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# A Comparison of Two Forms of Cryotherapy on Post-Injury Edema and Range of Motion in the Ankle and Knee

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# A COMPARISON OF TWO FORMS OF CRYOTHERAPY ON POST-INJURY EDEMA AND RANGE OF MOTION IN THE ANKLE AND KNEE

BY

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To the Dean of the School of Human Performance and Leisure Sciences:

I am submitting herewith a thesis written by Justyna A. Krempin entitled "A Comparison of Two Forms of Cryotherapy on Post-Injury Edema and Range of Motion in the Ankle and Knee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Movement Science.

Dr. Sue Shapiro, Thesis Committee Chair

We, members of the thesis committee,
have examined this thesis
and recommend its acceptance:

Accepted:

Chair of Department of Sport and Exercise Sciences

Accepted:

Dean of School of Human Performance and Leisure Sciences

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## ABSTRACT

Cryotherapy is one of the most common forms of modality used by athletic trainers for the treatment of swelling and pain following an acute sport related injury. This study compares the traditional application of ice bag with static compression method and a more sophisticated application of cryotherapy via active continuous-flow cold therapy unit with intermittent compression. The purpose of this study was to determine if active continuous-flow cold therapy units are more effective in the reduction of edema and in the increase of range of motion than the traditional method used by athletic trainers. This study involved collecting data from various athletic trainers from secondary and collegiate school. A total of 10 anonymous data sheets were collected from athletic trainers who provided consecutive daily cryotherapy treatments via ice bag with static compression or active continuous-flow cold therapy unit with intermittent compression. A non-parametric statistical test (Mann-Whitney) was used to determine whether one of the two cryotherapy methods had significantly different outcomes. Results of the revealed no significant differences in the reduction of swelling between the use of active continuous-flow cold therapy units with intermittent compression and the ice bag with static compression method ($p = .732$, $p > .05$). Results also revealed no significant differences between the two groups in the increase in active range of motion ($p = .909$, $p > .05$). Although significant differences in swelling and range of motion between the two treatment groups were not found, further inspection focusing on specific joints revealed subtle difference. The results indicate that active continuous-flow devices with intermittent compression may provide accelerated reduction of edema and increase in range of motion shortly after initial injury. Future research is needed to further investigate if significant outcomes can be obtained and whether one modality is indeed more beneficial than the other.

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# CHAPTER 1

# INTRODUCTION

The application of snow and ice after musculoskeletal and soft tissue injury has been described since the time of Hippocrates (Lehman & DeLateur, 1982). Today, cryotherapy is one of the most common treatments in sports medicine. It is a form of modality that uses the application of ice or cold in the management of swelling and pain and accepted as very beneficial in the early management of soft tissue injuries (Kennet, Hardaker, Hobbs, & Selfe, 2007). Various modes of cryotherapy are used in rehabilitation process which includes ice bags, gel packs, cold whirlpools, ice immersions, cold compression units, etc. However, the most commonly observed practice of cryotherapy is the application of ice bags or gel packs (Block, 2010). These methods are easily accessible, convenient and relatively inexpensive compared to more sophisticated cold compression units.

Cold and compression has shown to be effective in the management of edema and pain (Nadler, Weingand & Kruse, 2004; Block, 2010) in not only acute and chronic injuries, but also following post-operative procedures where these signs and symptoms can be exacerbated (Block, 2010). However, the mechanism by which cryotherapy decreases pain and swelling may not always be well understood (Barber, McGuire & Click, 1998). Several physiological effects take place in order to achieve an overall therapeutic effect.

Ice bag treatment along with static compression of elastic bandage is regularly practiced by many athletic trainers following an acute soft-tissue injury or as a prophylaxis for chronic inflammatory problems (Block, 2010). The application of cold causes vasoconstriction which inhibits fluid flow to injured site. However, further reduction of swelling can be achieved with compression. By applying compression (i.e. elastic wrap), fluid is pushed and relocated away from the injured area and toward proximal tissue, where it can be resolved more easily and efficiently by the lymphatic system (Meeusen, van der Veen, Joos, Roeykens, Bossuyt & De Meirleir, 1998). When combined, cold and compression increase the rate, magnitude and depth of temperature decrease along with the rate of lymph removal (Meeusen et al., 1998).

Athletic training facilities and physical rehabilitation centers use various forms of cryotherapy methods such as ice bags, gel packs, ice-water immersion, cold whirlpool, ice-massage, the CryoCuff and other continuous-flow cold units to achieve therapeutic effects. However, researchers debate which form of cryotherapy is most beneficial. Many previous studies have compared the efficacy of various types of cryotherapeutic agents on edema reduction, but few studies have focused on the effectiveness of active continuous-flow cold therapy devices.

The majority of research studies done on efficacy of continuous-flow cold therapy, centered on post-operative treatments of swelling and not on non-surgical trauma (acute and chronic conditions). Furthermore, their main point of focus was on analgesic consumption and pain reduction; lacking research in effectiveness to reduce edema and increase range of motion.

## Statement of the Problem

Cryotherapy via continuous-flow cold therapy devices has repeatedly been proven to decrease post-operative pain, swelling, and narcotic use (Wilke & Weiner, 2003). However, the success of outcomes was greatly dependent on appropriate participant selection, education, and cooperation (Wilke & Weiner, 2003). Furthermore, the majority of research studies done on the effectiveness of continuous-flow cold therapy devices, lack investigation of its effectiveness on acute sport injuries in the traditional athletic training setting.

Therefore, the purpose of this study was to compare two forms of cryotherapy (active continuous-flow cold therapy versus standard ice bag with compression) and their effectiveness on edema reduction and range of motion progress. This study involved the collection of anonymous data from Certified Athletic Trainer at various south Florida colleges and secondary school. Anonymous date included athletes aged from 16-22 with lower extremity edema. The setting in which data was gathered was in a traditional athletic training room.

## Research Hypothesis

The following hypotheses will be tested:

Specific Aim 1: To determine the effect of different cryotherapies on edema in lower extremity injuries.

Hypothesis 1a: There will be a reduction using both methods of cryotherapy.

Hypothesis 1b: There will be no significant differences in edema reduction between the two methods of cryotherapy.

Specific Aim 2: To determine whether different cryotherapies will have a different effect on range of motion of lower extremity.

Hypothesis 2a: There will be no significant differences in range of motion increase between the two methods of cryotherapy.

## Variables

Independent Variables:

1. Ice bag with elastic compression methods.
2. Continuous-flow cold therapy method.

Dependent Variables:

1. Degree of range of motion at the joint.

2. Measure of edema at the joint.

## Assumptions of the Study

This study relied on the following assumptions:

1. Each tester followed the instructions and demonstrated precision in testing procedure.
2. No anti-inflammatory medication was consumed by subjects throughout course of study.

## Limitations of the Study

This study is limited by the following factors:

1. The participant sample was selected from the local school community and university student population, thus generalization to other populations may not be possible.
2. The results of the study may only be applied to individuals in the age group of the sample.
3. Data collection for the study was performed by several testers.
4. When bilaterally compared, participants with affected ankle or knee circumference of at least 3 mm greater than the unaffected leg are included for the study.

## Delimitations of the Study

This study is delimited to:

1. Athletes in secondary schools and universities.
2. Athletes with acute, and post-surgical trauma of lower extremity.
3. Athletes who present with inflammatory and edema conditions in lower extremity.

## Significance of the Study

This study is expected to provide unique and needed knowledge to the field of physical rehabilitation in sport medicine. The results will provide an insight concerning the effects of swelling reduction with the use of active continuous-flow cold therapy devices with intermittent compression. In addition, the results will provide information on which cryotherapy method is more beneficial and practical to use in tradition athletic training setting.

If it shows that active continuous-flow cold therapy devices with intermittent compression are indeed more effective in edema reduction, then there may be implications for transition from the use of standard ice bags with compression to these more sophisticated devices. If the reduction in swelling and an increase in range of motion occur in less time than with the traditional method, athletes may recover more quickly form injury. This knowledge may help reduce the amount of lost playing time for athletes.

## Definition of Terms

Anatomical Landmarks: "A recognizable skeletal or soft tissue structure used as a reference point in measurements or in describing the location of other structures"(Davis, 2005, p.1294).

Anterior: "before or in front of" (Davis, 2005, p.142).

Cryo: "combining forms concerning cold" (Davis, 2005, p.550).

Distal: "further away from center of the body" (Davis, 2005, p.674).

Edema: "a local or generalized condition in which body tissues contain an excessive amount of tissue fluid in the interstitial spaces" (Davis, 2005, p.723).

Elastic Compression Bandage: "a bandage that can be stretched to exert continues pressure" (Davis, 2005, p.239).

Game Ready: active continuous-flow cold therapy unit which utilizes ice, water, and intermittent compression for the treatment of edema.

Goniometer: "apparatus used to measure joint movements and angles" (Davis, 2005, p.974).

Hypoxia: "an oxygen deficiency in body tissues" (Davis, 2005, p.1142).

Inferior: "undersurface of an organ or indicating a structure below another structure" (Davis, 2005, p.1186).

Knee joint line: the joint "formed by the femur, patella, and tibia" (Davis, 2005, 1272).

Lateral: "Pertaining to the side" (Davis, 2005, 1304).

Malleolus: "the protuberance on both sides of the ankle joint" (Davis, 2005, p.1396).

Medial: "pertaining to middle" (Davis, 2005, p.1419).

Metatarsal: "any of the bones of the metatarsus" (Davis, 2005, p.1455).

Navicular tuberosity: "scaphoid bones in the ankle" (Davis, 2005, p.1546).

Nociceptor: "a free nerve ending that is a receptor for painful stimuli" (Davis, 2005, p.1591).

Pain: "an unpleasant sensory and emotional experience arising from actual or potential tissue damage or described in terms of such damage" (Davis, 2005, p.1680).

Patella: "a lens-shaped sesamoid bone situated in front of the knee in the tendon of the quadriceps femoris muscle" (Davis, 2005, p.1718).

Posterior: “toward the back” (Davis, 2005, p.1856).

Proximal: “close to center of the body” (Davis, 2005, p.1919).

Spasm: “an involuntary sudden movement or muscular contraction that occurs as a result of some irritant or trauma” (Davis, 2005, p.1516).

Spinal Cord: “part of the central nervous system, the spinal cord in an ovoid column of nerve tissue 40 to 50 cm long that extends from the medulla to the second lumbar vertebra; it consists of the cell bodies and dendrites of neurons” (Davis, 2005, p.2173).

Superior: “higher than; situated above something else” (Davis, 2005, p.2240)

Tibial tuberosity: “an elevated round process” on the tibia bone (Davis, 2005, p.2386).

Tibialis anterior: muscle “pertaining to front of tibia” (Davis, 2005, p. 2322).

Tissue Metabolism: “the consumption of energy by all cells, including those of muscle tissue, in order to perform work” (Davis, 2005, p1516).

Tonicity: “property of possessing tone, especially muscular tone” (Davis, 2005, p.2334).

