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The effect of cryotherapy technique on skin temperature measurement at the knee joint

Sara L. Ringle
San Jose State University

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Ringle, Sara Louise, M.A.

San Jose State University, 1994

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

THE EFFECT OF CRYOTHERAPY TECHNIQUE ON SKIN TEMPERATURE MEASUREMENT AT THE KNEE JOINT

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By

Sara L. Ringle

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Dr. Emily Wughalter

Dr. Mike Huang

Dr. Martin Trieb

APPROVED FOR THE UNIVERSITY

ABSTRACT

THE EFFECT OF CRYOTHERAPY TECHNIQUE ON
SKIN TEMPERATURE MEASUREMENT AT THE KNEE JOINT

By Sara Ringle

The purpose of this investigation was to examine the effects of three cryotherapy techniques (Aircast® Cryo/Cuff, Polar Care™ and ice bag) on skin temperature over treatment time.

Twenty-four male high school athletes were randomly chosen from a pool of 31 volunteers for inclusion in the study. A Yellow Springs thermometer was used to measure skin temperature. A 3 (Cryotherapy Technique) X 6 (Treatment Time) ANOVA with repeated measures on the last factor was conducted on skin temperature. The interaction of technique by treatment times was statistically significant as was the main effect of times. The Polar Care™ technique produced significantly colder skin temperatures at the 15 and 20 minute times than the Aircast® Cryo/Cuff. Also skin temperature differences were found between pre-test and 5 min, 5 min and 10 min, 10 min and 15 min, 15 min and 20 min, and 20 min and posttest times.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

INTRODUCTION

Cold therapy, also known as cryotherapy, is a treatment technique used for acute injuries and rehabilitation since the time of ancient Greece. McMaster (1982) reported that Hippocrates used it in 300 or 400 BC and found that ice decreased swelling and reduced pain by producing numbness. Mcmaster stated "Larrey, chief surgeon to Napoleon, was credited with using refrigeration anesthesia - probably fortuitously - on the Russian front in 1813" (p.112). Cryotherapy is an age-old remedy for pain relief, fever reduction, and control of bleeding. More recently, it has been applied to prevent or reduce edema of traumatic origin and inflammation, decrease muscle-guarding spasms, and temporarily diminish spasticity before exercise (Michlovitz, 1990). Two factors contributing to the quality of the rehabilitative effects of cryotherapy are: length of application time and consistency of a constant temperature.

According to Ogden, Biser, Akers and Lytle (1990) the application of ice and the equivalent cold to human skin produces four phases. In phase 1, the patient has a cold feeling (2-3 minutes). In phase 2, the patient experiences burning or aching (2-7 minutes). In phase 3, local numbness and anesthesia occur (5-12 minutes). In phase 4, pain and reflex impulses are inhibited, the pain spasm cycle is interrupted, and complete anesthesia occurs. Also, in phase 4 a reflex deep tissue vasodilatation occurs without a consequent increase in metabolism (12-15 minutes).

Recently literature in athletic training has focused on various cryotherapy techniques in relation to skin temperature and application time (Belitsky, Odam, & Hubley-Kozey, 1987; Kowal, 1983; Hillman, & Delforge, 1985). According to Bierman and Friedlander (1940), and Bugaj (1975), the extent of the influences of cold in reducing tissue temperature depend upon: 1) the nature of the substance applied to the skin, 2) its variation from the temperature of the skin surface, 3) the duration of its application, and 4) the region of the body upon which it is applied. Reductions in subcutaneous and intraarticular temperatures are directly related to drops in skin temperature.

Progressive decreases in skin and intramuscular temperature depend upon the initial temperature of the application of the cryotherapy technique and the duration of the treatment. To date no studies have been documented that use either the Aircast® Cryo/Cuff or the Polar Care™ technique. Therefore, the study proposed here could add to the literature on these two cryotherapy techniques when compared to an ice bag to find out which cryotherapy technique decreases skin temperature the most. Aircast®

Cryo/Cuff includes intermittent air compression combined with ice water which may be more effective than ice alone in reducing the circulation, tissue temperatures, and reducing the metabolism of injured tissue.

Problem Statement

The purpose of this study was to examine the effect of three cryotherapy techniques on skin temperature over six treatment times.

Hypotheses

The following null hypotheses were made for the purpose of this study:

1. Cryotherapy technique and treatment time will not affect skin temperature.
2. Cryotherapy technique will not affect skin temperature.
3. Treatment time will not affect skin temperature.

Limitations

The study was limited to:

1. The amount of compression applied between subjects' knees with the cryotherapy techniques was not controlled. The wet ace wrap was applied by the same certified athletic trainer throughout the testing, but it is difficult to get the exact compression on the two cryotherapy techniques

requiring an ace wrap and applying the compression pad of the Aircast® Cryo/Cuff.

Delimitations

The study was delimited by:

1. Subjects had no history of allergic reaction to ice or known disease or injury to the knee joint; therefore, only subjects with a healthy right knee were tested. Healthy subjects were chosen by the investigator so that no complications occurred from the cryotherapy technique applied.
2. The longest amount of time cryotherapy technique was in place was 20 minutes, therefore, generalizability beyond 20 minutes can not be made.
3. Only 24 high school student male athletes (14-18 years old) from Monta Vista High School in Cupertino, California were studied.

Definition of Terms

<u>Ace Wrap</u> - is a rubber elastic bandage. For this study one layer of a wet (dampened with cool tap water) 6" X 5 yards ace wrap was wrapped around the knee joint over the Yellow Springs skin probe thermometer. Also, the rest of the ace wrap was wrapped around the self sealing couplings

of the Polar Care™ and the ice bag to hold the cryotherapy techniques in place and apply compression.

Aircast® Cryo/Cuff - is a cryotherapy technique that applies cold and air compression at the same time. The Aircast® Cryo/Cuff contains a cooler that holds ice water. The cooler is attached to a rubber tube directing the ice cold water to a compression pad which applies air compression (30 seconds on 30 seconds off for every minute) by a motor. The Aircast® Cryo/Cuff used in this study held 5 cups of ice and 5 cups of water, recommended by the Aircast® Cryo/Cuff company.

Cryotherapy Technique - is an apparatus that contains a cold substance (ice or water) that is applied to an injury in acute and rehabilitation stages. For the purpose of this study three cryotherapy techniques were used: Aircast® Cryo/Cuff, Polar Care™, and an ice bag.

Healthy Subject - has no known history of allergic reaction to ice along with no past disease or injury (surgery) to the right knee. For the purpose of this study 24 male healthy subjects were studied.

Ice Bag - is a polyethylene bag that holds chips or cubes of ice. For this study each 12 X 18 polyethylene bag held 4 cups of chipped ice.

Polar Care™ - is a chest full of ice cold water. A rubber tube leading from the chest of cold water (end of tube has pump with thermometer and flow control valve-temperature was set at the coldest reading for all testing) to self sealing couplings which is applied to area with compression. The Polar Care™ used in this study held 24 cups of ice and 13 cups of water, recommended by the Breg company.

Skin Temperature - is a relative measure of cold on the skin measured before, during and after cryotherapy technique is applied. Skin temperature was measured in C° for this study.

Yellow Springs Thermometer - is a thermometer that is used to measure the temperature of the skin. For this study the thermometer was placed by two strips of Micropore® 3M surgical tape under the cryotherapy device on the lateral aspect of the knee joint (over the joint line between the lateral femoral condyle and the lateral aspect of the tibial plateau).

Importance of the Study

To study the impact of three cryotherapy techniques at six times on skin temperature was the purpose of this investigation. No previously recorded studies using the Aircast® Cryo/Cuff and Polar Care™ exist; therefore, this study can initiate more follow-up studies and provide important information to clinicians in sports medicine. Results from the study can provide information about which cryotherapy technique of three tested produces the coldest skin temperature. Perhaps, the cryotherapy technique that results in greatest skin temperature drop could be used in comparison to other cryotherapy techniques developed for future use.

The sports medicine clinician's decision to use locally applied heat or cold in the treatment of athletic injuries depends on a number of considerations (Hillman & Delforge, 1985). More than 30 years ago, the old remedy of using heat was the choice before the importance of cold emerged. During the past several years, the use of cold has been given increased recognition as a valuable therapeutic agent in the treatment of musculoskeletal injuries. The beneficial effects of localized cold in the treatment of athletic injuries include control of edema, a decrease in intramuscular temperature, a slowing of nerve conduction velocity, and facilitation of therapeutic exercise. Heat tends to have the reverse effect from ice on control of edema, decreasing intramuscular temperature, and slowing of nerve conduction velocity. On the other hand, heat is better tolerated psychologically than cold by persons with pain or muscle spasm. Also, heat decreases joint stiffness and increases connective tissue extensibility. However, in some instances, similar therapeutic effects can occur with the use of either heat or cold (relief of pain, reduction of muscle spasm) even though edema, temperature, and nerve conduction velocity differ.

Cryotherapy decreases hemorrhage and edema by the combined effect of a decrease in blood flow through damaged capillaries and a reduction in metabolic function at the cell level. By decreasing the amount of hemorrhage and edema, cryotherapy is of singular importance in achieving earlier resolution of the trauma (Kalenak, Medlar, Fleagle & Hochberg, 1975). The application of heat in acute trauma has exactly the opposite physiologic effect of cold application. Heat increases blood flow and the metabolic rate, thus enhancing the inflammatory response, and the production of edema.

In the sports medicine field, cryotherapy techniques are used frequently whether it be for an acute injury or for rehabilitation purposes. The present study can be beneficial to clinicians in sports medicine in choosing the most effective cryotherapy technique used in this study in reducing skin temperature. After all, the primary goal of certified athletic trainers in rehabilitation is to return athletes to activity as soon as possible. Also, the study can be beneficial in the cost effectiveness of using cryotherapy techniques. For example, if an ice bag proves to be more effective than the Aircast® Cryo/Cuff or Polar Care™ expenses could be minimal with the purchases of ice bags rather than the other two cryotherapy techniques.

