The Use of Thermal Agents to Influence the Effectiveness of a Low-Load Prolonged Stretch

Cary Lentell, MS, PT
Thomas Hetherington, PT
Jeff Eagan, PT, ATC
Mark Morgan, PT

Increased flexibility is one of the basic concerns addressed in the day-to-day practice of physical therapy. It is a goal for any patient recovering from a period of immobilization or injury involving the connective tissues. Optimal flexibility is also desirable for participants in most athletic activities.

Joint stiffness has been the focus of many laboratory and clinical studies. The histological changes that occur in the periaricular connective tissues following immobilization are well recognized. In the absence of normal joint movement, the normal orientation of the connective tissue's collagen fibers is lost (4,5). A significant increase in the intermolecular cross-links of periaricular connective tissues has been documented in animal studies to occur within 9 weeks of immobilization (1).

Consequently, it is in the clinician's interest to understand the normal properties of connective tissues and the conservative means to enhance their lengthening. Kottke et al (7) noted that the ability of a connective tissue to elongate is contingent on the amount of interweaving between the meshwork of its collagen fibers. Fewer the interweavings in the meshwork of fibers, the greater the mobility of the connective tissue. Conversely, the greater the amount of fiber interweaving, as in dense connective tissue, the more restricted the range of motion (ROM). Separation of adjacent collagen fiber attachments within the connective tissue meshwork hypothetically allows a long-lasting elongation to occur (8). This long-lasting or plastic elongation is produced by exposing connective tissue to prolonged tension.

The effectiveness of a low-load prolonged stretch (LLPS) to promote long-lasting elongation of connective tissue has been well documented by laboratory studies (8,10,19,20). Such studies have also found that the temperature of the connective tissue at the time of stretch may significantly influence the long-lasting deformation that is produced. Lehman et al (10), using in vitro rat tail tendons, reported that relatively small magnitude loads at room temperature produced no differences in tendon elongation. However, progressively raising the temperature during the stretch to 45°C produced substantially greater changes in tendon lengths. Furthermore, elevation of the tissue temperature prior to and during a low-load stretch has been shown to create less tissue damage compared with a similar stretch at lower temperatures (19,20). It has also been noted that allowing the tissue to cool in a
loaded position produces greater gains in length than tissue cooling without maintained tension (10).

Clinically, the use of LLPS has been found effective in the treatment of soft tissue contractures (2,5,11). Bohannon et al (2), using uncontrolled case studies involving orthopaedic pathologies, reported that a regimen of daily LLPS markedly decreased substantial knee extension contractures. Clinical improvement of long-standing knee stiffness using LLPS has also been documented in a nonambulatory geriatric population (11). The gains noted in this study were found to be significant when compared with high-load brief stretches manually administered to a second test group.

The benefits of prolonged loading in the management of shoulder stiffness have also been documented through a study utilizing 50 patients with adhesive capsulitis of the shoulder. Patients who received prolonged pulley traction at low loads in conjunction with transcutaneous nerve stimulation application demonstrated significantly greater gains in shoulder ROM than those who received heating modalities, active exercises, and gentle rhythmic stabilization manipulations (15).

While use of an LLPS to improve joint mobility has been documented clinically, the associated use of thermal agents to enhance the stretch has received little clinical examination. As discussed above, heat is commonly recognized for its therapeutic effect of increasing extensibility of connective tissue (9). However, support for this assumption through controlled clinical study is scarce. Wessling et al (21) found that the application of ultrasound to the belly of the triceps surae during a single session of LLPS promoted significantly greater immediate gains in ankle dorsiflexion than an LLPS alone. While statistically significant, the reported changes in flexibility (1–2.5°) were quite small by clinical standards. Also, the design of this work did not allow for documentation of long-term effects of such an approach over repeated treatment sessions.

The use of cryotherapy to optimize the permanent length changes in connective tissue structures has only been alluded to in previous research (10,14). It has been suggested that heating an area before and during a stretch, then cooling the area in the stretched or loaded position, will optimize the permanent plastic deformation of the connective tissue structure (16). While the application of ice following stretching is a daily practice in many clinics, the influence of such a practice on efforts to improve the flexibility of periarthritic tissues has not been objectively documented.

