Intra-articular Knee Temperature Changes

Ice Versus Cryotherapy Device

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Background: Cryotherapy is commonly applied without research documenting the intra-articular (IA) temperature changes or subject discomfort between ice and a cryotherapy device.

Hypothesis: The null hypothesis is that no difference would be observed in IA temperature decline or subject tolerance between ice and the cryotherapy device in normal knees.

Study Design: Prospective, within-subject controlled clinical trial.

Methods: Twelve subjects had IA temperature in suprapatellar pouch and skin recorded bilaterally after application of cryotherapy versus ice. Subject tolerance was recorded by 10-cm visual analog scale (VAS). Statistical evaluation was by Spearman's correlation analysis and paired, nonparametric Wilcoxon's signed rank test.

Results: Both significantly lowered ($P < 0.001$) skin and IA temperature with median decreases (ice/cryotherapy) at 30 (3.3°C/2.2°C), 60 (12.8°C/7.1°C), and 90 (15.2°C/9.7°C) minutes. However, ice lowered the IA temperature significantly more than the cryotherapy device ($P < 0.001$) and was more painful by VAS at 30 and 60 minutes ($P < 0.01$).

Conclusions: Both methods produced large declines in skin and IA temperatures. However, ice was more effective yet resulted in higher pain scores. The authors hypothesize that IA temperatures below a threshold are associated with increased perceived pain.

Keywords: cryotherapy; intra-articular; temperature; knee; ice

Cryotherapy, the use of cold as a beneficial modality, has a long history in the treatment of musculoskeletal injuries.[11] In fact, ice is often considered to be one of the most common modality choices used to treat physical disorders.[19] In the literature, cryotherapy has been shown to effectively reduce pain, narcotic consumption, nerve conduction, tissue metabolism, hypoxia, edema, and inflammatory mediator release.[1,2,4,8,9,12,14,17,18,20,21,23] For these reasons, cold as a modality often is used for postoperative management following total knee arthroplasty, simple arthroscopy, and anterior cruciate ligament (ACL) reconstruction.[2,4,5,12-16,18,20,21] Our previous studies have shown significant decreases in intra-articular (IA) temperature within all regions of the knee following simple arthroscopy.[13,14] These combined findings suggest that IA cooling must be considered a mechanism of providing the previously documented clinical effects after knee surgery.

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Use of an ice bag as a method of cryotherapy is commonplace in the sports medicine arena for treatment of both acute and chronic musculoskeletal conditions. Although studies have shown decreases in IA temperatures postoperatively, no studies to date have measured IA temperature changes in the normal knee between the traditional ice bag and a cryotherapy compression device. We investigated whether these two techniques of cooling the knee significantly decreased the IA temperature. Furthermore, we evaluated subject tolerance to temperature changes by a visual analog pain scale. Our null hypothesis was that no differences would be observed in IA temperature declines or subject tolerance between ice and a cryotherapy device.

MATERIALS AND METHODS

Following Institutional Review Board approval and informed consent, 12 subjects (7 females, 5 males; average age, 26 years) were enrolled in the study. Exclusion criteria included prior surgery on either knee, prior knee injury, or known medical history positive for peripheral vascular disease, rheumatoid arthritis, or osteoarthritis. On examination, all subjects had full, pain-free range of motion, no

tenderness to palpation, and no observable effusion bilaterally. Following sterile preparation, a thermocouple probe (Model IT-18, Physitemp, Clifton, New Jersey; diameter 0.25 inches, length 3 feet, time constant 0.1 seconds) was inserted intra-articularly into the suprapatellar pouch through an 18-gauge needle introduced to the lateral aspect of the knee. A second thermocouple probe was placed on the skin 2 cm proximal to the superior border of the patella of each knee.

A Cryocuff (Aircast, Inc., Summit, New Jersey) cryotherapy device was applied to the right knee and filled with ice water according to the manufacturer's recommendations, while crushed ice in a plastic bag was secured to the left knee with plastic wrap. Once the two forms of cryotherapy were applied, temperature data (degrees Celsius) from the suprapatellar pouch and skin were recorded every minute for 2 hours using a Thermes-16 Data Acquisition Card (Thermes, Physitemp, Clifton, New Jersey; accuracy of 0.1°C ± 0.2%, stability ± 0.1°C), which was installed in a standard personal computer. Opto-isolation was used to provide complete electrical isolation for the thermocouple circuitry and personal computer power supply.

Both methods of cryotherapy were applied for 1 hour and removed for the 2nd hour. The ice water in the cryotherapy device was changed at 30 minutes based on the findings of previous studies showing the device to be most efficient when using this protocol.[13,14] During the entire 2-hour data acquisition period, all subjects remained on bed rest. At the conclusion of the 2-hour study period, all probes were removed. Each subject served as his or her own control.

