A COMPARISON OF CRYOPRESS AND CRYO/CUFF EFFECTS ON ANKLE EDEMA AND PAIN

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This thesis entitled

A COMPARISON OF CRYOPRESS AND CRYO/CUFF EFFECTS ON
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BY

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has been approved for

the School of Recreation and Sport Sciences
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The purpose of this study was to compare the effects of cryopress and cryo/cuff treatments on ankle edema and pain during and after three consecutive days of treatment in Division I varsity athletes. Sixteen male and female athletes, between the ages of 18-22, volunteered for this study and were randomly assigned to either cryopress (CP) or cryo/cuff (CC) group. Volumetric and figure 8 techniques were used to measure edema. A Visual Analog Scale was used for pain measurements. A 2x3 (group x day) Factorial ANOVA was performed on group data for each variable and the alpha level was set at 0.05 ($p < .05$). Results indicated a significant group x day interaction for figure 8 measurements ($F_{2,28} = 4.72, p = .02$) and day main effect for pain levels ($F_{2,28} = 23.02, p = .00$) but no significant results for volumetric measurements ($F_{2,28} = 2.27, p = .83$).
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**Chapter 1**

*Introduction*

Ankle injuries are the most common joint injuries in athletics and account for 10-30% of all athletic time-lost injuries (Lynch, 2002; Payne, Berg, & Latin, 1997; Starkey & Ryan, 1996). Injury to the ankle occurs because the ankle is often placed in an abnormal position putting extensive forces on the ligaments, muscles, and capsule that provide stability to the ankle joint (Burks & Morgan, 1994; Hertel, 2002; Loveridge, 2002; Lynch; Starkey & Ryan).

When trauma occurs to soft tissue, such as the ligaments surrounding the ankle joint, the body’s response is to release chemicals (histamine, leucotaxin, necrosin) which causes swelling to occur (Houglum, 1992; Merrick, 2002; Starkey, 1993). Swelling that occurs is due to the body’s primary and secondary response to the trauma. The primary response, which is irreversible, causes tissue damage due to a traumatic injurious force. The secondary response is cell death due to lack of oxygen in the injured area (Houglum; Merrick; Starkey). As a result of the primary and secondary responses, inflammation, hemorrhage, and edema occur. Therefore, the purpose of cold treatment is to prevent further damage to the affected tissue and limit the amount of secondary response (Starkey). Secondary response is limited by cold therapy by decreasing cell metabolism and secondary tissue hypoxia (Merrick). There are many techniques to decrease swelling, such as ice bags, cryo/cuff, intermittent compression, ice cups, and ice packs. All these techniques are classified as forms of cryotherapy to treat acute trauma (Arnheim & Prentice, 2000; Coté, Prentice, Hooker, & Shields, 1988; Mac Auley, 2001a, 2001b;
Cryotherapy is used to remove heat from the body causing vasoconstriction, decreased metabolic rate, reduced inflammation, and pain relief (Hubbard, Aronson, & Denegar, 2004; Ingersoll, 1992; Merrick, 2002; Merrick, Knight, Ingersoll, & Potteiger, 1993; Prentice, 1999; Starkey, 1993). The function of ice application during immediate treatment is to slow cell metabolism, thereby reducing oxygen consumption in the injured area to limit tissue damage by preventing secondary hypoxic cell death.