# CHAPTER 2

## LITERATURE REVIEW

Athletic trainers in traditional settings follow the golden-rule called R.I.C.E. (Rest, Ice, Compression, Elevation), for the treatment of acute injuries in athletes. The conventional method involves the application of the standard ice bag with a compression wrap on the injury site. Literature has shown cryotherapy to be very effective in the reduction of tissue metabolism, blood flow, edema, pain, muscle spasms and loss of range of motion associated with swelling (Kennet et al., 2007; Nadler et al., 2004; Block, 2010; Knight, 1989). However, the exact mechanism by which these outcomes are achieved is not always implicit (Barbar et al., 1998).

According to Taber's Cyclopedic Medical Dictionary, pain is "an unpleasant sensory and emotional experience arising from actual or potential tissue damage" (p.1680). Pain is considered a subjective opinion that varies in level from person to person and "it's not solely dependent on the physical property of the stimulus" (Wikle & Weiner, 2003, p. 307). Typically, pain arises when our nociceptors are stimulated (Wikle & Weiner, 2003). These nociceptors transmit nerve signals through the spinal cord to the brain where the sensation of pain is recognized (Nadler et al., 2004). Cryotherapy has a direct effect on the nerves (Wikle & Weiner, 2003). When cold is applied, initially, it stimulates the receptors and causes uncomfortable sensation of cold, followed by stinging or burning, aching, and finally numbness (Prentice, 2009). But, ultimately, as it numbs the area, it reduces the stimulation of nociceptors and decreases nerve conductivity. Thus, less pain signals are transmitted to the brain (Meeusen et al., 1998; Wikle & Weiner, 2003).

Additionally, swelling indirectly contributes to pain (Meeusen et al., 1998; Wikle & Weiner, 2003). A decrease in pain is related to the reduction of edema (Meeusen et al., 1998).

The reduction in swelling, in turn, is related to increased range of motion. Therefore, another goal of cryotherapy is to help regain range of motion of a joint after trauma. The application of cold lowers the tissue temperature by withdrawing heat energy from the body via conduction (Bleakley, McDonough, & MacAuley, 2004; Kennet et al., 2007; Knight, 1989). It is through this decrease in tissue temperature that pain, metabolism, edema, and muscle spasm are reduced (Knight, 1989; Nadler et al., 2004; Wikle & Weiner, 2003). The use of cryotherapy is beneficial because cold causes vasoconstriction and lowers microcirculation, preventing the accumulation of local edema (Knight, 1989; Block, 2010). However, some studies, surveys, and metanalysis suggest that while ice is effective for pain reduction, when used alone it is not as valuable as when used in accordance with compression for the reduction of swelling (Markert, 2001).

Muscle spasticity can also occur following trauma. This response is triggered once pain is recognized. As the muscle motor activity and tonicity increases, it leads to reflexive muscle contractions or spasms (Nadler et al., 2004). These painful muscle spasms can further lead to tissue damage as blood flow and oxygen is decreased (hypoxia) to the injured area (Nadler et al., 2004; Ohkoshi, Ohkoshi, Nagasaki, Ono, Hashimoto, & Yamane, 1999). Cryotherapy impedes secondary tissue damage by lowering tissue temperature, slowing down the rate of tissue metabolism and subsequently, the rate at which oxygen is consumed by the tissue (Nadler et al., 2004; Ohkoshi et al., 1999). Thus, cryotherapy is a vital modality in prevention of tissue hypoxia.

Cold modalities may have different physiological effects depending on what method of application is being used (Nadler et al., 2004). Kennet et al. (2007) did a basic study comparing four common cryotherapeutic agents, crushed ice (CI), gel pack (GP), frozen peas (FP), and ice-water immersion (WI), and their cooling efficiency after twenty minutes of application at the ankle in nine healthy individuals. Applicants attended one testing session for each of the four cryotherapeutic agents. Each cryotherapeutic agent was applied to the right ankle while the left ankle served as the control. All four agents were applied for twenty minutes which is considered to be the most beneficial therapeutic time span. The baseline of skin temperature was taken prior to treatment as well as after twenty minutes of cold agent application. The results of the study showed that the application of CI produced a significantly greater reduction in skin surface temperature than GP and FP. The application of the CI, WI, FP and GP agents resulted in skin surface temperature reduction of 19.56 °C, 16.99 °C, 14.59°C, and 13.19°C, respectively. Thus, CI and WI had the greatest cooling efficiency. Of the four cryotherapy methods studied by Kennet et al. (2007), the crushed ice was shown to be most effective in lowering tissue temperature.

Furthermore, to obtain physiological and therapeutic effects from various cryotherapy methods, optimal cryotherapeutic temperatures must be reached. Studies suggest that local analgesia is accomplished when the skin surface temperature is between 10°C (50°F) and 15°C (59°F) (Shibuya, Schinke, Canales, 2007; Kennet et al., 2007; Wikle & Weiner, 2003). At 12.5°C the nerve conduction velocity is reduced by 10% (Kennet et al., 2007), and a 50% reduction in cellular metabolism is achieved in skin surface temperatures between 10°C and 11°C (Kennet et al., 2007). “Collectively, these findings define a therapeutic skin surface temperature range from 10°C and 15°C” (Kennet et al., 2007, p.344).

A study by Shibuya et al (2007) compared the efficacy and safety of three selected cryotherapy devices: Iceman Model 1100 Cold Therapy System (DonJoy Orthopedics, Vista, California), an active continuous-flow cryotherpy device with electrical pump; EBIce (EBI Medical Systems, Parsippany, New Jersey), also an active continuous-flow cryotherapy device with an electrical pump; and Ankle CryoCuff (Aircast Inc., Summit, New Jersey), a passive continuous-flow device which recirculates water using gravitational force by manually elevating the cooler above bladder. Four participants (2 men, 2 women; age 26-35) in relatively excellent overall health were selected for the study. Based on subjective and objective data gathered in their study, as well as from previous animal and clinical research, Shibuya et al (2007) concluded that the most comfortable and effective cryotherapy temperature range is between 20°C (68°F) to 30°C (86°F) for intermittent-flow cryotherapy units and 25°C (77°F) to 30°C (86°F) for continuous-flow units.

Sufficient depth of penetration of cryotherapy is necessary in order to have a physiological effect. According to Nadler et al (2004), cold treatment decreases skin surface temperature and underlying tissues to a depth of 2 to 4 cm. One study examined the effectiveness of two common types of external compressions on the magnitude of surface and intramuscular cooling during an ice bag treatment. Fourteen college students (10 women, 4 men; age 22.4±1.8 years) participated in a randomized controlled trial involving 30 minute ice bag application along with either an elastic compression bandage or Flex-i-Wrap compression and no compression treatment. The intervention involved an ice bag treatment applied to the posterior lower leg for 30 minutes and secured in place with elastic compression bandage or Flex-i-Wrap. An intramuscular thermocouple was inserted 2 cm into gastrocnemius muscle via 21-gauge sterile needle. The control group did not receive compression with ice bag treatment. The results revealed after 15 minutes of treatment the elastic compression bandage produced greater surface temperature reduction than no compression (P=.03), but no significant difference was found between elastic compression bandage and Flex-i-Wrap or Flex-i-Wrap and no compression. After 25 minutes, elastic wrap (8.03°C) produced greater intramuscular temperature reduction than Flex-i-Wrap (6.65°C) or no compression (4.63°C). At 30 minutes, the surface temperatures of the posterior leg were 14.95°C for no compression, 11.55°C for Flex-i-Wrap, and 9.49°C for elastic compression bandage (Tomchuk, Rubley, Holcomb, Guadagnoli, & Tarno, 2010). These outcomes are consistent with Kennet et al (2007) data on therapeutic surface temperature ranges. According to this study, ice bag application with elastic compression bandage is more effective in reducing intramuscular tissue temperature compared to Flex-i-Wrap. Based on these findings can conclude that the elastic compression bandage is more effective in swelling reduction. Therefore, in this study, the ice bag application with elastic compression bandage will be used.

Dykstra et al (2009), compared cooling effectiveness of ice packs made with cubed, crushed, and wetted ice on intramuscular and skin surface temperatures in twelve healthy participants (6 men, 6 women). None of the participants had preexisting inflammatory conditions or injuries to lower extremities. All ice packs were made by placing 2000 mL of either crushed or cubed ice. Wetted-ice packs were made with the same amount of cubed ice plus 300 mL of room temperature water in the bag. Intramuscular temperature was measured using 4 cm microprobe inserted into lateral gastrocnemius. Bags were place over the posterior gastrocnemius muscle without compression wrap. The results revealed that after 20 minute treatment period, wetted ice produced a lower mean intramuscular temperature (30.3°C) compared to cubed ice (31.1°C) or crushed ice (32.4°C).

Today, science has allowed us to develop more high-tech continuous cooling devices that allow manipulation of the temperature of cryotherapy, unlike with an ice bag where the temperature is at melting point. There are various types of continuous cooling therapy devices. These cooling devices use chilled water to decrease the local temperature of surrounding tissue.

The chilled water flows via tube connected from the cooling device to an extremity specific cuff which wraps around the injured area. The two basic types of cooling devices available are gravity-fed devices (passive), that requires manually circulating the water by raising and lowering the water filled container or by using a built-in hand pump (i.e. CryoCuff®, PolarCare); and, the motorized pump units (active) (i.e., Ready™ Accelerated Recovery) that both cool and circulate the chilled water. Though passive cooling devices offer some compression with elastic straps holding the cuffs in place, active cooling devices typically provide pneumatic compression in conjunction with cool water circulation. These devices are often used in post-operative orthopedic procedures and are viewed as being more convenient and effective in the treatment of edema than the standard ice bag and compression bandage

A study done by Webb, Williams, Ivory, Day, & Williamson (1998) comparing a cold compression device (CryoCuff) to no-cold compression treatment in a randomized controlled study of 40 patients who have undergone total knee replacement, examined postoperative blood loss, pain level, swelling reduction and ROM. The treatment group received a cold compression applied prior to the release of the tourniquet while the control group received a wool and crepe dressing. According to the study, no significant difference in early regain of ROM or swelling was observed between the two groups. However, Webb et al. (1998), found that the cold compression group, indeed, had less postoperative blood loss as well as better pain control. The results of this study indicated that although ice is a good analgesic, it is the compression that has the greatest effect on the swelling reduction.

Morsi (2002) studied the effects of cold compression therapy in 30 patients, all having staged bilateral total knee arthroplasty. In all cases, the first operated knee had a continuous flow cold compression device applied postoperatively and the second knee, operated upon six weeks later, had no cold or compressive treatment. Pain scores and analgesic requirements were evaluated at daily intervals for the initial six days postoperatively, whereas range of motion was evaluated weekly for six weeks. Morsi (2002) found that mean post-operative VAS (Visual Analog Scale) pain severity scores were lower with a cold compression device versus the control group (4.2 vs 6.3, P=0.001). The total use of continuous ice flow device has also shown to provide less analgesic consumption (950 vs 1400 mg, P=0.01) and less blood loss. (1214 vs 1867 mL, P=0.001). Lastly, the average range of motion of knee flexion were 68° and 54° in the experimental versus the control group, one week after surgery (P=0.01). However, no significant differences were observed at six weeks.

