing our study, we were interested in delineating the course of changes among our treatment groups, so we set up the control group to mirror the experimental groups except for the heating and stretching. We measured each of our subjects 6 times per day on the sit-and-reach test (3 pretest measurements and 3 posttest measurements). This method of testing hamstring flexibility stretched all of our subjects and increased their flexibility. According to 2 groups of researchers,<sup>24,25</sup> increased flexibility is not due to increased elasticity of the muscles but rather to an increased pain (stretching) tolerance. Apparently, performing 6 sit-and-reach tests each day for 5 days is effective in increasing one's stretch tolerance and flexibility.

## Limitations

The first limitation to our study involves the use of the sit-and-reach test to measure hamstring length. Past research has shown that the back-saver sit-and-reach test has good test-retest reliability ( $r = 0.90$ ) and has compared favorably with the Leighton Flexometer (Leighton Flexometer, Inc, Spokane, WA) and goniometer measurements.<sup>26–28</sup> Some researchers, however, argue that due to spinal and pelvic movement, the sit-and-reach test is not sensitive enough to isolate hamstring flexibility and have replaced it with the active knee-extension test.<sup>6,7,29–31</sup>

A second limitation of our study was the method of stretching. Our method of bending at the waist and reaching for the toes posteriorly rotates the pelvis. Researchers have shown that keeping the pelvis in anterior rotation, with a more upright position of the trunk, actually increases flexibility more than when stretching with the pelvis rotated posteriorly.<sup>30</sup>

Another limitation is the duration of our stretch (3 stretches for 30 seconds each, daily for 1 week). After this study, we completed another study that used a 10-minute stretch during pulsed short-wave diathermy treatment daily for 3 weeks. The group with diathermy increased flexibility significantly more than the sham group.<sup>32</sup> Apparently a heat and stretching routine is more effective when long-duration stretching is employed and repeated for longer than a week.

Another limitation involved our measuring the range of motion of the control group on a daily basis. We did not know that this short exercise would actually increase range of motion. We suggest that the control group should be tested only on the first and last day of the experiment to avoid the stretching and increased flexibility gained during the intermediate sit-and-reach measurements.

A last limitation is that we did not use a randomized-block design so that subjects were similar in initial flexibility. Subjects in our diathermy and stretching group began with better hamstring flexibility than those in the stretching-only and control groups, leaving more room for improvement in the last 2 groups. If all groups began with similar flexibility, our results might have been different.

## CONCLUSIONS

In our study, flexibility increased in all of our subjects. Although numerically different, the increases in flexibility between the diathermy and stretching, stretching-only, and control groups were not statistically significant. No group outperformed another.

Our study is important and adds to the knowledge base of athletic training. First, we have learned that the sit-and-reach test not only measures flexibility but also increases it, and as such, flexibility studies should not measure daily range of motion of a control group. Second, our results support previous research that stretching increases flexibility. Last, our findings do not support previous reports that deep heat applied before short-duration stretching caused greater increases in flexibility than stretching alone. Based upon subsequent studies, we suggest that a heat and stretching regimen include low-load, long-duration stretches over a period of a few weeks.

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