Chapter 2

REVIEW OF LITERATURE

This chapter is divided into sections describing: cryotherapy, physiologic effects of cryotherapy, acute care of injury with cryotherapy, rehabilitation of injury with cryotherapy, indications of cryotherapy, contraindications of cryotherapy, and measurement of intraarticular and skin temperatures while using cryotherapy.

Cryotherapy

Cryotherapy is the application of cold. It is found in the form of ice, chemical packs, or commercial devices for first aid and rehabilitation of athletic injuries. The following is a list of cryotherapy techniques being used today: ice bags, cold towels, refreezable packs, cold packs, immersion, whirlpools, contrast baths, ice massage, vapocoolant spray, cold boot, hot/ice, hot/ice thermal blanket, cryokinetics, Aircast® Cryo/Cuff, and Polar Care™.

Physiologic Effects of Cryotherapy

The application of cold therapy initially causes vasoconstriction. Vasoconstriction decreases blood flow, thereby diminishing the amount of hemorrhage in traumatized tissue (Olson & Stravino, 1972). This reaction is explained by Olson and Stravino "As the reaction of the body to preserve the internal core temperature by alterations in the peripheral of skin temperature through vasomotor regulation of small blood vessels in the skin" (p. 840). In 1930 it was found that skin temperature initially fell rapidly when a subject's finger was immersed in ice water (Lewis, 1930; Clarke & Hellon, 1958; Taber, Contryman, Fahrenbruch, LaCount, & Cornwall, 1992). This temperature drop (vasoconstriction) was followed by a spontaneous rise in skin temperature (vasodilation) after the first few minutes. Lewis called this phenomenon the "Hunting Response". First identified in the fingers, Lewis subsequently identified this response in the toes, nose, ears and chin (Lewis; Taber et al.). If deep tissue vasodilation occurs with cutaneous hunting reaction vasodilation, then to minimize the possibility of increasing blood flow to acutely injured tissue, cold should not be applied for more than approximately 20-30 minutes at one time, followed by 20 minutes of rest (Kowal, 1983). Recent research by Knight (1985) has shown that cold-induced vasodilation does not occur (Loane, 1988). According to Knight and Londeree (1980) and Prentice (1990), "The hunting response had been accepted for a number of years as fact; in reality, however, these investigations have talked about measured temperature changes rather than circulatory changes. Thus the hunting response is more likely a measurement artifact than an actual change in blood flow in response to cold" (p. 93).

Taber et al. (1992) studied application of a cold pack on blood volume in a nontraumatized ankle. An impedance plethysmograph, in combination with venous occlusion, was used to measure the changes in local blood volume at the ankle over a 20 minute period for the following three conditions: rest, room-temperature gel pack application, and cold gel pack application. A significant reduction in local blood volume was found for the cold gel pack condition in comparison with the resting condition. The reduction in local blood volume was attributed to a combination of the pack's temperature and pressure from the weight of the cold gel pack. Maximum decrease in blood volume occurred at 13.5 minutes after cold gel pack application.

Along with decreasing the amount of hemorrhage cryotherapy also causes: reduction in muscular spasm, a decrease in intramuscular temperature, a slowing of nerve conduction velocity, a decrease in connective tissue distensibility, induces local analgesia, and causes an increase in pain threshold. The aim of cryotherapy in acute injuries is mainly to reduce edema and speed up rehabilitation by allowing earlier exercise intervention.

Thorsson, Lilja, Ahlgren, Hemdal and Westlin (1985) studied the effect of therapeutic cooling on blood flow in large muscles and compared the flow in rested and warmed up individuals. Eight male (17-27 year olds) distance runners were studied. The muscular blood flow was determined by the Xe clearance technique. The radioactive Xenon isotope was dissolved in isotonic sline, and 2-5 MBq in 0.1 ml was injected into the lateral part of the vastus lateralis of the quadriceps muscle in each leg using a fine needle (0.6mm). The injections were deposited at a depth of 20-25mm below the skin surface about 15cm, proximal to the patella. Skin temperature was recorded using a temperature probe connected to a digital display. Local cooling was carried out by placing two activated instant cold packs (Johnson and Johnson) side by side at the injection site of one leg. The response of tissue blood flow to extended cold application varied, mainly depending on the decrease in tissue temperature. The minimum skin temperature of 15.7°C after rest and 17.5°C after running was recorded after an average cooling time of 4.5 minutes. Thorsson et al. found that 20 minutes of cooling with instant cold packs is sufficient to cause a significant reduction of muscular blood flow at 20-25mm depth. A reduction of blood flow after 5-10 minutes of cold application was found. Most subjects experienced a major gradual reduction in blood flow over a 2-5 minute period, followed by a continued reduction for additionally 10-20 minutes. The reduced blood flow is initiated by a direct cooling effect on the blood vessels causing vasoconstriction and possible increase blood viscosity.

A study by Baker and Bell (1991) was designed to evaluate blood flow responses to cold by using an ice pack and ice massage. Nine subjects (mean age 21.2 years) participated in the study. Treatment was limited to a four by six inch area (belly of the gastrocnemius muscle) between the inner and outer electrodes of the impedance plethysmograph. Four electrodes were placed on the calf. The Minnesota Impedance Cardiograph model 304A was connected to a Surcom Microcomputer to analyze the output. The ice pack consisted of four measured cups of crushed ice placed in a plastic bag held in place by a strip of tape. A styrofoam cup of water was frozen for use during the ice massage session. The ice pack was left on for a 20 minute period, and ice massage to the point of numbness. Blood flow was not significantly affected following treatments of ice pack and ice massage. In conclusion, results from studies involving the effect cryotherapy has on blood flow has been shown to be equivocal.

Reduction in muscular spasm, a decrease in intramuscular temperature, a slowing of nerve conduction velocity, and a decrease in connective tissue distensibility are all physiological effects of cryotherapy (Loane, 1988).

Cold induces local analgesia, and increases pain threshold (depresses the excitability of free nerve ending and peripheral nerve fibers).

Acute Care of Injury With Cryotherapy

Application of ice or cold should begin immediately following an injury. Early applications of ice are more effective in reducing secondary hypoxic injury. Cold lowers the metabolic rate of the tissue and hence decreases the extent of secondary hypoxic injury. Reduced cellular metabolism is often recognized as the beneficial effect of cryotherapy in reducing swelling and edema formation during the acute phase of injury (Loane, 1988).

Cryotherapy should be continued daily until the acute signs and symptoms subside completely and full range of motion is restored. The local anesthetic effect of cold therapy helps diminish the intensity of pain during the acute phase of an injury and, during the rehabilitation phase, the effect encourages early active motion (Kalenak et al., 1975).

Rehabilitation of Injury With Cryotherapy

Applications of ice facilitate exercise by decreasing pain and muscular spasm, thus allowing earlier exercise intervention (cryokinetics) and a faster rate of progress

(Lowdon & Moore, 1975). If cryotherapy is applied continuously and judiciously it is a significant factor in rehabilitation and return of the patient to athletic activity (Kalenak et al., 1975).

Starkey (1976) examined the use of cold, compression, and massage to injured subjects. A cold boot that provided 1 to 2 pounds of alternating pressure was tested on 13 male football players. All subjects had experienced an inversion ankle sprain. The time of treatment was varied between 20 and 40 minutes with 37°F being the temperature of the boot. Edema was reduced by the alternating compression, and elevation was used to assist venous return. Time lost from practice was reduced by approximately two days after using the cold boot when compared to the normal ice, compression, and elevation treatments.

Indications of Cryotherapy

Cryotherapy is indicated in the treatment of muscle spasm, relief of pain, and reduction of inflammation. It is used for a variety of musculoskeletal injuries, including sprains, strains, contusions, and fractures; and, it is used in treating the acute phase of inflammatory conditions of bursitis, tenosynovitis, tendinitis, and arthritis. Applications of cold can be useful for treating heat illness, minor burns, and contractures, and in postoperative treatment.

Cohn, Draeger and Jackson (1989) studied the effect of the Hot/Ice Thermal Blanket on the postoperative course, focusing especially on narcotic consumption for pain. In their study 54 patients who had anterior cruciate ligament reconstruction using patella tendon-bone autografts were randomly divided into two groups (one group used the Hot/Ice Thermal Blanket Postoperatively and the other group did not use the Hot/Ice Thermal Blanket). The Hot/Ice Thermal Blanket consists of two rubber pads connected by a rubber hose to the main cooling unit. Fluid is circulated via the hose through the thermal blankets. The temperature of the fluid was set at 50°F. A significant reduction in pain medication consumption in those patients in the Hot/Ice Thermal Blanket group was found. The patients with the Hot/Ice unit required 53% less injectable Demoral, and 67% less oral Vistaril than the patients without the Hot/Ice unit.

Munst, Bonnaire and Kuner (1988) studied the effects of a Hot/Ice cryotherapy technique as a cold therapy after surgery to the knee joint. The cryotherapy technique consists of a control set, and insulated double feeding tube, and a sterile flexible thermo-cushion. Thirty percent isopropyl alcohol circulates in a closed system which can be held at a constant, continuously variable temperature preselected at +4°C. Pain, swelling and need for analgesic drugs were all dramatically reduced in a majority of the patients tested as a result of the treatment.

Contraindications of Cryotherapy

The use of cryotherapy is contraindicated for patients with Raynaud's phenomenon (vasoconstriction of the tips of the fingers or toes when exposed to cold), cold allergy (hives and joint pain), cold hypersensitivity, compromised local circulation, and cardiac disorder. Cryotherapy should not be used on patients who are unconscious, semiconscious, have collagen diseases (lupus erythematosus), rheumatoid arthritis, cryoglobulinemia, neurological deficits, and paroxysmal cold hemoglobinuria, or vasospastic conditions. Frostbite can occur along with ischemic necrosis of the part being treated which can result in subsequent amputation or extensive skin loss (McMaster, 1977). Also, cryotherapy is contraindicated when used directly over a superficial nerve which can cause temporary disability.