In a similar study by Barber et al. (1998), comparing continuous-flow cold compression devices (Orthopedic Technology, Tracy, CA, USA; Aircast Inc., Summit, NJ, USA) (17 of 51 [33%] female, mean age: 34 years) to no treatment at all (9 of 49 [18%] female, mean age: 34 years) of 100 patients following an ACL reconstruction surgery, showed that constant cold therapy for three days was effective in reducing pain, decreased consumption of drug use, and helped increase range of motion. Pain severity (VAS and Likert scales) was measured daily for one week post-operatively. The results showed the VAS pain scores were 25% higher in the control group on the first post-operative day compared to the experimental group, reaching borderline statistical significance (P=0.06). Thereafter they converged during one week of follow-up. On each post-operative day through one week, use of analgesics was always lower among patients treated with cold compression (P =0.01). A physical examination was performed at one week post-operatively. Knee flexion measurements were greater in cold compression treatment versus no treatment, with borderline significance (88°F vs 77°F, P =0.06). However, Barber et al. (1998) did not find any significant differences in knee extension and swelling across treatment groups. Similar to the previous study, the Barber et al. (1998), study focused on effects of continuous flow cold therapy on analgesic use and range of motion achieved post-surgery. One major limitation in this study is the lack of evidence showing the influence of swelling on range of motion in both groups.

Schroder and Passler (1994) evaluated 44 patients who had undergone ACL reconstruction surgery, comparing post-operative swelling, range of motion, pain, analgesic consumption and return to function in two groups. Twenty one patients (6 of 21 [29%] female, mean age: 25 years) were randomly assigned to continuous cold compression treatment with the CryoCuff device (Aircast Inc, Summit, NJ, USA), and 23 patients (5 of 23 [35%] female, mean age: 24 years) were randomly assigned to receive an ice bag three times per day for the length of their hospitalization. All patients were hospitalized for 14 days and had clinical assessment performed on days 1, 2, 3, 6, 14 and 28. Functional knee scores were also obtained after 12 weeks of follow-up. Results showed that patients who were treated with cold compression had significantly greater range of motion on all post-operative days (P=0.02 for all comparisons), compared to standard ice bag treatment group. Additionally, there was a general trend of lower average pain scores among cold compression patients at all follow-up intervals, with statistical significance (P=0.01) reached on the sixth post-operative day. The mean functional knee scores were significantly higher in patients treated with cold compression compared to controls (90 vs 82, P=0.03) after three months of follow-up. Although the CryoCuff group reported significant decrease in pain, swelling, and analgesic use, the study did not, however, report how frequently the cool water was recirculated in the device. Furthermore, in this study participants were hospitalized for 14 days, thus the setting is not related to the traditional athletic training facility which may have produced a different outcome.

Konrath, Lock, Goitz, & Scheidler (1996) evaluated 100 consecutive patients scheduled for arthroscopic ACL reconstruction randomized to one of four treatment groups: an active continuous flow unit, called Polar Care 500 pad device (Breg Inc, Vista, CA, USA), secured with an elastic wrap set at 40°F to 50°F (n =27), the same device regimen set at 70°F to 80°F (n =23), a bag of crushed ice (n =23), or no treatment (n =27). They investigated the effectiveness of four different treatment regimens on range of motion, pain medication consumption and drain output. During the study, the water in the Polar Care system and the ice packs were changed every four hours. All data in this study were collected prior to discharge. The results of Konrath et al's. (1996) study revealed no significant differences in range of motion at discharge, use of oral and intramuscular pain medicine and drain output between the groups. This study suggests that the active continuous flow cold therapy unit provides no better benefit than the ice pack when used with the same intermittent treatment regimen.

Healy, Seidman, Pfeifer, & Brown (1994) compared two different modes of cold compression in 76 patients (105 knees) undergoing primary total knee arthroplasty with respect to range of motion, swelling, wound drainage, and narcotic requirements. Fifty knees were randomly allocated to treatment with the CryoCuff device and 55 knees were treated with an ACE compression wrap and crushed ice pack. Post-operative follow-up evaluations were undertaken at three intervals: 2 to 4 days, 7 to 14 days, and 4 to 6 weeks. Both groups showed similar levels of improvement over baseline, but there were no notable or statistically significant differences between treatment groups for any outcome evaluated at any interval through six weeks of postoperative follow-up. However, the potential for meaningful comparisons of functional endpoints, as measured in this study, may have been compromised by the wide time window in which measurements were taken (e.g., day seventh evaluation could be quite different if taken on day 14). Furthermore, no data was provided on number of ice pack exchanges. However, water inside the CryoCuff was recirculated every one to four hours. Additionally, the study does not provide clear information on the type of setting the treatment was provided in (i.e., inpatient or outpatient setting) nor the duration of therapy. A notable detail about the CryoCuff device is that it is a passive continuous flow cooling system and, unlike the active continuous flow cooling system, it does not provide intermittent pneumatic compression, but rather, a static compression similar to that of an elastic compression wrap often applied in conjunction with the ice pack. Active vasopneumatic continuous-flow cold therapy devices provide intermittent compression, which is preferable to static compression as it strongly imitates the muscle contractions that our bodies use to force tissue waste and excess fluid out of the injured area and into the lymphatic system for proper drainage.

Stockle, Hoffmann, Schutz, von Fournier, Sudkamp, & Haas (1997), compared the effectiveness of three treatment modalities in reducing acute post-traumatic and post-operative swelling following foot and ankle trauma. Sixty patients, were randomized to receive either cool packs (n =20, mean age: 33.1 years), continuous cryotherapy with the Polar Care device (n =20, mean age: 31.9 years), or intermittent impulse compression with the A-V Impulse System (Novamedix Services Ltd, Andover, Hants, UK) (n =20, mean age: 36.8 years) without simultaneous cryotherapy. Patients randomized to cool pack treatment had the pack changed four times per day and fixed around the swollen area with an elastic dressing providing static compression. Patients receiving continuous cryotherapy had a flexible cool cuff wrapped around the swollen area with a continuous flow of ice water. Lastly, patients treated with impulse compression used a foot pump device that simulated weight-bearing by intermittently compressing and stretching the venae comitantes of the lateral plantar artery. With this device, an under the foot air pad inflates every 20 seconds, squeezing and flattening the plantar arch resulting in the rapid evacuation of 20 to 30 mL of blood from the plantar venous plexus. The following results were observed after 24 hours of treatment: a 47% reduction in swelling with A-V Impulse compression device, 33% with continuous cryotherapy and 17% with cool packs. After four days of post-operative treatment, the A-V Impulse compression device reduced swelling by as much as 74% compared to 70% with the continuous Polar Care cryotherapy and only 45% with cool packs. Contrary to Healy et al (1994), in Stockle et al's. (1997), study "all of these comparisons reached statistical significance in favor of either impulse compression or continuous cryotherapy over standard use of cool packs with mild static compression" (Block, 2010, p. 110). Active continuous flow cooling systems perform similarly to the A-V Impulse System in that both apply intermittent compression which has shown to have better results in treatment in edema.

In Su and Gerlinger's (2011) randomized six week study comparing the effectiveness of Game Ready device versus ice with static compression in patients with total knee arthroplasty revealed no significant difference in knee flexion and extension range of motion between the Game Ready group and the control group. Swelling at 10 cm above midline patella has shown to be less in control group than in Game Ready group both at two weeks (2.1cm vs 2.5cm) and at six weeks (0.1cm vs 1.0cm) post operation. At midline of patella, swelling was less in the Game Ready group (2.3 cm) versus control group (2.6 cm) at 2 weeks and greater than the control group (1.1cm vs 1.0 cm) at week six. At 10cm below midline of patella, the control group had less swelling than the Game Ready group (1.0cm vs 0.9) at two weeks but at week six control group had greater swelling than the Game Ready group (0.8cm vs 0.3cm).

In conclusion, some studies have shown continuous-flow cryotherapy to be effect in the reduction of edema. In addition, previous studies have shown continuous-flow cryotherapy devices to be more successful in assisting with restoration of range of motion. Other studies, on the other hand, showed no significant differences between continuous-flow cryotherapy devices and the traditional ice bag with compression. It is difficult to conclude that a bag of "crushed ice is equivalent modality to continuous-flow cold therapy" (Barbar, 2000, p.97), however, factors such as patient selection, parameters of application of cold, and patient cooperation have influence study outcomes. Most research studies of continuous-flow cold devices are in post-operative settings. This study intended to investigate the effects of continuous-flow therapy in traditional athletic training setting such as those in high schools, colleges, and universities. For this study, regular ice bag with static compression and active continuous-flow cryotherapy with intermittent compression were chosen to be investigated. Ice bag with compression has been shown to effectively cool intramuscular tissue and help reduce edema. Likewise, continuous-flow cold therapy has shown to do the same in post-operative settings. It is interesting to investigate which compression (static or intermitted) is more effective in the reduction of swelling in sports related conditions.

# CHAPTER 3

# METHODS

## Participants

Investigator decided on several south Florida colleges and secondary schools for the study. Certified Athletic Trainers from various south Florida colleges and secondary schools were contacted via phone and informed of the study. A total of 16 athletic training sites were selected. Anonymous data was gathered from eight athletic training sites that use active continuous-flow cold therapy. Anonymous data was also gathered from eight athletic training sites that use standard ice bag with compression method. The researcher had no contact with participants. Certified Athletic Trainers received complete verbal and written information on anonymous data gathering process. All data was collected at the end of the semester.

Certified Athletic Trainers at various south Florida colleges and secondary schools are actively recording measurements of swelling and range of motion on daily basis following cryotherapy treatments. As a regular standard of practice for management of acute and post-operative injuries, the Certified Athletic Trainers are providing appropriate cold therapy treatment (ice bag with compression or continuous-flow cold therapy device) and recording swelling and range of motion data prior and post treatment. These treatments and measurements are done on daily basis by Certified Athletic Trainers regardless of this study. This study only required the collection of anonymous reports from the information that was already actively being gathered by the Certified Athletic Trainers. All anonymous data from the Certified Athletic Trainers at various south Florida colleges and secondary schools were collected at the end of the semester.

Only data from subjects between 16-22 years old with acute or post-operative swelling were collected for the study. To be included in data gathering, participants must have had a minimum greater ankle or knee circumference of 3 mm and obvious signs of swelling when compared bilaterally. All subjects remained completely anonymous. Data from male and female subjects were included. A standard cold therapy application treatment was used by all Certified Athletic Trainer in the management of acute and post-operative swelling. The standard of practice for the treatment of acute and post-operative swelling advices Certified Athletic Trainers to follow the R.I.C.E. method (Rest, Ice, Compression, Elevation). Regardless of this study, this is a typical standard of treatment which is performed by all Certified Athletic Trainers to individuals who have suffered a sports related injury and present with signs of swelling. This study expected to collect 60 data reports.

