Cryotherapy Effects, Part 1: Comparison of Skin Temperatures and Patient-Reported Sensations for Different Modes of Administration

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**Context:** Alterations in skin sensations may be responsible for pain reduction provided by cryotherapy, but the exact physiological mechanism is unknown. **Objective:** To investigate perceptions of skin sensations associated with different modes of cryotherapy administration and skin temperature at the point of perceived numbness. **Design:** Repeated measures. **Participants:** 30 healthy subjects (12 Male, 18 Female, Age = 21.1 ± 1.9 years). **Interventions:** Crushed ice bag, ice massage, and cold water immersion. **Main Outcome Measures:** Perceptions of sensations during each mode of cryotherapy administration were derived from a Modified McGill Pain Questionnaire. Skin temperature was recorded when numbness was reported for each treatment. **Results:** Participants experienced sensations that included cold, tight, tingling, stinging, and numb. Ice massage sensations transitioned rapidly from cold to numb, whereas cold water immersion and ice bag treatments produced altered sensations for longer duration. Ice massage decreased skin temperature significantly more than the other two modes of cryotherapy administration. **Conclusions:** Ice massage may be the best mode of cryotherapy administration for achievement of anaesthesia as rapidly as possible, whereas cold water immersion and ice bag application may be better for attainment of pain reduction associated with noxious stimulation of skin receptors. **Key Words:** cold water immersion; ice massage; ice bag; pain; McGill Pain Questionnaire
cold-water immersion.\textsuperscript{1,9} Despite cryotherapy being the most common treatment intervention for acute and chronic injuries, there are no definitive application parameters. The application mode and duration are often based on convenience or an attempt to get the deep tissues cold as quickly as possible.\textsuperscript{10} The lack of clear clinical guidelines relates to an incomplete understanding of the effect of cold on pain reduction. Because beneficial effects have been reported for the use of vapocoolant sprays\textsuperscript{11} and short-duration ice bag application (5–10 min),\textsuperscript{12} their analgesic effect is probably linked to changes in skin sensation, rather than cooling of deep tissues. Perhaps the primary benefit of cold therapy relates to its effect on the skin in one of two ways: either by reducing sensory information (anaesthesia) or by inducing a painful stimulus that initiates a complex central nervous system pain-reducing response.

The skin acts as a thermosensory organ that is capable of detecting small changes in surface temperature.\textsuperscript{13} To achieve localized analgesia, the skin temperature must decrease below 13.6°C.\textsuperscript{14} In a clinical setting, the duration of cryotherapy treatments ranges from 30 seconds to 30 minutes.\textsuperscript{15} Examining the sensations that cryotherapy induces may provide insight about the mechanisms by which pain relief is achieved. The purpose of this study was to investigate perceptions of skin sensations associated with different modes of cold application, as well as the skin temperature corresponding to a sensation of numbness. Part 2 of this two-part report will address the treatment duration required to attain a sensation of numbness and the length of time that numbness persists after treatment termination.

**Procedures and Findings**

Thirty healthy adults (12 males, 18 females, age = 21.1 ± 1.9 years) received one of three different modes of cryotherapy application to the lower leg on three separate occasions. Potential participants were excluded if they reported a history of neurological disorder known to affect sensation, cardiovascular disease, peripheral nerve disease, cold allergies or sensitivity, or lower extremity injury within six weeks prior to testing. A modified version of the McGill Pain Questionnaire, replacing the word pain with the word sensation, was used to quantify localized sensation.\textsuperscript{16–18} A document with the detailed procedures and methods is available with the online version of this article.

**Cryotherapy Intervention**

The order of administration of different modes of cryotherapy was randomized through use of a random number generator. Ice massage was administered with a 6-ounce frozen block of ice in a paper cup, which was applied in continuous circular motions at a speed of 4 cm/sec (timed with a metronome). Each ice bag was assembled by placing 1.5 L of crushed ice into a plastic bag (38 × 21 cm), with excess air evacuated prior to bag closure. Ice bags were secured against the skin surface by an elastic wrap. Cold water immersion of the lower leg utilized a 10-gal tub of water and ice that was maintained at 12°C (periodically stirred). Each application of cold was terminated when the subject reported a sensation of numbness.