Bassett, Kirkpatrick, Engelhardt and Malone (1992) reviewed six cases of peripheral nerve injury in five patients. Among these cases cryotherapy caused neural injury to three peroneal nerves, two lateral femoral cutaneous nerves, and one supraclavicular nerve. Based on a qualitative evaluation, all of the patients studied had very little subcutaneous fat, thereby reducing the distance between the cold source on the skin and the nerve and minimizing the insulation provided by fat. Cryotherapy for acute injuries may cause disabling neuropathies in rare cases. The disability may be transient (1 to 4 days) or prolonged (4 to 6 months), with all patients eventually obtaining full recovery. Some signs and symptoms of nerve palsy in the peroneal nerve are: footdrop, inability to dorsiflex or evert the foot, and decreased feeling.

Measurement of intraarticular and skin temperature

McMaster (1982) stated: "Due to the insulating effects of the subcutaneous fat and the circulation to the skin, it takes 20 to 30 minutes to cool deep tissues. It takes only ten minutes for a topical effect on the skin" (p.115).

Many variables can influence intramuscular response. For example, form of ice (crushed or large cubes), pressure applied, anatomical site (vascularity and thickness of subcutaneous fat), nature of lesion (extent of vascular damage), depth of measurement, cryotherapy technique and duration of application (Kowal, 1983). Numerous studies have been documented on the effects of cryotherapy on intraarticular and skin temperatures in animals and humans (Bocobo, Fast, Kingery, & Kaplan, 1991). No studies, however, have been documented on the Aircast® Cryo/Cuff and Polar Care™ cryotherapy techniques on intraarticular and skin temperatures.

Borken and Bierman (1955) studied the temperature changes produced by spraying with ethyl chloride. They examined the spray on 10 human subjects. Ethyl chloride was sprayed on the skin over a five inch area on the calf (five subjects) and on the knee (five subjects). Determinations were made with iron-constantan-thermocouples inserted into size 19 hypodermic needles. These were connected to a six-channel leeds and Northrup Micromax® which automatically indicated and recorded temperatures at one-minute intervals. Intramuscular determinations were made in the triceps surae and in the vastus medialis surface. The intra-articular needles were inserted behind the patella (medial margin). The greatest decrease in temperature occurred on the skin surface and in the subcutaneous tissues. Temperatures in the calf muscles decreased from 2° to 7.5°F, and in the knee joints from 3.5° to 5.7°F. Intramuscular temperatures continued to decline after cessation of the ethyl chloride spray and had not returned to the original levels during this test (1 to 2 hours). Therefore, the spraying of the skin surface with ethyl chloride causes a marked lowering of temperatures, to the greatest extent on the skin, and to a lesser degree in subcutaneous areas and least, but still substantial, in muscles at a depth (Borken and Bierman). Ethyl chloride did not appear to make a significant change in the intramuscular temperatures. The decrease in temperature resulting from ethyl chloride spray may be accompanied by other changes, such as in circulation, metabolism, and nerve conductivity.

Bugaj (1975) observed the cooling and rewarming effects of a 10 minute application of cold to the skin overlying the right gastrocnemius muscle. Sixteen subjects (16-27 years old) volunteered for their study. A portable thermistor unit, YSI Telethermometer model 44, was used to record skin temperatures. The cold technique used was ice massage. The ice was cooled to approximately 2°C in a five-ounce paper cup. The technique of application consisted of slowly moving the ice cup over the skin's surface in a gently, circular massage stroke for 10 minutes. The area for testing was 10 centimeters in diameter. The testing session lasted approximately 90 minutes and consisted of pretreatment, treatment, and posttreatment sessions. Peripheral skin temperatures were monitored at one-minute intervals during the treatment session. During the posttreatment phase, temperatures were recorded at one-minute intervals for the first 15 minutes and then at five-minute intervals during the remaining 35 minutes. The most rapid decrease in skin temperature occurred during the first two minutes of cold application, with an average decrease of 14.8°C during the first minute and an additional decrease of 5.7°C during the second minute (Bugaj, 1975). The lowest mean record of skin temperature was 5.8°C which occurred at the tenth minute of cold application. At this time the temperature was 26.6°C below the mean pretreatment temperature. Rewarming did not occur as fast as cooling. For instance, cooling occurred at a rate of 2.7°C per minute and warming occurred at the rate of only 1.9°C per minute. The first two minutes following removal of ice application reported the most rapid increase in skin temperature. There was an average increase of 4.3°C during the first minute and an additional 3.1°C increase during the second minute.

Lowdon and Moore (1975) examined the intramuscular temperature response during an ice massage treatment to determine what time regime resulted in the most effective stimulus to circulation. As a change in intramuscular temperature is related to a variation in blood flow, the rate of temperature change was used as a measure of circulation response. Twelve physically fit male physical education students (21-30 years old) participated in this study. The intramuscular temperature change in the biceps brachii muscle was recorded during ice massage applications of 5, 10, and 15 minute durations. Four consecutive days were used for the study with one regimen on each treatment day. Ice was applied to the entire length of the biceps brachii muscle of the nondominant arm. Fine wire (diameter 0.002 in) Chromel-alumel thermocouples of the beaded junction were used to measure intramuscular temperature. The thermocouple was placed at a depth of approximately two centimeters midway between the cubital fossa and the axillary fold. A resting intramuscular temperature was recorded four times at 1 min intervals prior to application of ice massage. Also, intramuscular temperature was recorded at 1 min intervals during each of the ice massage regimens.

Ice massage caused an immediate decrease in intramuscular temperature. The rate was most rapid in the first two minutes, and continued to decline until the fifth minute. A slow and steady decline continued from 5 to 15 minutes. Ice massage for periods greater than five minutes did not cause significant additional decrease in muscle temperature at two centimeters depth, nor did it intensify the circulatory response obtained, as measured by the change in intramuscular temperature. Therefore, according to the results of Lowdon and Moore (1975) 5 minutes is a valid measure for the beneficial amount of time ice massage should be applied.

In 1978, McMaster, Liddle, and Waugh evaluated the potential of four modalities to cool soft tissue using canines. They compared chipped ice, frozen gel pack, inflatable bladder filled with refrigerant gas, and a chemical ice envelope. Temperatures were recorded using a hypodermic thermistor probe, which was inserted beneath the skin in the deep quadriceps muscle mass immediately adjacent to the femoral shaft. Readings were taken at 15-min intervals for 1 hour. Ice performed best with an average temperature reduction of 11.3°C at the 1 hour duration. The frozen gel pack provided an overall satisfactory performance (8.4°C temperature reduction). The inflatable bladder filled with refrigerant gas and an endothermic chemical reaction were least efficient in cooling deep muscle temperature.

In 1979, Johnson, Moore, Moore and Oliver investigated the effect of a 10°C water bath on the intramuscular temperature of both the ipsilateral (treated) and the contralateral (non-treated) lower legs during treatment and a four-hour recovery period. Ten subjects (20-24 years old) without any known physical disabilities volunteered. Each subject participated in a five-hour testing session divided into three parts; pretreatment (30 minutes), treatment (30 minutes), and recovery (4 hours). A 24-gauge hypodermic thermistor probe, Yellow Springs Instrument Model 524 was inserted 25.3mm into the lateral head of the gastrocnemius muscle to measure intramuscular temperature. A telethermometer, Yellow Springs Instrument Model 43TD was used to record temperatures to the nearest 0.1°C. Intramuscular temperature was recorded before treatment, once every minute during the 30-minute treatment period, and then every 30 minutes during the four-hour recovery period. A rectangular steel tank 76 cm wide, 76 cm deep, and 150 cm long measured at 10°C was used for the treatment. Intramuscular temperature decreased 12.0°C in the treated leg and 2.78°C in the non-treated leg. The 30-minute intramuscular temperature for the treated leg ranged from 15.71°C to 25.78°C and the non-treated leg ranged from 29.02°C to 33.46°C. The authors concluded that the decrease in intramuscular temperature of the non-treated lower leg was apparently caused by physiological adjustments resulting from cold application to the treated lower leg.

Belitsky, Odam, and Hubley-Kozey (1987) evaluated and compared the ability of wet ice (WI), dry ice (DI), and cryogen packs (CGPs) to reduce and maintain the reduction of skin temperature. Ten healthy female (23.3 $\pm$ 2.2 years old) volunteers participated in the study. A Yellow Springs Model 44TD Telethermometer was recorded to the nearest 0.1°C to record skin temperature. Each cryotherapy technique used was wrapped in a wet (dampened with cool water), uniformly sized terry-cloth towel. Each subject participated in three, 45-minute sessions that were performed at least 6 hours apart. Each session consisted of 15 minutes rest, 15 minutes of treatment, and 15 minutes without treatment. Skin temperatures were recorded at 5 minute intervals during the cold application. After 15 minutes of cold application, the skin temperatures decreased to 17.9°C (WI), 20.1°C (DI), and 22.1°C (CGP). After removal of cold there were no significant differences between the three treatments. Therefore, data revealed that WI was significantly more efficient in reducing skin temperature than DI and CGP.

Oosterveld, Rasker, Jacobs and Overmars (1992) studied the effect of cold therapy on the intraarticular and skin surface temperature of the knee. Forty-two healthy subjects (no history of disease or injury to the knee) participated in their study. Group 1 were subjects treated with local application of ice chips (0°C) for 30 min. The ice chips were placed in a plastic bag and applied to the front of the knee (average weight of bag was 3kg). Group 2 subjects were cooled by means of a 6.5 minute application of -160°C nitrogen-cold air from a Medivent NL (Hoek Loos Cryo Service, Schiedam, The Netherlands). To measure intraarticular temperature, an Intraflon-2 infusion needle with an outer diameter of 1mm (Vigon Laboratories, Exoven, France) was inserted into the lateral side of the knee joint. An Exacon C-f04.30 probe was used to measure the skin temperature. The tip of the probe was placed over the joint line between the medial femoral condyle and the medial aspect of the tibial plateau. Ice chips and nitrogen-cold air lowered both skin temperature (from a mean of 27.9°C to 11.5°C and from 28.8°C to 13.8°C, respectively) and intraarticular temperature (from 31.9°C to 22.5°C and from 32.9°C to 28.8°C, respectively).