Certain data were excluded from collection. Data from individuals with fractures, hypersensitivity to cold, diabetes, poor circulation or sensation, peripheral vascular disease, open wounds, and infections were excluded from gathering as these are contraindication to the use of cold therapy (Prentice, 2009). All Certified Athletic Trainers were aware of contraindication of cold therapy.

Subjects were informed that cold therapy is a normal treatment that is regularly used by athletic trainers in the management of acute sport injuries. Certified Athletic Trainers are actively recording measurements of swelling and range of motion on daily basis following cold therapy treatments. This study only required the collection of the subjects' anonymous data from the information that was already being gathered by the Certified Athletic Trainers. Any information the subjects provided was kept anonymous and no names or other identifiers were collected on any of the instruments used. Subjects were asked to simply come in to get standard treatment from their school's athletic trainer as they would have for any injury. Subjects were informed that absolutely no risks are involved in this study and in no shape or form will refusal to participate had adverse affect on their health condition. Subjects had the right to decline treatment at any time without any consequences.

**Application of Cryotherapy**

The following sections are describing the regular treatments that take place in the typical athletic training facilities. Various south Florida colleges and secondary schools are using the standard methods of cold therapy in the management of swelling. Anonymous data from eight athletic training sites that were using active continuous-flow cold therapy device (Game Ready Accelerated Recovery System) for the treatment of acute and post-operative swelling were collected. Anonymous data from another eight athletic training sites that were using the standard ice bag with elastic compression method for the treatment of acute and post-operative swelling were collected.

For the purpose of this study, only data of lower extremity swelling were considered (i.e., ankles, knees). Individuals received treatment daily, but only data of up to five consecutive treatments within first week of onset of injury were collected for this study. The same Certified Athletic Trainer that worked at a particular site was the one applying cold therapy method during each treatment. Subjects were asked not to take any anti-inflammatory medication or do at home ice treatments as this may accelerate reduction of edema and alter measurements. Certified Athletic Trainers regularly begin cold therapy treatment within 48 hours after onset of injury.

The eight sites that were using the standard practice of ice bag with elastic compression application method used the following method of application: the ice bag was placed on the treatment area (i.e. ankle or knee) ensuring it surrounded the injured site completely. The ice


**Figure 1: a) Ankle figure-eight compression wrapping technique, b) ice bag wrapped with compression bandage, c) elevation of 13-14 inches**

bag was held in place with elastic compression bandage. A compression bandage was wrapped around the injured extremity in direction from distal to proximal to the body. To wrap the bag of ice on the ankle, Certified Athletic Trainers positioned the athlete in a sitting or lying position with the ankle at a 90-degree angle. A 4 inch elastic compression bandage was used. The wrap was stretched to approximately 75% of its elongation capacity when it was being applied to allow optimal tightness (Draper and Knight, 2010). Figure 1a demonstrates the typical application of compression bandage around the ankle: (1) the athletic trainer begin to wrap starting from the area where the toes meet the body of the foot. Holding the loose end of the wrap at the side of the foot, the athletic trainer wrapped the bandage around the ball of the foot once maintaining it somewhat tight; (2) wrapping was continued slowly, circling around the arch of the foot, then pulling the wrap diagonally from bottom of the toes across the dorsal aspect of foot and circling it around the ankle. The athletic trainer then brought the wrap diagonally across the top and under the arch to form a figure-eight pattern; (3) once at the ankle bone, the athletic trainer wrapped the elastic wrap around so that the bag of ice stayed securely in place. The figure-eight pattern as continued around the ankle, moving from heel on the bottom and up toward the calf at the top of the eight; (4) the compression bandage covered the entire foot and ended several inches above ankle. Clips or tape was used to fasten the wrap in place. The athletic trainer elevated the injured extremity 13-14 inches (Figure 1b,c). The total regular treatment time after compression was applied was 20 minutes.

To wrap the bag of ice on the knee, a spiral application method was used by Certified Athletic Trainers (Figure 2a). A 6 inch elastic compression as used for this method. The starting end of the compression wrap as anchored just distal to tibial tuberosity (Figure 2b) and spiraled around the area towards the mid thigh. The ends of wrap were secured with clips or tape. The injured knee was then elevated approximately 13-14 inches (Figure 2c). Timing of the cryotherapy started as soon as the compression bandage was fixed in place. Standard treatment time was 20 minutes. The same Certified Athletic Trainer that worked at the particular site was the one applying cold therapy and elastic compression during each treatment session.

**Figure 2: a) Spiral wrapping method, b) distal tibial tuberosity, c) ice bag wrapped and elevated 13-14 inches.**

The eight athletic training sites that used the active continuous-flow cooling device (Game Ready Accelerated Recovery System), followed these steps and parameters: the Certified Athletic Trainer first filled the reservoir with ice and water. Then connected control unit to AC adapter and plugged it into a wall outlet unless it contained a portable battery pack (Figure 3). An extremity appropriate sleeve was applied (i.e., ankle or knee). The sleeve was connected to control unit via connector hose (Figure 4a, b). The sleeve provided intermittent compression as it inflated and deflated with the preset cycle. The device was turned on and appropriate parameters were selected. The water temperature was set to 45F°. The cooled water circulated via tube into the sleeve and around the entire injured area.

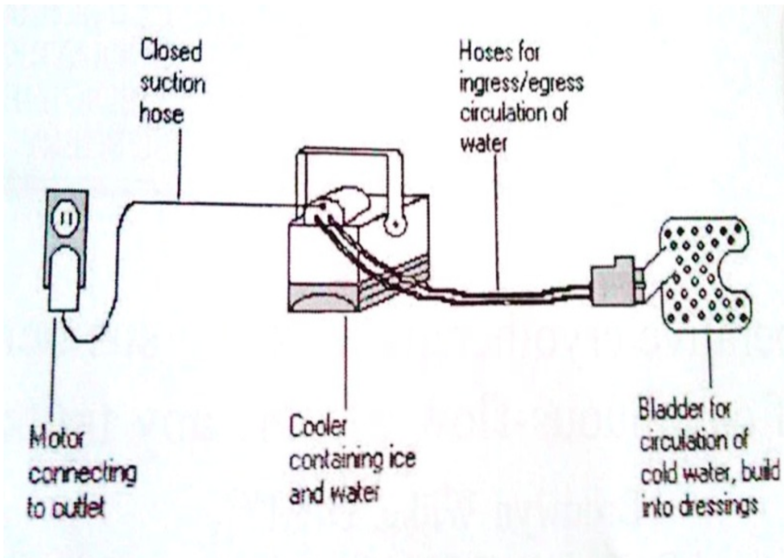

**Figure 3. General illustration of continues-flow cold therapy unit.**

The continuous-flow cooling system has four different pressure settings: No pressure, low-pressure (5 to 15 mm Hg), medium pressure (5 to 50 mm Hg), and high pressure (5 to 75 mm Hg). The Certified Athletic Trainers at various sites only used low-pressure setting which inflated the wrap as compression ramped up for 2.5 minutes and then down (deflation) for another 2.5 minutes (a compression cycle of 5 min.). Most continuous-flow cold therapy units routinely recommend around-the-clock application of treatment (Wilke & Weiner, 2003). However, such parameters are designed for post-surgical trauma. Since these athletic training sites were dealing with less traumatic swelling, the normal application time was 20 minutes. As with the other method, normal elevation of injured extremity was approximately 13-14 inches. The model of Game Ready System used for treatments do not affect results because application parameters were the same. The same Certified Athletic Trainer that works at particular site was the one applying the continuous-flow cold therapy unit during each treatment session.

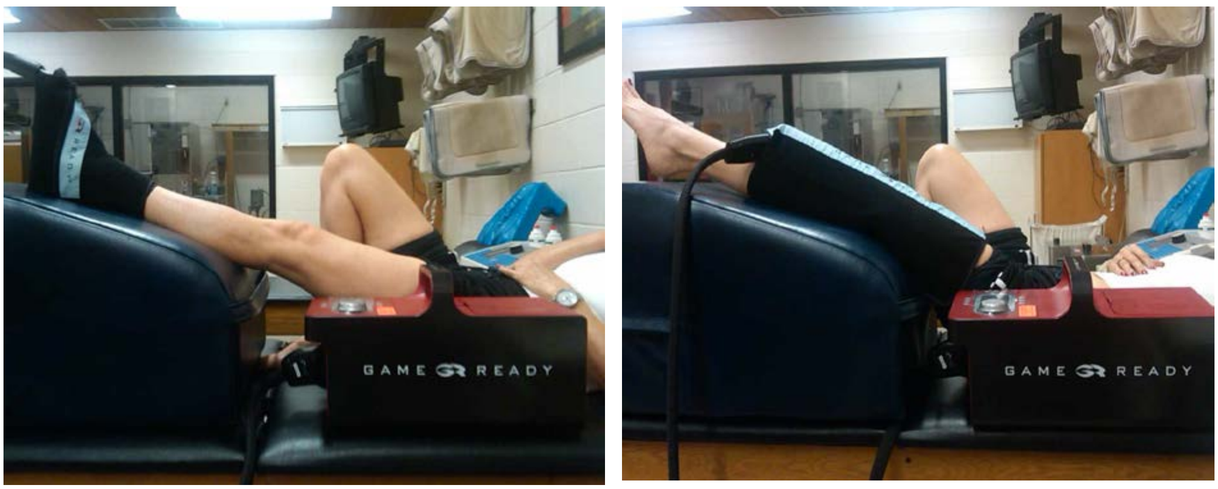


**Figure 4: Continues-flow extremity wraps and elevation; a) ankle, b) knee**

## Measurements

Range of motion and swelling measurements were performed by Certified Athletic Trainers on daily basis during each treatment before and after the application of cryotherapy. This is regularly done in order to monitor the swelling and range of motion progress. Measurements of unaffected leg, goniometric and circumference of joint were also taken just once for bilateral comparison purposes. Range of motion was measured by all Certified Athletic Trainers using a Universal Goniometer instrument. Certified Athletic Trainers used specific anatomical landmarks when performing goniometric measurements in order to get accurate readings. As a normal part of athletic training practice, both active and passive pain-free ranges of motion were measured. The same Certified Athletic Trainer that worked at particular site was the one performing measurements and recording findings during each treatment. Additionally, each measurement was recorded three times for reliability.

Edema is normally recorded using a standard measuring tape using metric system (cm). Ankle circumference is measured using Esterson's (1979) standardized figure-eight method. Knee circumference is normally measured at the joint line; proximal of superior aspect of patella; 2 inches above the superior aspect of patella; and below the joint line at tibial tuberosity. As a normal part of athletic training practice, measurements are taken before and after the application of cryotherapy. These measurements were performed by Certified Athletic Trainers on daily basis in order to monitor swelling following an injury. Later, all data was collected anonymously from Certified Athletic Trainers and used for this study. The investigator collecting the data did not partake in measurement or have any contact with participants.