Participants experienced various sensations during the cryotherapy treatments, with the most common being described as cold, tight, tingling, stinging, and numb. During ice massage, participants primarily reported cold during the first 3 minutes, which transitioned to altered sensation from minutes 3–5, and numbness at minute 5. During cold water immersion, participants reported feeling cold for the first 3 minutes, altered sensation for minutes 4–5, and numbness at minute 6. During the crushed ice bag treatment, participants reported cold for the first 2 minutes, altered sensation during minutes 3–9, and numbness at minute 10. The types of sensations reported during each mode of treatment are presented in Figure 1.

We also compared the decreases in surface temperature among the 3 types of cryotherapy treatments, with statistical comparison based on the mean decrease in temperature at treatment termination. Ice massage was found to produce a significantly greater decrease in skin temperature than the ice bag and cold water immersion modes (Table 1).

**Discussion**

Ice massage produced an average skin temperature of 6.3°C at the time numbness was reported, compared to 16.1°C for ice bag and 14.6°C for cold water immersion. Thus, ice massage is the treatment of choice for rapid lowering of skin temperature to a level that produces localized analgesia (<13.6°C) and reduced nerve conduction velocity (<12.5°C).\textsuperscript{5} Numerous studies have documented that cryotherapy is effective in reducing pain.\textsuperscript{5,12,20,21} The analgesic effect of
cryotherapy is probably associated with the sensory responses, because pain reduction has been shown to result from short-duration treatment that is unlikely to reduce deep tissue temperature. We found differences in responses to ice massage, crushed ice bags and cold water immersion. Prior to conducting the study, we did not know that participants would be able to identify a specific point in time corresponding to the onset of numbness. Our results suggest that selection of treatment parameters might be better focused on attainment of pain reduction, rather than a target amount of reduction in intramuscular temperature.

One mechanism of pain relief associated with ice application is achieved through an anaesthetic effect, which is believed to relate to a reduction in nerve conduction velocity (NCV). To achieve cold-induced analgesia, the skin surface temperature must be lowered to approximately 13.6°C, whereas skin temperature must reach 12.5°C for a 10% reduction in nerve conduction velocity. Algafly et al. reported that a reduction in NCV was associated with an increase in pain threshold and pain tolerance. Although change in NCV was not directly related to analgesia, the neural signal transmission velocity probably affects the manner in which the nervous system processes information.

Another possible mechanism of pain reduction from the use of cryotherapy relates to the hypothesis of diffuse noxious inhibitory control (DNIC). To maximize the noxious stimulus provided by cryotherapy, the application mode that produces the greatest magnitude of “altered” sensations (e.g., pain, tightness, tingling, and discomfort) would be preferred. The crushed ice bag treatment and cold water immersion produced altered sensations for a longer duration than ice massage. Whether cryotherapy provides analgesia through the DNIC mechanism is unknown at present, but future research may provide evidence to support the use of cold therapies that prolong and intensify noxious sensations.

An important limitation of this study’s findings is that they were derived from the responses of healthy individuals who were not experiencing pain. Another factor that may have affected the results is that differing portions of the lower extremity were affected by the different modes of cryotherapy. An elastic wrap

Table 1. Skin Temperature in the Treatment Area at Pre- and Postintervention for Three Modes of Cryotherapy. Presented as Mean ± Standard Deviation, N=30.

<table>
<thead>
<tr>
<th></th>
<th>Ice Bag</th>
<th>Ice Massage</th>
<th>Cold Water Immersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preintervention</td>
<td>33.7 ± 2.0</td>
<td>32.9 ± 3.0</td>
<td>33.9 ± 1.4</td>
</tr>
<tr>
<td>Postintervention</td>
<td>15.7 ± 5.1</td>
<td>6.5 ± 2.0</td>
<td>14.4 ± 1.5</td>
</tr>
</tbody>
</table>
was used to secure the ice bag to the calf, which may have yielded different results from application of an ice bag without compression.

**Conclusions**

Ice massage reduced skin temperature to a greater extent, with a lesser amount of altered sensation, prior to numbness. Thus, ice massage may be the best mode of cryotherapy administration for achievement of anaesthesia as rapidly as possible. Cold water immersion and ice bag application produced altered sensations for longer duration, which would be best for attainment of the analgesic effect that may result from a noxious stimulus.