Theories differ among researchers regarding what form of cold application reduces tissue temperature and is effective in preventing further edema. Questions have also arisen regarding what type of cold application is most effective to treat acute and postoperative traumas. Research has been conducted on different cold modalities effects on tissue-cooling efficiency (Johnson, Moore, Moore, & Oliver, 1979; Jutte, Merrick, Ingersoll, & Edwards, 2001; Konrath & Lock, 1996; Myrer, Measom, & Fellingham, 1997; Otte, Merrick, Ingersoll, & Cordova, 2002), cryotherapy and intermittent compression (Airaksinen, Partanen, Kolari, & Soimakallio, 1991; Mora, Zalavras, Wang & Thordarson, 2002; Stockle et al., 1997), cryotherapy and compression (Healy, Seidman, Bernard, & Brown, 1994; Merrick et al., 1993; Levy & Marmar, 1993; Merrick, Jutte, & Smith, 2003; Sloan, Giddings & Hain, 1988; Smith, Stevens, Taylor, & Tibbey, 2002), and comparing different cryotherapy techniques (Dervin, Taylor, & Keene, 1998; Edwards, Rimmer, & Keene, 1996; Gibbons, Solan, Ricketts, & Patterson, 2001). However, the body of professional literature does not contain research regarding the effects of the cryopress on edema and pain levels in the ankle joint.
The cryopress, a sequential cryocompression unit used for treating edema and post-surgical, acute, and chronic injuries, has received limited attention in the literature. This study was designed to determine if cold therapy with intermittent sequential compression affects the amount of edema and pain in the ankle joint after 3 consecutive days of treatment. Specifically, the present research was designed to study the effects of the cryopress on Ohio University (OU) NCAA Division I varsity athletes with ankle pathologies after 3 consecutive days of cryopress treatment compared to cryo/cuff treatments. Therefore, the purpose of this study was to compare the effects of the cryopress and cryo/cuff treatments on ankle edema and pain after 3 consecutive days of treatment in Division I varsity athletes.

**Statement of the Problem**

Scientific research is lacking concerning the cryopress and its effects on edema and pain in the ankle joint. Specifically, this study was designed to evaluate the following questions:

1. Is there a difference in ankle joint edema after 3 consecutive treatments of the cryopress compared to the cryo/cuff?

2. Is there a decrease in ankle joint edema between pre and post measurements on days 1, 2, and 3 of the cryopress compared to the cryo/cuff?

3. Is there a difference in athlete’s pain levels after 3 consecutive treatments of the cryopress compared to the cryo/cuff?

4. Is there a decrease in pain levels in the ankle joint between pre and post measurements on days 1, 2, and 3 of the cryopress compared to the cryo/cuff?
Purpose of the Study

The purpose of this study was to compare the effects of the cryopress and cryo/cuff treatments on ankle edema and pain during and after 3 consecutive days of treatment in Division I varsity athletes. This study was conducted to observe how a combination of intermittent sequential compression and cold therapy treatments prevents further edema, decreases current edema, and pain in the ankle compared to a common technique, the cryo/cuff. Information from this study will provide certified athletic trainers, athletes, coaches, and other medical professionals with evidence of the possible benefits of using a cryopress compared to a cryo/cuff to treat edema and pain for inversion ankle injuries.

Delimitations

The results of this study were established by the following delimitations:

1. The study evaluated ankle edema.
2. The study evaluated self reported pain levels.
3. The study was performed on 16 male and female collegiate NCAA Division I athletes.
4. All subjects in the study had injured his or her ankle within the past 24 hours.
5. All subjects in the study had been diagnosed with a grade 1 inversion ankle sprain by the team physician within a week of the injury.
6. All subjects in the study were full weight bearing on his or her injured ankle.
7. All subjects were tested between 11:00 a.m. to 3:00 p.m.
8. Subjects were placed in one of two groups as follows: Cryopress (CP) and Cryo/cuff (CC).
9. There was no control group.

10. A certified athletic trainer initially evaluated the ankle sprain.

**Limitations**

The results of this study were interpreted after careful consideration of the following limitations:

1. Compliance of the subjects.
2. Athletes participated in a variety of different sports.
3. Some athletes had previous ankle injuries.
4. Athletes have different pain tolerances.
5. The magnitude of the injury may affect the healing process.

**Assumptions**

1. The test instruments were calibrated.
2. Zero point is similar for all participants on the Visual Analog Scale (VAS).
3. All athletes complied with instructions honestly and correctly.
4. There was no other injury to the ankle beyond the sprain.
5. All measurements were taken accurately.