Edema Measurements

*Ankle Circumference:*

The normal steps for measuring ankle swelling are as follows: subject were seated in long sit position on treatment table with their ankle and distal one third of their lower leg off the base of the table. The ankle was in a relaxed, slight plantarflexed position. With a hypoallergenic, washable marker the Certified Athletic Trainers marked several anatomical landmarks to minimize discrepancy in measurements. The anatomical landmarks included (Figure 5a,b): navicular

**Figure 5: Antatomical landmaks of the ankle a) medial view: navicular tuberosity, distal tip of medial malleolus, tibialis anterior; b) lateral view: base of the 5th metatarsal, distal tip of lateral malleolus, tibialis anterior.**

tuberosity; distal tip of medial malleolus; base of 5th metatarsal; distal tip of lateral malleolus; and, tibialis anterior tendon. Certified Athletic Trainers used the following steps for accurate measurements (Figure 6a,b): 1) beginning of the tape was placed halfway between the tibialis anterior tendon and the lateral malleolus; 2) the tape was drawn medially across the dorsal aspect of the foot, over the tarsal bones, and placed just distal to the navicular tuberosity; 3) tape was pulled across the arch of the foot and up just proximal to the base of the 5th metatarsal; 4) tape crossed the tibialis anterior tendon and was continued around the ankle joint just distal to the distal tip of the medial malleolus; 5) tape was pulled around, crossing the Achilles' tendon; 6) finally, tape was placed just distal to the distal tip of the lateral malleolus. The measurement ended at the starting point of the tape. This process was repeated 3 times on each subject, during each treatment, by the same Certified Athletic Trainer that worked at that particular site.

**Figure 6: Ankle circumference measuring technique; a) lateral view, b) medial view.**

*Knee Circumference:*

Normal steps for measuring knee swelling are as follows: subject were in supine position. With a hypoallergenic, washable marker the Certified Athletic Trainers marked several anatomical landmarks to minimize discrepancy in measurements. The landmarks include (Figure

7a): tibial tuberosity; lateral and medial joint line; superior border of patella; 2 inches proximal from the superior aspect of patella. Circumference measurements were taken at these four landmarks with a standard tape using the metric system (Figure 7b). This process was repeated 3 times on each subject, during each treatment, by the same Certified Athletic Trainer who worked at that particular site.

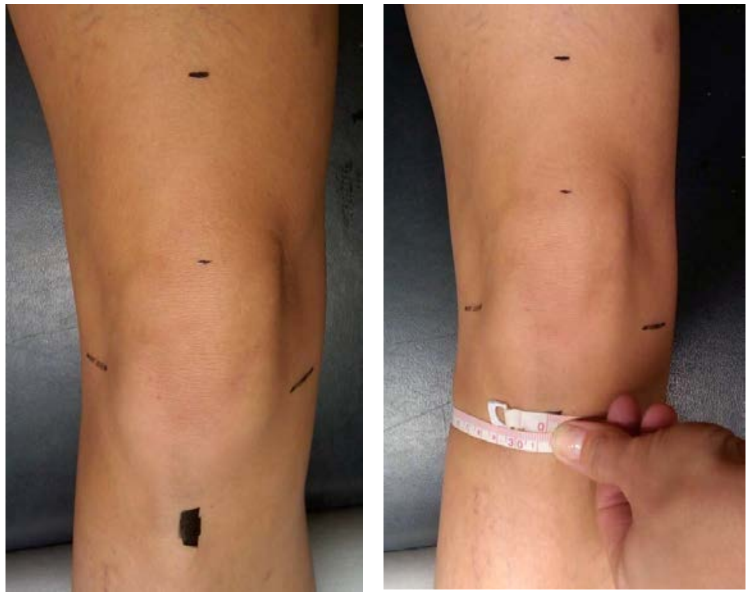

**Figure 7: The knee; a) anatomical landmarks, b) girth measurement at each landmark.**

Goniometric Measurements

The steps below describe the standard techniques for measuring ankle and knee ranges of motion. These measurements were performed by Certified Athletic Trainers in order to monitor improvements in range of motion following an injury. Anonymous data was collected on the motions below.

*Knee flexion*: (Figure 8)

Start Position: subject is supine. Hip is in anatomical position and the knee is in extension (tester makes mental note of starting degrees)

Stabilization: the pelvis is stabilized by the weight of the patient's body. The tester stabilizes the femur.

Goniometer Axis: the axis is over the lateral epicondyle of the femur.

Stationary Arm: parallel to the femur, pointing toward the greater trochanter, and stabilized by the tester.

Movable Arm: parallel to the fibula, pointing toward the lateral malleolus.

End Position: from knee extension the hip and knee are flexed actively by the subject, the degrees are recorded, then tester passively increases range of motion and records. Three measurements are recorded for both active and passive range of motion.

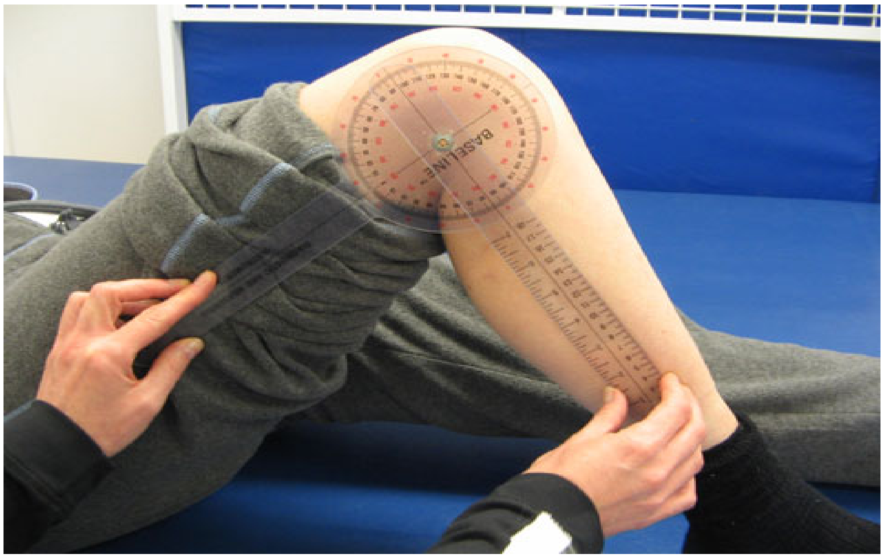


**Figure 8: Knee flexion goniometric measurement**

*Ankle Dorsiflexion/Plantarflexion*: (Figure 9a,b)

Start Position: subject is sitting with lower leg and knee hanging down from treatment table. Ankle is in relaxed and in anatomical position (0°) passively.

Stabilization: tester stabilizes the tibia and fibula distally.

Goniometer Axis: inferior to lateral malleolus.

Stationary Arm: parallel to the fibula

Movable Arm: lined up with 5$^{th}$ metatarsal

End Position: while tester stabilizes stationary arm of goniometer, the subject is asked to flex ankle towards the body. Both active and passive ROM is recorded. Then, back from starting position the subject is asked to flex ankle away from the body (plantar flex). Three measurements of active and passive range of motion are recorded.

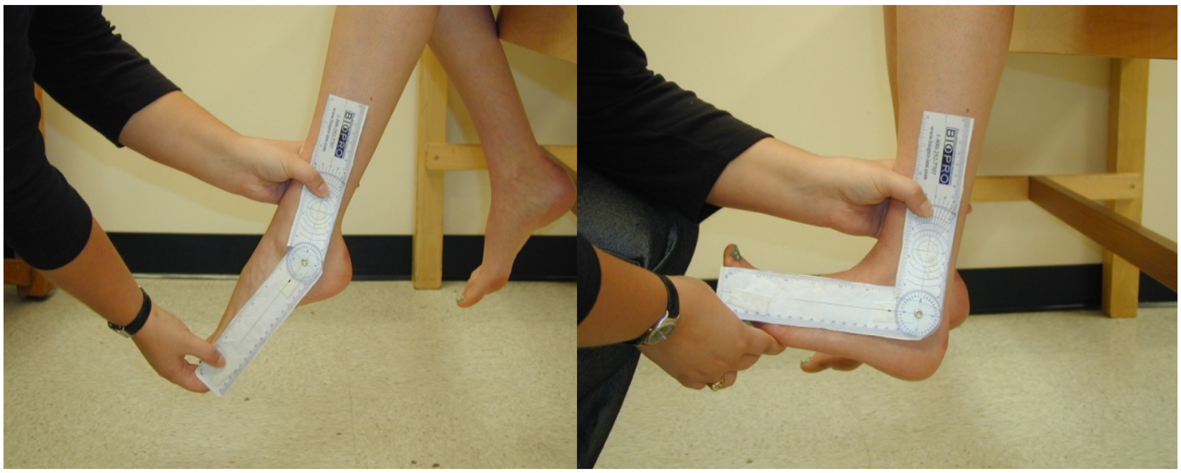

**Figure 9: Ankle goniometric measurements; a) plantarflexion, b) dorsiflexion.**

*Ankle Inversion/Eversion* (Figure 10 a,b):

Start Position: patient is sitting with legs off the table.

Stabilization: tester stabilizes the tibia and fibula distally.

Goniometer Axis: between the two malleoli with ankle in subtalor neutral position (slight plantarflexion).

Stationary Arm: parallel to the tibia.

Moveable Arm: lined up with $2^{nd}$ metatarsal.

End Position: while stabilizing the stationary arm the subject is asked to invert or evert the foot and ankle. Three measurements of active and passive range of motion are recorded.


**Figure 10: Goniometric measurements; a) ankle inversion, b) ankle eversion.**

# CHAPTER 4

# RESULTS

The results of this study compared the effectiveness of active continuous-flow cold therapy unit (Game Ready) and standard ice bag cryotherapy method on edema reduction and range of motion increase. The goal was to determine if one form of cryotherapy is ultimately better than the other. We hypothesized that both forms of cryotherapy woulb be effective in edema reduction, however, no significant differences would be present. Furthermore, we hypothesized that there would be no significant differences in the increase of ROM between the two methods of cryotherapy.

## Participants

Of the sixteen schools contacted to participate in the research study, only five had injuries to lower extremity from which data was collected. Ten total data sheets were collected and analyzed. Of those, seven used the Game Ready therapeutic modality (n=7) and three used the traditional ice bag with elastic compression bandage modality (n=3). Of the ten cases, five involved the knee joint and five involved the ankle joint. The Game Ready group had four knee and three ankle cases whereas the traditional ice bag with compression group had only one knee and two ankle cases. In addition, one knee joint case in the Game Ready group was incomplete with missing measurements of swelling at superior patella. Furthermore, one ankle joint case in the Game Ready group was also incomplete as it was missing measurements of ankle dorsi flexion and plantar flexion active range of motion. Of the ten collected data sheets, only four had completed the required five consecutive days of treatment. Therefore, the results were analyzed using only three consecutive days of treatment which is the highest number of consecutive treatment days collected.