In 1991, Bocobo, Fast, Kingery and Kaplan evaluated intraarticular temperature changes during and after superficial knee cooling with ice compresses or ice bath immersion. The effect of the duration of the cryotherapy application was also examined. For this study 24 adult mongrel dogs weighing between 11.8 and 20.9 kg were used. A fast-response stainless steel needle microprobe (MT-23/5 Physitemp (formerly Sensortek) Clifton, NJ; 0.64 mm in diameter, 5 cm in length, time constant 0.15) was used to record intraarticular temperatures. Temperatures were recorded on a BAT-12 digital microprobe thermometer (physitemp) with a total system accuracy of 0.3°C. Temperature was also monitored periodically in all dogs with skin surface probes placed directly beneath the cryotherapy and with rectal probes. The dogs were divided into four treatment groups. The first group had ice compresses applied to the knee for 5 min, the second group for 15 min and the third group for 30 min. The compress consisted of crushed ice wrapped in a cloth and applied to the lateral aspect of the joint. The fourth group underwent immersion of the knee joint in ice water for 15 minutes. Recordings were taken from all temperature probes before the application of cryotherapy and at 1-min intervals during cryotherapy. After the removal of cryotherapy, recordings were made at 1-min intervals until the intraarticular temperatures returned to baseline or plateaued. After the removal of the cryotherapy the intraarticular temperature continued to drop for a short period of time and then began to rise. The return to baseline temperature was very gradual (some cases requiring more than 1 hour). Immersion in ice water was much more effective than application of crushed ice to skin for an equivalent period of time in terms of lowering intraarticular joint temperature (Bocobo et al., 1991). The maximum intraarticular drop in temperature after 15 minutes of ice bath immersion was 20.2 $\pm$ 8.4°C compared with 4.1 $\pm$ 1.3°C after 15 minutes of ice compress treatment. Ice water immersion was also more effective in prolonging the intraarticular rewarming period, with the immersed knee joint requiring an average of 59.8 $\pm$ 11.5 minutes to rewarm and the iced knee requiring an average of 33.2 $\pm$ 8.1 minutes.

Walton, Roestenburg, Hallwright and Sutherland (1986) measured the temperature changes in skin and muscle at various depths during and after the application of an ice pack on sheep. Thermocouples were used to measure tissue temperature. They were positioned at depths of 1.0, 2.0, 3.0, and 4.0cm. A 5.0cm diameter area slightly anterior to the femoral shaft was the area measured. A single ice pack placed on the thigh produced rapid changes down to a depth of 1.0cm. At 4.0cm depth the temperature continued to fall long after the pack was removed. Tests were also performed using two ice pack applications. This included two 20 minute sessions with 20 minutes in-between. By the end of the second ice pack application, temperatures of the deep tissues had fallen further than after the first ice pack application. On the other hand, the superficial tissues fell again to similar values as on the first application. Therefore, it was found that multiple applications of an ice pack will incrementally lower the temperature of deep tissues without necessarily lowering the superficial tissues to potentially damaging tissues.

In 1989, Kaempffe performed a study to determine if a reduction in skin temperature occurs after the application of cryotherapy to a casted upper extremity. The casts used were conventional short arm casts constructed on a normal subject. Each cast consisted of an inner layer of stockinette, a layer of cast padding, and an outer layer of casting material. One cast was made of plaster bandages while the other was synthetic fiberglass casting tape. The average thickness of both casts was similar, measuring 0.90cm in the plaster cast and 0.85cm in the fiberglass model. Temperature measurements were taken using thermistor probes and a telethermometer (Yellow Springs Instruments, model 42SC; Yellow Springs, OH). The baseline cast and skin temperatures were recorded after cast placement. A cold gel pack (cooled to -5-0°C) was applied to the dorsal aspect of the cast for 60 minutes. Temperature readings were obtained at 2 minute intervals from both the cast and skin surfaces. A series of three trials were performed for each cast. A reduction and difference in the skin surface temperature occurred for each cast. There was a more rapid skin surface temperature drop from cold gel packs applied to the plaster cast than the fiberglass cast. The maximum reduction in skin temperature was 3.5°C. The lowest skin surface temperatures occurred after 12 minutes, with gradual rewarming throughout the remainder of the trial. The maximum drop in temperature with the fiberglass cast was the same (3.5°C). But, this level was reached 40 minutes after the initiation of cold. Therefore, rewarming occurred over a much shorter period of time.

Merrick, Knight, Ingersoll and Potteiger (1993) studied the effects of ice and compression wraps on intramuscular temperatures at various depths. Eleven subjects (23.5 $\pm$ 2.1

years old) with a mean of anterior thigh skinfold measurement of 15.8 $\pm$ 3.7mm volunteered for their study. Thermocouples interfaced with an electronic thermometer (Columbus Instruments, ISO-Thermex 16-channel) were used to measure skin, tissue, and air temperatures. Two tissue implantable and two surface thermocouples were used. The implantable thermocouples were inserted perpendicular to the skin using 21-gauge hypodermic needles. Insertion depth was based upon skinfold measurements for each subject. Temperature was measured every 30 seconds. The testing session included a 5-minute preapplication, a 30-minute application, and a 20-minute post-application. The four treatment conditions included control, ice only, compression only, and ice with compression. The ice treatments consisted of a crushed ice pack (1kg of ice in a 10L plastic bag) placed directly on the skin. The compression treatment consisted of a 1.34m X 15cm elastic wrap (Depuy, Warsaw, IN) placed around the treated limb. The ice with compression treatment consisted of wrapping an ice pack to the treatment area. All treatments lasted for 30 minutes. Treatment effect was defined as the greatest difference between mean treatment temperature and mean preapplication temperature for each measurement depth and condition. The greatest treatment effects were used for analysis. Results showed that there was no significant treatment effect for the control condition. For the compression only condition, the only significant treatment effect was an increase in skin temperature of 1.88°C. At the skin surface, temperature decreased immediately and rapidly with the application of either ice or ice with compression. At 1-cm into the muscle, temperature changes were less pronounced than at the skin surface. Temperatures at this depth continued to decrease for five minutes after the ice was removed. At 2-cm into the muscle, temperature changes were even less pronounced than at 1-cm. Temperatures continued to fall for 7 minutes after the cold was removed. At all measurement depths ice with compression produced significantly colder temperatures than ice alone. In conclusion, during all of the treatment conditions, skin temperature was significantly cooler than either of the deep temperatures.

Summary

Cryotherapy is the use of cold in the form of ice, chemical packs, or chemical devices for first aid and rehabilitation of athletic injuries. Many different types of cryotherapy techniques are used today.

The application of cryotherapy initially causes vasoconstriction. Vasoconstriction decreases blood flow, thereby diminishing the amount of hemorrhage in traumatized tissue (Kalenak, Medlar, Fleagle & Hochberg, 1975).

Cryotherapy causes a reduction in muscular spasm, a decrease in intramuscular temperature, slowing of nerve conduction velocity, and a decrease in connective tissue distensibility. Also, cold induces local analgesia, and increases pain threshold.

Cryotherapy is used for a variety of injuries, including sprains, strains, contusions, and fractures. Also, cold can be used to treat bursitis, tenosynovitis, tendinitis, arthritis, heat illness, minor burns, contractures, and in postoperative treatment.

Sports medicine clinicians must take careful precaution to the contraindications of cryotherapy. Cryotherapy can cause Raynaud's phenomenon, cold allergy, cold hypersensitivity, compromised local circulation, and cardiac disorder. Frostbite can occur along with ischemic necrosis of the part being treated which can result in subsequent amputation or extensive skin loss (McMaster, 1977). Also, cryotherapy is contraindicated when used directly over a superficial nerve which can cause temporary disability.

The efficiency of cryotherapy techniques is measured in many ways with perhaps skin temperature and intraarticular temperatures being the most frequent. The literature provides many studies of different cryotherapy techniques being measured for skin temperature and intraarticular temperature.

McMaster et al. (1978) found that ice was better than frozen gel pack, inflatable bladder filled with refrigerant gas, and a chemical ice envelope in lowering intramuscular temperature. Oosterveld et al. (1992) studied the effect of ice chips in a plastic bag and nitrogen-cold air from a Medivent NL on the intraarticular and skin temperature. The reductions in skin temperature did not differ between the two procedures, but the reductions in intraarticular temperature differed significantly. Another example of measuring intraarticular temperature was comparing ice compresses and ice bath immersion on intraarticular temperature. Bocobo et al. (1991) found that ice bath immersion was more effective in the drop of intraarticular temperature along with prolonging the intraarticular rewarming period.

In conclusion, recent literature provides a wealth of studies investigating various cryotherapy techniques used for cryotherapy in relation to skin temperature and time. However, the question still remains as to which cryotherapy technique is the best for providing decrease in temperatures, penetrates the deepest the fastest, and remains the coldest for the longest amount of time? The purpose of the present study will be to compare three cryotherapy techniques on skin temperature. Two of the techniques, Aircast® Cryo/Cuff and Polar Care™, have not been tested in the literature.

An understanding of the physiological effects of cryotherapy is necessary to evaluate objectively the clinical success of cryotherapy techniques. As techniques for cold application are developed they should be tested and evaluated (Bugaj, 1975). Therefore, verification of the advantages of one method over another substantiates the basis for clinical application. Perhaps future studies would be to compare the best cryotherapy techniques from past studies to find out the most beneficial one. For example, McMaster et al. (1978) found chipped ice to be the best cryotherapy technique from their selections tested. Belitsky et al.(1987) found wet ice to be better than dry ice and cryogen packs. Bocobo et al. (1991) found ice immersion to be more beneficial than ice compresses. Therefore, perhaps a future study would be to compare chipped ice, wet ice, and ice immersion. Also, consideration can be taken into account that no cryotherapy techniques should be used postoperatively unless the wound is covered extensively enough so that it does not get wet.

