Difference in Tissue Temperature After Therapeutic Ultrasound Using Biofreeze Mixture and Ultrasound Gel as Coupling Media

Justin H. Rigby, MS, ATC; Shaylene B. Dye, MS, ATC; and David O. Draper, EdD, ATC, FNATA

ABSTRACT

Biofreeze, a topical analgesic, is commonly used as a coupling medium during therapeutic ultrasound to add greater relief of pain, although it may block transmission of ultrasound energy. Our objective was to compare a mixture of 1-part Biofreeze and 3-parts ultrasound gel to 100% ultrasound gel to assess intramuscular heating and perceived sensation of heat. Fifteen participants received a continuous 3-MHz ultrasound treatment with the Biofreeze mixture or 100% ultrasound gel on 2 different days. We measured intramuscular tissue temperature and visual analog scale scores for heat sensation. The Biofreeze mixture produced a tissue temperature increase similar to the 100% ultrasound gel ($P = .32$), while producing a greater perceived sensation of heat ($P < .0001$). However, due to Biofreeze’s viscosity, more of the mixture (12.9 ± 2.6 mL) was needed than the ultrasound gel (10 ± 0 mL) to prevent overheating of superficial tissues. [Athletic Training & Sports Health Care. 2013;5(x):xxx-xxx.]

Therapeutic ultrasound is inaudible, acoustic vibrations of high frequency, sending ultrasound energy into the tissues, thus increasing temperatures deep within the tissues. For ultrasound energy to be absorbed into the tissues, a coupling medium is required. The most common type of coupling medium is ultrasound gel. It is mainly composed of distilled water and inert, nonreflective material that increases the viscosity of the mixture. A thin layer of ultrasound gel between the skin and the sound head serves 2 purposes. First, it allows an efficient transfer of ultrasound energy to enter the target tissues by minimizing the air between the sound head surface and tissues.1,2 Second, ultrasound gel acts as a lubricant during an ultrasound treatment.1

Topical analgesic gels and creams have been used as ultrasound coupling media. Topical analgesics are used for the same purpose as common ultrasound gel, while also providing an added benefit of a counterirritant to the treatment area. Topical analgesics provide a counterirritant to the treatment area by using the active ingredients of menthol, methyl salicylate, or capsaicin.1 The active ingredients in topical analgesic gels and creams stimulate thermoreceptors, which is similar to the effect of when either cold or heat is applied, thus creating a sensation of cold or heat.3 These sensations, in turn, have been shown to reduce the amount of pain perceived by patients.4,5

Although topical analgesics are used as coupling media, they are not always successful at allowing the transmission of ultrasound energy from the device into the tissues. Many topical analgesics have been shown to have poor transmission of ultrasound energy,6,7 but some have qualities that may aid in the better transmission of ultrasound energy. First, aqueous gel–based analgesics have been shown to allow the transmission of ultrasound energy better than cream–based agents.7 Second, using a mixture of topical analgesic and ultra-
sound gel has allowed for adequate transmission of ultrasound energy.8,9

Biofreeze (Hygenic Corp, Akron, Ohio) is a menthol (4%)-based topical analgesic gel often used as a coupling medium during ultrasound treatments to create an additive effect for pain relief. The active ingredient—menthol—in Biofreeze is used to create a cooling sensation1 and has been shown to decrease pain after delayed-onset muscle soreness.3 When Biofreeze has been used as a ultrasound coupling medium by itself, it has been shown to have poor transmission of ultrasound energy.7

Although, by itself, Biofreeze has shown to be a poor transmitter of ultrasound energy, it may work well if mixed with ultrasound gel. The purpose of this study is to determine whether there is a difference in 1-part Biofreeze and 3-parts ultrasound gel compared with regular ultrasound gel in conduction ultrasound energy measured by intramuscular tissue temperature and whether there is a different perception of heat by the study participants when the Biofreeze mixture is used compared with ultrasound gel. Our hypotheses were:

- The application of a Biofreeze mixture as a coupling medium will allow for an equal transmission of ultrasound energy compared with regular ultrasound gel, resulting in similar intramuscular tissue temperature throughout an ultrasound treatment.
- The application of a Biofreeze mixture as a coupling medium will create a cooling sensation, resulting in a lower perceived heating sensation.