Descriptive statistics were summarized with medians and ranges since the data were not normally distributed. The distributions were also presented graphically using box plots, demonstrating median values ± one quartile and the range. Spearman's correlation analysis was used to assess the association between pain and temperature data. Groups were compared and changes over time were assessed using paired, nonparametric, Wilcoxon's signed rank tests. Statistical significance was defined as $P < 0.05$.

RESULTS

The median initial temperatures of the skin were very similar for the ice (29.4°C) and cryotherapy device (29.6°C) groups (Fig. 1). Likewise, initial IA temperatures of both groups were similar with median temperatures of 33.7°C and 33.4°C, respectively, for ice and cryotherapy device groups (Fig. 2). With the application of ice for 30 minutes, the IA temperature showed a median decrease of 3.3°C ($P < 0.001$) from the initial temperature. The median decreases in temperature at 60, 90, and 120 minutes were 12.8°C, 15.2°C, and 11.2°C, respectively, all with $P < 0.001$. Skin temperatures decreased from the initial temperature with the use of ice with median decreases of 21.4°C at 30 minutes, 26.2°C at 60 minutes, 12.3°C at 90 minutes, and 5.8°C at 120 minutes, all with $P < 0.001$. When the cryotherapy device was applied to the knee, IA temperatures showed median decreases from initial temperature of 2.2°C for 30 minutes, 7.1°C for 60 minutes, 9.7°C for 90 minutes, and 5.7°C for 120 minutes, all with $P < 0.001$. Skin temperatures with the use of the cryotherapy device had median decreases from initial temperature of 14.8°C at 30 minutes, 16.7°C at 60 minutes, 8.2°C at 90 minutes ($P < 0.001$), and 4.4°C at 120 minutes.

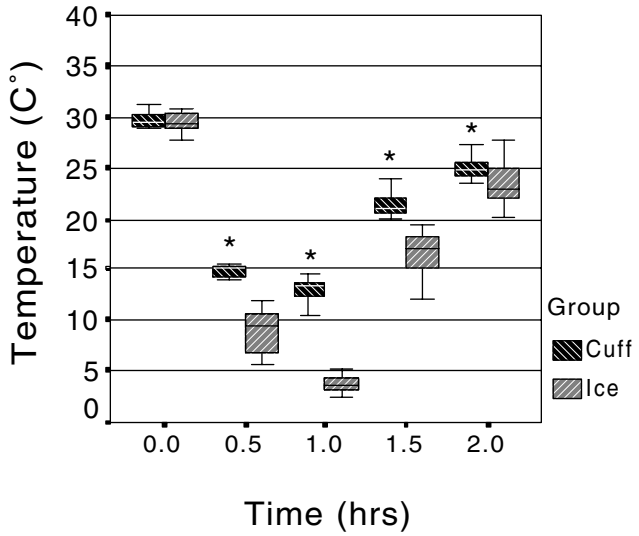

Figure 1. Box plots of skin temperatures measured with the use of an ice bag and cryotherapy device (cuff) for cooling the knee for the 1st hour, removed for the 2nd hour. Horizontal markers within the box plot indicate median temperature; boxes represent 25th to 75th percentile, and entire range of temperature values is indicated by horizontal markers outside the box plot. Total measurement time of 2 hours is shown on the x-axis and temperature measured in degrees Celsius is depicted on the y-axis. *, skin temperature of ice group significantly declined from cuff group at 95% confidence interval.

As expected, ice showed significantly lower skin temperatures versus the cryotherapy device at 30 minutes (–5.4°C, $P < 0.001$), 60 minutes (–9.3°C, $P < 0.001$), 90 minutes (–4.3°C, $P < 0.001$), and 120 minutes (–1.4°C, $P = 0.04$). IA temperatures were significantly lowered from baseline in both groups with treatment. However, ice dropped the IA temperature significantly more than the cryotherapy device with median differences between groups of -5.3°C ($P < 0.001$), –5.7°C ($P < 0.001$), and –2.5°C ($P = 0.01$) at 60, 90, and 120 minutes, respectively. VAS pain scores revealed ice to be more painful than the cryotherapy device at 30 minutes and 60 minutes, with median differences in scores of 0.7 ($P = 0.01$) and 2.2 ($P < 0.001$), respectively (Fig. 3). Pain was correlated with lower IA temperature in the ice group at 90 minutes (rho = –0.65, $P = 0.02$).