Chapter 3

METHODS

The purpose of this chapter is to present the methods used to examine the effects of three cryotherapy techniques on skin temperature over treatment time. Provided are explanations of the subject selection, cryotherapy techniques, procedures used, pilot study, design and analysis of data.

Subjects

Male athletes at a high school in the Central Coast Section of California Athletics were asked to volunteer to participate. The researcher obtained permission to conduct the study from the district and high school (Appendix A and B) prior to testing. Only those athletes with no known allergy to ice or who had no prior history of disease or injury to the right knee joint were selected to participate. The researcher chose to select subjects with no prior injury (surgery) to right knee so that no complications occurred from the use of cryotherapy. A sign-up sheet was posted in the athletic training room for volunteers (Appendix C). Twenty-four athletes were randomly selected from the pool of volunteers by using the simple random sample of drawing names out of a hat. Once selected for inclusion in the study, subjects were randomly assigned by the simple random sample method (drawing names of subjects and techniques out of a hat) to a cryotherapy treatment: Aircast® Cryo/Cuff, Polar Care™, or an ice bag.

Cryotherapy Techniques

The study included three cryotherapy techniques: 1) Aircast® Cryo/Cuff (Aircast® Incorporated, Summit, New Jersey), 2) Polar Care™ (Model 0242, Breg Incorporated, Vista, California), and 3) ice bag.

The Aircast® Cryo/Cuff (Figure 1) is a cryotherapy technique that applies cold and air compression at the same time. It is a cooler that holds ice water (5 cups of ice and 5 cups of water) along with a rubber tube that directs ice cold water to a compression pad that applies air compression (30 seconds on and 30 seconds off for every minute) by a motor. The ice water in the compression pad can be rechilled whenever needed. By doing this the Aircast® Cryo/Cuff is lowered below the knee joint to drain water out. After all water is drained, the Aircast® Cryo/Cuff is then raised above the knee joint to allow rechilled ice cold water back into compression pad. The Aircast® Incorporated recommends doing this once an hour or as needed. The investigator chose not to include this procedure with subjects being tested with the Aircast® Cryo/Cuff since it was applied for only 20 minutes.

Figure 1. Presented is the Aircast® Cryo/Cuff (Aircast® Incorporated, Summit, New Jersey).

The Polar Care™ (Figure 2) consists of a chest full of ice water (13 cups of ice and 24 cups of water). A rubber tube leading from the chest of cold water (end of tube has pump with thermometer and flow control valve-temperature set at coldest temperature for all testing) to self sealing couplings which was applied to area with compression.

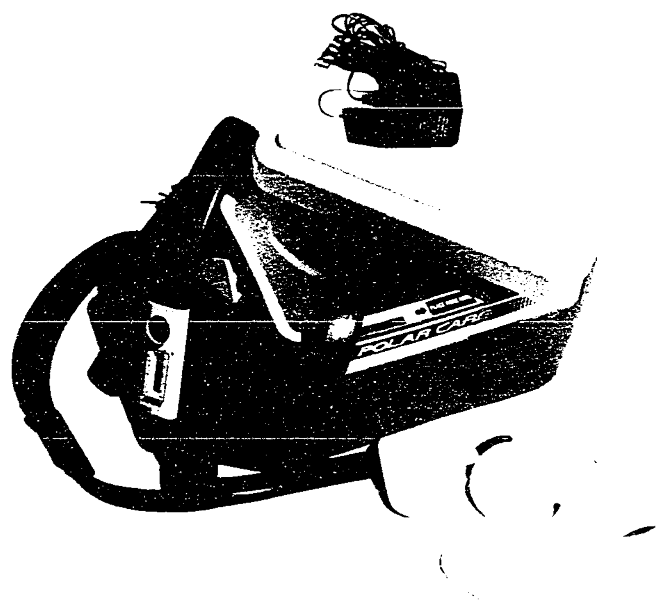


Figure 2. Presented is the Polar Care™ (Model 0242, Breg Incorporated, Vista, California).

The ice bag was a 12 X 18 polyethylene bag that contained chipped ice (4 cups). It was placed on top of the knee over one layer of ace wrap.

One layer of a wet (dampened with cool tap water) rubber elastic ace wrap (6" X 5 yards) was wrapped once around the knee joint directly over the skin probe thermometer (taped onto skin) under each cryotherapy technique. This minimized any chance of an allergic reaction occurring. Also the rest of the wet ace wrap was used to wrap around the self sealing couplings of the Polar Care™ and the ice bag when applied around the knee joint. This was done to apply compression and to hold the cryotherapy techniques in place. Only one certified athletic trainer applied the rubber elastic ace wrap in order to control the amount of pressure applied to each subject's knee.

A Yellow Springs thermometer (Model 43TD, Yellow Springs, OH) was the thermometer used to measure skin temperature in C° (Figure 3). The skin probe of the thermometer was placed on the knee joint directly on the skin under the cryotherapy technique. Two layers of Micropore® 3M surgical tape were used to keep thermometer probe in place. Also, this was done to reduce the chance of receiving temperature recordings of cryotherapy techniques by the thermometer rather than skin temperature recordings.

Figure 3. Presented is the Yellow Springs Thermometer (Model 43TD, Yellow Springs, OH).

PROCEDURES

Subject information sheets (Appendix D) were distributed to all volunteers. Any volunteers reporting known allergic reaction to ice or a non-healthy right knee were excluded. Each subject selected had to read and sign a consent form (Appendix E.), obtain parental permission when under the age of 18 years old (Appendix F). Oral instructions (Appendix G) were provided to each subject prior to participation in the study. Each minor received a parent consent form to take home to be signed by their parent or guardian two weeks before testing. Subject and parent consent forms were collected two days before the test date. Before any testing or any data collection was performed the study proposal was approved for use by San Jose State University's Human Subjects-Institutional Review Board. All data were recorded on the data collection form (Appendix H).

The subjects were welcomed and comfortably seated when they first arrived in the training room at the high school. After subject information sheets were completed and instructions provided subjects received the cryotherapy technique that was randomly assigned to them; group A (Aircast® Cryo/Cuff, group B (Polar Care™), or group C (ice bag). Each cryotherapy technique was tested on eight subjects. All cryotherapy techniques were placed on the same surface area of the right knee joint. Each cryotherapy technique contained a pre-determined amount of ice. The Aircast® Cryo/Cuff and the Polar Care™ contained a pre-determined amount of water (same temperature). The Yellow Springs thermometer was placed on the lateral aspect of the right knee under the cryotherapy technique on each subject. Skin temperature was recorded before the cryotherapy technique was applied (pre-test). Skin temperature measurements were recorded at 5, 10, 15, and 20 min intervals while the cryotherapy technique was in place. Also, temperature was recorded at 5 minutes (posttest) after the apparatus was removed. While the cryotherapy technique was in place the investigator checked visually and asked verbally if any allergic reaction was occurring and if the subject was comfortable.

Pilot Study

A pilot study was performed on six volunteers (three males and three females) to familiarize the investigator with testing procedures. The pilot study provided knowledge of necessary changes before actual testing began. First, the investigator realized that another person was needed to help record skin temperatures while the investigator applied the techniques. Temperature recordings during the pilot study were not usable because they were not taken at the accurate times. This occurred because the investigator was overwhelmed with applying cryotherapy techniques, reading temperatures at 5 min intervals and removing cryotherapy techniques once the 20 minutes was over. Secondly, the pilot study informed the investigator of proper usage of each cryotherapy technique so that valid and reliable results could be determined in the actual study. Finally, after using a dry ace wrap in the pilot study, the investigator realized that for the actual study a wet ace wrap would be better to mimic best use of cryotherapy techniques. A wet wrap is favored by sports medicine clinicians to provide better conductivity of the cold treatment on the skin and intramuscular temperatures except for post operative reasons when wound is new.

Design

Two independent variables were studied: 1) Cryotherapy technique - three levels (Aircast® Cryo/Cuff, Polar Care™, and an ice bag). 2) Treatment time - six levels (pre-test, 5, 10, 15, 20 min intervals, and 5 minutes after removal of the cryotherapy technique). The dependent variable was skin temperature. The skin temperature was measured with a Yellow Springs Thermometer.

Analysis of Data

A 3 (Cryotherapy Technique) X 6 (Treatment Time) ANOVA with repeated measures on the last factor was conducted on skin temperature. Profile contrasts were used to analyze differences between adjacent pairs to determine differences in the levels of the repeated factor. Also, a one-way ANOVA at each time interval was conducted to determine simple effects. When a significanct simple effect was found

Scheffe multiple comparison tests were used to determine where statistical differences existed.

Descriptive statistics of the subjects included means and standard deviations of age in years, sport participation at the high school, prior injury to right knee, prior injury to the left knee and prior ice use to any injury.

Chapter 4

RESULTS

The effectiveness of three cryotherapy techniques: 1) Aircast® Cryo/Cuff, 2) Polar Care™, and 3) ice bag on skin temperature over six treatment times (pre-test, 5 min, 10 min, 15 min, 20 min and posttest) was investigated. A two-way ANOVA, 3 (Cryotherapy Technique) X 6 (Treatment Time), with repeated measures on the last factor was conducted on skin temperature. Significant differences between adjacent pairs of the repeated measures factor were determined by profile contrasts. Simple effects analyses were determined by a one-way ANOVA. Null hypotheses were rejected when alpha was less than .05 level of significance. Additional descriptive statistics were calculated to provide demographic information.

DESCRIPTIVE ANALYSIS

Thirty-one male high school athletes from a high school in Cupertino, California volunteered to participate in the study. The subjects were selected from a pool of athletes that competed in the DeAnza League in the Central Coast Section of California Athletics. Five subjects were excluded from participation: two did not meet the healthy subject criteria (any prior injury to the right knee) and three subjects did not return parental consent forms. Among the remaining volunteers, 24 out of 26 subjects were randomly chosen to participate in the study. Presented in Table 1 are the raw data for descriptive variables for all subjects.

