Flexibility is an attribute that may positively influence athletic performance, and there is a widespread belief that it is important for injury prevention. Consequently, stretching exercises are frequently used in injury rehabilitation, and flexibility is viewed as a component of overall physical fitness. The hamstring muscle group is particularly susceptible to injury, especially during participation in activities that involve sprinting and other explosive motions. Inadequate muscle flexibility, inadequate warm-up, lack of hamstring strength, and muscle fatigue are factors that may contribute to the occurrence of a hamstring injury.

Hamstring stretching has long been used both in hamstring rehabilitation programs as well as warm-up and injury prevention programs. Numerous studies have assessed the possible benefits and liabilities associated with stretching. Muscle warm up prior to static stretching has been shown to enhance muscle extensibility, and increased joint ROM has been associated with increased muscle extensibility. Optimal flexibility is believed to decrease the frequency and severity of injuries. Subjects with a history of previous hamstring injury exhibit reduced flexibility, which makes them more susceptible to reinjury. Heat application has been shown to increase blood flow, increase the extensibility of connective tissues, decrease reflexive muscle excitability, and decrease pain. Thus, elevating the tissue temperature can increase the amount of elongation produced by stretching. Superficial heat therapy, deep heat therapy, and active exercise are different options for elevation of intramuscular temperature. Examples of superficial heat include paraffin wax, moist heat pack, warm whirlpool, and infrared radiation. Ultrasound and short wave diathermy are examples of deep heating modalities. Active exercise is another commonly used method for elevation of tissue temperature.

Numerous thermotherapy approaches have been combined with stretching exercises, including warm whirlpool, active exercise, moist hot pack, short wave diathermy, and ultrasound. The effects of different heating modalities on hip flexion passive range of motion are unknown. The objective of this study was to assess the relative effects of active exercise on a stationary bicycle, moist hot pack treatment, and warm whirlpool treatment on hip flexion PROM. The design was a repeated measures design with 24 males and 20 females between the ages of 18 and 24 years. The main outcome measure was hip flexion PROM measured by an inclinometer. Repeated measures analysis of variance identified a significant difference among the heating methods, F(1, 43) = 32.41; p < .001. Active exercise produced the greatest change in hip flexion PROM. All three treatment methods produced an increase in hip flexion PROM, but active exercise produced a significantly greater increase than moist hot pack and warm whirlpool treatments.
of different heat modalities need to be assessed without stretching to determine the relative effectiveness of each one for increasing ROM. Heat application is known to increase tissue extensibility, which should increase joint ROM without administration of a stretching protocol. Furthermore, there is a lack of information in the literature on the comparative effectiveness of deep and superficial heating modalities for promotion of muscle extensibility. The purpose of this study was to assess change in hip flexion passive range of motion (PROM) attributable to the administration of common heat modalities, including active exercise on a stationary bicycle, moist hot pack, and warm whirlpool.

**Procedures and Findings**

Sixty-one subjects initially volunteered to participate in the study, which was approved by an Institutional Review Board. Prospective subjects who had a history of hamstring injury in the past two years, or who had greater than 100 degrees of hip flexion PROM, were excluded. Other exclusionary criteria included a history of a thermoregulatory disorder involvement in a strenuous exercise regimen. Nine potential subjects were excluded and seven subjects were discontinued participation. Thus, 45 subjects (24 male, 20 female, age = 19.83 ± 1.02 years, mass = 80.47 ± 26.12 kg, height = 180 ± 5.27 cm) completed the study. Pretreatment hip flexion PROM was measured by an inclinometer, using previously validated methods. With the subject in a supine position, the right knee was extended and the extremity was passively lifted to the end-range of hip flexion. The average of the three trials was recorded. All measurements were obtained by the same researcher. Piva et al. reported this method to have an intersession correlation of .88 and an intertester reliability of .99.