**METHOD**

A 2×21 (condition × time) repeated measures was used to guide this study. Each participant received an ultrasound treatment using each of the ultrasound coupling conditions. The dependent variable was tissue temperature of the triceps surae muscle group at 2 cm deep, measured to the nearest 0.1 °C, and perceived heat sensation measured via a modified visual analog scale (VAS). The independent variables were ultrasound coupling condition and time. The ultrasound coupling condition had 2 levels—(1) a Biofreeze mixture of 1-part Biofreeze and 3-parts ultrasound gel and (2) 100% ultrasound gel. Time was measured pretreatment as baseline, followed by measurements over the course of a 10-minute ultrasound treatment at 30-second intervals. This study was approved by the university’s institutional review board before participants were enrolled.

**Participants**

Fifteen healthy college-aged volunteers (men = 7, women = 8; age = 23.7 ± 2.2 years; subcutaneous fat thickness = 0.7 ± 0.2 cm) were enrolled and completed this study. Before participating in the study, volunteers were included if they were healthy and aged 18 to 35 years and were excluded if they presented with fever, lower-leg infection or open wound, compromised circulation or sensation to the area to be treated, or injury to the lower leg within the past 2 months.

**Instruments**

Single MT-23/5 needle microprobe thermocouples (Physitemp Instruments Inc, Clifton, New Jersey) were implanted into the participants’ triceps surae muscle and interfaced with an Iso-Thermex electrothermometer (Columbus Instruments, Columbus, Ohio) to record intramuscular tissue temperature. The reliability and validity of the MT-23/5 needle microprobes were tested prior to participants being enrolled in the study in 5°C and 43°C water baths using methods that were reported previously and are shown in the Table.10 The reliability and validity of the Iso-Thermex electrothermometer has also been reported previously.11 The depth of insertion of the needle microprobes and the participant’s subcutaneous fat thickness was verified with a musculoskeletal imaging ultrasound (LogiQ 5e; General Electric Company, Fairfield, Connecticut).

Ultrasound treatments were given using the Omnisound 3000 Pro device (Accelerated Care Plus LLC, Reno, Nevada). We used a 5-cm² ultrasound head, which has an effective radiating area (ERA) of 4.2 cm² and a beam non-uniform ratio of 3.0:1 for frequency of 3 MHz.

**Procedures**

Participants reported to the Modalities Research Laboratory for each visit. At the first visit, participants were screened for the inclusion and exclusion criteria, and they reviewed and signed an institutional review board–approved consent form.

During the study, participants received 2 ultrasound treatments with a different coupling medium for each treatment. The coupling media used were (1) 1-part Biofreeze and 3-parts ultrasound gel mixture (Biofreeze mixture) and (2) 100% ultrasound gel. The order of application for the coupling medium condition was randomized using a computer random
number generator before participants were enrolled in the study. Participants were instructed not to exercise within 24 hours of testing.

Participants were asked to lie prone on a treatment table. Their left posteromedial calf was shaved and cleansed with an iodine swab. The insertion of the needle microprobe was performed following the methods described previously. We visually noted the skin surface of the posterior calf that had the largest girth, measured 2 cm down (anteriorly) the inside (medial) portion of the calf, and marked the skin’s surface with a felt marker. At that point, a sterile 23-gauge needle microprobe was inserted into the posteromedial calf muscle at a direction parallel to the treatment table. A musculoskeletal imaging ultrasound was used to view the temperature probe and measure the exact depth of the probe from the surface of the skin. The probe’s receiving end was attached to the Iso-Thermex electrothermometer, allowing us to measure and record the intramuscular tissue temperature. Tissue temperature was recorded every 30 seconds during baseline measurements and throughout the treatment.

Immediately after the probe was inserted, the participant marked a modified VAS to measure their perception of heat. The modified VAS consisted of a continuous 10-cm length line with anchor points of “no heat” and “extreme heat.” The reliability and validity of the VAS in measuring pain has been previously reported. This initial VAS score was recorded as the participant’s baseline score.

A treatment area template with a 15-cm² oval cut-out (3.6 × ERA) was taped onto the posterior calf. Our treatment area was slightly larger than the recommended 2 to 3 × ERA but was consistent between conditions, allowing for an appropriate comparison. Either 10 mL of the Biofreeze mixture or 100% ultrasound gel, as determined by the random number generator assignment, was applied to the treatment area. The coupling medium was applied before baseline temperatures were recorded to measure the true heating capacity of the ultrasound treatment and account for a small decrease, if any, in tissue temperature that may have occurred due to the application of room-temperature media. We recorded tissue temperatures for 5 minutes, and the mean of these measurements was calculated to establish the baseline tissue temperature. With the coupling medium applied, and while the baseline tissue temperatures where being recorded, the participants marked a second VAS score, establishing their pretreatment score.