Table 1

Raw data for descriptive variables for all subjects

Aircast® Cryo/Cuff Technique

Age in Years	Number of Sport Participation	Prior Injury to Right Knee	Prior Injury to Left Knee	Prior Ice Use
15	2	uninjured	uninjured	none
17	3	uninjured	injured	prior use
16	2	uninjured	uninjured	prior use
15	3	uninjured	uninjured	prior use
15	2	uninjured	uninjured	prior use
16	1	uninjured	uninjured	prior use
16	2	uninjured	uninjured	prior use
14	2	uninjured	uninjured	prior use

Polar Care™ Technique

Age in Years	Number of Sport Participation	Prior Injury to Right Knee	Prior Injury to Left Knee	Prior Ice Use
18	2	uninjured	uninjured	prior use
18	1	uninjured	injured	prior use
17	2	uninjured	uninjured	prior use
16	2	uninjured	uninjured	prior use
15	2	uninjured	injured	prior use
17	1	uninjured	uninjured	prior use
16	2	uninjured	uninjured	prior use
16	2	uninjured	uninjured	prior use

Ice Bag Technique

Age in Years	Number of Sport Participation	Prior Injury to Right Knee	Prior Injury to Left Knee	Prior Ice Use
18	1	uninjured	uninjured	prior use
16	2	uninjured	injured	prior use
16	2	uninjured	uninjured	prior use
15	2	uninjured	injured	prior use
18	2	uninjured	uninjured	prior use
15	1	uninjured	injured	prior use
17	2	uninjured	uninjured	prior use
14	2	uninjured	uninjured	prior use

The mean age of the subjects was 16.1 $\pm$ 1.2 years. The mean number of sports participated in at the high school by the subjects was 1.9 $\pm$ .5. None of the subjects had prior injury to the right knee; however, the number of subjects having had a prior injury to the left knee was six. Only one subject had not used ice for any injury prior to testing. All subjects were able to withstand the cryotherapy technique assigned to them. The means and standard deviations for demographic characteristics of the sample are presented in Table 2.

Table 2

Means and standard deviations for demographic characteristics of the sample

	Age in Years	Number of Sport Participation	Prior Ice Use
Aircast® Cryo/Cuff			
M	15.50	2.13	0.88
SD	0.93	0.64	-
Polar Care™			
M	16.63	1.75	1.00
SD	1.06	0.46	0.00
Ice Bag			
M	16.13	1.75	1.00
SD	1.46	0.46	0.00
Column Total			
M	16.08	1.88	0.96
SD	1.21	0.54	0.20

STATISTICAL ANALYSIS

A two-way ANOVA, 3 (Cryotherapy Technique) X 6 (Treatment Time), with repeated measures on the last factor was conducted on skin temperature. Presented in Table 3 is the summary table of the two-way ANOVA conducted.

Table 3

Two-way ANOVA table of technique by times

	df	MS	F
Technique	2	11.50	1.70
Error	21	6.76	
Times	5	229.90	570.71*
Technique by Times	10	3.60	8.93*
Error	105	.40	

*$p<.05$

A significant main effect of times was detected. Profile contrasts were conducted to determine significant difference between adjacent pairs. With cryotherapy techniques in place skin temperature decreased as time duration increased from pre-test to 5 min, 5 min to 10 min, 10 min to 15 min, and 15 min to 20 min. However, when cryotherapy techniques were removed the skin temperature increased from 20 min to posttest. Presented in Table 4 are the means and standard deviations of times effect collapsed over cryotherapy techniques.

Table 4

Means and standard deviations of times effect collapsed over cryotherapy techniques

	Means	Standard Deviations
Pre-test	31.43°	1.24
5 minutes	25.81°	1.01
10 minutes	24.39°	1.10
15 minutes	23.55°	1.20
20 minutes	22.80°	1.19
Posttest	26.23°	1.23

A significant interaction effect of technique by times was found on skin temperature. Simple effect analyses were conducted to examine the difference between the three cryotherapy techniques at each of the six time intervals. Six one-way ANOVA's were used to determine simple effects. The results of the one-way ANOVA on cryotherapy techniques at the pre-test skin temperature are presented in Table 5.

Table 5

Source table for simple effects ANOVA at pre-test

	df	MS	F
Between	2	3.29	1.86
Within	21	1.77	
Total	23		

The results of the one-way ANOVA on cryotherapy techniques at the 5 minute skin temperature are presented in Table 6.

Table 6

Source table for simple effects ANOVA at 5 minutes

	df	MS	F
Between	2	1.41	1.30
Within	21	1.08	
Total	23		

The results of the one-way ANOVA on cryotherapy techniques at the ten minute skin temperature are presented in Table 7.

Table 7

Source table for simple effects ANOVA at 10 minutes

	df	MS	f
Between	2	4.91	3.92
Within	21	1.25	
Total	23		

The results of the one-way ANOVA on cryotherapy techniques at the 15 minute skin temperature are presented in Table 8.

Table 8

Source table for simple effects ANOVA at 15 minutes

	df	MS	F
Between	2	8.49	5.67*
Within	21	1.50	
Total	23		

*$p<.05$

The results of the one-way ANOVA on cryotherapy techniques at the 20 minute skin temperature are presented in Table 9.

Table 9

Source table for simple effects ANOVA at 20 minutes

	df	MS	F
Between	2	10.41	7.17*
Within	21	1.45	
Total	23		

*$p < .05$

The results of the one-way ANOVA on cryotherapy techniques at the posttest skin temperature are presented in Table 10.

Table 10

Source table for simple effects ANOVA at posttest

	df	MS	F
Between	2	.98	.57
Within	21	1.72	
Total	23		

Indicated in these analyses was a significant difference for the three cryotherapy technique at 15 minutes and 20 minutes. A follow-up Scheffe test for the 15 min time indicated that the Polar Care™ (22.38°) technique was significantly colder than the Aircast® Cryo/Cuff (24.33°) technique. No other significant differences were detected.

A follow-up Scheffe test for the 20 min duration indicated a significant difference between Polar Care™ (21.61°) and the Aircast® Cryo/Cuff (23.89°). No other significant differences were detected. Presented in Table 11 are the means and standard deviations of all cryotherapy techniques at each of the six time intervals.

Table 11

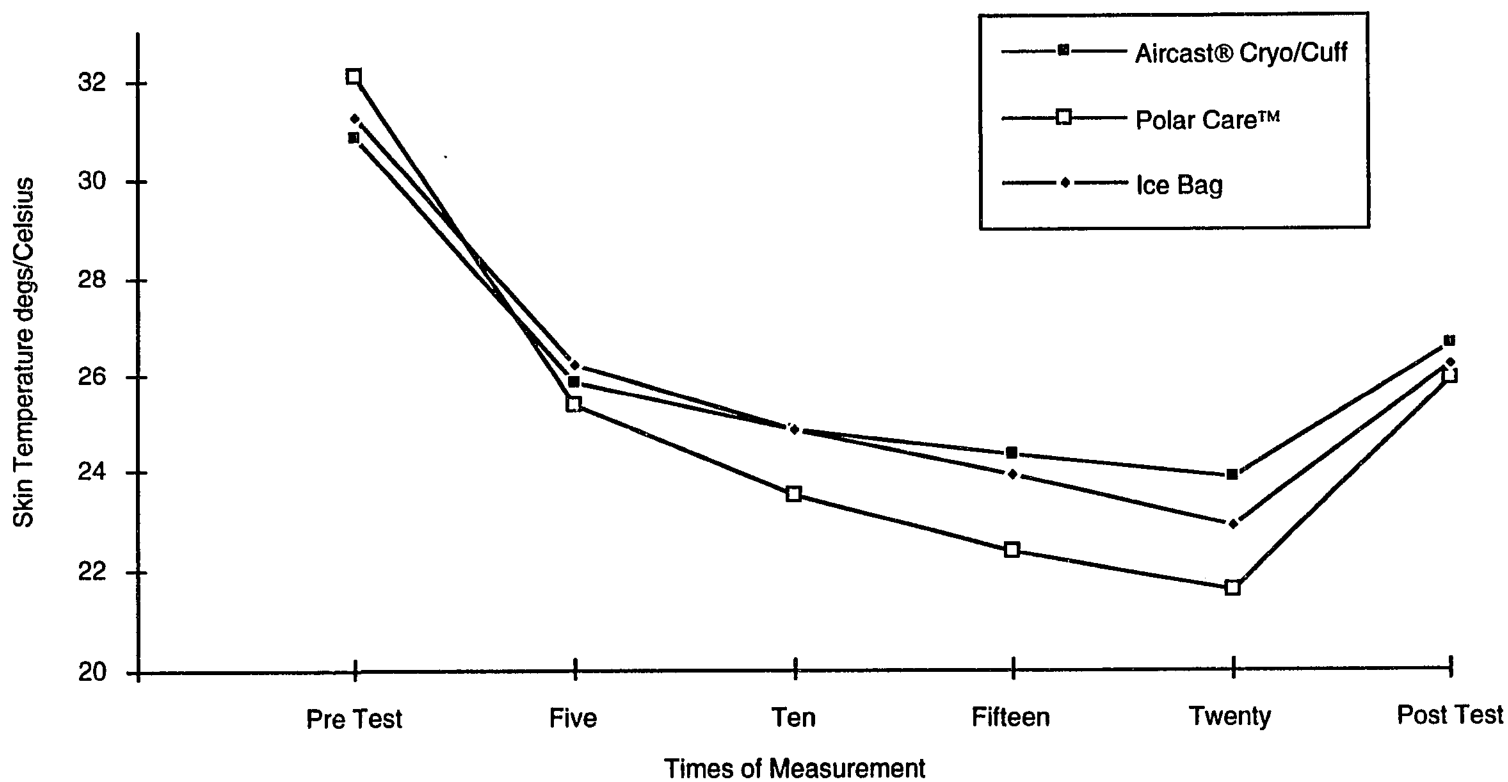
Means and standard deviations of cryotherapy techniques on skin temperatures at pre-test, 5, 10, 15, 20, and posttest time intervals

	Means	**Standard Deviations**
Pre-test		
Aircast® Cryo/Cuff	30.86°	1.82
Polar Care™	32.13°	0.63
Ice Bag	31.30°	1.26
5 minute		
Aircast® Cryo/Cuff	25.85°	1.24
Polar Care™	25.38°	0.65
Ice Bag	26.21°	1.13
10 minute		
Aircast® Cryo/Cuff	24.86°	1.09
Polar™ Care	23.49°	0.82
Ice Bag	24.83°	1.38

	Means	Standard Deviations
<u>15 minute</u>		
Aircast® Cryo/Cuff	24.33°	1.25
Polar™ Care	22.38°	0.89
Ice Bag	23.93°	1.46
<u>20 minute</u>		
Aircast® Cryo/Cuff	23.89°	1.26
Polar™ Care	21.61°	0.91
Ice Bag	22.90°	1.39
<u>Posttest</u>		
Aircast® Cryo/Cuff	26.59°	1.87
Polar Care™	25.89°	1.02
Ice Bag	26.21°	0.81

The mean temperatures recorded in C° for all cryotherapy techniques for the six temperature times (pre-test, 5 min, 10 min, 15 min, 20 min and posttest) are illustrated in Figure 4.