**Statistical Analysis**

The mean swelling (SW) and mean active range of motion (AROM) differences were used to analyze data for significant differences between the two forms of cryotherapy (Table 1). The mean SW differences were calculated by subtracting day 3 of post-treatment measurements from day 1 of pre-treatment measurements. The mean AROM differences were calculated by subtracting day 1 of pre-treatment measurements from day 3 of post-treatment measurements. The percent difference in the decrease of mean swelling and an increase in mean AROM between pre-treatment day 1 and post-treatment day 3 in both groups are shown in Table 2. An SPSS software was used to run statistical analysis (Table 3 & 4). A non-parametric statistical test (Mann-Whitney) was used to determine whether one of the two cryotherapy methods had significantly different outcomes. The Mann-Whitney test was chosen because the sample size is too small to determine if variables are part of normal distribution. Results of the statistical test revealed no significant differences in the reduction of swelling between the Game Ready cryotherapy and the ice bag with static elastic compression cryotherapy ($p = .732$, $p > .05$). Results of Mann-Whitney test also revealed no significant differences between the two groups in the increase in active ROM ($p = .909$, $p > .05$). Table 5 shows the significance level of the two groups after 3 days of treatment.

**Table 1. Mean swelling difference and active ROM differences of Ice bag w. compression group (1) and Game Ready device group (2).**

| GROUP | Mean SW diff | Mean AROM diff |
|---|---|---|
| 1 | **0.3** | **3.09** |
| 1 | **1.4** | **3.34** |
| 1 | **1.06** | **9** |
| 2 | **20.63** | **5.00** |
| 2 | **1** | **7.59** |
| 2 | **1.17** | **10** |
| 2 | **1.05** | **1** |
| 2 | **-0.05** | **-8** |
| 2 | **0.65** | **12.33** |
| 2 | **0.83** | **-1.7** |

**Table 2. Percent difference in average swelling mean and Average range of motion mean FROM Pre-treatment of DAY 1 compared to Post-treatment of day 3 of two groups.**

| **GROUP** | **Avg. SW Mean Pre- Day 1** | **Avg. SW Mean Post-Day 3** | **% Difference** |
|---|---|---|---|
| *Ice Bag* | 47.6 | 13.1 | 27.5% |
| *Game Ready* | 40.7 | 37.1 | 91.2% |
| | **Avg. ROM Mean Pre- Day 1** | **Avg. ROM Mean Post- Day 3** | **% Difference** |
| *Ice Bag* | 59.4 | 60.0 | 101..0% |
| *Game Ready* | 45.9 | 49.7 | 108.3% |

**Table 3. Descriptive statistics of mean Swelling and mean active range of motion.**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Swell | 10 | -.05 | 20.63 | 2.8040 | 6.27811 |
| ROM | 10 | -8.00 | 12.33 | 4.1650 | 6.06226 |
| Valid N (listwise) | 10 | | | | |

**Table 4. Mean swelling and range of motion between ice bag with compression group and game ready group.**

| Dependent Variable | Group | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Swell | Ice | .955 | 4.000 | -8.832 | 10.742 |
| | Gameready | 4.110 | 2.494 | -1.993 | 10.213 |
| ROM | Ice | 6.108 | 3.785 | -3.153 | 15.368 |
| | Gameready | 4.219 | 2.360 | -1.556 | 9.994 |

**Table 5. Mann-Whitney test for significance between two groups.**

**Hypothesis Test Summary**

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Swell is the same across categories of Group. | Independent-Samples Mann-Whitney U Test | .732 | Retain the null hypothesis. |
| 2 | The distribution of ROM is the same across categories of Group. | Independent-Samples Mann-Whitney U Test | .909 | Retain the null hypothesis. |

Asymptotic significances are displayed. The significance level is .05.

Although no significant differences were observed, the Game Ready group has shown to have a greater decrease in mean swelling difference compared to the ice bag with compression group after three days of treatment. The Game Ready group evidenced a mean decrease in swelling of 3.61cm and the ice bag with compression group had a mean decrease of 0.92 cm. The mean increase in active ROM was found to be greater in ice bag with compression (5.14°)

compared to the Game Ready group (3.75°). Figures 11 and 12 illustrate the differences between the two cryotherapy groups.

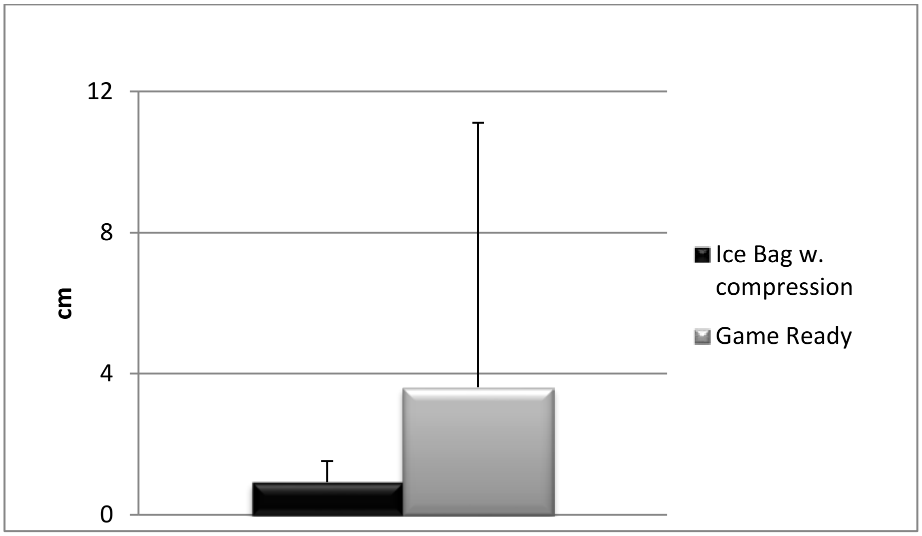


**Figure 21. Mean swelling difference between ice bag with compression group (0.92cm) and Game Ready group (3.61cm) with standard deviation.**

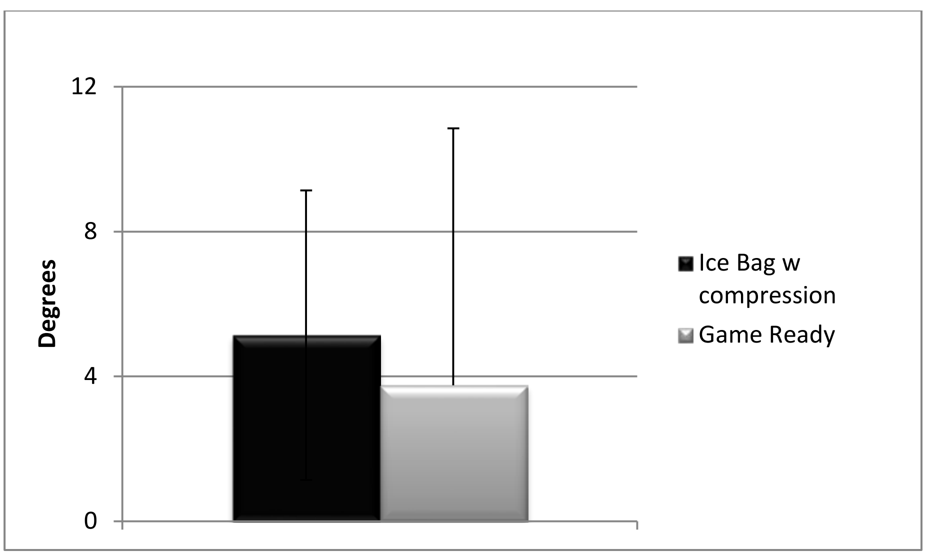


**Figure 13. Mean AROM difference between ice bag with compression group (5.14cm) and Game Ready group (3.75cm) with standard deviation.**

When looking at swelling difference at the different joints, the Game Ready group had a greater mean swelling reduction at the ankle joint (7.6 cm) compared to the knee joint (.62 cm) and compared to the ice bag with compression group, with ankle and knee being .85 cm and 1.1 cm, respectively (Table 6). Although, very little difference in swelling and AROM was observed between the two groups at the knee joint (Figures 13 and 14), the Game Ready group did have a greater mean active ROM difference at the ankle compared to the ice bag with static elastic compression with 7.5° and 3.2°, respectively.

**Table 6. Mean difference in joint swelling and joint AROM at ankle and knee between ice bag with compression and Game Ready.**

| | Group | Joint | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| Swell | Ice | Ankle | .8500 | .77782 | 2 |
| | | Knee | 1.0600 | . | 1 |
| | | Total | .9200 | .56321 | 3 |
| | Gameready | Ankle | 7.6000 | 11.28463 | 3 |
| | | Knee | .6200 | .47567 | 4 |
| | | Total | 3.6114 | 7.51538 | 7 |
| ROM | Ice | Ankle | 3.2150 | .17678 | 2 |
| | | Knee | 9.0000 | . | 1 |
| | | Total | 5.1433 | 3.34231 | 3 |
| | Gameready | Ankle | 7.5300 | 2.50054 | 3 |
| | | Knee | .9075 | 8.49754 | 4 |
| | | Total | 3.7457 | 7.12173 | 7 |