DISCUSSION

At temperatures of 35° to 36°C, as in synovitis and inflammatory joint disease, enzyme activity can increase exponentially leading to cartilage breakdown, whereas joint temperatures of 30°C or lower result in negligible destruction.[7,22] In a study evaluating the influence of cold therapy

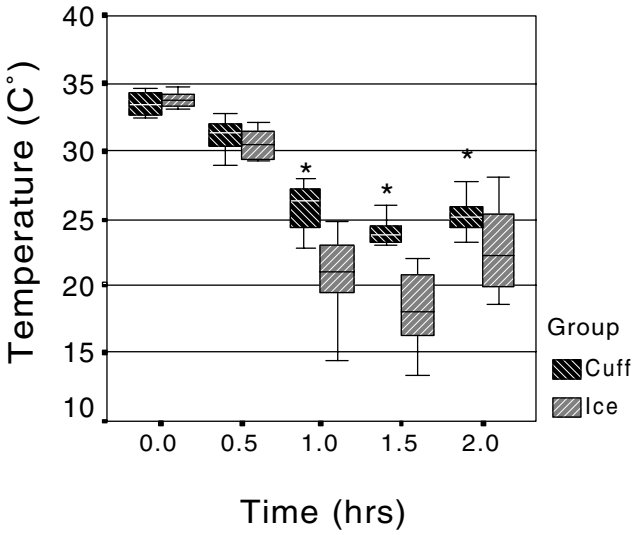

Figure 2. Box plots of intra-articular temperatures measured with the use of an ice bag and cryotherapy device (cuff) for cooling the knee for the 1st hour and removed for the 2nd hour. Horizontal markers within the box plot indicate median temperature; boxes represent 25th to 75th percentile, and entire range of temperature values is indicated by horizontal markers outside the box plot. Total measurement time of 2 hours is shown on the x-axis and temperature measured in degrees Celsius is depicted on the y-axis. *, intra-articular temperature of ice group significantly declined from cuff group at 95% confidence interval.

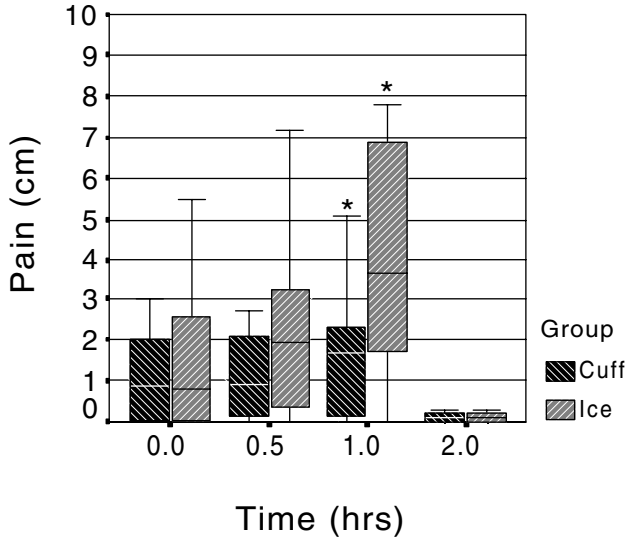

Figure 3. Box plots of visual analog scale (VAS) pain scales measured over a 2-hour period with the use of an ice bag and cryotherapy device (cuff). Horizontal markers within the box plot represent median pain scores, boxes represent the 25th to 75th percentile, and entire range of pain scores is indicated by horizontal markers outside the box plot. Total measurement time of 2 hours is shown on the x-axis and VAS pain scores, measured in centimeters, are depicted on the y-axis. *, ice was significantly more painful than the cryotherapy device at 95% confidence interval.

via the traditional ice bag on IA temperature of the knee, Oosterveld et al[17] found that IA temperature of a healthy knee can be decreased from a mean temperature of 31.9°C to 22.5°C. Results of the current study demonstrate the ability to lower IA temperature to 30°C within just more than 30 minutes of cold therapy and maintain temperatures well below the threshold of decreased enzymatic activity up to 120 minutes.

Just as decreases in skin temperature through the use of cryotherapy serve as a poor predictor of intramuscular temperature,[10] it is unlikely that measuring decreases in skin temperature would be valuable in predicting temperatures at the much deeper IA level of the knee. Thus, numerous studies have used direct measures of IA temperatures as a means of evaluating the effectiveness of cooling this environment. Bocobo et al.[3] found ice immersion to be superior to ice compresses in decreasing the IA temperature of the dog knee. However, immersion does not serve as a treatment option for immediate postoperative patients and is impractical since most patients do not have ice immersion capabilities for the knee readily available.

Several authors have found either beneficial effects or decreases in IA temperatures with cold therapy following knee surgery. Barber found that continuous-flow cold therapy led to decreases in reported pain scores and analgesic use when compared to no treatment[2] and crushed ice[1] following ACL reconstruction. Although Ohkoshi et al.[16] did not find a decrease in IA temperature from baseline, there was a noted blunting effect with the use of cold therapy following ACL reconstruction. Still, few studies have evaluated both IA temperature and pain levels.

