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By

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Context: Cryotherapy is a form of electromagnetic energy that utilizes the therapeutic effects of cold. Mounting evidence suggests that cryotherapy is the most effective treatment for acute and sub-acute care of musculoskeletal injuries. Cryotherapy decreases secondary metabolic injury by slowing down metabolism and reducing oxygen demands in the affected area. Cryokinetics is a technique that combines cryotherapy and rehabilitative exercise to allow an injured patient to perform rehabilitative exercises sooner and more effectively. Current literature on the efficacy of different cryotherapy modalities with a cryokinetics protocol is absent. **Purpose:** The purpose of this study was to examine rewarming trends of ankle skin surface temperature during a cryokinetics protocol, and to determine which modality is most effective for use with a cryokinetics protocol. **Participants:** Eleven college aged University of Montana Athletic Training students (age 18-35) participated in this study. **Methods:** A repeated measures design was used for this study whereby all participants underwent one cold whirlpool treatments, one ice pack treatment and one ice water immersion treatment, each lasting 15 minutes. Immediately following each treatment, the participants completed a series of six ankle exercises. The temperature of the dominant ankle was measured at the anterior talofibular ligament (ATFL) prior to treatment, immediately post-treatment, and immediately post exercise using an infrared thermometer. **Results:** A 3X4 repeated measures ANOVA revealed statistical significance between the cooling modalities and ankle surface temperature ($p= 0.05$). Pairwise comparisons revealed statistical significance among the different cooling modalities immediately after treatment minutes and immediately after exercise. Ice water immersion cooled the ankle the most and for the longest duration. **Conclusion:** Modalities that underwent a phase change (ice pack and ice water immersion) cooled skin surface tissue better than those that did not undergo a phase change (cold whirlpool). It was discovered that ice water immersion provided slightly

greater cooling than ice pack, and sustained cooling most effectively when combined with a cryokinetics protocol.

Introduction

Cryotherapy is a form of electromagnetic energy that utilizes the therapeutic effects of cold.[1] The use of cryotherapy dates back to at least 2500 BC, when the Egyptians used it to treat injuries and inflammation.[2] Mounting evidence suggests that cryotherapy is the most effective treatment for acute and sub-acute care of musculoskeletal injuries. Cryotherapy decreases secondary metabolic injury by slowing down metabolism and reducing oxygen demands in the affected area. A greater cooling effect leads to greater decrease in metabolism.[3] Cryotherapy has other beneficial effects as well. The use of cold relieves pain, allowing the patient to perform rehabilitative exercises sooner and more effectively and it limits the amount of edema in the injured area by decreasing tissue permeability.[3]

Cryotherapy can be combined with rehabilitative exercise to decrease pain during the exercise using a technique called cryokinetics. Cryokinetics allows the patient to perform exercises sooner and more effectively.[3] Using this technique, cold is applied to the affected body part for a maximum of 20 minutes, or until the area is numbed. The patient then performs exercises. This process can be repeated for 5 minutes to re-numb the area if necessary.

Clinicians on a daily bases utilize many different cryotherapy modalities for injuries such as ankle sprains. Some studies attribute 45% of all athletic injuries to ankle sprains, making them the most common injury in sports.[4] The lateral structures of the ankle, the anterior talofibular ligament and the calcaneofibular ligament, are most commonly injured. In many cases, there is a loss of function due to pain. Restoring function is the primary goal of rehabilitation. Applying cryotherapy to the ankle assists in the restoration of function by decreasing nerve conduction velocity, nociception, and muscle spasms. These effects are believed to occur once the skin temperature is below 56.5°F and can last for up to 30 minutes.

It has been observed that cryotherapy modalities that undergo a phase change have the greatest cooling effect on skin and intramuscular temperatures.[6] Research indicates ice packs provide the most subcutaneous cooling.[6] However, literature is conflicted as to which modality provides the longest cooling effect. Different studies show that ice packs, cold whirlpool, and ice bath have the longest post application cooling effects, [7-9] but no literature was found directly comparing these three modalities. There is also a lack of literature comparing the rewarming trends of these three modalities with a cryokinetics protocol. Therefore, the purpose of this study is to examine the rewarming trends of ankle skin surface temperature during a cryokinetics

protocol with three cryotherapy modalities, and to determine which modality is most effective for use with cryokinetics.