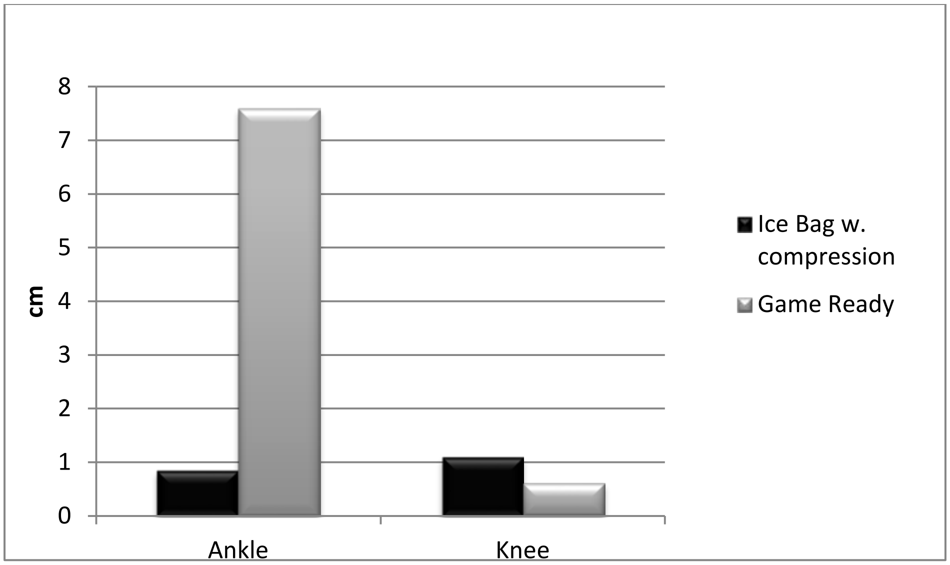


**Figure 14. Mean swelling difference between the ice bag with compression and Game Ready at ankle and knee joints.**

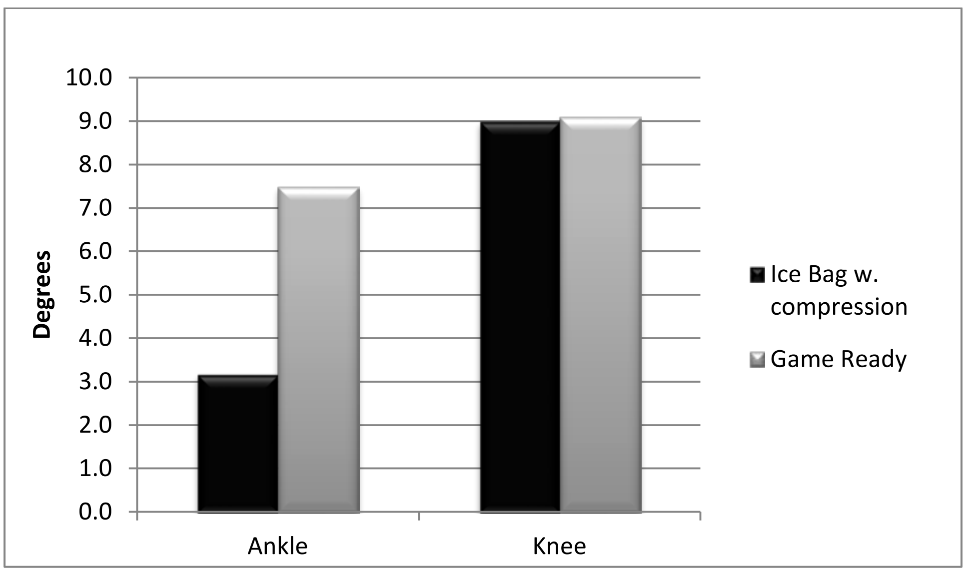


**Figure 15. Mean active ROM difference between ice bag with compression and Game Ready at ankle and knee joints.**

# CHAPTER 5

# DISCUSSION

## Purpose of the Study

The purpose of this study was to investigate the benefits of standard ice bag with compression modality versus the active continuous-flow with intermittent compression device on acute injuries in a traditional setting of athletic training. The focus of the study was on the effectiveness of the two cryotherapeutic modalities on edema reduction and range of motion increase. The goal was to determine whether one modality is potentially more beneficial than the other in reducing edema and increasing range of motion.

## Findings

This study intended to find out the therapeutic effects of the two forms of cryotherapy on lower extremity edema. When investigating the first hypothesis, that reduction of inflammation will be present using both methods of cryotherapy, results support this statement. Various cryotherapy studies support the finding in this study that cold therapy does indeed reduce swelling (Konrath et al, 1996; Barber et al, 1998; Kennet et al, 2007; Morsi, 2002; Su and Gerlinger, 2011;Webb et al, 1998). When it comes to the second hypothesis, that no significant differences in swelling will be observed between the two methods of cryotherapy, non-significant results were found. This is contrary to the findings from Stockle et al (1997) where the comparison of active continuous flow device to the standard use of cool pack with mild compression reached statistical significance in favor of active continuous flow device.

Furthermore, the last hypothesis that no significant differences in active range of motion will exist between the two groups of cryotherapy, the study revealed non- significant outcomes. Similar to the findings from Su and Gerlinger (2011), the application of cold therapy via ice bag with compression versus active continuous flow cold therapy device with intermittent compression (Game Ready) produced no significant differences in range of motion (ROM) between the two groups. Several possible reasons for no significant difference in the results are the selection of subjects (post-operative versus grade I and II acute injuries), small sample size, duration and frequency of treatment. Additionally, Konrath et al (1996) found similar outcomes with no significant differences in range of motion when they compared four cold therapy treatments involving an active continuous flow unit secured with an elastic wrap set at 40°F to 50°F, the same device regimen set at 70°F to 80°F, a bag of crushed ice and no treatment groups. Konrath et al (1996) provided treatment four times per day whereas the current study provided treatment only once per day, suggesting that the active continuous flow cold therapy unit provides no better benefit on range of motion improvement than the ice pack.

Although significant differences in edema reduction and active range of motion (AROM) were not found, the two methods of cryotherapy did show some differences. The active continuous-flow with intermittent compression device has shown to have a greater mean swelling and mean AROM differences at the ankle joint. We can speculate that the active continuous- flow device, unlike an ice bag, allows the sleeve of specific joint (i.e. ankle) to mold around the odd shape of the ankle and at the same time add some compression. With the pumping action of the intermittent compression along with cool water circulating within the sleeve, the device may have a slightly better effect on edema reduction but, not a significant effect. In fact, the use of intermittent pneumatic compression has been shown to be effective in the prevention of edema formation (Capps and Mayberry, 2009). In Su and Gerlinger's (2011) randomized six week study comparing the effectiveness of Game Ready device versus ice with static compression revealed less swelling in the Game Ready group (2.3 cm) versus control group (2.6 cm) at end of 2 weeks of treatment. One possible reason for these results is that the intermittent compression generated from an active continuous flow device optimizes lymphatic drainage. This, in turn, can accelerate recovery from soft tissue injury by improving lymphatic function through the removal of edema (Capps and Mayberry, 2009).

Another theory as to why mean swelling reduction difference was greater in the active continuous flow device is the inability to control for exact tightness of elastic bandage application. Previous studies have shown elastic compression bandage to be very effective in reducing intramuscular tissue temperature when combined with cold therapy, thus being an effective therapy for acute tissue injuries (Tomchuk et al., 2010). However, unlike with active continuous flow devices where the application of compression is pre-set at low, medium or high pressures, the pressure of elastic bandage is subjected to the individual who wraps it on and may vary between each application.

Mean active range of motion was found to be greater in the active continuous flow with intermittent compression device. Although results were not significant, this is similar to the findings by Su and Gerlinger (2011) who have found a greater increase in ROM in the Game Ready group versus standard ice bag with compression. As previous studies have shown, range of motion is directly related to the magnitude of edema formation (Barber et al, 1998; Healy et al, 1994; Schroder and Passler, 1994). The greater the edema reduction, the more gain in range of motion. Bleakley et al (2004) reported in their study that cold seemed to be more effective in limiting edema and decreasing pain in the short term when applied immediately after injury and up to 1 week post-injury. Likewise, this study has shown a decrease in edema in both groups after three days of treatment.

Although, pain level was not assessed in this study, it is a contributing factor to the improvement of ROM. Pain is often associated with swelling and swelling is often connected with limitation in range of motion. Since cold therapy reduces edema formation and acts as an analgesic, we speculate that decrease in pain level contributes to an increase in pain free active ROM. Morsi's (2002) study of continuous flow cold compression device versus no treatment applied postoperatively revealed that mean post-operative pain severity scores were lower with a cold compression device versus the control group and the average ROM of knee flexion were 68° and 54° in the experimental versus the control group, one week after surgery. In a similar study by Barber et al (1998), comparing continuous-flow cold compression devices to no treatment at all revealed that constant cold therapy for three days was effective in pain reduction, decreased consumption of drug use, and helped increase range of motion. It is evident that continuous flow cold therapy is not only effective in the management of swelling but also helps to reduce pain leading to an increase in joint active range of motion over time which could help to explain the increase in ROM in the test group of our current study.

At the knee joint, however, no major differences were observed in swelling reduction or AROM. These findings agree with that of Su and Gerlinger (2011), who, after two weeks of treatment in patients post total knee arthroplasty, have found no major difference in swelling between the two groups. We may speculate the following factors contributing to the outcomes: the knee is surrounded by numerous soft tissue (unlike the ankle which is predominately bony extremity) through which cryotherapy can penetrate about 2cm deep. The swelling typically accumulating within the joint line of the knee may be too deep for cryotherapy to have therapeutic effect. In addition, accumulated edema in the knee tends to distribute towards the lower leg and ankle with gravitational pull. Another factor to consider is the fact that the knee joint exhibits a greater normal range of motion than the ankle. Therefore, the difference in ROM may not be as limited with edema in the knee joint as it would in the ankle joint.

**Limitations**

This study was limited by several factors. First, the sample size was very small, thus not allowing for definite statistical data. Second, a variation in tightness of elastic compression application exists among individuals and between each treatment. Lastly, due to the difficulty of collecting treatment data for five consecutive days, this study was limited to only three days of consecutive data collection.

**Conclusion**

The results of this study show that both forms of cryotherapeutic modalities are effective forms of therapy for acute soft-tissue injuries. Although significant differences in swelling and range of motion between the two treatment groups were not found, further inspection focusing on specific joints revealed subtle difference. The results indicate that active continuous-flow devices with intermittent compression may provide accelerated reduction of edema and increase in range of motion shortly after initial injury.

Further research is needed to investigate significant differences between the two cryotherapeutic modalities. The traditional parameters of active continuous flow devices and ice bag with compression are typically similar in duration and on/off time for acute injuries. However, future studies should focus on whether altering these parameters may produce significant differences between the two modalities.

**Suggestions for Future Studies**

There is limited number of studies on active continuous- flow cold therapy units with intermittent compression, therefore, much more research is needed in this area. Future studies should focus on comparing active continuous-flow devices to other forms of cryotherapy such as crushed ice, cold gel packs, cold whirlpool, and standard ice bag. To increase reliability of data, a single examiner should perform all cryotherapy applications and measurements. In addition, a larger sample size is necessary to produce reliable results.

In this study, we used figure eight method to measure ankle edema. Volumetry is another method of measuring ankle edema which involves immersing the ankle in a water-filled voumeter and measuring the amount of water that is displaced. Other more sophisticated methods include magnetic resonance imaging (MRI) or CT scan.

Furthermore, this study used a standard one size sleeve for the ankle or knee that was connected to the active continuous-flow cold therapy unit. We know that not all individuals have the same size extremities; a football player is more likely to have a larger ankle or knee than let say a female volleyball player. Therefore, having an appropriate size that best fits the body part may be more beneficial in reducing edema and producing more accurate results. Lastly, this study design involved five consecutive days of data collection with no further follow up. One suggestion for future research is to conduct a follow up study two weeks or so after completion of treatment to determine whether the treatment was indeed effective.

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# APPENDICES

# Barry University

## Cover Letter

Dear Research Participant:

Your participation in a research project is requested. The title of the study is A COMPARISON OF TWO FORMS OF CRYOTHERAPY ON POST-INJURY EDEMA AND RANGE OF MOTION IN THE ANKLE AND KNEE. The research is being conducted by JUSTYNA KREMPIN, a graduate student in the Sport & Exercise Sciences department at Barry University, and is seeking information that will be useful in the field of Athletic Training. The aims of the research are to examine two forms of cryotherapy (active continuous-flow cold therapy versus standard ice bag with compression) and their effectiveness on edema reduction and range of motion. Certified Athletic Trainers are actively recording measurements of swelling and range of motion on daily basis following cold therapy treatments. This study will require the collection of anonymous data that has been previously gathered by the Certified Athletic Trainers regardless of this study. This study does not involve the treatment of injury; rather it only involves accessing your anonymous data that has been collected by Certified Athletic Trainer. We anticipate collecting 60 anonymous data reports.