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**References**


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Detail Procedures and Methods

Study Procedures

1. Study procedures for all participants are presented as a flowchart in Figure 1.

![Flowchart](image)

**Figure 1.**

Subject Measurement Tools

1. Subjects were given the Modified McGill Pain Questionnaire to become familiar with prior to the start of the session.
   a. The subject was asked to pick one word from as many categories as necessary on the Modified McGill Pain Questionnaire for accurate description for their sensation at baseline and every minute during treatment, with the end goal of numb.
      i. The subject was asked to verbalize their sensation each minute.
Subject Positioning and Intervention Area

1. Subjects were instructed to lie prone on the table prior to each session:
   a. The researcher outlined the intervention area on the largest portion of the posterior calf using the standard 14 cm circular template (Figure 2).
   b. The intervention area was shaved on subjects with excessive hair.
   c. The intervention area was then cleaned with isopropyl alcohol.

2. The researcher recorded girth measurements for the nondominant calf using a tape measure.

![Figure 2.](image)

Thermocouple Attachment

1. The researcher attached the surface thermocouple to the intervention area using transparent tape (Figure 3).

2. The skin temperature thermocouple was plugged into the Physitemp Thermes USB electrothermometer (Physitemp Instruments, Inc., Clifton, NJ).

![Figure 3.](image)
Baseline Measurements

1. The researcher assessed baseline measurements for sensation of pressure, determined by the Semmes-Weinstein monofilaments (Figure 4).

2. Subjects were then instructed to choose their current sensation of their nondominant calf on the Modified McGill Pain Questionnaire.

3. The researcher then recorded the subject’s baseline skin temperature.

Interventions

1. For ice bag and ice massage treatments, subjects remained prone after baseline measurements and the intervention was applied to the intervention area.
   a. Ice massage consisted of a 6-ounce frozen block of ice in a paper cup and was applied in continuous circular motions at a speed of 4 cm/sec and timed with a metronome (Figure 5).
   b. Each ice bag was made by placing 1500 mL of crushed ice into a 38 x 21 cm thin flexible plastic bag with excess air evacuated prior to bag closure. Ice bags were secured with consistent compression using an elastic wrap (Figure 6).
2. For cold-water immersion, subjects sat on the side of the table with the lower leg immersed to the knee (Figure 7).
   a. Cold water immersion consisted of a 10-gallon water tub with a mixture of water and ice that was kept at 12°C.
   b. CWI was periodically stirred by the researcher.
   c. Subjects wore a toe cover (PRO Orthopedic Devices, Tucson, AZ).

![Figure 7.](image)

**Intervention Measurements**

1. Once the intervention was in place, the researcher began keeping time on a stopwatch to monitor the length of time needed for numbness to occur.
2. Subjects were asked to rate their current sensation on the Modified McGill Pain Questionnaire every minute.
3. The researcher recorded skin temperature every minute.
4. The intervention remained on the subject until numb was chosen as the current sensation on the Modified McGill Pain Questionnaire.
5. Once numb was reported, the intervention remained on the subject for an additional 1 minute.
6. After the additional minute, the subject was asked to rate the Modified McGill Pain Questionnaire once again. If numb was chosen again, the intervention was removed.
7. The time on the stopwatch was stopped, and the length of intervention was recorded.

**Postintervention Measurements**

1. Once the intervention was removed, the researcher began keeping time on a stopwatch to monitor the length of time needed for baseline sensation to return.
2. At this time, immediate post-intervention measurements of sensation of pressure (Semmes-Weinstein Monofilaments, skin temperature, and Modified McGill Pain Questionnaire were recorded until the subject reported a return to baseline sensation via the Semmes-Weinstein Monofilaments. This concluded the visit.
3. Postintervention time was recorded on the stopwatch.
4. All subjects were asked to return no sooner than 24 hours, at their convenience, until all three interventions were completed.
Statistical Tests

1. After examining the times to numbness, it was determined that the data were non-normally distributed. Most data has a "normal" or bell-shaped distribution so means and standard deviations are used to compare group differences. Since our data was skewed and did not show this bell-curve, we used nonparametric statistics to compare group differences.

2. A Freidman Test that evaluates differences between median scores was used to compare the time to numbness and the time to return to baseline measures.

3. Post-hoc analyses to determine the specific differences among the treatments were conducted with Wilcoxon Signed Ranks Tests. The level of significance was set prior to the study at $P \leq 0.05$. 