Therefore, the purpose of this investigation was to determine the clinical effectiveness of superficial heat and cold modalities when used in conjunction with an LLPS to improve the flexibility of an extremity joint limited by soft tissue tightness. Our hypotheses were twofold. First, we anticipated that a single treatment regimen of superficial heat applied in the initial phase and cold applied in the final phase of an LLPS into shoulder extension rotation would produce greater gains in ROM than other combinations of LLPS with heat or cold. Secondly, we hypothesized that long-term gains in shoulder external rotation (ER) ROM following three sessions of an LLPS would be greatest when the stretch was applied in conjunction with a combined heat and cold application.

**METHOD**

**Subjects**

A convenience sample of 92 healthy male volunteers between the ages of 19 and 36 participated in and completed this study (mean age, 24.3 ± 4.1 years). An additional seven individuals started the data collection process but did not return for all required follow-up sessions. Two other individuals reported increased discomfort at the third treatment session and were not allowed to complete the study.

All subjects were attending California State University, Fresno at the time of data collection. Subjects were recreational athletes, for whom the authors believed efforts to maximize shoulder flexibility would be advantageous or cause no harm. Instructions were given to the subjects to maintain their normal level of activity for the duration of the study. This study received approval by the Committee on the Protection of Human Subjects at California State University, Fresno, and informed consent was obtained from all participants prior to beginning treatment. A summary of subject characteristics is presented in Table 1.

A potential subject was excluded from this study if: 1) there was a history of orthopaedic injury about the shoulder girdle to be tested, 2) a positive apprehension test was elicited from the shoulder to be tested, 3) the initial ROM measurement of passive shoulder external rotation was less than 75° or greater than 120°, 4) at any point in the study a

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Age*</th>
<th>Weight (kg)*</th>
<th>Initial ROM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Stretch alone</td>
<td>18</td>
<td>25 ± 4.1</td>
<td>177 ± 25.8</td>
<td>102 ± 9.9</td>
</tr>
<tr>
<td>B: Heat + stretch</td>
<td>22</td>
<td>25 ± 4.8</td>
<td>182 ± 21.5</td>
<td>100 ± 7.4</td>
</tr>
<tr>
<td>C: Stretch + ice pack</td>
<td>18</td>
<td>25 ± 4.1</td>
<td>170 ± 26.1</td>
<td>96 ± 8.1</td>
</tr>
<tr>
<td>D: Heat + stretch + ice pack</td>
<td>22</td>
<td>25 ± 4.2</td>
<td>169 ± 29.3</td>
<td>99 ± 7.0</td>
</tr>
<tr>
<td>E: Control</td>
<td>16</td>
<td>24 ± 3.1</td>
<td>178 ± 34.8</td>
<td>100 ± 12.2</td>
</tr>
</tbody>
</table>

* Mean ± SD.

**Table 1. Subject characteristics by intervention groups.**
measurement of more than 130° was obtained, and 5) the subject reported any discomfort that the testers assessed to be beyond the normal sensation of stretched tissue.

**Design Statement**

This prospective study was designed to document the changes in ROM of shoulder ER after an LLPS in conjunction with heat and/or cold. The arm to be tested was randomly chosen, except in cases of previous unilateral injury. Subjects were assigned to one of three groups by stratified random sampling. These groups were broken down into classifications according to the subject's initial ROM of ER of the tested shoulder as follows:

1) tight:
   ER ROM = 75–90°
2) moderately tight:
   ER ROM = 91–105°
3) normal:
   ER ROM = 106–120°

Subjects within these classifications were then randomly assigned to one of five groups:

A) stretch alone.
B) heat during the initial phase of stretch.
C) cold during the final phase of stretch.
D) heat during the initial phase and cold during the final phase of stretch.
E) control (no intervention).

Subjects in the experimental groups received three stretching treatments over a 5-day period; each was 24–48 hours apart. For subjects in the experimental groups, a final measurement of ER was performed 72 hours after the final treatment session. The follow-up measurement for the control group was performed 1 week after the initial measurement. Consistent daily treatment times for each subject were maintained across the duration of the study.

**Instrumentation**

A standard plastic goniometer, marked in 1° increments, was used to measure shoulder ER. The scale of the goniometer was covered to blind the investigator during all measurements. Range of motion procedures were performed by two individuals during the course of data collection, with this responsibility transferred approximately halfway through the data collection phase of the investigation. Pilot studies using eight subjects found the intrarater reliability of these two individuals to be .98 and .97, respectively, while interrater reliability between the two individuals was .96.