After the 5-minute baseline measurement, a continuous 3-MHz ultrasound treatment at 1.0 W/cm² (2520 J) was applied to the area for 10 minutes. The ultrasound head was moved at an approximate speed of 4 cm per second in a linear motion within the template. If the investigator performing the treatment believed that more coupling medium was needed to ensure a proper treatment, more coupling medium was added, and the amount added was recorded. At the completion of the treatment, the participants again marked their perception of heat on a VAS to establish their posttreatment score.

After completion of the treatment, the area was wiped clean of the coupling medium. The microneedle probe was removed, and the area was cleansed with isopropyl alcohol; the insertion wound then received an application of bacitracin ointment and an elastic bandage.

The participants made a second visit to the laboratory within a 1-week time period, where the same procedures were followed, except the opposite ultrasound coupling medium was used. The visits were separated by at least a 48-hour recovery period.

### Statistical Analysis

A 2×21 (condition × time) repeated measures analysis of variance (ANOVA), with baseline tissue temperature as a covariate, was used to assess the differences in intramuscular tissue temperature (condition main effect) and rate of heating differences (condition × time interaction). A 2×3 (condition × time) repeated measures

### TABLE

<table>
<thead>
<tr>
<th>ACTUAL WATER BATH TEMPERATURE (°C)</th>
<th>THERMOCOUPLE MEASUREMENT RELIABILITY (MEAN ± SD)</th>
<th>ABSOLUTE THERMOCOUPLE-MERCURY THERMOMETER DIFFERENCES (MEAN VALIDITY ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9</td>
<td>4.59 ± 0.08</td>
<td>0.07 ± 0.08</td>
</tr>
<tr>
<td>43.2</td>
<td>42.45 ± 0.33</td>
<td>0.13 ± 0.30</td>
</tr>
</tbody>
</table>

*Physitemp Instruments Inc, Clifton, New Jersey*
ANOVA was used to assess changes in VAS scores for heat sensation. Descriptive statistics were performed for the amount of coupling medium used for each condition.

RESULTS

No difference was noted between the Biofreeze mixture and 100% ultrasound gel for mean intramuscular tissue temperature ($F_{1,13} = 1.03, P = .32$) and rate of heating ($F_{20,280} = 1.45, P = .10$) (Figure 1). The Biofreeze mixture and 100% ultrasound gel allowed for a temperature change of $4.43 \pm 0.31^\circ C$ and $5.01 \pm 0.33^\circ C$, respectively, during the ultrasound treatment. The Biofreeze mixture produced a greater sensation of heat when compared with 100% ultrasound gel ($P < .0001$). The mean difference of heat sensation produced from baseline to posttreatment for the Biofreeze mixture and 100% ultrasound gel was $63.0 \pm 19.7$ and $50.7 \pm 14.5$, respectively. However, the Biofreeze mixture was thick and became clumped together during the ultrasound treatments. As a result, more of the Biofreeze mixture was used ($12.9 \pm 2.6 \text{ mL}$) compared with the ultrasound gel ($10 \pm 0 \text{ mL}$) to prevent overheating and discomfort.

DISCUSSION

Topical analgesic balms have been widely used by the public and in physical medicine and rehabilitation clinics for temporary relief of minor aches and pains. The active ingredients in topical analgesics—menthol, methyl salicylate, and capsaicin—act as a counterirritant, stimulating cutaneous sensory receptors, and is theorized to depress an individual's pain sensation through the gate-control mechanism. Biofreeze is an aqueous topical analgesic gel that creates a cooling sensation through the active ingredient of menthol. Biofreeze has been shown to decrease pain associated with low back pain and delayed-onset muscle soreness. Topical analgesics have also been used as a coupling medium during therapeutic ultrasound treatments. When using a topical analgesic as a coupling medium, the goal is to provide a sensation of pain relief while simultaneously administering an ultrasound treatment. Unfortunately, many of the topical analgesic gels or creams do not have similar transmission rates of ultrasound energy to ultrasound gel or water. For example, another commonly used topical analgesic, Flexall (Ari-Med Pharmaceuticals, Tempe, Arizona), was compared with ultrasound gel at a 1:1 ratio of Flexall and ultrasound gel. The Flexall mixture did not allow for the same level of intramuscular tissue temperature rise as the 100% ultrasound gel. Similar to our study, a follow-up study revealed that a ratio of 1:3 of Flexall and ultrasound gel allowed for the same heating capacity as 100% ultrasound gel.