**Null Hypothesis**

\[ H_{01} \]: There will be no significant difference in edema reduction in the ankle joint in athletes receiving 3 consecutive days of cryopress treatment compared to athletes receiving 3 consecutive days of cryo/cuff treatment.

\[ H_{02} \]: There will be no significant difference in pain levels in athletes receiving 3 consecutive days of cryopress treatment compared to athletes receiving 3 consecutive days of cryo/cuff treatment.
H₀₃: There will be no significant difference in edema reduction in the ankle joint between pre and post measurements on days 1, 2, and 3 in athletes receiving cryopress treatment compared to athletes receiving cryo/cuff treatment.

H₀₄: There will be no significant difference in pain levels between pre and post measurements on days 1, 2, and 3 in athletes receiving cryopress treatment compared to athletes receiving cryo/cuff treatment.

Definition of Terms

For the purpose of this study, the following terms were defined as:

1. Ankle: The joint between the leg and foot; the articulation of the tibia, fibula, and talus (Thomas, 1999).

2. Athlete: An individual who participates in a Division I NCAA collegiate level sport in and out of season.

3. Conduction: Heat loss or gain through direct contact (Prentice, 1999).

4. Controlled Cold Therapy Unit: Combine static external compression and cold application while contouring the specific body areas (Starkey, 1993).

5. Contusion: An injury in which the skin is not broken; a bruise (Thomas, 1999).

6. Cryopress: A device used to treat the lower extremity for swelling by applying sequential intermittent compression and cryotherapy.

7. Cryotherapy: To describe the application of cold modalities that has a temperature range between 0º C and 18º C (Starkey, 1993).

8. Certified Athletic Trainer: An individual who successfully passed the National Athletic Trainers Association Board of Certification exam and is qualified in the
prevention, evaluation, initial care, and rehabilitation of athletic injuries (Arnheim & Prentice, 2000).

9. *Dislocation*: The displacement of any part, especially the temporary displacement of a bone from its normal position in a joint (Thomas, 1999).

10. *Edema*: A local or generalized condition in which the body tissues contain an excessive amount of tissue fluid (Thomas, 1999).

11. *Figure 8*: A method of determining ankle girth measurements for edema with a flexible measuring tape. The procedure is as follows: Start the tape measure midway between the tibialis anterior tendon and the lateral malleolus; move the tape medially across instep just distal to the navicular tuberosity; pull the tape across the arch of the foot just proximal to the base of the fifth metatarsal (styloid process); across the tibialis anterior tendon and around the ankle joint distal to the tip of the medial malleolus; across the achilles tendon; distal to the lateral malleolus; returning to the starting position (Magee, 2002).


13. *Hemorrhage*: Abnormal internal or external discharge of blood (Thomas, 1999).

14. *Ice Bags*: A plastic bag that is filled with flaked or cubed ice (Starkey, 1993).

15. *Ice Cups*: A cup filled with frozen water that is used for therapeutic cold massage.

16. *Injury*: Trauma or damage to the ankle’s bones, ligaments, tendons, or muscles that causes swelling in that specific area.
17. *Instant Cold Packs*: Contain two chemicals separated from each other by a plastic barrier; when seal is ruptured chemicals mix and react producing a cold temperature (Starkey, 1993).

18. *Intermittent compression*: Intervals of a minute and a half of compression followed by 30 seconds of no compression for a total of 2 minute cycles. This cycle is repeated for the allotted treatment time.

19. *Macrophage*: A cell having the ability to devour particles; a phagocyte (Starkey, 1993).

20. *Pain*: Sensory or emotional experience associated with actual or perceived tissue damage (Thomas, 1999).

21. *Reusable Cold Packs*: Contain a gel consisting of silica, water, and a form of antifreeze sealed in a plastic pouch that is stored in a cooling unit (Starkey, 1993).

22. *Phagocytosis*: The ingestion and digestion of bacteria and particles by phagocytes (Starkey, 1993).

23. *Sprain*: Trauma to a joint that causes pain and disability depending upon degree of injury to ligaments (Thomas, 1999).