Three upper extremity positioning stands were manufactured by the experimenters. Each stand was adjustable in the vertical plane and was positioned to support the tested shoulder in 90° of abduction and 20° of horizontal adduction and to allow maximal ER (Figure 1).

**Procedures**

Prior to the initial treatment session, subjects completed a biographical and general health screening questionnaire. Subjects were required to elicit a negative apprehension test from the shoulder to be studied to screen for glenohumeral joint instability (5).

At the beginning of each session, the subject's arm under study was covered with foam prewrap. A 1-in. strip of cloth tape, extending from the ulnar styloid process to the medial aspect of the olecranon process, was then placed over the prewrap. A straight-edge was used to draw a line connecting the same two points (Figure 2).

**FIGURE 1.** Subject positioning using treatment table and upper extremity positioning stand.

**FIGURE 2.** Identification of forearm reference line for range of motion measurements.
Subjects were then placed in the supine position on the treatment plinth, with the arm to be tested resting comfortably on the positioning stand. The upper extremity was positioned in 90° of abduction, 20° of horizontal adduction, 90° of elbow flexion, and a neutral forearm position. The positioning stands were placed so that the olecranon process was directly over the vertical plumb line attached to the stand (Figure 1).

Investigator 1 made the initial gravity-assisted ER measurement using the covered goniometer. This was done by aligning the arms of the goniometer with the vertical plumb line on the test stand and the line previously drawn on the test arm of the subject (Figure 3).

Following the initial measurement, Investigator 2 attached a cuff to the wrist of the test arm, with the cuff's superior edge consistently positioned just proximal to the ulnar styloid process. The ability for a right angle pull of the forearm into external rotation was then obtained by attaching a monofilament line to the wrist cuff and running it over a movable eye on the test stand (Figure 4). A calculated weight of 0.5% of each subject's body weight could then be attached and removed as needed during the stretch protocol.

Investigator 2 then applied the appropriate treatment option for each group. An LLPS, consisting of 0.5% of each subject's weight, was performed for all groups, except the control, in the following manner.

*Group A (stretch alone)* Subjects were initially placed unweighted in the test position of full ER for 10 minutes, followed by a 1-minute rest period. All 1-minute rest periods included unweighting of the arm and movement of the arm back to neutral. After the initial 10-minute period of end range positioning with gravity assistance, the calculated weight was then attached to the wrist cuff and the arm was again positioned at the end range of ER. At this time the subject underwent three 5-minute weighted stretch periods, each followed by a 1-minute rest period in which the arm was again returned to a neutral position. After the third and final weighted stretch period, the unweighted arm was returned to the test position for 10 minutes. Shoulder ER ROM was then measured by Investigator 1 immediately following this last 10-minute period. Throughout this protocol, the actual time of weighted stretch was 15 minutes, with 10 minutes of unweighted positioning at end range before and after the weighted stretch.

*Group B (heat and stretch)* Subjects followed the same protocol as Group A, with the addition of moist hot packs (approximately 66°C) applied to the shoulder during the initial 10-minute unweighted stretch position and during the next two 5-minute stretch periods. Hot packs were placed on the anterior and posterior aspects of the shoulder (Figure 5). During the first 1-minute rest period, the anterior hot pack was re-placed to promote a consistent heating temperature.

*Group C (stretch and cold)* The Group A protocol was followed, with the addition of an ice pack (approximately 0°C) applied to the anterior shoulder during the third 5-minute stretch and the final 10-minute unweighted stretch periods.

*Group D (heat, stretch, and cold)* Again, the same basic protocol was performed, with the addition of applying hot packs to the shoulder during the initial unweighted, 10-minute period and during the next two 5-minute stretch periods. An ice pack was then applied to the anterior shoulder for the last 5-minute stretch and the final unweighted 10-minute period.

*Group E (control or no stretch)*

These subjects reported for an initial measurement of shoulder flexibility, and returned for a second measurement 1 week later.

The stretching weight, the positioning of the shoulder, and the time factors of the actual stretch were determined by pilot study. For our population of young, healthy males,
In all cases of statistical analysis, further post hoc testing using the Duncan procedure was performed for individual comparisons if significance was apparent.

