AN ABSTRACT OF THE THESIS OF

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Title: The Cooling Ability of a Cold Source Used With a Wet Versus Dry Elastic Bandage Medium

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Purpose: The purpose of this study was to evaluate the efficiency of eight combinations of cryotherapy in terms of rate and absolute cooling ability of the skin.

Methods of Research: 12 subjects, male and female, ages ranging from 19 - 26 volunteered for the study. Each subject was exposed to eight combinations of a cold source (Kwik Kold, Flex-i-cold, Ice Pack or Water Bath) and medium. Measurements of the skin temperature were taken every minute for 20 minutes. Temperature measurements of the skin were analyzed using nonparametric statistics including the Chi-square, Probability Z Score, Friedman, T_4 LSD and Wilcoxon tests. The level of significance was set at .05.

Conclusions: There was indeed a significant difference between the four cold sources in terms of rate and absolute cooling. The use of any of the cold sources except the Flex-i-cold, and a wet

medium was significantly more effective than their use with a dry medium in both rate and absolute cooling.

The most effective cold source and medium combination in both rate and absolute cooling was the Water Bath and wet medium, followed by the Water Bath and the dry medium. The least effective medium and cold source combination was the Flex-i-cold and dry medium followed by the Flex-i-cold and a wet medium.

THE COOLING ABILITY OF A COLD SOURCE

USED WITH A WET VERSUS DRY

ELASTIC BANDAGE

MEDIUM

A Thesis

Presented to

The Division of Health, Physical Education,

Recreation and Athletics

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Last but not least, a most grateful thanks to my subjects, who gladly donated their time, patience, and ankles, and withstood the rigors of the dreaded ice bucket.

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Chapter 1

INTRODUCTION

Although there is conflicting research concerning the actual effects during and after cryotherapy, there is undeniable evidence that the use of cryotherapy immediately after the incidence of soft tissue injury is extremely effective in reducing hemorrhage and edema that occur (Hocutt, 1982). The use of cryotherapy in soft tissue first aid goes back at least fifty years to 1930 when Lewis first examined it in terms of the circulatory changes it produces (Lewis, 1930).

Recently, the use of cryotherapy to treat specific soft tissue injuries has become even more contraversial as more research concerning blood flow changes and its use with other types of rehabilitative therapy is examined. Among the additional therapy techniques is the use of an elastic bandage to serve as a "medium" between the cold and the skin. Little is known about the changes that arise from the use of this type of medium when it is used with a cold source. It is, therefore, the aim of this study to compare the effectiveness of four different types of cold sources when combined with a wet as compared to dry medium in reducing skin temperature as measured by rate of cooling and absolute cooling ability.

Theoretical Formulation

There is undeniable evidence that the use of cryotherapy reduces the physiological damage that results from soft tissue injury. Hocutt (1982) assessed recovery from ankle sprains using either heat or cold therapy for a minimum of three days. His study showed that cryotherapy was statistically more efficient than heat for complete and rapid recovery. No mention of a physiological basis for this superiority was made. Unfortunately, little is known about the actual underlying physiological factors involved.

Because of this lack of knowledge concerning the physiological effects of cold, the use of cryotherapy in acute soft tissue care and treatment has been highly disputed in recent years (Knight, 1978). Lewis' (1930) early research concerning the use of cryotherapy as a treatment to cause constriction (vasoconstriction) or dilation (vasodilation) of the local vascular system has been contradicted by Knights' (1980a) later research which replicated Lewis' (1930) study and showed the effects of cold being only vasoconstrictive in nature. In another study, Knight (1980b) measured blood flow in the ankle of injured subjects during and after therapeutic applications of heat, cold and exercise. He concluded that the increase in blood flow to the ankle was enhanced only when heat or cold and exercise were used, but again, the isolated application of cold had no dilating influence on the blood vessels in the ankle.

There also has been very little research to compare the cooling ability of different types of cold applications or the change, if any, in this ability when a medium is placed between the cold application and the skin surface. It is a fairly common practice to combine some form of compression with a cold application. Typically this compression takes the form of an elastic bandage, which is frequently water saturated and wrung out. It is known that water conducts heat 25 times faster than air, and because of this fact, the saturation of a medium in water, could increase the cooling ability (i.e., rate, absolute temperature) of a cold source used with it. Conversely the use of a water saturated medium might reduce the amount of time that a cold source is effectively cold by increasing the amount of heat dissipated away from the skin.

When a dry medium is used, it too may diminish overall cooling ability of a cold source by preventing conduction of the cold to the skin and trapping heat near the skin. It is important to know if the use of a medium, wet or dry, alters the effects of the cold source in terms of rate of cooling and overall skin cooling ability and if one medium, wet or dry, is more effective than the other.

The Problem

Although there is conflicting research concerning the actual circulatory effects during and after cryotherapy, there is some evidence which demonstrates that application of cryotherapy immediately after the incidence of soft tissue injury is extremely effective in reducing the hemorrhage and edema that occurs. The rapid reduction of skin temperature in the area may be accomplished many ways, the most common being the application of a cold source directly to the area of trauma. Begining the cooling as quickly as possible and controlling of local hemorrhage is extremely important in early resolution of tissue destruction.

Hocutt (1982) assessed the recovery from ankle sprains using either cryotherapy or heat therapy for a minimum of three days. The study showed that cryotherapy started within 36 hours after the injury, was statistically more effective than heat therapy in reducing additional trauma and healing time.

It is possible that the use of a medium, wet or dry, between the skin and the cold source may enhance the cooling effect of a cold source. There are numerous types of cold sources, and an equally large number of application techniques (e.g., application with or without a medium, that is wet or dry). It is the aim of this study to examine only four of the popular types of cold applications and two application techniques namely, wet and dry mediums. Each of the eight cold combinations (i.e., four cold sources with either a wet or dry medium) absolute ability to cool the skin and its ability to sustain the coolness will be measured in this study. A secondary objective of this study is to determine if the use of a wet versus dry medium layer changes the cooling ability of a cold source. This information will enable a coach or athletic trainer to make a more valid decision when selecting methods for treating an acute soft tissue injury.

Statement of the Problems

Is there a significant difference in the absolute cooling ability and rate among eight different types of cold combinations used in the treatment of soft tissue injuries?

Is there a significant change in the rate of cooling among eight different types of cold combinations through the use of a wet versus dry medium between the cold source and the skin?

Statement of the Hypotheses
(Null Forms)

There is no significant difference in the absolute cooling ability among eight different types of cold combinations as they are used in the treatment of soft tissue injuries.

There is no significant difference in the rate of cooling among eight different types of cold combinations through the use of a wet versus dry medium between the cold application and the skin surface.