Figure 4. Cryotherapy technique as a function of time of measurement on skin temperature readings.



All normality and homogeneity of variance assumptions at the 15 and 20 minute durations were met. A two-way ANOVA failed to reveal a statistically significant main effect of technique. Therefore, the null hypothesis of the main effect of technique was accepted. A two-way ANOVA detected a significant treatment time effect. Therefore, the null hypothesis that treatment time will not affect skin temperature was rejected. A two-way ANOVA produced a statistical significance interaction of technique by treatment times. Therefore, the null hypothesis of technique by treatment times was rejected.

SUMMARY

The two-way ANOVA of technique by treatment times produced a statistical significant main effect of times and interaction effect of cryotherapy technique by treatment times. Profile contrasts were conducted to determine significant difference between adjacent pairs. With cryotherapy techniques in place skin temperature decreased as time duration increased from pre-test to 5 min, 5 min to 10 min, 10 min to 15 min, and 15 min to 20 min. However, when cryotherapy techniques were removed the skin temperature increased from 20 min to posttest. Simple effect analyses were conducted to uncover statistical significance between cryotherapy techniques over treatment time. The simple effect analyses indicated significant differences between the Aircast® Cryo/Cuff and Polar Care™ at the 15 and 20 minute durations. The Polar Care™ produced colder skin temperatures than the Aircast® Cryo/Cuff. Also, Polar Care™ technique resulted in the largest drop in skin temperature from pre-test to the 20 min duration (10.51°C). The ice bag resulted in reducing skin temperature (8.40°C) while the Aircast® Cryo/Cuff difference between pretest and 20 min duration was 6.98°C. No other studies are reported in the literature using the Aircast® Cryo/Cuff or Polar Care™ techniques.

Chapter 5

SUMMARY, DISCUSSION, CONCLUSIONS, RECOMMENDATIONS

Most studies involving cryotherapy techniques have been performed with various types of cryotherapy techniques; however, none has been reported using the Aircast® Cryo/Cuff or Polar Care™. Therefore, the aim of this investigation was to study the impact of the Aircast® Cryo/Cuff, Polar Care™ and ice bag techniques on skin temperature. The purpose of the study was to determine if cryotherapy technique and treatment time affect skin temperature. This chapter includes summary, discussion, conclusions and recommendations for future research.

SUMMARY

In summary, 24 healthy male subjects participated in the study. Once selected for inclusion in the study, subjects were randomly assigned to a cryotherapy technique: Aircast® Cryo/Cuff, Polar Care™, or an ice bag. Six different treatment times (pre-test, 5 min, 10 min, 15 min, 20 min and posttest) were recorded to investigate which cryotherapy technique resulted in the coldest skin temperature on the knee joint over time. A two-way ANOVA of cryotherapy technique by treatment times produced a statistical significant main effect of times and interaction effect of cryotherapy technique by treatment times. Profile contrasts were conducted to determine significant difference between adjacent pairs. With cryotherapy techniques in place skin temperature decreased as time duration increased from pre-test to 5 min, 5 min to 10 min, 10 min to 15 min, and 15 min to 20 min. However, when cryotherapy techniques were removed the skin temperature increased from 20 min to posttest. Simple effect analyses were conducted to uncover statistically significance between cryotherapy techniques over treatment time. The simple effect analyses indicated significant differences between the Aircast® Cryo/Cuff and Polar Care™ at the 15 and 20 minute duration. These results cannot be compared to any other study since no studies have been reported using the Aircast® Cryo/Cuff and Polar Care™. This study uncovered that Polar Care™ was statistically significantly colder than Aircast® Cryo/Cuff at the 15 and 20 minute durations.

DISCUSSION

Profile contrasts revealed significant difference between pre-test and 5 min, 5 min and 10 min, 10 min and 15 min, 15 min and 20 min, and 20 min and posttest. The ANOVA of skin temperature for the 15 and 20 minute durations indicated significant differences between the Aircast® Cryo/Cuff and the Polar Care™. The mean temperature and standard deviation at 15 minutes for the Aircast® Cryo/Cuff was 24.33 ± 1.3 and the Polar care™ was 22.38° ± .9. At the 20 minute duration the mean temperature and standard deviation for the Aircast® Cryo/Cuff was 23.89° ± 1.3 and Polar Care™ was 21.61° ± .9.

Many variables could have influenced skin temperature readings in this study. For example, region of body upon which the cryotherapy technique was applied (bony area rather than muscle), procedure of using cryotherapy technique, the compression applied (was not controlled), duration of application (20 minutes), and type of cryotherapy technique used.

The most surprising finding was the poor results with the use of the Aircast® Cryo/Cuff resulting in the warmest temperature readings at the 15 and 20 minute durations. Perhaps, this finding was due to the lack of circulation of ice water through the tube throughout the testing like in the Polar Care™ technique. Also, due to researcher's choice the Aircast® Cryo/Cuff was not lowered below the knee joint (to drain ice water out of compression pad) nor was it raised above the knee joint to circulate additional water in after being drained. Therefore, the temperature of the ice water in the Aircast® Cryo/Cuff may have been warmer than the ice water being circulated in the Polar Care™ throughout testing. Also, the Polar Care™ had a temperature control valve (set on coldest temperature).

The Aircast® Cryo/Cuff had a pump that intermittently applied air pressure for 30 seconds on 30 seconds off for each minute. Perhaps, this pressure could have hindered the effectiveness of the Aircast® Cryo/Cuff technique compared to the other two techniques which had compression applied to them constantly throughout testing with an ace wrap. An ace wrap was not applied around compression pad of the Aircast® Cryo/Cuff due to recommendation by Aircast® Incorporated. Merrick et al. (1993) used a manometer (Aircast Inc, Summit, NJ) to ensure consistency between treatment conditions involving compression which showed that ice plus compression produced significantly cooler temperatures.

The application of cold therapy initially causes vasoconstriction. Vasoconstriction decreases blood flow, thereby diminishing the amount of hemorrhage in traumatized tissue (Olson & Stravino, 1975). Most studies involving cryotherapy techniques do not require the technique to be in place longer than 20-30 minutes. According to Kowal (1983), if deep tissue vasodilation occurs with cutaneous hunting reaction vasodilation, then to minimize the possibility of increasing blood flow to acutely injured tissue, cold should not be applied for more than approximately 20-30 minutes at one time. This study showed statistical significant differences between the Aircast® Cryo/Cuff and Polar Care™ at the 15 and 20 minute durations.

The study was limited to three cryotherapy techniques: Aircast® Cryo/Cuff, Polar Care™ and an ice bag. The Polar Care™ produced statistical significant colder temperatures than the Aircast® Cryo/Cuff on skin temperature at 15 and 20 minutes on the knee joint. This finding is beneficial to sports medicine clinicians who want to use a cryotherapy technique that is suitable in reducing skin temperature for acute injuries and rehabilitative purposes. The Polar Care™ could be used in future research to compare to new cryotherapy techniques that are developed in the future.

The use of the Polar Care™ technique resulted in significantly colder temperatures than the Aircast® Cryo/Cuff at the 15 and 20 minute durations on skin temperature. From a practical standpoint the Polar Care™ technique was only 1.95°C colder at the 15 minute duration and 2.28°C colder at the 20 minute duration than the Aircast® Cryo/Cuff technique. This compares to 3.51°F difference at 15 minutes and 4.10°F at 20 minutes. These differences may be debatable with regard to practical significance in using these cryotherapy techniques for acute injuries and rehabilitation purposes.

CONCLUSIONS

In conclusion, significant difference between the Aircast® Cryo/Cuff and the Polar Care™ on skin temperature at the 15 and 20 minute durations were found. This finding indicates that the Polar Care™ is the best cryotherapy technique of the three tested in this study in decreasing skin temperature at 15 and 20 minutes.

The Polar Care™ technique has a flow control valve that was set at coldest temperature allowing ice cold water to circulate throughout testing. This may have resulted in why it tested the coldest. Therefore, this valuable information regarding the Polar Care™ is useful to sports medicine clinicians in choosing a good cryotherapy technique for acute injuries and rehabilitative purposes. However, for cost effective reasons the ice bag is a good cryotherapy technique since it tested slightly warmer than the Polar Care™.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. When using the Aircast® Cryo/Cuff lower the cryotherapy technique below the knee joint (to drain ice cold water out of compression pad) and raise above the knee joint to circulate additional water in after being drained. This could be performed a set amount of times throughout testing.

2. Use a manometer (Aircast® Inc. Summit, NJ) to measure the consistency of each ace wrap applied for compression with all cryotherapy techniques.

3. Measure the skin temperature at a duration longer than 20 minutes to see if any statistically significant differences exist between the cryotherapy techniques at longer durations.

4. Measure the skin temperature at a longer duration than 20 minutes to see if a "Hunting Response" occurs.

5. Measure intraarticular temperature to see which cryotherapy technique penetrates the deepest.

6. Comparison of cryotherapy techniques that apply intermittent compression and circulation of water can be made to determine significant differences in skin temperature.