24. *Strain*: Trauma to the muscle or the musculotendinous unit from violent contraction or excessive forcible stretch (Thomas, 1999).

25. *Swelling*: An increase in tissue fluid (equal to or greater than 2 cm) due to trauma within 24 hours of the injury compared to the non-injured limb.

volumes caused by swelling due to hemorrhage, edema, or inflammation (Arnheim & Prentice, 2000).
Chapter 2

Review of Literature

Ankle

Anatomy. Ankle injuries are the most common joint injuries in athletics and account for 10-30% of all athletic time-lost injuries (Lynch, 2002; Payne, et al., 1997; Starkey & Ryan, 1996). Injury to the ankle occurs because the ankle is often placed in an abnormal position placing extensive forces on the ligaments, muscles, and capsule that provide stability to the ankle joint (Hertel, 2002; Loveridge, 2002; Starkey & Ryan).

The bones that make up the ankle joint (talocrural joint) are the distal ends of the tibia, and fibula, and the talus bone (Arnheim & Prentice, 2000; Burks & Morgan, 1994; Hertel, 2002; Loudon & Bell, 1996; Lynch, 2002; Norkus & Floyd, 2001). Inert structures that support the ankle consist of the articular capsule (encases the ankle), three lateral ligaments, two ligaments that connect the tibia to the fibula, and three medial ligaments (Burks & Morgan; Hertel; Loudon & Bell; Lynch; Norkus & Floyd; Starkey & Ryan, 1996).

The three lateral ligaments of the ankle that resist ankle inversion are the anterior talofibular (ATF), calcaneofibular (CF), and posterior talofibular (PTF) ligaments. These ligaments extend from the distal end of the fibula (lateral malleolus) to the talus and calcaneous. These inert structures can be damaged when the ankle is placed in excessive inversion with plantarflexion or dorsiflexion (Burks & Morgan, 1994; Hertel, 2002; Lynch, 2002; Norkus & Floyd, 2001; Prentice & Voight, 2001; Starkey & Ryan, 1996).

The anterior and posterior tibiofibular ligaments connect the distal ends of the tibia and fibula and form the distal portion of the interosseous membrane. These
ligaments are injured most often with dorsiflexion and external rotation of the ankle joint. This motion causes the talus to be pushed between the tibia and fibula, spreading the two structures apart and placing a strain on the tibiofibular ligaments (Burks & Morgan, 1994; Hertel, 2002; Loudon & Bell, 1996; Lynch, 2002; Norkus & Floyd, 2001; Prentice & Voight, 2001; Starkey & Ryan, 1996).

On the medial side of the ankle, the deltoid ligaments are present. The deltoid ligaments are thick ligaments that provide resistance to ankle eversion. The ligaments appear as one thick ligament but really consist of three separate ligaments that overlap one another. The deltoid ligament is divided into the anterior tibiotalar (ATT), tibiocalcaneal (TC), and posterior tibiotalar (PTT) ligaments that extend from the distal end of the tibia (medial malleolus) to the talus and calcaneous (Burks & Morgan, 1994; Hertel, 2002; Loudon & Bell, 1996; Lynch, 2002; Norkus & Floyd, 2001; Prentice & Voight, 2001; Starkey & Ryan, 1996). These ligaments are rarely injured and will be discussed later in this chapter.

Function. Sports are played at the recreational, high school, collegiate, and professional level. An individual who participates in a sport at any level must be able to use his or her body to perform multiple functions at one time. An athlete’s ability to perform sport specific skills, agility, flexibility, neuromuscular control, and strength depends on the muscles and inert structures of the body to function correctly and provide stability.

Athletes utilize many muscles, especially those in the lower extremity when running, biking, or jumping. Muscles work together with ligaments, joint capsules, and bony structures to allow the body to function properly. In the lower extremity the ankle
joint works as part of a kinetic chain that allows walking and running to occur (Hertel, 2002; Loudon & Bell, 1996; Norkus & Floyd, 2001; Starkey & Ryan, 1996). For the ankle to function accurately, there are two joints (talocrural and subtalar) that must work together to allow an athlete to walk, jog, sprint, and change direction.