Purpose of the Study

The purpose of this study is to investigate the absolute cooling ability and rate of cooling between for cold sources combined with a wet medium and those same sources combined with a dry medium. Cooling effectiveness will be evaluated by measuring skin temperature and examining the data in terms of rate and absolute cooling ability. The data from this study will provide information that will enable those concerned with the treatment of acute soft tissue injuries to make a more valid decision in their choice of cold source and medium combination.

Definition of Terms

Cold Source

A specific type of cold producing media. In this study, the cold sources include, Kwick Kold packs (KK), Cramer Flex-i-cold packs (FC), Ice packs (IP), and a Cold water bath (WB).

Cryotherapy

The use of various types of cold applications to aid in soft tissue injury repair and treatment.

Cold Combination

Any one combination of a cold source and medium Appendix E.

Cold Application

The use of a cold combination to treat a soft tissue injury, or in the case of this study, to indicate the use of a cold combination during testing.

Medium

A 6" elastic bandage which is sewn into a three layer patch, with two of these layers sewn together at the bottom to form a pocket in which a cold source may rest. The entire unit is attached to the ankle by velcro fasteners.

Chapter 2

REVIEW OF RELATED LITERATURE

To date, the use of cryotherapy (cold therapy) to treat soft tissue injuries has been largely empirical. It is agreed, that during first aid injury care, a reduction in circulation to the injured area is desirable to help reduce further tissue damage and hemorrhaging. During the repair phase of an injury, an increase in circulation is desired to speed up removal of dead tissue and cellular debris and enhance the physiological repair work. Early research proposed the idea of vasoconstriction followed by vasodilation, as the mechanism (or underlying physiological change) by which changes in blood flow were induced as a result of cryotherapy application (Lewis, 1930). Later research, however, claimed these findings to be untrue (Knight 1980a).

The phenomena of cold induced vasodilation (CIVD) was first described in 1930 (Lewis, 1930). Investigators found that during continued immersion in ice water, the temperature of the skin fell rapidly for the first few minutes. Thereafter, spontaneous rewarming took place upon removal of the cold source (Lewis, 1930). This spontaneous rewarming is thought to take place as previously constricted blood vessels begin to dilate. Although this concept does not have a scientific basis, cryotherapy applications based on this concept are used with much success when an injury situation calls for prompt control of local hemorrhage.

In recent years there has been widespread publicity given to the use of cold applications as therapeutic modalities in the treatment of athletic injuries. Unfortunately, such practices persist due to word-of-mouth rather than establishment of a sound factual basis. This trend has continued and resulted in the development of many techniques and types of cold applications, but none with a physiologically proven basis for its use.

This chapter, organized into five topic areas, will present a review of literature regarding factors related to use of cryotherapy in treatment of soft tissue injuries. The topic areas include, cold versus heat, blood flow and injury repair, modality choice, medium layer, and a summary of the literature.

COLD VERSUS HEAT

Cold sources of one type or another have been used for the treatment of musculoskeletal and neurological conditions by many different practitioners of medicine since the 1930's when Lewis began investigating this theory (Lewis, 1930). This early research (Lewis, 1930) showed a definite increase in circulation after cold exposure, but the data are unclear as to whether this increase above and beyond what is considered normal at room temperature. Increased blood flow is desired during the rehabilitation phase of injury and the aim of modality application during musculoskeletal rehabilitation, is to increase blood flow to the specific injured part. Lewis'(1930) data which investigated vasodilation in various anatomical parts, provided a very plausible explanation for the clinical success in increasing blood flow to a specific cooled area of the body. The main question concerning this blood flow increase is whether it was above and beyond the normal blood flow to the specific body part.

Knight and Londeree (1980a) replicated Lewis' study of vasodilation in various human body parts in an attempt to clarify this question of circulation. Upon commencement of the study, they observed changes in skin circulation of the ankle and the finger. Blood flow to the ankle and fingers of the uninjured subjects decreased during 25 minutes of immersion and further decreased during the 20 minutes following the immersion, up to the point of pre-immersion. The results confirmed Lewis' findings with respect to an increase in temperature, but there clearly was no cold induced vasodilation (i.e., blood flow increase) above and beyond what was normal, during nor after immersion in the water bath.

The rationale for the use of cold rather than heat has both a physiological and practical basis, but this basis is derived from contradictory evidence. Much of this controversy arises from the question of when an increase in circulation is needed during the treatment of a soft tissue injury. In the case of immediate injury care, a rapid decrease in circulation is desired to reduce the bleeding and tissue damage that occurs. When dealing with an older injury that has progressed beyond the point of hemorrhage and tissue destruction, an increase in circulation to assist in removing dead tissue and blood cells from the injured area, is desired. While it is true that application of cold will eventually increase circulation in the area, the initial decrease it provides during the 24 - 48 hour period of time after injury is the prime reason for its immediate use in injury first aid. Tepperman (1983) relates information about cold versus heat in relation to colds usefulness in immediate first aid. He feels that generally, if heat is applied to the skin, it is thought to produce immediate vasodilation and increase metabolic activity, with resulting increase in circulation and exacerbation of inflammation, while cold in most cases has the opposite, more desirable result of first creating a constrictive effect and later allowing a gradual dilating effect (Tepperman, 1983). Chambers also refers to the benefits of cold in relation to immediate care by stating, "If cold is applied to a local area of the skin, the resulting decreased blood flow initially diminishes heat transport from the body core to the skin and enhances the direct cooling effect which reduces soft tissue trauma....This initial decrease in blood flow is soon reversed as the cooling continues and the body attempts to rewarm the cooled part, but the initial trauma is controlled and bleeding is markedly reduced," (Chambers, 1969, p. 245). Hocutt illustrates what happens when heat is used. He states, "When heat is introduced to an injured site it potentiates the body's inflammatory reaction to trauma and results in discomfort and increased irratation to damaged tissues" (Hocutt, 1981, p. 317).

BLOOD FLOW AND INJURY REPAIR

More recent interest in the effects of cold has been limited to research concerning hypothermia, refrigeration in surgery or hibernation in space. Little is known about the actual effects of cold penetration on blood flow. If there truly is an increase in blood flow, does this additional blood flow actually penetrate the muscle, or is the flow increase mostly confined to the skin vessels? The limited physiological evidence on this point indicates that both heat and cold therapy enhance muscle blood flow (Abraham, 1974). Pappenheimer, Eversole, and Soto-Rivera (1950), cooled arterial blood from 40 C to 5 C in a cat hind limb by using an arterial bypass through a cooling chamber. Below 25 C blood flow to the muscle increased progressively (Pappenheimer, Eversole, and Soto-Revera, 1950). Barcroft and Edholm (1943) recorded a decrease in deep muscle temperatures of 20 C in their human subjects in a 11 C water bath after their forearms had been exposed for 20 minutes (Barcroft, 1943) This information would indicate that cryotherapy in the form of a 11 C water bath was indeed an effective vasodilator at the muscle tissue level. These results appear to be in agreement with those of Pappenheimer et al. However, there is no conclusive evidence of any relationship between muscle temperature and skin temperature.