Methods

Design

A repeated measures design was used for this study whereby all participants underwent three randomized trials consisting of a cold whirlpool treatment, an ice pack treatment, and an ice water immersion treatment. Immediately following treatment, the participants completed a series of six standardized ankle exercises.

The temperature of the dominant ankle was measured at the anterior talofibular ligament (ATFL) prior to treatment, immediately post-treatment, and immediately post exercise. In order to avoid carry over effects of treatments a wash out period of at least two hours between treatments occurred and participants refrained from exercise for at least 12 hours prior to each treatment.

Participants

Eleven college aged University of Montana students (age 18-35) participated in this study. Participants had no prior lower extremity injury within the last six months and had no history of adverse reactions to cryotherapy. Prior to the first treatment each participant's height and weight was measured in addition to skinfold measurements over the ATFL (Table 1).

Instruments

An ILLE Hydrotherapy Unit Model T HM100-42 PM (Williamsburg, PA) was used with crushed ice and cold water for all cold whirlpool treatments. Standard plastic ice bags with four cups of crushed ice per bag were used for all ice pack treatments. Ice packs were secured to participants with a standard four-inch double elastic wrap. A 15-liter, plastic, rectangular (15inch X 5.5inch X 8.5inch) bucket with crushed ice and cold water was used for all ice bath treatments. All water temperatures were measured with a water thermometer. Participants' heights were measured with a measuring stick, weights were taken using a standard scale and skin fold calipers were used to collect skin and adipose tissue measurements over the ATFL.

Three skin temperature readings were taken per treatment at the anterior talofibular ligament. Readings were taken immediately prior to treatment, immediately post treatment, and immediately post exercise. All skin temperatures were measured with a Ryobi Tek 4 Professional

Infrared Thermometer. This model is accurate to within two degrees Fahrenheit. Post treatment, participants' ankles were dried off with a clean, dry terrycloth towel.

Procedures

Each participant received three separate cryotherapy treatments to the lateral ankle of the dominant leg. The ankle was selected for this study because it is commonly injured and does not contain a significant amount of adipose tissue, which acts as an insulator and is a poor conductor of cold.[1] Treatments occurred at least two hours apart. Treatments were randomized and consisted of cold whirlpool at 55 degrees Fahrenheit, [3] an ice bath at 33 degrees Fahrenheit[3] and an ice pack of crushed ice. Three temperature readings were recorded during each trial; a baseline reading immediately prior to treatment, immediately post-treatment, and immediately post exercise. Temperature readings were taken over the anterior talofibular ligament. For each treatment, participants sat upright with the knee bent to approximately 90 degrees flexion. The recommendation for sub-acute cryotherapy treatment is 10-20 minutes to establish numbness; [3] following this recommendation a 15-minute treatment time was selected for this study. After each treatment concluded, participants completed six ankle exercises. The six exercises consisted of; Achilles towel stretch (30 seconds), four way ankle pumps (10 each direction), heel and toe walks (20 each), marble pick-ups (1 minute), single leg stance on Airex pad (30 seconds X 2), single leg hops on Airex pad (10 hops). Through the course of this experiment, one researcher (JS) was responsible for taking all temperatures, measurements, recording all data, and drying the ankle. Another researcher (NI) was responsible for preparing all whirlpools, ice packs, and ice baths, applying ice packs to participants, and running participants through exercises. One faculty mentor was also present to assist with the exercise protocol. This reduced inter-rater error.

Crushed Ice Pack Setup

Four cups of crushed ice were placed in one standard size plastic ice bag with as much air as possible removed, and tied off at the top. Participants then sat with their knee and ankle flexed to about 90 degrees and one researcher secured the ice bag over the lateral malleolus and anterior talofibular ligament with a four-inch double elastic wrap. A small hole was put in each ice bag as it was secured to the participants to force any remaining air out of the bag. Immediately post treatment the participants' ankle was dabbed dry with a clean, dry terrycloth towel prior to taking first post treatment temperature.

Ice Water Immersion Setup

Ice and cold water were placed in a 15 liter plastic bucket until the temperature reached 33 degrees Fahrenheit, as measured with a water thermometer. The bucket was filled so that there was enough water to completely cover the participant's ankle. Participants sat with their knee and ankle both flexed to about 90 degrees. The treatment began as soon as the water temperature reached 33 degrees Fahrenheit. Participants moved their ankle in a circular motion every minute to avoid the buildup of a thermopane.[3] Immediately post treatment the participant's ankle was dabbed with a clean, dry terrycloth towel prior to taking first post treatment temperature.