RESULTS

The mean intrasession improvement in ROM for each of the intervention groups is presented in Table 2. A one-way ANOVA was performed for each session to determine the effects of treatment interventions on increasing short-term (mean intrasession) improvements in shoulder flexibility. A significant difference was found for the first two treatment sessions. Further analysis was done using a Duncan post hoc procedure. In session one, only Group B, which used heat at the beginning of the stretch, promoted significant gains ($p \leq 0.05$) compared with the stretch alone group. For session two, only the use of heat combined with ice (Group D) promoted significant gains ($p \leq 0.05$) compared with the stretch alone. There were no significant differences ($p \leq 0.05$) between the stretch interventions during session three.

The long-term improvements in flexibility for each of the intervention groups, as well as for the control group, are presented in Figure 6. Long-term improvement in this study was defined as the gain in ROM noted upon the final measurement, taken 3 days following the third treatment session, compared with the initial measurement at session 1. The greatest long-term gain occurred in the group treated with heat in conjunction with LLPS (Group B), with a mean increase of $8.5 \pm 9.0^\circ$. The groups treated with heat and ice and ice alone (Groups D and C) displayed smaller gains, with mean increases of $6.5 \pm 7.2$ and $5.6 \pm 6.9^\circ$, respectively. The group treated with LLPS alone (Group A) demonstrated the smallest gains of the four intervention groups, with a mean improvement of $1.5 \pm 6.7^\circ$. Minimal change was noted in the control group (Group E), which had a mean change of $0.3 \pm 3.6^\circ$ over the period of 1 week.

A one-way ANOVA was performed between the five groups to determine if significant differences ($p \leq 0.05$) were present in the long-term ROM gains (Table 3). A significant difference was found ($p \leq 0.05$) between long-term gains in ROM and intervention. Further analysis using a Duncan post hoc procedure was then performed. All three groups using a thermal agent pro-

![Figure 5](image-url) Application of moist heat to the shoulder during a low-load prolonged stretch.

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**Table 2. Short-term gains of ROM by treatment sessions.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Session 1*</th>
<th>Session 2*</th>
<th>Session 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Stretch alone</td>
<td>6 ± 5.4</td>
<td>8 ± 5.4</td>
<td>8 ± 5.5</td>
</tr>
<tr>
<td>B: Moist heat + stretch</td>
<td>11 ± 7.1*</td>
<td>12 ± 7.3</td>
<td>11 ± 5.7</td>
</tr>
<tr>
<td>C: Stretch + ice pack</td>
<td>7 ± 6.2</td>
<td>9 ± 6.0</td>
<td>9 ± 4.7</td>
</tr>
<tr>
<td>D: Moist heat + stretch + ice pack</td>
<td>8 ± 5.6</td>
<td>13 ± 6.3*</td>
<td>11 ± 6.0</td>
</tr>
</tbody>
</table>

* Mean ± SD.
** Significant ($p \leq 0.05$) differences found compared to stretch alone group.
nated significant improvements in ROM compared with the control group, while the stretch alone group did not. Of these three, only the group using heat in the beginning stages of the stretch led to significant gains compared with the stretch alone group.

Statistical analysis using the real values of shoulder external ROM, rather than the change values, found no short- or long-term significant differences between the groups.

**DISCUSSION**

This study documented the effects of applying superficial heat and cold modalities in conjunction with an LLPS for the purpose of improving flexibility of an extremity joint limited by soft tissue tightness in healthy subjects. Each of the four intervention groups showed marked short-term gains in ROM following single treatment sessions. The greatest gains were consistently produced when the intervention included the application of moist heat in the initial stages of the stretch. The additional use of an ice pack to cool the area during the end stages of the stretch did not substantially improve the short-term outcome. Therefore, our initial hypothesis that the combined use of superficial heat during the beginning stages of an LLPS with cooling applied during the end stages would produce superior immediate gains in flexibility was not supported.

The outcomes regarding the long-term gains in flexibility among the four intervention groups were enlightening. While clinically substantial immediate gains were documented using an LLPS alone, there was a minimal carryover effect with this intervention across the three treatment sessions. The cumulative gain of 1.5° for this group was not statistically or clinically different from the control group, which received no intervention.