Many sports medicine authorities accept the hearsay concerning the CIVD theory and the physiological evidence concerning blood flow as an explanation for the dramatic success of cryotherapy in the treatment of acute musculoskeletal and neurological injuries. One of the basic assumptions of rehabilitation of musculoskeletal injuries is that blood flow to the injured area must be increased (Fischer, 1965). It has been felt that increasing blood flow, after any danger of hemorrhage and edema, speeds up removal of cellular debris from the injury site and increases delivery of nutrients to be used in rebuilding the damaged area. In a 1981 study of cryotherapy and its implications, Hocutt (1982) stated that cryotherapy diminshes the inflammatory reaction to trauma and reduces edema, hematoma formation, and pain. In addition, cold application enables the patient to develop strength and mobility in an injured area with minimal inflammation and discomfort (Hocutt, 1981).

Literature available on the effects of cold on nerve transmission has shown evidence of an anesthetic effect. It has been observed that cold will first diminish the rate of transmission of impulses along a nerve and then at about 27 C or lower, nerve conduction will begin to fail (Chambers, 1969). This anesthetic effect is what Grant (1964) felt was the greatest benefit from using cold. "The use of ice is simply an adjunct measure utilized to relieve pain and allow (such) early motion," (Grant, 1965, p. 236). Handling (1982) outlined the sequential chain of sensory events that occur when cold is applied to an injury. Numbness occurs as the last of these four stages of sensation (cold, burning, aching, and numbness) that are experienced when the skin is exposed to cold. This cycle is experienced in all forms of cryotherapy.

MODALITY CHOICE

In order to provide the highest degree of effectiveness as well as comfort and safety, the injury and injury site should be matched with the appropriate cold source both during and after the initial first aid. Most research to date has not explored modality appropriateness in specific cases, but has instead investigated the cause and effect relationship of cryotherapy.

Cryotherapy has, according to the majority of sports medicine practioners, been associated with ice packs and cold water whirlpools (Kalenak, 1975). Increased knowledge and advanced technology, better, more effective methods of applying cold to an injured site have been introduced along with a better understanding of modality selection.

Many factors must be considered when selecting a modality. For areas with bony prominences and irregular surfaces, immersion in ice water should be used instead of ice massage because of the ability of the water to surround the entire area and provide cooling to the area of concern. In this technique, the involved part (e.g., hand, foot, elbow, etc.) is immersed in tap water and ice is added to lower the temperature progressively until the cycle of cold, burning, aching, and numbness has been achieved. With the immersion technique, from 20 to 30 minutes is usually required to reach this stage of numbness. When the last stage of this cycle has been achieved, the part being treated must be closely observed to insure prevention of frostbite or other cold induced skin trauma. This procedure is more uncomfortable than other procedures and occasionally must be discontinued due to the patients' intolerance (Kalenak, 1975).

In cases where the injury is to a deep muscle and cold must be applied immediately to reduce hemorrhage and edema, the most effective form is ice packing and support with an elastic bandage (Kalenak, 1975; Klafs, 1975). In this method, ice cubes, crushed ice or even snow are placed in a plastic bag and applied to the injured area either directly on the skin or over the elastic wrap which holds it in place. With this type of deep muscle injury, other forms of cold application such as ice massage would be inappropriate and might even aggrevate the injury. Other alternatives to using an ice pack include the use of chemical cold packs and reuseable cold packs. These types of cold applications however, are typically expensive and appropriate for short term use only.

MEDIUM LAYER

There has been no research done to determine the most beneficial type of medium that can be used with a cold application. Typically an elastic wrap is used to perform a dual role of providing support and compression and of maintaining proper placement of the cold application. Consideration should be given to the insulatative as well as compressive properties that this form of medium provides. In addition, any changes in effectiveness resulting from water saturation, under or over-stretching, thickness, or material construction, must be considered when using this type of medium layer between a cold source and the skin.

The main elements of injury first aid (ice, compression, elevation and support, ICES) are of primary concern to the sports medicine professional. Typically, during the initial care phase of an acute soft tissue injury, some form of cold application is used to control bleeding and swelling. Swelling (edema) is the main threat to an injured site, and its swift rehabilitation. Edema can be controlled or decreased by increasing the tissue pressure outside the the blood vessel and by decreasing the hydrostatic pressure within the blood vessel. This is accomplished by compression and elevation. An elastic wrap or elastic tape provides compression to the body part which in turn increases the pressure outside of the blood vessel (Knight, 1978). In some situations, the use of an elastic wrap to provide compression may interfere with the cooling ability of the cold application. This problem can totally negate the beneficial effects of the cold and the compression. Conversely, the absence of some form of compression would greatly increase the amount of swelling which would occur if the cold were applied without compression.

The need for the cold application (ice pack, etc.) and compressive medium to work together quickly in stopping the secondary destructive processes at the cell level is paramount. If used together incorrectly, the beneficial effects of one element could nullify those of the other. As an example, placing a dry, compressive medium, which is several layers thick, between the cold source and the injured site, negates the immediate benefits of the cold. Eventually the cold will penetrate to the skin and deeper tissues, but the insulative properties of the medium delay this for several valuable minutes.

If a medium is not used between the skin and cold, the possibility of frostbite is a recognized danger. In a 1981 study, Drez (1981) examined five cases of temporary nerve palsy resulting from ice application directly on the skin. The results of the study indicate this complication may be avoided by not using ice for more than 30 minutes and by using a medium to guard superficial nerves in the area (Drez, 1981).

Little research has been done to examine the change in effectiveness of a medium when it is wet or dry. Research has shown that water dissipates heat 25 times faster than air. This fact would indicate that a wet cold source or medium would produce greater heat dissipation and therefore more cooling than a dry medium or cold source. It is also possible that a wet medium may enhance heat transport to an externally applied cold source, thereby reducing the amount of time it provides effective cooling.

In conclusion, the decision on choice of medium layer, if any, to use with a cold source should not be an arbitrary one. Many important factors are involved, most of which are not thoroughly understood. To better understand these effects, more research needs to be done in this area.

SUMMARY

There are conflicting opinions as to the effects of cold versus heat on the circulatory system of the skin and muscles. Early research says cold is first a vasoconstrictor then, upon removal, causes vasodilation above what was normal (Lewis, 1930).