Although the use of the ice bag as a cold modality has been a mainstay in the treatment of sports injuries, the addition of compression as an adjunct treatment is believed to decrease swelling by increasing the extravascular hydrostatic pressure and minimizing fluid extravasation.[5] A study by Webb et al. in 1998[20] showed that the use of cold and compression following total knee arthroplasty resulted in decreased blood loss and pain levels. We proposed simultaneous evaluation of a cold-compression device (Cryocuff) and the traditional ice bag for effectiveness in decreasing the IA temperature of the knee and reported patient discomfort via VAS pain scales.

When compared to ice with an elastic wrap in patients following arthroscopic surgery, the Cryocuff resulted in decreased use of pain medications and higher patient satisfaction.[10] Schroder and Passler[18] found similar results when the Cryocuff was compared to the use of an ice bag following ACL reconstruction. This study demonstrated the apparent benefit of cold with compression over cold alone through decreased swelling, analgesic use, and pain scores while showing increased range of motion in the knee following use of cold and compression. The current study attempted to eliminate any contributory factors possibly affecting IA temperature prior to treatment. It was our design to evaluate the two methods of cryotherapy used in this study in their ability to decrease temperatures without postoperative changes to the IA environment.

As discussed previously, although various methods of cryotherapy have proven to have beneficial clinical effects

or observed IA temperature changes in both postoperative and healthy knees, this study is the only one to compare IA temperature and perceived pain between cryotherapy techniques (ice versus device). It was our hypothesis that the IA temperature of the knee could be lowered significantly from baseline through the use of both modes of cryotherapy; however, subjects' perceived pain to cold could differ in the two groups. Although the cryotherapy device group and the ice bag group did indeed show significant declines in IA temperatures from baseline, the ice group clearly demonstrated significantly greater decreases in temperature at 60, 90, and 120 minutes. Two studies conducted by Ho et al.[8,9] used technetium bone scans to show that soft-tissue blood flow, skeletal blood flow, and skeletal metabolism could be significantly decreased through cooling of the knee. As previously mentioned, Merrick et al.[15] found that secondary hypoxic injury could be reduced through the use of cryotherapy. However, neither Merrick[15] nor Ho[8,9] evaluated threshold IA temperature levels at which the beneficial effects of cryotherapy would occur. Oosterveld[17] referenced knee IA temperature of 30°C as the threshold for decreasing cartilage-degrading inflammatory enzyme activity. We noted median IA temperature values well below this proposed 30°C threshold in both the ice and cryotherapy device groups at 60, 90, and 120 minutes.

In regard to decreased blood flow following the application of cryotherapy, this study provided an unexpected finding. It has been well documented that decreases in soft-tissue and skeletal blood flow occur secondary to the use of cold therapy.[8,9,11] The belief that a reflexive phenomenon occurs with the use of cold therapy is commonly taught in sports medicine.[6,11] The Hunting reflex (reaction) has been described as a reflex vascular vasodilation in an extremity following the initial vasoconstriction caused by prolonged application of cold. Under this theory, a threshold temperature exists in which the body would attempt to warm an extremity through reflexive vasodilation. Although an exact temperature at which this reaction occurs has not been determined, it is generally thought to occur following 15 to 20 minutes of continuous cold therapy. The current study demonstrated steady decreases in IA and skin temperatures with the use of both the cryotherapy device and ice bag throughout and even beyond the 1-hour treatment time. We hypothesize, based on the Hunting reflex, that there would be a noted increase in either skin or IA temperature if indeed a reflexive vasodilation occurred. Thus, with no observed skin or IA warming, we hypothesize that the classic response of the Hunting reflex was not found to occur in the knee with the use of either mode of cryotherapy.

When evaluating perceived pain (VAS scale) to cold therapy, the current study found the ice group to have significantly higher pain scores, via VAS pain scales, than the cryotherapy device group at 30 and 60 minutes. Although scores at both 30 and 60 minutes were statistically different, it should be noted that a clinically significant change in VAS scores is thought to be 2.0 cm or greater. Thus, ice showed a clinically significant higher pain score only at 60 minutes (mean 2.42 cm). Spearman's correlation analysis also revealed that pain was inversely correlated with temperature in the ice group at 120 minutes.

There are several potential limitations of this study. First, since the subjects were not blinded to which knee had ice versus the cryotherapy device, although skin or IA temperature would not be altered, it is possible their perceived pain on VAS could be biased. Second, the study was done on normal subjects, not patients after injury to the knee.

This study demonstrated that cryotherapy through the use of an ice bag and a cryotherapy device produces significant decrease in IA knee temperature. Although the ice bag group showed greater decrease in IA temperature than the cryotherapy device group over equal time frames, patients may have less tolerance for these greater decreases in temperature. Future research is needed to determine critical temperature threshold levels for pain tolerance and correlated with the beneficial effects clinically observed from cold therapy to the knee.

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