It was found that the application of any of the three variations of superficial heating or cooling agents applied during the LLPS produced a significant cumulative improvement in flexibility across the three treatment sessions. However, the greatest gains were produced when only moist heat was applied in the initial stages of the stretch (Figure 6). This was the only intervention group involving modalities that produced significantly greater gains in flexibility compared to the stretch alone. The application of ice during the end stages of the stretch, following the moist heat, actually diminished the cumulative gains in flexibility. Therefore, our second initial hypothesis, that long-term gains in flexibility LLPS would be greatest when the stretch was applied in conjunction with heat and cold applications, must also be rejected.

The degree of temperature changes that actually occurred in the connective tissues under stretch during this study is unknown. While topical heat and cold applications have the potential to promote temperature changes in the connective tissues about a moderately superficial joint such as the shoulder, the magnitude of such changes would vary.
We postulate that a reflexive decrease in muscle tone, associated with the application of heat, may have also been a contributing factor to the changes in flexibility seen in this study.

In turn, indirectly reduces alpha motor neuron activity, resulting in muscle relaxation (12). Laboratory work shows that when a relaxed muscle is physically stretched, most, if not all, of the resistance to stretch is derived from the extensive connective tissue framework and sheathing within and around the muscle (3,17). We believe that the application of superficial heat promoted muscle relaxation, which, in turn, allowed a greater degree of connective tissue lengthening to occur during the LLPS.

The application of ice over muscle bellies to facilitate their activity is a technique used by therapists in neurological rehabilitation (18). While such facilitory techniques utilize relatively short applications of ice, we propose that the use of ice following heat during the LLPS may have offset the reflexive decrease in muscular activity associated with the initial application of heat. This increased muscular activity would not allow the connective tissue to remain in its maximally lengthened position during the final phases of the stretch, decreasing the potential for a more permanent elongation to occur.

This may account for the differences between the results of our study and those of Lehman et al (10,19,20), which showed that heating the tissue during an LLPS and cooling it in its lengthened position would produce lasting connective tissue deformation. The conclusions of these earlier works were based on results using exclusively in vitro connective tissue samples. In contrast to a purely mechanical model, our investigation utilized a living system, which inherently includes reflexive sensory, vascular, and motor components in its response to stretch and thermal agents.

Clinical Implications

Increasing the ROM of extremity joints is a common goal in the management of many patients, and intentional stretching of some kind is frequently used to achieve this effect. This study has shown that using superficial heat in the beginning stages of an LLPS is a clinically superior method for attaining rapid and lasting increases in ROM when compared to an LLPS alone. Our study demonstrated that three 40-minute treatments of moist heat with an LLPS within 1 week produced substantial gains in shoulder ROM.

The small magnitude of force required to create such a substantial, long-lasting gain in flexibility was surprising. The LLPS used in this study was subjectively found to be very comfortable, with many subjects indicating that they did not even feel a sensation of stretch during the procedure. While good gains in ROM were facilitated with this protocol, we had no reports of any residual problems with function or sensation.

Caution must be used in generalizing these conclusions to patients with shoulder pathology. It is unknown if similar magnitudes of stress in conjunction with thermal agents would produce relatively greater or smaller gains in flexibility when applied to conditions of abnormal joint restrictions, such as end stage adhesive capsulitis.

Conclusions using these findings regarding the use of ice as part of a treatment strategy for improving flexibility in a patient population should also be guarded. Subjects treated with ice and LLPS in this study did demonstrate clinically substantial, long-lasting gains over the period of 1 week. Other work has found the use of cold followed by a brief stretch to effectively reduce EMG activity in muscles experiencing postexercise-induced fatigue (13). Therefore, we suggest that the use of ice and LLPS may be an effective treatment for increasing ROM in patients with substantial inflammatory or painful components to their clinical dysfunction.

A logical and needed extension of this work would be to document the effectiveness of thermal modalities with LLPS in the treatment of patients with shoulder pathology. We would also suggest that the use of ultrasound to obtain a deeper tissue temperature increase with this protocol be investigated. The effects of the application of superficial heat and cold on underlying muscle activity during an LLPS through EMG analysis would also be insightful.

CONCLUSION

Statistically significant immediate and residual increases in shoulder

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ER ROM were produced with the use of superficial heat in conjunction with an LLPS compared to an LLPS alone. We conclude that the use of superficial heat in conjunction with an LLPS is a superior method for obtaining lasting changes in soft tissue extensibility when compared to an LLPS alone.

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REFERENCES