Because Biofreeze produces a cooling sensation when applied, we hypothesized that the use of a Biofreeze mixture may reduce the sensation of heat during an ultrasound treatment. However, our study produced similar results to other studies that used Flexall, whose active ingredient is also menthol (16%), and topical analgesics during ultrasound treatment, where the participants reported a greater sensation of heat on the VAS scale.

Two reasons may explain why the study participants reported that the Biofreeze mixture produced a greater sensation of heat compared with 100% ultrasound gel. First, the sensation of menthol is often described as a cool burning sensation. The use of a Biofreeze mixture as a coupling medium for ultrasound may produce more of a burning sensation, thus creating a greater sensation of heat. Second, the Biofreeze mixture was thick and clumpy, causing the mixture to stick to the ultrasound head (Figure 2), which made it difficult to perform a proper ultrasound treatment. Consequently, we had to continually add more of the Biofreeze mixture during the treatment. It is unclear whether the increase in heat sensation noted by the participants was due to the menthol in Biofreeze or whether it was due to an inadequate amount of cou-
pling medium. The inadequate amount of coupling medium may have led to greater attenuation of the ultrasound energy into the cutaneous tissues, rather than allowing for the ultrasound energy to travel deeper into the tissues. This greater attenuation of ultrasound energy into the cutaneous tissues would have created the greater sensation of heat noted by our participants.

The frequency of the ultrasound treatment may have a role in the transmission of ultrasound energy through a topical analgesic coupling media. During our study, we used a frequency of 3 MHz, but previous studies using 1-MHz frequency have shown poor results when topical analgesics are used as a coupling medium. When comparing Biofreeze’s relative transmission of ultrasound energy to 100% ultrasound gel measured by a power meter, Cage et al. found that 3 MHz allowed for a greater transmission of ultrasound energy than 1 MHz. With Biofreeze, 3 MHz allowed for 79% of energy to be transmitted, whereas 1 MHz allowed for 60% of the energy to be transmitted.

Two explanations may clarify why 3 MHz allows for a greater transmission of ultrasound energy than 1 MHz. A 3-MHz frequency has a greater number of pulses per second and creates a wider beam. We theorize that the wider beam profile of 3-MHz frequency allows for a greater area for ultrasound energy transmission through the coupling medium. Second, it has also been hypothesized that a higher frequency may break down the polymer chains in topical coupling media, which in turn fluidizes the formation’s structure, leading to less attenuation by the topical coupling medium itself.

Because a 3-MHz frequency in ultrasound treatments allows for greater transmission of ultrasound energy, our results should not be inference to a treatment with 1-MHz frequency. Further research may be needed to understand the heating capacity of a 1-MHz treatment when a mixture of Biofreeze is used as a coupling medium. Also, we used the Omnisound 3000 Pro ultrasound device; therefore, our absolute tissue temperature increases with the Biofreeze mixture should not be inference to other ultrasound devices, as there is an inequality between devices.

A limitation to this study is that we measured only intramuscular tissue temperature and perceived sensation of heat. We are assuming that a greater rise in tissue temperature and an increase in perceived sensation of heat will lead to clinically successful ultrasound treatments, with an accompaniment of decreased pain. However, future research is needed to understand the effects of ultrasound treatments with topical analgesics used as a coupling medium for decreasing pain in pathological participants.

Also, based on our methods, the clinical benefit of combining the 2 modalities of therapeutic ultrasound and topical analgesic into one treatment, when they can easily be performed separately, is unclear. That is, is there an added benefit of using a topical analgesic as a coupling medium, or is it more efficacious to apply the topical analgesic before or after the ultrasound treatment when 100% ultrasound gel is used? Future research should establish clinical outcomes when an ultrasound treatment with a topical analgesic coupling medium is performed compared with applying them separately.

IMPLICATIONS FOR CLINICAL PRACTICE

The use of Biofreeze as a coupling medium during an ultrasound treatment may provide a greater sensation of heat for the patient, but Biofreeze should be mixed with ultrasound gel to allow for proper transmission of ultrasound energy into the tissues. We recommend a mixture of 1-part Biofreeze and 3-parts ultrasound gel. We also found that the Biofreeze mixture became thick and clumped together; therefore, more of the mixture should be added throughout duration of the treatment to prevent overheating of the superficial tissues.

REFERENCES