The talocrural joint is a hinge joint and its function is dorsiflexion ($20^\circ$) and plantarflexion ($50^\circ$) (Burks & Morgan, 1994; Hertel, 2002; Loudon & Bell, 1996; Lynch, 2002; Norkus & Floyd, 2001; Prentice & Voight, 2001). Dorsiflexion is the most stable position of the talocrural joint because the talus is larger anteriorly. Therefore, the talus is wedged tighter between the malleoli when the ankle is in dorsiflexion compared to when the talocrural joint is in plantarflexion (Denegar & Miller, 2002; Prentice & Voight). The talocrural joint needs at least $10^\circ$ of dorsiflexion for proper heel to toe walking gait (Norkus & Floyd, 2001; Starkey & Ryan, 1996). However, the inversion and eversion motions of the ankle during gait occur from the subtalar joint of the ankle.

The subtalar joint is the articulation between the talus and calcaneus. The motions of the subtalar joint are inversion ($5^\circ$) and eversion ($20^\circ$) (Starkey & Ryan, 1996). The subtalar joint also plays an important role in walking and running gait (Hertel, 2002; Loudon & Bell, 1996). Both the talocrural joint and the subtalar joint must work together in order for athletes to have the proper gait to perform sport activities.

The combination of the two joints allows the ankle to go through the proper heel to toe walking and running motion. The ankle joint motions during the gait cycle are as follows: during the initial contact phase, the ankle motions are inversion and dorsiflexion; as the foot continues to make contact with the ground, the ankle shifts to eversion and plantarflexion in the loading response phase and moves to eversion and dorsiflexion in
the midstance phase; at terminal stance phase, the motion of the ankle is inversion and
dorsiflexion, moving to inversion and plantarflexion for the preswing phase. These
motions describe the weight-bearing forces on the ankle during the gait cycle (Donatelli,
1996; Hertel, 2002; Loudon & Bell, 1996; Starkey & Ryan, 1996). An athlete’s ability to
exercise properly relies on the two joints functioning correctly together during the gait
cycle. In addition to the ankle motions, inert structures must work properly to provide
stability to the ankle joint for the motions to stay within their anatomical limits (Hertel;
Loudon & Bell, 1996).

Etiology of an ankle sprain. Injuries are a common occurrence in sports and can
range from contusions, strains, and sprains to dislocations, concussions, and fractures.
Sports, such as, basketball, volleyball, gymnastics, and track and field require athletes to
perform jumps and land on one or both of their feet. Landing from a jump, especially on
other athletes around or on uneven surfaces, can lead to ligament tissue damage.

Sprains occur when a joint is stressed beyond its normal anatomical limits,
resulting in the stretching or tearing of the ligaments (Burks & Morgan, 1994; Hertel,
2002; Loveridge, 2002; Starkey & Ryan, 1996). Sprains are classified in three grades and
are based on the amount of laxity present in the joint compared to the opposite limb.
A first-degree sprain involves stressing of the fibers that result in little or no tearing.
Point tenderness and swelling are present along with local pain. A firm end-point is felt
when the joint is stressed and no abnormal motion is produced (Lynch, 2002; Starkey &
Ryan, 1996). The presence of joint laxity and a range of motion end-point define a
second-degree sprain. Partial tearing of the ligament’s fibers, swelling, moderate pain,
and loss of the joint’s function are signs and symptoms of a second-degree sprain. A
third-degree sprain involves a complete rupture of the ligament, which will cause total loss of function. Signs of a third-degree sprain include: gross joint instability, empty endpoint, swelling, and pain (Lynch, 2002; Starkey & Ryan). In order for an ankle sprain to occur there must be a mechanism of injury (MOI).

Ankle sprains are one of the most common musculoskeletal injuries in the athletic population (Arnheim & Prentice, 2000; Hertel, 2002; Loudon & Bell, 1996; Lynch, 2002; Norkus & Floyd, 2001; Prentice & Voight, 2001). Ankle sprains are caused by a sudden inversion or eversion with plantarflexion or dorsiflexion and are classified by their mechanism of injury and amount of laxity in the joint (Arnheim & Prentice; Hertel; Lynch; Norkus & Floyd).