Cold Whirlpool Setup

A whirlpool was filled with cold water and ice until it reached 55 degrees Fahrenheit with the turbine on. Participants sat so their knee and ankle were both flexed to about 90 degrees and the ankle was completely submerged. The treatment began as soon as water temperature reached 55 degrees Fahrenheit as measured by a water thermometer. Immediately post treatment, the participant's ankle was dabbed dry with a clean, dry terrycloth towel prior to taking first post treatment temperature.

Data Analysis

Descriptive statistics were calculated for each subject's age, height, weight, and temperature measurements. A 3X3 repeated measures (condition x time) ANOVA was used to evaluate significance where alpha was set a priori at 0.05. If significant interactions were found, pairwise comparisons were run using a Bonferonni adjustment. Microsoft Excel 2013 and IBM SPSS version 22 were used to analyze the data.

Results

A 3X3 repeated measures ANOVA revealed statistical significance between the cooling modalities and ankle surface temperature ($p = 0.05$). Pairwise comparisons revealed statistical significance between cold whirlpool and ice pack ($p = 0.013$) and cold whirlpool and ice water immersion ($p = 0.001$). Figure 1 illustrates the cooling trends for each modality.

Discussion

Cryotherapy is a commonly used modality for acute and sub-acute musculoskeletal injuries. Cold modalities are used to decrease pain, decrease swelling, minimize secondary metabolic injury, and to promote numbness in a cryokinetics protocol.[3] This study was originally designed to compare the effectiveness of ice bath, ice pack and cold whirlpool with cryokinetics. Multiple studies have compared the effectiveness of cryotherapy modalities.[6-9] Ice pack, ice bath, and cold whirlpool have all been shown to provide the longest lasting effects by separate studies. However none of those studies directly compared these three modalities. Also, literature on the effectiveness of these modalities in a cryokinetics protocol is absent.

An inverse relationship has been observed between amount of cooling and metabolism.[10] Greater cooling leads to a greater decrease in metabolism. Furthermore, skin temperatures must be lowered to 56.5°F to produce analgesic effects.[11] Therefore, cryotherapy modalities that lead to greater cooling and keep skin temperatures below 56.5°F for the longest period of time would be most beneficial.

The results of this study show a statistically significant relationship between cryotherapy modality and ankle skin temperature in a cryokinetics protocol. Ice water immersion was the most effective of the three modalities tested. It had the greatest cooling effect, producing the coldest temperature readings immediately post treatment and post exercise. Similar trends were observed with ice pack, however overall cooling was not as effective as ice water immersion. Cold whirlpool showed the least cooling, but it showed the lowest rate of rewarming. Ice pack and ice water immersion were the most effective at cooling with ice water immersion showing the greatest decrease in skin temperature. Cold whirlpool and ice water immersion showed the longest lasting effects. A possible explanation for this is that the entire foot and lower leg were submerged. Therefore, more tissue needed to be reheated compared to ice pack, where only the ankle and distal fibula are covered.

The results of the current study support the existing theory that modalities that undergo a phase change have the greatest cooling effect.[6] There may be a relationship between mechanism of heat transfer and duration of effects. Ice pack and ice water immersion, which cool tissue by conduction, showed similar rewarming patterns. Cold whirlpool cools tissue by convection and showed longer lasting effects than ice pack and ice bath. We could not find existing literature to explain this relationship, so further research is necessary. The current study contradicts the

results of a Kennet et al.[7], in which ice pack produced a lower skin temperature than ice water immersion. The differences could be attributed to the fact that Kennet et al. used a 20-minute treatment time compared to a 15-minute treatment time in the current study.

Limitations

There were numerous limitations involved in this study. First, the small sample size. There were eleven participants in this study. Coordinating the exercises and temperature measurements was also a challenge. There was a learning curve for the researchers in which the completion of exercises and obtaining temperature measurements became more coordinated as the study went on. Lack of control of the ambient temperature was another limitation.

We believe that following the skin surface temperatures for longer duration would have been beneficial for this study. Many times in cryokinetics, cryotherapy and rehabilitative exercises are alternated multiple times to achieve desired results. Measuring skin temperatures over multiple bouts of cryokinetics would better mimic a real world scenario and give us a better view of rewarming trends. Obtaining subcutaneous temperatures would have also been beneficial to gain a better understanding of rewarming trends.