Later research and replicated studies show cold as being solely a vasoconstrictor to the point of normal blood flow (Knight, 1980). This controversy, and the lack of physiologically based reasons for changes in circulation has not, however, reduced the popularity of cryotherapy in the treatment of soft tissue injuries. Experience and continued research have demonstrated the importance of matching the injury and the injury site with the proper cold source to achieve the most effective treatment possible. Modality appropriateness is as important as its application.

To achieve the best results from cryotherapy when a medium layer is used, consideration should be given to the type, thickness, dryness or wetness, elasticity and number of layers used between the cold and the skin. Also, care must be taken to control the duration of cold treatments. As research shows, the dangers of over exposure and uselessness of underexposure are very important considerations as well.

In conclusion, cryotherapy is effective in diminishing hemorrhage and edema presumably by the combined effect of a decrease in blood flow through damaged capillaries and a reduction in metabolic function at the cellular level. By diminishing the amount of hemorrhage and edema, through the use of ICES, cryotherapy is of singular importance in achieving earlier resolution of soft tissue trauma. Research is being continued to evaluate the effectiveness and selection of cryotherapy in specific cases of acute soft tissue injury and repair.

Chapter 3

METHODS AND PROCEDURES

This chapter describes the methods and procedures utilized in the study of the cooling rate and absolute cooling ability of eight different cold combinations, and the change in this ability when a wet versus dry medium is placed between the skin and the cold. Data were collected and statistical procedures were run, with intentions of answering two principal questions: (1) Is there a differential effect between the eight combinations of treatment in reference to the absolute cooling effect, and (2) Is there a differential effect between the eight combinations of treatment in reference to the rate of cooling?

The design of the study, the equipment used, the population involved and the external influencing factors have been presented. In addition, the data collected and the methods used for statistical analysis of the data have been included in this chapter.

Population and Sampling

The nature of the experiment and the equipment employed determined to a considerable extent the number and type of subjects suitable for the study. The fact that each member of the test group was subjected to a number of testing sessions made it necessary that full cooperation be assured from each subject prior to enlisting their services.

Since several of the combinations of cold and mediums were potentially painful for the first few minutes of application, it was necessary to explain this fact, and the sensations that would accompany it, to each subject. After explanations of the testing procedures and potential dangers involved, six male and four female, ex-varsity athlete, injury-free students with ages ranging from 19 to 26, volunteered to participate.

Before any testing was begun, two conditions had to be met by each subject. These included the subject's exclusion from any form of cryotherapy for one week prior to the begining of the testing, and at least a one hour period of time between the testing sessions and any strenuous activity or exposure to unusual temperatures. In addition, a 12 hour period elapsed between testing periods.

Design of the Study

Because the sampling plan was of necessity, casual, a repeated measures design in which all combinations were applied to each subject, was employed. This type of experimental design is very powerful because it can be relied upon to control most of the extraneous variables in an experiment. Thus, any observed differences between groups, can, with considerable confidence, be attributed to the variable or variables that are being tested. This experimental design required that all subjects arranged a one hour time slot each day for eight days within a two week period, to complete all eight combinations. This was arranged with each subject during the briefing session. Following the briefing session, concerning procedures and pre-test conditions, each subject was given an informed consent form to read, sign, and date confirming their willingness to voluntarily participate. Next, a mark was placed on the skin of the right ankle below the distal fibula and approximately two inches (5 cm) anteriorly towards the toes. This was used throughout the testing sessions as the area where skin temperature was taken. Upon entering the testing room, each subject was instructed to remove the shoe and sock on their right foot. A ten minute acclimization period then followed where the experimentor darkened the testing mark, and prepared the test materials and instruments, while the subject rested their testing foot on a short foot stool. This preparation consisted of calibration of the Tele-Thermometer, saturation of the medium in water at 15 C (if needed), placement of the probe on the cold source and securing it with surgical tape, and positioning of the subjects test ankle.

At the end of the acclimization period, measurements of the skin and atmosphere were recorded. A stopwatch was used to begin the testing period. In the first minute, the combined medium and cold source were placed on the ankle and a measurement representing the begining cold source temperature was taken. For the water bath, the medium, wet or dry, was placed on the ankle and the ankle was lowered into the water.

For the next 20 minutes, temperature readings of the skin were taken for 10 seconds, after lifting the medium and cold source from the skin and placing the probe on the skin mark. In the case of the water bath, the subjects' foot was lifted out of the water while measurements were taken. This action of lifting the foot in and out served as a whirlpool effect to maintain a somewhat consistant temperature in the water. Temperature readings were recorded for the cold source every five minutes by reading the temperature scale on the Tele-Thermometer at the appropriate time.

The cold sources used in the study were considered to be among the more widely used types of cryotherapy currently availible to the sportsmedicine professional and coach. The four cold sources used in the study were as follows:

(1) Kwik Kold packs - This consisted of two parts, ammonium nitrate pellets ($(NH_4)_2NO_3$) and water. The water was contained in a smaller packet inside the external package which contained the pellets. The package is squeezed causing the water packet to break and begin a chemical reaction that causes cooling.

(2) Cramer Flex-i-cold packs - This is a 6" x 8" packet of gel which remains flexible when frozen. It was the only reuseable cold source tested. This source was cooled by placing it in a freezer at 15 C for at least 24 hours prior to its use.

(3) Ice Pack - This application is composed of 600 grams of ice cubes measuring approximately 3/4" x 3/4" x 1" encased in a 9" x 8" x 18" x 1.01 mil small garbage bag.

(4) Ice Bath - This is possibly the most popular source of application. It is simply water or a combination of ice and water at 12 C in a large rectangular plastic bucket into which the subject placed their entire foot and ankle.

The medium used in the study consisted of a 6 inch wide elastic wrap which was sewn into a three layer pocket. Two layers were sewn together at the bottom to form a pocket in which the cold source was held. The top side of the pocket had one side of a strip of velcro, and a long flap extending from the edge of the pocket had the other side. During a treatment, the cold source was placed inside the medium pocket and two layers of the medium were between the cold source and the skin. The flap was stretched around the back of the ankle and heel, and fastened with the velcro strips in front. During the water bath treatment, no cold source was placed inside the medium pocket, and the medium was placed over the test area so only two layers were directly over the test mark. The water bath when used with a dry medium was not kept dry during the test period. Normal saturation that occurs during immersion in water was allowed.