Inversion ankle sprains are the most common form of ankle sprains and result in damage to the lateral ligaments of the ankle (Arnheim & Prentice, 2000; Beynnon, Murphy, Alosa, 2002; Denegar & Miller, 2002; Hertel, 2002; Hubbard & Kaminski, 2002; Lynch, 2002; Norkus & Floyd, 2001; Prentice & Voight, 2001). The weakest lateral ligament is the ATF, which prevents anterior subluxation of the talus and is the most commonly injured ligament followed by the CF, then the PTF (Arnheim & Prentice; Baumhauer & O’Brien, 2002; Hertel; Lynch). Injuries to the ATF ligament occur when the ankle is plantarflexed and inverted. As there is an increase in force with plantarflexion and inversion, the CF and PTF ligaments can tear. However, because the PTF ligament prevents posterior subluxation of the talus, it is rarely injured. When injury does occur, the injury is severe (ankle dislocation) (Lynch; Prentice & Voight).

The other MOI of an ankle sprain is eversion of the ankle joint due to excessive external rotation of the talus on the talocrural joint causing an eversion ankle sprain.
(Lynch, 2002; Starkey & Ryan, 1996). Eversion ankle sprains only occur in about 3–10% of all ankle sprains (Arnheim & Prentice, 2000; Lynch). There is a low percentage of eversion ankle sprains because excessive eversion is decreased due to the length of the fibula (lateral malleolus), extending farther down the leg than the tibia (medial malleolus). Therefore, there is less motion occurring in subtalar eversion, preventing stretching of the deltoid ligaments. Another factor is the thickness of the deltoid ligaments. Since the deltoid ligament is three ligaments that overlap, the ligaments strength is increased and prevents excessive eversion from occurring (Norkus & Floyd, 2001; Starkey & Ryan).

Cryotherapy

Cryotherapy overview. When an injury occurs the body reacts to the trauma, resulting in hemorrhage and edema depending on the severity of the injury (Denegar & Miller, 2002; Fincher, Woods, & O’Connor, 2004; Houglum, 1992; Mattacola & Dwyer, 2002; Starkey, 1993; Tsang, Hertel, & Denegar, 2003). When trauma occurs, the body reacts with a primary and secondary response. The primary response, which is irreversible, causes tissue damage due to an injurious traumatic force. The secondary response is cell death due to lack of oxygen in the injured area (Houglum, 1992; Hubbard & Denegar, 2004; Merrick, 2002, 2004; Starkey). As a result of the primary and secondary responses, inflammation, hemorrhage, edema, and secondary tissue hypoxia occur (Merrick, Rankin, Andres, & Channing, 1999; Merrick, 2002). Therefore, the purpose of treatment is to prevent further damage to the affected tissue and limit the amount of secondary response (Houglum; Merrick, 2002, 2004; Starkey). A treatment that limits the amount of secondary response is cryotherapy.
Several studies have revealed that cryotherapy is a common form of treatment during the acute phase of a soft tissue injury because it helps prevent secondary response and is beneficial to the healing process (Arnheim & Prentice, 2000; Coté et al., 1988; Houglum, 1992; Hubbard & Denegar, 2004; Mac Auley, 2001a, 2001b; Merrick, 2002; Stamford, 1996; Thompson et al., 2003; Weston et al., 1994). The previous studies explain the physiological factors that occur due to cryotherapy and why it is useful during the initial treatment of a soft tissue injury.