Future Research

This study showed ice water immersion was the most effective modality for use with a cryokinetics protocol. Ice water immersion cooled the skin the most and kept the skin coolest following the cryokinetics protocol. Further research following the rewarming trends of each modality for a longer duration would be beneficial. This study used both conduction and convection modalities, further research could compare the effects of different mechanisms of heat transfer. Further research could also examine a different area of the body to determine if rewarming trends are similar.

Conclusion

The goal of this research was to compare ice pack, ice water immersion and cold whirlpool to determine which cryotherapy modality was most effective for use with a cryokinetics protocol. The results of this study support the existing literature. Modalities that underwent a phase change (ice pack and ice bath) produced more cooling than the modality that did not undergo a phase change (cold whirlpool). Ice water immersion proved to be most

effective modality for use with a cryokinetics protocol, cooling the ankle the most and for the longest duration.

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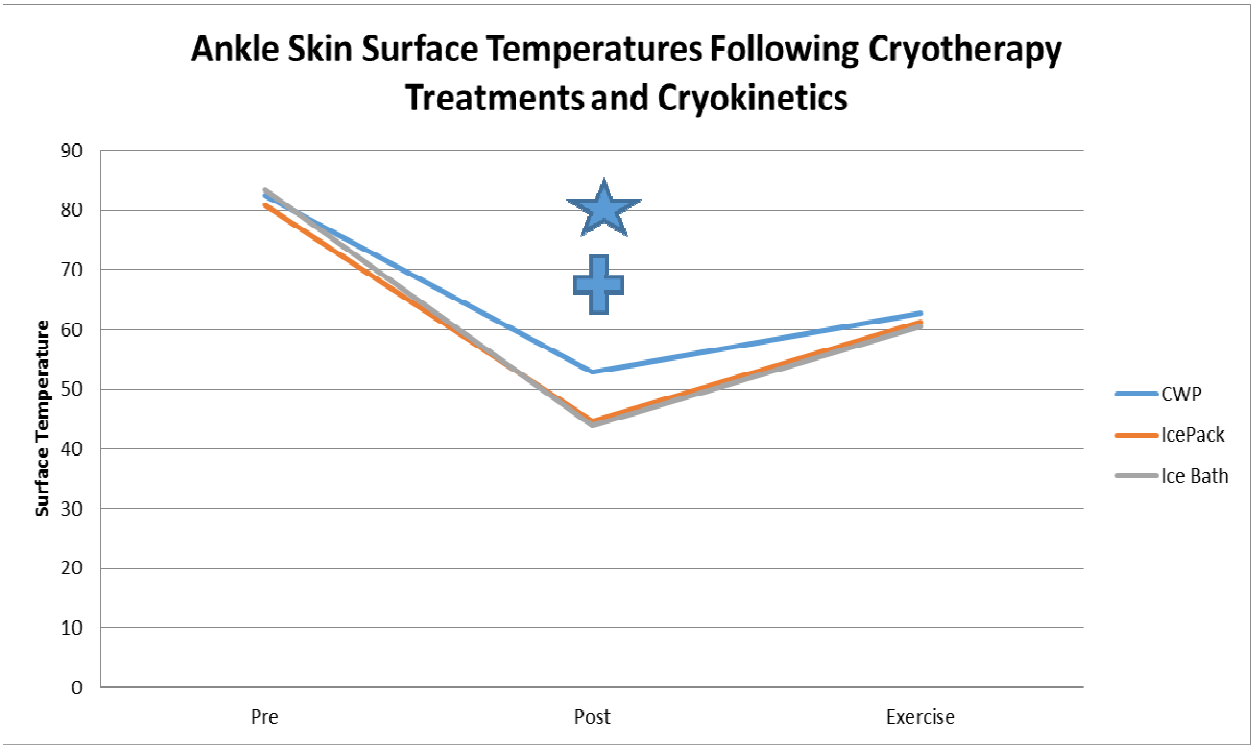
Tables and Figures

Table 1: Group Demographics

Group Demographics	Avg.	SD (+/-)
Age	23	2.83
Height (cm.)	176.09	8.44
Weight (kg)	79.29	12.04
ATFL Skin Fold	3.65	0.94

Figure 1: Skin Temperature Before and After Different Cryotherapy Modalities with Cryokinetics Protocol



P = 0.00 CWP vs IB

P = 0.01 CWP vs IP