Data Collection

Temperature measurements of the skin, cold source, and atmosphere were taken using a YSI Model 46 Tele-Thermometer and series 400 temperature probes. The probes for cold source measurement were taped to the exterior of the cold source. In the case of the water bath, a rectal type probe was placed in the water itself. The skin temperature probe was placed on top of a tongue depressor and all but the sensor surface of the probe lead was insulated with 1/8 inch foam which covered the entire tongue depressor. This unit was covered and sealed with surgical adhesive tape to protect the sensitive probe surface from the influences of the cold application while measurements were being taken, and to insure accurate and uninfluenced temperature readings of the skin. This setup was used for all skin temperature measurements. Recording sheets (Appendix D) for each subject were used to record temperatures and individual session information such as combination used, time of session, and experimenter comments.

Data Analysis

The family of techniques that were chosen to complete a statistical analysis of the test data came from nonparametric statistics. This type of statistical analysis was chosen because the test population was not randomly sampled; it was of necessity, casual sampling and because of this, any assumptions made were not based on a sample population. The statistics chosen to analyze the data included the Chi-square (Roscoe, 1973), Probability Z Score test, (L. D. Tompkins, personal communications, April 15, 1984), Friedman test (Wynne, 1982; Siegel, 1956; and Connover, 1971), T_4 LSD test (Connover, 1971), and the Wilcoxon test (Wynne, 1982; Spatz, 1984).

Absolute Cooling

The first major question to be answered was if there was an overall significant difference between treatments. This question was necessary in order to begin making comparisons and assumptions on the rest of the data. At this point a general test was needed to indicate significant difference within the entire set of data. This decision was made on the premise that by simple visual survey of the data, it was evident that there was a tremendous variation in cold source and medium groups with regard to the variety of ranges of temperatures.

The second major question to be answered was whether a significant difference could be found between the wet and dry medium groups. To accomplish this, a set of two, 1 x 4 Chi-square tests were run on temperature ranges; one for the wet medium and one for the dry medium. If either or both of these tests would show no significant difference, a decision would be made whether or not further investigation was necessary to pinpoint a possible true difference which may have been hidden by several other groups within the same block. It was decided to examine the absolute cooling of the two medium groups, to help identify a superior treatment. To do this, the range in temperature of each subject for each of the eight combinations of cold source and wet or dry medium was found. Next, the overall median range of both groups (wet and dry), was found. This information was entered into the Chi-squares by finding the total number of range scores above and below the group median. After entering the data into a data file, the Funstat computer program #15 was used to run a Chi-square test for independence of medians. The results of this test indicated a significant difference was within the dry group. Any difference within blocks of the wet medium group were too small to be conclusive. Due to a significant difference in the dry medium group, a further examination was necessary to insure its freedom from family wise error that arises when testing is done on a group of data. The Probability Z Score (PZS) test was used to do this. The wet medium Chi-square did not show a significant difference so the PZS test was done on the dry medium data only. The obtained frequencies for each block in the dry medium group were used in the formula to give this nonparametric Z score. The Probability Z Score formula is listed in Appendix A.

Absolute Cooling Individual Comparisons

The Wilcoxon test was used to test the difference between two correlated samples such as those that are found in a repeated measures design of this type. This particular test was performed on each of the four cold sources, and on the entire wet medium group versus the entire dry medium group.

By using the Wilcoxon, a more definitive difference in effectiveness between a cold source when it is used with a wet versus dry medium can be made. To compare each of the cold sources that were used with the wet medium, to those of the same cold source with a dry medium, the ranges in temperature of each combination for each subject were entered into a matrix. The range score of one cold source and dry medium were subtracted from the same range scores of the wet group to show a difference. The differences between the range scores were ranked, and added according to their sign (i.e., positive or negitive). By comparing the smaller of the two sums with an appropriate level of significance, a decision was made whether to accept or reject the null hypothesis. If the null hypothesis was rejected, a comparison of the medians for both cold sources would show one number that was larger, and this cold source and medium combination were judged to be superior to its treatment opposite.

Rate of Cooling

Information concerning the rate of cooling is important with respect to the use of cold during injury first aid. A cold source and medium combination that takes 30 minutes to reach its absolute temperature is not as useful as one which takes 10 minutes. Although there was no significant difference found within the wet group in terms of its absolute cooling ability, this does not rule out the possibility of a significant difference in terms of the rate of cooling. The Friedman test was used to find this difference.

The Friedman test was used to analyze rate of cooling by answering the question of whether it is likely that the four related samples in each medium group could possibly have come from the same population with respect to ranks. It is an overall test to show an obvious similarity or dissimilarity within a treatment group (i.e., wet medium group or dry medium group).

To test the rate of cooling, it was necessary to examine the gradual drop in temperature during the 20 minute test period. To gauge this cooling progression, the temperature reading for every fourth minute was used. A smaller time increment would not have illustrated the progressive drop in temperature as well. Every fourth temperature reading for each subject was entered into a matrix for each of the eight combinations. Each temperature reading in the wet medium group was ranked 1 - 20 until all fifty temperatures had a rank score. The same procedure was used on the dry medium group.

This ranking procedure is somewhat different than that of other statistical tests. The scores for each subject, are rank-ordered among themselves; there is a separate set of ranks for each row of scores. Accordingly, each subjects scores are ranked across the four design conditions, (4 wet, 4 dry), assigning the rank of 1 to the lowest temperature and working up to 20 from there. Ties are averaged in the usual way.

The ranks for the two medium groups were totalled for each of the four combinations to give eight numbers (4 from the wet and 4 from the dry medium group). The four numbers from each medium group were entered into a Friedman formula. This formula is found in Appendix B.

To correct any family wise error that arises when a test such as the Friedman, which examines a group of data, is used for multiple tests, a T_4 LSD (Least Significant Difference) test is used. Like the PZS test, the T_4 LSD test is used to find the level of significance, or the maximum probability of rejecting the true null hypothesis. The T_4 LSD test does this by computing the probability that the test statistic will assume one of the values that results in rejection of the null hypothesis under the assumption that the null hypothesis is true (Conover, 1971).

The T_4 LSD uses the variance of ranks (Appendix B), and the resultant figure from the Friedman (Appendix B), in the formula. This formula may be found in Appendix C.

The use of these nonparametric statistics to analyze the collected data will determine the medium, cold source, and cold source combination that is statistically the most effective. Nonparametric statistics were used and these results cannot be assumed to apply to a random population. They can however, be applied to a population similar to that used in the study (i.e., ex-varsity athletes, male or female, ages 19-26). By this premise, it is felt that the results from this study can be assumed to apply to most cryotherapy usage situations in athletics and recreational sports.

Chapter 4

ANALYSIS OF DATA

This chapter contains the results of the analysis of data from the comparison of eight combinations of cold source (Kwik Kold, KK; Flex-i-cold, FC; Ice Pack, IP; Water Bath, WB) and medium (wet, W; dry, D) in terms of rate and absolute cooling ability, for all subjects. The statistical procedures used for analysis included the Chi-square, Probability Z Score test, the Friedman test, T_4 LSD (Least Significant Difference) test, and the Wilcoxon test.