Cryotherapy is the therapeutic use of cold treatments that occur through conduction, when heat is transferred from a warmer object to the cooler one (Arnheim & Prentice, 2000; Knight, 1995). Cold therapy (0° C and 18° C) causes a decrease in temperature one to two centimeters below the skin, limits tissue damage, controls symptoms, and returns the injured body part to pre-injury status (Hubbard et al., 2004; Ingersoll, 1992; Merrick, 2002; Merrick et al., 1993; Prentice, 1999; Starkey, 1993). Cold treatments allow heat to be removed from the injured area and absorbed by the cold modality, which causes the body to respond with a series of local and systemic reactions (Arnheim & Prentice; Starkey). Indications for the use of cryotherapy during the acute phase of an injury are inflammation, pain, muscle spasm, and reduced range of motion (Hubbard et al.; Ingersoll; Merrick; Merrick et al.; Prentice; Starkey).

Cryotherapy is beneficial during the acute phase of a soft tissue injury because it decreases tissue temperature, edema, muscle spasm, metabolic activity, secondary tissue hypoxia, and has analgesic effects (Arnheim & Prentice, 2000; Hubbard et al., 2004; Ingersoll, 19991; Jutte et al., 2001; Knight, 1995; Merrick, 2002; Merrick et al., 1993; Prentice, 1999; Starkey, 1993). However, to obtain beneficial outcomes the skin
temperature must reach 13.9° C in order for there to be a decrease in local blood flow, and 14.4° C for analgesic effects to occur (Starkey). Since cryotherapy is beneficial in many different areas, what is the primary reason for using it?

Starkey (1993) and Prentice (1999) both agree that the primary reason for using cryotherapy for an acute injury is to decrease the temperature in the injured area, which, decreases the need for oxygen. This limits the amount of secondary hypoxia caused by the injury, reducing inflammation and extent of the injury.

However, Hubbard et al. (2004), Merrick (2002, 2004), and Knight (1995) state the primary reason for cryotherapy is to decrease metabolism which decreases secondary tissue hypoxia and prevents further edema and swelling. Regardless of the primary function of cryotherapy, it prevents further inflammation by limiting the release of inflammation mediators, decreasing prostaglandin synthesis, and decreasing capillary permeability. The restriction of inflammatory mediators and decreased capillary permeability inhibits the secondary formation of edema and hemorrhage, which reduces pressure on nerve endings and decreases pain (Starkey, 1993). The goal of cryotherapy is to prevent further swelling and reduce current edema in the injured joint. Therefore, certain parameters must be set to obtain a change in physiological effects within the body.

There is inconsistency in the literature regarding the recommended parameters for cold application following tissue trauma. Mac Auley (2001a) studied cryotherapy guidelines in sports medicine textbooks and found no consistent advice on the duration, frequency, and mode of application of cold therapy in acute soft tissue injuries. Smith (2003) discusses the issue of treatment time for cold therapy on ankle sprains and sites
research studies that have been conducted. Mac Auley found that all the studies had
different lengths of time to apply cold therapy to produce beneficial results. Therefore,
cold therapy research is still being conducted to determine the optimal parameters for
beneficial outcomes in soft tissue trauma.

Effects on edema. Cryotherapy is used during immediate treatment to remove heat
from the body causing vasoconstriction, decreased metabolic rate, decreased
inflammation, and decreased pain (Hubbard et al., 2004; Ingersoll, 1991; Merrick, 2002;
Merrick et al., 1993; Prentice, 1999; Starkey, 1993). A decrease in metabolic rate causes
a decrease in the need for oxygen in the injured area. Lower oxygen need limits tissue
damage because secondary hypoxic cell death is delayed or decreased. Several studies
have shown that cold therapy (cold gel pack, ice bag, cold immersion, and cryo/cuff)
decreases local blood volume, metabolism, edema, has analgesic effects, and prevents
secondary tissue hypoxia (Coté et al., 1988; Stamford, 1996; Thompson et al., 2003;
Weston et al., 1994).