You are considered as a participant in this study only in a sense that your anonymous data will be reviewed by me. Certified Athletic Trainer may provide to me your treatment information, but any information provided will be kept completely anonymous. In other words, your name or identification will not be included with the data.

If you decide to participate in this research, any of your treatment information data previously collected by your Certified Athletic Trainer may become available to me for the purpose of this study. Your participation to be part of the research study is strictly voluntary. At any time, you may decline me from accessing your information without any consequences. There are absolutely no risks involved in this study and there are no direct benefits to you.

As a research participant, information you provide will be kept anonymous, that is, no names or other identifiers will be collected on any of the instruments used. Data will be kept in a locked file in the researcher's office. All data will be destroyed after five years.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me, Justyna Krempin, at (305) 731-3553, my supervisor, Dr. Sue Shapiro, at (305) 962-6788, or the Institutional Review Board point of contact, Barbara Cook, at (305) 899-3020.

Thank you for your participation.

Sincerely,

*Justyna Krempin, ATC/LAT*

DATA COLLECTION SHEET

**KNEE**

Age:___ Gender: M/F

**Unaffected Knee Measurements**

ROM Knee Flx:
1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______
Knee Girth:
Tibial Tub: ______cm ______ cm _______cm
Joint Line: _______cm ______ cm _______cm
2” prox. Pat: ______cm ______ cm _______cm
Sup. Patella: ______cm ______ cm _______cm

**Affected Knee Measurements**

Treatment #1 Date:__________
ROM Knee Flx:
Pre- A:______ P:______ 2) A:______ P:______ 3) A:______ P:______
**Post-** A:______ P:______ 2) A:______ P:______ 3) A:______ P:______
Knee Girth:
Pre- Tibial Tub: ______cm ______ cm _______cm
**Post-** Tibial Tub: ______cm ______ cm _______cm
Pre- Joint Line: _______cm ______ cm _______cm
**Post-** Joint Line: _______cm ______ cm _______cm
Pre- 2” prox. Pat: ______cm ______ cm _______cm
**Post-** 2” prox. Pat: ______cm ______ cm _______cm
Pre- Sup. Patella: ______cm ______ cm _______cm
**Post-** Sup. Patella: ______cm ______ cm _______cm

Treatment #2 Date:__________
ROM Knee Flx:
Pre- A:______ P:______ 2) A:______ P:______ 3) A:______ P:______
**Post-** A:______ P:______ 2) A:______ P:______ 3) A:______ P:______
Knee Girth:
Pre- Tibial Tub: ______cm ______ cm _______cm
**Post-** Tibial Tub: ______cm ______ cm _______cm
Pre- Joint Line: _______cm ______ cm _______cm
**Post-** Joint Line: _______cm ______ cm _______cm
Pre- 2” prox. Pat: ______cm ______ cm _______cm
**Post-** 2” prox. Pat: ______cm ______ cm _______cm
Pre- Sup. Patella: ______cm ______ cm _______cm
**Post-** Sup. Patella: ______cm ______ cm _______cm

Treatment #3 Date:___________
ROM Knee Flx:
Pre- A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Knee Girth:
Pre- Tibial Tub: _______cm _______ cm ________cm
**Post-** Tibial Tub: _______cm _______ cm ________cm
Pre- Joint Line: ________cm _______ cm ________cm
**Post-** Joint Line: ________cm _______ cm ________cm
Pre- 2” prox. Pat: _______cm _______ cm ________cm
**Post-** 2” prox. Pat: _______cm _______ cm ________cm
Pre- Sup. Patella: _______cm _______ cm ________cm
**Post-** Sup. Patella: _______cm _______ cm ________cm

Treatment #4 Date:___________
ROM Knee Flx:
Pre- A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Knee Girth:
Pre- Tibial Tub: _______cm _______ cm ________cm
**Post-** Tibial Tub: _______cm _______ cm ________cm
Pre- Joint Line: ________cm _______ cm ________cm
**Post-** Joint Line: ________cm _______ cm ________cm
Pre- 2” prox. Pat: _______cm _______ cm ________cm
**Post-** 2” prox. Pat: _______cm _______ cm ________cm
Pre- Sup. Patella: _______cm _______ cm ________cm
**Post-** Sup. Patella: _______cm _______ cm ________cm

Treatment #5 Date:___________
ROM Knee Flx:
Pre- A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Knee Girth:
Pre- Tibial Tub: _______cm _______ cm ________cm
**Post-** Tibial Tub: _______cm _______ cm ________cm
Pre- Joint Line: ________cm _______ cm ________cm
**Post-** Joint Line: ________cm _______ cm ________cm
Pre- 2” prox. Pat: _______cm _______ cm ________cm
**Post-** 2” prox. Pat: _______cm _______ cm ________cm
Pre- Sup. Patella: _______cm _______ cm ________cm
**Post-** Sup. Patella: _______cm _______ cm ________cm

DATA COLLECTION SHEET

**ANKLE**

Age:___ Gender: M/F

**Unaffected Ankle Measurements**

ROM

Ankle Drsflx: 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Plntrflx: 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Inversion: 1)A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Eversion: 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Girth: 1) ______ cm 2)______ cm 3)______ cm

**Affected Ankle Measurements**

Treatment #1 Date:__________

ROM

Ankle Drsflx: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Plntrflx: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:_____

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Inversion: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Eversion: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Girth:

Pre- 1) ______ cm 2)______ cm 3)______ cm

**Post-** 1) ______ cm 2)______ cm 3)______ cm

Treatment #2 Date:__________

ROM

Ankle Drsflx: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Plntrflx: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:_____

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Inversion: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Eversion: Pre- 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

**Post-** 1) A:______ P:______ 2) A:______ P:______ 3) A:______ P:______

Ankle Girth:

Pre- 1) ______ cm 2)______ cm 3)______ cm

**Post-** 1) ______ cm 2)______ cm 3)______ cm

Treatment #3  Date:___________
ROM
Ankle Drsflx: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Plntrflx: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Inversion: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Eversion: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Girth:
Pre- 1) _______ cm 2)_______ cm 3)_______ cm
**Post-** 1) _______ cm 2)_______ cm 3)_______ cm

Treatment #4  Date:___________
ROM
Ankle Drsflx: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Plntrflx: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Inversion: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Eversion: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Girth:
Pre- 1) _______ cm 2)_______ cm 3)_______ cm
**Post-** 1) _______ cm 2)_______ cm 3)_______ cm

Treatment #5  Date:___________
ROM
Ankle Drsflx: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Plntrflx: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Inversion: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Eversion: Pre- 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
**Post-** 1) A:_______ P:_______ 2) A:_______ P:_______ 3) A:_______ P:_______
Ankle Girth:
Pre- 1) _______ cm 2)_______ cm 3)_______ cm
**Post-** 1) _______ cm 2)_______ cm 3)_______ cm

MEAN SWELLING & ROM DIFFERENCE CALCUATIONS
1=Ice Bag, 2= Game Ready

| Grp | Extrmty | Pre treatment Day 1 Sw (cm) | Post treatment Day 3 Sw (cm) | Mean SW diff | | Pre treatment Day 1 ROM | Post treatment Day 3 ROM | Pre/ Post | *AROM* |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ankle | 50 | 49.7 | **0.3** | | 20 | 32.67 | 12.67 | *DF* |
| | | | | | | 51.67 | 50.67 | -1 | *PF* |
| | | | | | | 23.33 | 26.67 | 3.34 | *IN* |
| | | | | | | 24.67 | 22 | -2.67 | *EV* |
| | | | | 0.03 | mean | | | **3.09** | |
| 1 | ankle | 54.23 | 52.83 | 1.4 | | 24.33 | 21.67 | -2.66 | *DF* |
| | | | | | | 29.67 | 39.33 | 9.66 | *PF* |
| | | | | | | 37.33 | 35 | -2.33 | *IN* |
| | | | | | | 5 | 13.67 | 8.67 | *EV* |
| | | | | **1.4** | mean | | | **3.34** | |
| 1 | knee | 34.7 | 32.1 | 2.6 | *Tib Tub* | 110.67 | 119.67 | **9** | *Knee Flx* |
| | | 38 | 37.57 | 0.43 | *Jt Line* | | | | |
| | | 44 | 44.03 | -0.03 | *2" Pat* | | | | |
| | | 38 | 36.77 | 1.23 | *Sup Pat* | | | | |
| | | | | **1.06** | | | | **9** | |
| 2 | ankle | 58.5 | 37.87 | 20.63 | | -3 | 6 | 9 | *DF* |
| | | | | | | 20.67 | 35.33 | 14.66 | *PF* |
| | | | | | | 20 | 14.33 | -5.67 | *IN* |
| | | | | | | 4 | 6 | 2 | *EV* |
| | | | | **20.63** | | | | **5.00** | |
| 2 | ankle | 49 | 48 | 1 | | 6 | 9 | 3 | *DF* |
| | | | | | | 27 | 27 | 0 | *PF* |
| | | | | | | 6 | 6.67 | 0.67 | *IN* |
| | | | | | | 7 | 33.67 | 26.67 | *EV* |
| | | | | **1** | | | | **7.59** | |
| 2 | ankle | 28.17 | 27 | 1.17 | | | | | *DF* |
| | | | | | | | | | *PF* |
| | | | | | | 18.67 | 29 | 10.33 | *IN* |
| | | | | | | 1 | 10.67 | 9.67 | *EV* |
| | | | | **1.17** | | | | **10** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | knee | 35.07 | 35 | 0.07 | *Tib Tub* | 69 | 70 | 1 | *Knee Flx* |
| | | 38.33 | 36.5 | 1.83 | *Jt Line* | | | | |
| | | 39.25 | 38 | 1.25 | *2" Pat* | | | | |
| | | | | | *Sup Pat* | | | | |
| | | | | **1.05** | | | | **1** | |
| 2 | knee | 36 | 36 | 0 | *Tib Tub* | 53 | 45 | -8 | *Knee Flx* |
| | | 38 | 37 | 1 | *Jt Line* | | | | |
| | | 44 | 45.7 | -1.7 | *2" Pat* | | | | |
| | | 40 | 39.5 | 0.5 | *Sup Pat* | | | | |
| | | | | **-0.05** | | | | **-8** | |
| 2 | knee | 31.33 | 31.37 | -0.04 | *Tib Tub* | 115 | 127.33 | 12.33 | *Knee Flx* |
| | | 35.83 | 34.87 | 0.96 | *Jt Line* | | | | |
| | | 37.77 | 36.2 | 1.57 | *2" Pat* | | | | |
| | | 35.97 | 35.87 | 0.1 | *Sup Pat* | | | | |
| | | | | **0.65** | | | | **12.33** | |
| 2 | knee | 34.2 | 33.4 | 0.8 | *Tib Tub* | 52.7 | 51 | -1.7 | *Knee Flx* |
| | | 39.2 | 37.9 | 1.3 | *Jt Line* | | | | |
| | | 36.5 | 37.57 | -1.07 | *2" Pat* | | | | |
| | | 38.57 | 36.3 | 2.27 | *Sup Pat* | | | | |
| | | | | **0.83** | | | | **-1.7** | |