Absolute Cooling Ability

The median scores of the two medium groups were each subjected to a 1 x 4 Chi-square test to determine if a significant difference existed within the data at the .05 level. In addition, a Probability Z Score test was run on any resulting significant differences, to further clarify and insure those significant differences found from any family wise error.

Chi-square Analysis of Data

The median score of the range of temperatures for all subjects for the dry medium group was 4.50 while the same median score for the wet medium group was 5.30. Median values for all subjects, and all combinations are shown in Table 1 for wet combinations and Table 2 for the dry combinations.

Table 1

Median Values of the Ranges of Temperatures For All Subjects for Wet Medium Combinations

Source	KKW	FCW	IPW	WBW
MEDIAN	5.75	4.80	6.10	4.80

Table 2

Median Values of the Ranges of Temperatures For All Subjects for Dry Medium Combinations

Source	KKD	FCD	IPD	WBD
MEDIAN	5.30	2.90	4.30	6.20

The medians score of each of the subjects that were above or below the group median were entered into a 1 x 4 Chi-square matrix for each medium group. These numbers are shown in Table 3 for the wet group and Table 4 for the dry medium group.

Table 3

Chi-square Matrix For Wet Medium For All 10 Subjects

Source	KKW	FCW	IPW	WBW
ABOVE MEDIAN	6	4	6	4
BELOW MEDIAN	4	6	4	6

Table 4

Chi-square Matrix For the Dry
Medium For All 10 Subjects

Source	KKD	FCD	IPD	WBD
ABOVE MEDIAN	6	1	6	8
BELOW MEDIAN	4	9	4	2

Using the Funstat program (Roscoe, 1973), a Chi-square value of 1.60 at 3 degrees of freedom was found for the wet medium, and 10.73 at 3 degrees of freedom for the dry medium. This figure is significant at a .05 level of probability. The difference in results from the wet medium were not, however, judged to be significant, so no further analysis was run. This analysis does not mean the wet medium is not effective. It means that the differences between the cold sources are not as large as they are in the dry medium group. To find where the difference was within the dry medium a Probability Z Score (PZS) test was run (Appendix A).

Probability Z Score test

The results of the PZS test showed where in the dry medium group these significant differences were found. These contrasts between cold sources are illustrated in Table 5.

Table 5

Probability Z Score test

Source	(5) KKD	(6) FCD	(7) IBD	(8) WBD
(5) KKD		*		
(6) FCD	*		*	*
(7) IPD		*		
(8) WBD		*		

* = A significant difference exists between these combinations.

Individual Absolute Cooling

The Wilcoxon test was a final test of absoulte cooling ability between the four cold sources and between the wet versus dry medium groups. In all, five Wilcoxon tests were performed. The median scores for each subject for each cold source and dry medium were subtracted from the same subjects median scores of the wet medium. Differences not equal to zero were ranked 1 - 10, and ranks were signed according to the sign of their difference (positive or negative). The smaller sum of ranks, W, was compared with the critical value of 6 assigned to the number of pairs (which was 10). A W value equal to or less than that critical value demanded a rejection of the null hypothesis which assumes the two treatments were equal.

The resulting acceptance or rejection of each Wilcoxon test of the cold sources is shown in Figure 1.

Figure 1

Results of Wilcoxon tests
for All Cold Sources

Comparison	Accept	Reject
KKW = KKD	X	
FCW = FCD		X
IPW = IPD		X
WBW = WBD	X	

An examination of the median scores of each cold source and medium combination allows a superior combination to be found in those treatment blocks where the null hypothesis was rejected. Rejection of the null hypothesis was found in the Ice Pack and Flex-i-cold groups. The median score for the dry Ice Pack was 4.30 and for the wet Ice Pack, 6.10. The median score of the dry Flex-i-cold was 2.90 and for the wet Flex-i-cold 4.80. On the basis of a superior score, it was assumed that both the wet Ice Pack and wet Flex-i-cold were the more effective combinations. The Wilcoxon showed no significant difference in absolute cooling ability between the wet Kwik Kold or dry Kwik Kold, or between the Water Bath and wet medium, and Water Bath and dry medium. These findings are similar to those found in the sum of ranks shown in Table 6.

The fifth Wilcoxon test performed was on the entire wet medium group versus the entire dry medium group. Upon comparison of W, 219, to the critical value, 250, rejection of the null hypothesis was indicated as the value of W was less than the critical value. Examination of the group median for the wet, (5.30), and of the dry, (4.50), indicated that by the standards of this test, the most effective medium when used with a cold source was the wet one. This finding is in agreement with that found in the Friedman and T_4 LSD tests with regards to the superiority of one medium over another.

Rate of Cooling

The rate of cooling is an important consideration in choosing a cold combination. When using cold during first aid to treat an injury, a combination of cold source and medium that will cool the area rapidly is needed. An injury that is past the point of hemorrhaging may need a cold combination that cools gradually and for a long period of time. To find a test difference in treatment within the mediums, the Friedman test (Appendix B) was used. To clarify any significant difference found as a result of the Friedman test, and adjust for family wise error, a T_4 LSD test (Appendix C) was run on both groups.

Friedman test

The data were separated into 4 wet and 4 dry combinations. The individual subjects skin temperature readings for every fourth minute was entered into a matrix for each combination and these readings were ranked. An explanation of the ranking procedure is found in Appendix B. The 10 sets of ranks for each of the eight combinations (4 wet and 4 dry), were totalled to give 8 numbers. These sums of ranks for the wet and dry mediums were separated, and the sums for each medium was subjected to the Friedman formula. Table 6 lists these figures.

Table 6

Sums of Ranks For
Rate of Cooling For
Wet and Dry Mediums

Source	WET	DRY
KK	590.50	396.00
FC	553.00	771.50
IP	438.00	633.00
WB	298.00	299.50

The results from the Friedman on the dry medium showed an obtained value of 80.76 compared to the wet medium which showed an 85.34.

$\underline{T_4 \text{ LSD Test}}$

The results from both Friedman tests indicated a significant difference based on a comparison of the obtained value to that of the critical Chi-square value at .05, which was 16.92. Again to further illustrate and clarify this difference, the T_4 LSD test was used. The formula for this test is found in Appendix C. A critical value of 33.67 for the wet medium group and 45.23 for the dry medium group were found from this test.