7. Compare any of the cryotherapy techniques in this study with new cryotherapy techniques that are developed in the future.

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APPENDIX A
PERMISSION LETTER

MONTA VISTA HIGH SCHOOL

21840 McClellan Road
Cupertino, CA 95014

(408) 366-7600

February 8, 1994

Human Subjects - Institutional Review Board
San Jose State University
Administrative Building, Room 150
One Washington Square
San Jose, CA 95192

Re: Master's Thesis Research study titled "Effect of Cryotherapy Technique on Skin Temperature Measurement at the Knee Joint"

To Whom It May Concern:

The purpose of this letter is to verify that Sara Ringle, graduate student, has the permission of Monta Vista High School and Fremont Union High School District to perform her research study on our students in the athletic training room.

We understand that the anticipated risk involved in participating in the study is an allergic reaction to ice. We feel that Sara Ringle, our certified Athletic Trainer, is capable of observing and recognizing if an allergic reaction does occur. If you have any questions, please feel free to contact me at the above address and phone number.

Sincerely,

Joanne Laird
Assistant Principal
Activities / Athletics

APPENDIX B
PERMISSION LETTER

DEPARTMENT OF ATHLETICS

Monta Vista High School
21840 McClellan Road
Cupertino, CA 95014
(408) 366-7628

February 14, 1994

Human Subjects - Institutional Review Board
San Jose State University
Administrative Building, Room 150
One Washington Square
San Jose, CA 95192

Re: Master's Thesis Research study titled "Effect of Cryotherapy Technique on Skin Temperature Measurement at the Knee Joint"

To Whom It May Concern:

The purpose of this letter is to verify that Sara Ringle, graduate student, has the permission of Monta Vista High School and Fremont Union High School District to perform her research study on our students in the athletic training room.

We understand that the anticipated risk involved in participating in the study is an allergic reaction to ice. We feel that Sara Ringle, our certified Athletic Trainer, is capable of observing and recognizing if an allergic reaction does occur. If you have any questions, please feel free to contact me at the above address and phone number.

Sincerely,

Buck Shore

Buck Shore
Athletic Director

Poppin' Purple Pride

Athletic Directors
Buck Shore 366-7628
Jerra Rowland 366-7624

Principal
Jim Warren 366-7601

APPENDIX C
VOLUNTEER SIGN-UP SHEET

STUDENT MALE ATHLETES NEEDED
FOR
RESEARCH PROJECT IN ATHLETIC TRAINING

TITLE OF STUDY: The Effect of cryotherapy technique on skin temperature measurement at the knee joint.

INVESTIGATOR: Sara Ringle, graduate student

You are invited to participate in a Master's Thesis research study designed to test the effectiveness of three cryotherapy techniques. Cryotherapy is the application of cold. The study will test these techniques on the knee joint to determine the most effective technique. The purpose is to provide sports medicine clinicians with valuable information about which cryotherapy technique is the most effective.

If you are interested in participating in this study, please print your name, age, and phone number. You will be contacted via phone, or in person. If you have any questions please contact Sara Ringle at (408) 292-4511.

NAME(PRINT)	AGE	PHONE

NAME(PRINT)	AGE	PHONE #

APPENDIX D
SUBJECT INFORMATION SHEET

Name______________________________

Date_______________

Age_________

Home Phone Number_______________

Sport_____________________________

Prior Injury To Right Knee Yes__________ No___________

Prior Injury to Left Knee Yes__________ No___________

Have You Ever Used Ice For An Injury Before Yes______
No________

If So For What Injury_________________

Have You Ever Had An Allergic Reaction Or Any Other
Reaction From Using Ice Yes__________ No___________

If So What Reaction Occurred___________________________

Subject Code___________________

Group Code____________________

APPENDIX E
SUBJECT CONSENT FORM

AGREEMENT TO PARTICIPATE IN RESEARCH
SAN JOSE STATE UNIVERSITY

RESPONSIBLE INVESTIGATOR: Sara Ringle, graduate student

TITLE OF PROTOCOL: The Effect of cryotherapy technique on skin temperature measurement at the knee joint.

I understand that:

1) I will be asked to participate in a research study involving cryotherapy techniques on skin temperature measurements of the knee joint. Cryotherapy is the use of cold for therapeutic requirements.

2) I will be asked to provide one hour of my time to have a cryotherapy technique (Aircast® Cryo/Cuff, Polar Care™, or an ice bag) tested on my knee at the Monta Vista High School training room. These techniques are all devices that contain ice or ice and water. Cryotherapy techniques will provide a stinging burning sensation for the first five minutes followed by a feeling of numbness. The numbness will fade approximately 5-20 minutes following the removal of the cryotherapy technique. A Yellow Springs thermometer will be used to measure skin temperature. Every two minutes during the test the investigator will check the area being tested to confirm that no red rash or allergic reaction is occurring.

3) The only anticipated risk involved in participating in the study is an allergic reaction to ice. If allergic reaction occurs please inform the investigator immediately.

4) The possible benefits of the study for the subjects are that they may gain insight into which cryotherapy technique is most comfortable and effective for applying to their injuries.

5) The results from the study may be published, but any information from the study will remain confidential and will be disclosed only with my permission or as required by law.

Subject Initialize___________

6) Any questions about my participation in the study may be addressed to Sara Ringle at (408) 292-4511. Complaints about the procedures may be presented to Emily Wughalter, Ed.D. at (408) 924-3043. Questions or complaints about research, subjects' rights, or research-related injury may be presented to Serena Stanford, Ph.D., Associate Academic Vice President for Graduate Studies and Research, at (408) 924-2480.

7) My consent is given voluntarily without being coerced; I may refuse to participate in this study or in any part of this study, and I may withdraw my consent at any time, without prejudice to my relations with SJSU or the individual high school involved.

8) I have received from Sara L. Ringle a signed and dated copy of this consent form.

HAVING READ THE INFORMATION PROVIDED ABOVE, I HAVE MADE A DECISION WHETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I WILL PARTICIPATE.

_________________________ __________

SUBJECT'S SIGNATURE DATE

_________________________ __________

INVESTIGATOR'S SIGNATURE DATE

APPENDIX F
PARENT/GUARDIAN CONSENT FORM

AGREEMENT TO PARTICIPATE IN RESEARCH
SAN JOSE STATE UNIVERSITY

RESPONSIBLE INVESTIGATOR: Sara Ringle, graduate student

TITLE OF PROTOCOL: The Effect of cryotherapy technique on skin temperature measurement at the knee joint.

I understand that my child

1) Will be asked to participate in a research study involving cryotherapy techniques on skin temperature measurements of the knee joint. Cryotherapy is the use of cold for therapeutic requirements.

2) Will be asked to provide one hour of time to have a cryotherapy technique (Aircast® Cryo/Cuff, Polar Care™, or an ice bag) tested on the knee joint at the Monta Vista High School training room. These techniques are all devices that contain ice or ice and water. Cryotherapy techniques will provide a stinging burning sensation for the first five minutes followed by numbness. The numbness will fade approximately 5-20 minutes following the removal of the cryotherapy technique. A Yellow Springs thermometer will be used to measure skin temperature. Every two minutes during the test the investigator will check the area being tested to confirm that no red rash or allergic reaction is occurring.

3) The only anticipated risk involved in participating in the study is an allergic reaction to ice. If allergic reaction occurs please inform the investigator immediately.

4) The possible benefits of the study for the subjects are that they may gain insight into which cryotherapy techniques are most comfortable and effective for applying to their injures.

5) The results from the study may be published, but any information from the study will remain confidential and will be disclosed only with my permission or as required by law.

Parent/Guardian Initialize_________
Subject Initialize_________

6) Any questions about my child's participation in the study may be addressed to Sara Ringle at (408) 292-4511. Complaints about the procedures may be presented to Emily Wughalter, Ed.D. at (408) 924-3043. Questions or complaints about research, subjects' rights, or research-related injury may be presented to Serena Stanford, Ph.D., Associate Academic Vice President for Graduate Studies and Research, at (408) 924-2480.

7) My consent is given voluntarily without being coerced; my child may refuse to participate in this study or in any part of this study, and I may withdraw my consent at any time, without prejudice to my relations or my child's with SJSU or the individual high school involved.

8) I have received from Sara L. Ringle a signed and dated copy of this consent form.

HAVING READ THE INFORMATION PROVIDED ABOVE, I HAVE MADE A DECISION WHETHER OR NOT MY CHILD MAY PARTICIPATE. MY SIGNATURE INDICATES THAT MY CHILD HAS MY CONSENT TO PARTICIPATE.

______________________ ______________________ __________
PARENT/GUARDIAN SIGNATURE PRINT CHILD'S NAME DATE

______________________ __________
INVESTIGATOR'S SIGNATURE DATE

APPENDIX G
TAPED INSTRUCTIONS

You will be comfortably seated in a supine position (Bottom down) on an athletic treatment table. You will be asked to not move around much while experiment is taking place. A skin probe thermometer will be placed by surgical tape on the skin and a wet ace wrap will be wrapped around the skin probe thermometer. A cryotherapy technique will be placed on the right knee joint for 20 minutes. Skin temperature will be recorded before the cryotherapy technique is added (pre-test), 5, 10, 15 and 20 minutes while cryotherapy technique is in place, and at 5 minutes after the cryotherapy technique is removed (posttest). Every two minutes during the test the investigator will check the area being tested to confirm that no red rash or allergic reaction is occurring and ask the subject if they are comfortable with the cryotherapy technique. After the 20 minutes is over the cryotherapy technique will be removed. You will need to stay seated until the last temperature is recorded (5 minutes after cryotherapy technique is removed). The entire experiment could take up to one hour.

If at any time you feel you cannot proceed with the experiment, please notify the experimenter. Any questions?

APPENDIX H
DATA COLLECTION FORM

Cryotherapy Technique

AIRCAST® CRYO/CUFF	POLAR CARE™	ICE BAG

Time recorded during test

_____	_____	_____	_____	_____	_____

Skin Temperature recorded during test

PRE-TEST	5	10	15	20	POSTTEST
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____