Subjects received the various heat treatments on different days, each of which were 10 minutes in duration and which were administered in a randomized order. To avoid any possible carry-over effects, treatments were not administered on consecutive days. Water temperature was 44°C (+/- 1°C) for the warm whirlpool treatment. Subjects stood motionless for 10 minutes with the extremities submerged in water to the level of the gluteal fold. The moist hot pack was 71°C, which was covered with terry cloth and placed on the subject’s hamstring muscles. The active exercise condition involved a stationary bicycle. Subjects were instructed pedal at an intensity level of 100 W (75-85 RPM) for 10 minutes. Hip flexion PROM measurements were obtained immediately following the administration of each treatment.

Repeated measures analysis of variance was used to analyze the data for differential treatment effects on hip flexion PROM (SPSS version 19.0). Pretreatment hip flexion PROM values are presented in Table 1. Tables 2 and 3 present pretreatment to posttreatment change in hip flexion PROM values. A significant differences (p < .05) was found among the heating methods, 

**Table 1. Pretreatment Hip Flexion PROM (Degrees)**

<table>
<thead>
<tr>
<th>Population</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>44</td>
<td>76.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Male</td>
<td>24</td>
<td>70.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>82.8</td>
<td>7.2</td>
</tr>
</tbody>
</table>

**Table 2. Change in Hip Flexion PROM (Degrees) for Each Treatment**

<table>
<thead>
<tr>
<th>Treatment Type</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm whirlpool</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Moist hot pack</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Active exercise</td>
<td>3.8</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Table 3. Change in Hip Flexion PROM (Degrees) for Each Treatment by Gender**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm whirlpool</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>24</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Moist hot pack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>24</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Active exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>24</td>
<td>3.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>3.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>3.8</td>
<td>2.2</td>
</tr>
</tbody>
</table>
F(1,43) = 52.41; p < .001. Active exercise produced a larger change in hip flexion PROM compared to the effects of the warm whirlpool and the moist hot pack treatments.

**Discussion**

A greater increase in hip flexion PROM was observed following active exercise compared to warm whirlpool and moist hot pack treatments. Active exercise has previously been advocated as the best mechanism to generate a deep heating effect.1

Our female subjects demonstrated pretreatment hip flexion PROM that was over 10 degrees greater than that for the male subjects, which was consistent with the findings of other researchers.7,25 However, we found no difference in average change of hip flexion ROM between genders for any of the treatments. Previous research has demonstrated that multiple methods of therapeutic heat application increase PROM.1,26

The purpose of this study was to identify the mode of thermotherapy that would increase hamstring extensibility to the greatest extent. Our results clearly indicated that active exercise produced a significantly greater increase in hip flexion PROM than the other heat treatments, without the performance of hamstring stretching exercises.

Superficial heating modalities can only raise tissue temperature to a maximum depth of 2 cm.13 Active exercise increases blood flow to the exercising muscles, which warms the adjacent subcutaneous tissues from the inside out.8,25 Consequently, heating derived from active exercise is not hindered by the thickness of the layer of adipose tissue surrounding the muscle. Most studies have combined thermotherapy with stretching exercises.1,9,15-21 Robertson et al.14 reported that a deep heating modality (i.e., short wave diathermy) was more effective than superficial modes for increasing muscle extensibility. However, Boone et al.22 found that continuous ultrasound without stretching did not affect hip flexion PROM. Therefore, the results of studies that have demonstrated an increase in PROM following superficial heating and stretching may have been due to an alteration of the stretch reflex or an analgesic effect that promotes muscle relaxation.

**Summary**

The findings of this study suggest that low-intensity active exercise will increase hip flexion PROM without stretching, which lends support to the performance of warm-up activities before athletic competition.28-31 Combining superficial heating with a deep-heating modality (i.e., ultrasound) has been shown to provide an incremental increase in muscle temperature.27 Future research should assess the effect of combining superficial heating with active exercise.

**References**


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**Tricia Turner, PhD, ATC,** University of North Carolina at Charlotte, is the Report Editor for this article.

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