The individual results from the T_4 LSD test are shown in Table 7 for the wet medium and Table 8 for the dry medium group. These results were found by subtracting the rank sum of one combiation from that of all the other combinations until all had been compared. The resulting figures from the subtractions gave a group differance number, and when this number was compared to that of the T_4 LSD test result, a figure greater than or equal to the T_4 LSD test critical value indicated a significant difference between the two combinations.

Table 7

T4 LSD Results For
Dry Medium Group

Source	(1) KKD	(2) FCD	(3) IPD	(4) WBD
(1) KKD			*	*
(2) FCD			*	*
(3) IPD	*	*		*
(4) WBD	*	*	*	

* = A significant difference exists between these combinations.

Table 8

T4 LSD Results For
Wet Medium Group

Source	(5) KKW	(6) FCW	(7) IPW	(8) WBW
(5) KKW		*	*	*
(6) FCW	*		*	*
(7) IPW	*	*		*
(8) WBW	*	*	*	

* = A significant difference exists between these combinations.

The T_4 LSD test results showed a significant difference in overall comparisons of the cold sources in the wet medium group, and all but two in the dry medium group. A ranking was done using the sums of ranks for each cold source within the medium group, assigning 1 to the highest sum and 2, 3, and 4 to the next lowest numbers. The medium with the highest rank sum is the least effective. Results of this are shown in Table 9 for the wet group and Table 10 for the dry group.

Table 9

T4 LSD Test Results
Comparison of the Wet
Combination Group

Combination	Rank Sum	Rank Number
WBW	298.00	1
IPW	438.00	2
FCW	553.00	3
KKW	590.50	4

Table 10

T4 LSD Test Results
Comparison of the dry
Combination Group

Combination	Rank Sum	Rank Number
WBD	299.50	1
KKD	396.00	2
IPD	633.00	3
FCD	771.50	4

Summary

The results of the Chi-square showed a significant difference in the dry medium group, and none in the wet medium group in terms of absolute cooling ability. A more defined look at the dry medium group using the Probability Z Score test showed this difference in the dry medium to be specifically located in the Cramer Flex-i-cold. The Flex-i-cold was so much less effective than the rest of the cold sources that it caused the original significant difference to show up in the 1 x 4 Chi-square test. The Wilcoxon test was used as a final test of absolute cooling ability. Each of the cold sources was compared as it was used with either the wet or dry medium.

Rate of cooling was the other main area of concern. It was first examined with the Friedman test. The results of this test showed both medium groups to have a significant difference within the blocks of treatments. A T_4 LSD test further defined this difference and ruled out any family wise error that may have occured. Specific differences between cold sources and cold combinations, and recommendations for their use are given in Chapter 5.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study was completed to determine if a significant difference could be found among eight different cold sources with mediums in terms of rate and absolute cooling ability. Data were collected and analyzed as previously described in Chapters 3 and 4.

SUMMARY

Absolute Cooling

The median score of the ranges for all subjects showed the wet medium group to have a .80 higher median value at 5.30. This was expected on the basis of water being able to dissipate heat faster than air.

A Chi-square value of 1.60 for the wet medium group indicated no significant difference existed between the cold sources. In other words, the difference in absolute cooling ability between the cold sources was not significant enough to be revealed by the Chi Square test. A Chi-square value of 10.73 for the dry group did indicate significant difference at the .05 level of probability between the cold sources. These findings are in opposition to those of the wet medium group in that there is a definite difference among the cold sources when they are used with a wet medium. The Probability Z Score test was done on the dry medium group to further intrepret the significant differences found between treatments. The PZS test demonstrated a significant difference between the Flex-i-cold and all other cold sources when used with a dry medium. Compared to the other cold sources, the Flex-i-cold was markedly less effective.

Examination of the differences in absolute cooling between those cold sources combined with a wet medium and those combined with a dry medium, using the Wilcoxon test, showed the Water Bath with a wet medium to be equal, in terms of absolute cooling ability, to the Water Bath with a dry medium. This was also demonstrated in the Kwik Kold with wet medium and the Kwik Kold with dry medium treatments. These findings correlate with the Chi-square and PZS tests which concluded that the Kwik Kold and Water Bath were not the cause of the significant difference within the dry medium group.

Interpretation of the null hypothesis of the Ice Pack and Flex-i-cold treatments by the Wilcoxon test showed a rejection was indicated. In both cases, the cold source when combined with the wet medium was significantly better than when used with the dry medium. Between the wet and dry groups as a whole, again the null hypothesis was rejected in favor of the alternate hypothesis and median scores showed the wet medium group to be superior in terms of total cooling.

Rate of Cooling

The obtained value of the Friedman for the wet medium group was 85.34 and for the dry group, 80.76. These values reveal a significant difference among cold sources in both medium groups in terms of cooling rate. A T_4 LSD test which was used to control family wise error in the Friedman test indicated significant differences within the dry group, between all treatments except the Kwik Kold and Flex-i-cold. This means that in relationship to rate of cooling, Kwik Kold and Flex-i-cold do not show any significant differences.

The T_4 LSD test on the wet medium group showed significant differences between all treatments. No two cold sources when used with a dry medium, had a similar cooling rate.

By using the rank order of group medians, it was possible to rank the cold sources in order from most to least effective. In rate of cooling, Water Bath, Ice Pack, Flex-i-cold/Kwik Kold were the most effective when used with a dry medium, in relationship to rate of cooling.

As was shown in the T_4 LSD test of the dry medium group, all but the Kwik Kold and Flex-i-cold showed significant differences. This fact dictates that the Kwik Kold and Flex-i-cold be judged equal in their rate of cooling. The order of effectiveness changes when a wet medium is used. In order from best to worst, Water bath, Kwik Kold, Ice Pack and Flex-i-cold were the most effective in rate of cooling when used with a wet medium.

CONCLUSIONS

From the results of the statistical analysis and within the limitations of this study, the following conclusions were made:

(1) The combination of a wet medium and any of four cold sources, (Kwik Kold, Flex-i-cold, Ice Pack, Water Bath) is more effective in achieving the lowest possible temperature than the

same cold sources combined with a dry medium.

(2) The dry medium was less effective than the wet medium especially when the Flex-i-cold was used.

(3) The Water Bath combined with the wet medium was just as effective as the Water Bath combined with the dry medium as an absolute cooler.

(4) The Kwik Kold combined with the wet medium was just as effective as the Kwik Kold combined with the dry medium as an absolute cooler.

(4) Both the Ice Pack and Flex-i-cold were more effective as absolute coolers when used with the wet medium than when used with a dry medium.

(6) The rate of cooling is not different between Kwik Kold with a wet medium and Flex-i-cold with a wet medium.

(7) The quickest coolers when used with a wet medium are Water bath, Kwik Kold, Ice pack, and Flex-i-cold from best to worst respectively.

(8) The quickest coolers when used with a dry medium are Water Bath, Ice Pack, Flex-i-cold, and Kwik Kold from best to worst respectively.

(9) For quick cooling the use of a wet medium and any of four cold sources except Flex-i-cold, is better than the use of a dry medium with any of the four cold sources.

(10) The most effective cold combination in terms of both rate and absolute cooling ability is the Water Bath.

(11) The least effective cold combination in terms of rate and absolute cooling ability is the Flex-i-cold.

RECOMMENDATIONS FOR FURTHER STUDY

On the basis of the results of this study, the following questions are posed for further investigation. What effects would exercise during treatment have on the eight combinations used in this study? Would other types of cold sources be similarily changed by the use of a wet or dry medium? Would a change in the technique of application of a medium (e.g., an ace wrap wound onto the foot) affect the cooling rate or absolute temperature of a cold source? What changes would be found if the begining temperature of the Cramer Flex-i-cold or ice bath was lower? What would the skin temperature measurements during a treatment be like if exercise was done immediately before the treatment? Does injury to an area cause changes in skin circulation thereby changing the cooling of the skin? Would elevation, or lack of it, of the treated ankle improve skin cooling? Would it impair it? Would the use of an insulative sleeve over the cold source and medium improve or impair effectiveness?

Other recommendations concerning the testing of this type of cryotherapy include the use of skin blood temperature measurements to judge cooling effectiveness. Because each time a measurement was taken, the cold source was temporarily lifted from the skin, the true amount of cooling that any one application could achieve was not known precisely.

The use of temperature probes to measure a cold source would be aided by the use of a temperature sensor inside the contents of each cold source. This would prevent any discrepency concerning the actual overall temperature of a cold source during it's application use during testing.

SUGGESTIONS

The recommendations for the use of these different cold sources is dependent upon the type and area of the injury. The Water Bath with either medium was found to be superior to all other cold combinations, but this combination would not be satisfactory if the injured area was on the torso. In addition, it may be that when treating an injury the use of cold is secondary in importance to the elevation of the injured part. Again, using a Water Bath would not be feasible with this type of cold application.

In reference to the type of injury, limitations are set by the size of the area, and the age of the injury. If a large bruise to the low back is in need of treatment, slower cooling in a large area is desired. Three or four Kwik Kold or Flex-i-cold packs and a wet medium would be useful to achieve gradual cooling, but this cold would not be a lasting one, and most likely, not economically well-advised. Immediate first aid to a joint area demands immediate cooling for a long period of time. The best cold combination for this is Ice Packing over a wet medium. Although the Water Bath with a wet medium would be the most desirable treatment, the addition of elevation makes the Ice Pack with the wet medium the treatment of choice.

The injury situation that occurs away from proper medical help or equipment still requires prompt use of cold. The only one of the four sources that can be transported without the need of refrigeration is the Kwik Kold. Although the rate of cooling of this cold source is poor even when used with a wet medium, even the slightest bit of cold that reaches the injured area is better than none. The injury situation that occurs away from availible ice or refrigeration would indicate the needto use a Kwik Kold pack and wet medium.

The Flex-i-cold is the only one of four cold sources that is reuseable. This source is re-cooled by placing it in a refrigerator, if available, or an insulated cooler with ice. The results of this study showed that ice packing was superior in all tested situations to the Flex-i-cold. The Flex-i-cold then, is not economically or physiologically advised for use in any situation where refrigeration or ice is available for use.

Research has shown the need for a medium between the cold source and the skin in order to reduce the possibility of frostbite. There is also supporting evidence of a need for some form of compression during injury first aid. By combining these two facts with the results of this study, the most effective type of a medium for compression, protection from cold over-exposure, and assistance in cooling, is the wet elastic wrap.

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APPENDIX A

Probability Z Score Test

APPENDIX A

PROBABILITY Z SCORE TEST

$$Z = \frac{(f_1 - f_2)}{\frac{f_1\ (1 - f_1)}{n} + \frac{f_2\ (1 - f_2)}{n}}$$

Where:

f_1 = Frequency Obtained in Block 1

f_2 = Frequency Obtained in Block 2

n = Number of Subjects in Block

APPENDIX B

Friedman Test

APPENDIX B

FRIEDMAN TEST

$$T = \frac{(k - 1)}{k} \left| \frac{R - E(Rj)) + (R - E(Rj)) + \ldots + (R - E(R))}{V(Rj)} \right|$$

Where:

k = Number of treatments

b = Number of blocks

m = Replications per treatment

R(Xij) = Sum of squares of ranks in each k *

V(Rj) = Variance of ranks

$$V(Rj) = \frac{m(k - 1)}{k(mk - 1)} \left| R(Xij) - \frac{(mkb(mk + 1)}{4} \right|$$

E(Rj) = Expected ranks per column

$$E(Rj) = \frac{bm(mk + 1)}{2}$$

* Ranking- The scores for each subject or each block of matched subjects are rank ordered. These ranks are summed for each treatment group. If the groups are different, these sums will differ and a statistic is calculated to evaluate this difference.

APPENDIX C

T_4 LSD (Least Significant Difference) test

APPENDIX C

T_4 LSD (LEAST SIGNIFICANT DIFFERENCE) TEST

$$T4\ LSD = \frac{2kb(mk - 1)\ V(Rj)}{(k - 1)\ (mbk - k - b + 1)} \left| 1 - \frac{T}{b(mk - 1)} \right|$$

Where:

k = Number of treatments

b = Blocks

m = Replications per treatment

T = Friedman test (Appendix B)

V(Rj) = Varience of ranks (Appendix B)

APPENDIX D

DATA COLLECTION SHEET

SUBJECT # ______

BEGINING TEMPERATURES:

DATE ____________________

ATMOSPHERE ____________________

TIME ____________________

SKIN ____________________

COMBINATION ______________

COLD SOURCE ____________________

MINUTES	SKIN TEMPERATURE	COLD SOURCE TEMPERATURE	REMARKS
1	________	________	
2	________		
3	________		
4	________		
5	________	________	
6	________		
7	________		
8	________		
9	________		
10	________	________	
11	________		
12	________		
13	________		
14	________		
15	________	________	
16	________		
17	________		
18	________		
19	________		
20	________	________	

APPENDIX E

COLD COMBINATION IDENTIFICATION

Table 11

Identification of
Combinations of Cold Source
and Medium Used

Source	(KK) KWIK KOLD	(FC) FLEX-I-COLD	(IP) ICE PACK	(WB) WATER BATH
(W) WET MEDIUM	(1) KKW	(2) FCW	(3) IPW	(4) WBW
(D) DRY MEDIUM	(5) KKD	(6) FCD	(7) IPD	(8) WBD