Weston et al. (1994) studied changes in local blood volume during cold gel pack
application on 15 subject’s injured ankles. A bilateral Tetrapolar Impedence
Plethysmograph was used to measure the change in local limb volumes of the ankle over
a 20 minute treatment. Subjects were tested during two conditions (a) at rest and (b) with
cold gel pack application. Results revealed a significant (50%) decrease in local blood
volume when a cold gel pack was applied to the injured ankle compared to the control
group (no cold therapy, only rest). The authors theorized this to be a result of
vasoconstriction and external compression from the weight of the gel pack, which caused
the decrease in temperature. Therefore, the combination of the cold gel pack,
vasoconstriction, and compression caused a decrease in the amount of blood to the injured area. The researchers theorized that the application of a cold gel pack after an inversion mild to moderate ankle sprains produce an immediate vasoconstriction and the constriction is sustained during the application period. They also concluded that a decrease in blood volume leads to a decrease in edema within the injured area, supporting that cryotherapy is a valid tool to reduce edema during the acute phase of an ankle sprain.

Thompson et al. (2003) and Coté et al. (1988) also studied cryotherapy and its effects on edema in ankle injuries. Thompson et al. studied the best form of modality (heat or ice) to treat 32 subjects with acute ankle sprains (grade 1 and 2). This research found cold therapy to be more beneficial than heat therapy for ankle sprains during the acute phase of the injury. Individuals were able to return to activity (ability to walk, climb stairs, run, and jump without pain) quicker with cold therapy than heat. Subjects recovered in 11 days with cold therapy verses 14.8 days with heat therapy for grade 1 ankle sprains and 13.2 days verses 30.4 days for grade 2 ankle sprains (Thompson et al.).

Coté et al. (1988) supports cold therapy as the most beneficial form of therapy in minimizing ankle sprain swelling and returning the athlete to play the quickest. They studied cold immersion, warm whirlpool, and contrast bath on grade 1 and 2 ankle sprains in 30 subjects over a 3 day period. Subjects were placed in one of three groups and were tested on day 3, 4, and 5 post-injury. Pre and post treatment volumetric measurements were taken during the 3 day study. Cold treatment differed significantly from both the heat and contrast bath treatments. Results from the study revealed that cold treatment was the most beneficial of the three treatments in decreasing ankle swelling. Coté et al. theorized that cold treatment decreases the inflammatory response, which
decreases hemorrhage and local edema. A decrease in edema allows the damaged tissues to return to homeostasis and the ankle is then able to begin the healing process quicker than it would if treated with a warm whirlpool or contrast bath.

In addition to the previous three studies, a review of literature on cold therapy was conducted by Stamford (1996). The review of literature found the same findings as the previous three studies, cold therapy reduces blood flow which causes a decrease in hemorrhage and prevents swelling, muscle spasm, and pain during the acute phase of a soft tissue injury. This information is beneficial when dealing with ankle sprains because an ankle sprain is damage to soft tissue. Ankle sprains cause swelling, which interferes with the healing process of an ankle. If cold application can prevent or maintain swelling then the injured ankle will heal quicker and the athlete will return to play faster.

Cryotherapy is a valuable tool in treating acute soft tissue injuries and is the primary treatment during this phase (Coté et al., 1988; Stamford, 1996; Thompson et al., 2003; & Weston et al., 1994). When the goal of treatment is to decrease swelling, edema, inflammation, and pain, cryotherapy should be used.

Effects on pain. Pain is a subjective variable to study and measure because subjects can rate their pain differently than another subject. However, pain is an indicator of the severity of an injury and the phase of the healing process. A decrease in pain indicates that there is tissue healing occurring and that the athlete is “feeling better”. Cryotherapy is one of many factors that contribute to a decrease in pain levels after an injury.

Several studies have investigated the effects of cryotherapy on pain levels (Dervin et al., 1998; Edwards et al., 1996; Gibbons et al., 2001; Levy & Marmar, 1993). Two
studies found that cold therapy helps decrease the amount of pain an individual experiences after a soft tissue injury (Gibbons et al.; Levy & Marmar). However, Dervin et al. and Edwards et al. found that pain was not decreased after cold therapy treatment.

Gibbons et al. (2001) compared the use of cold compression dressing to a modified Robert Jones bandage on 60 subjects with total knee replacement. Subjects were placed in one of two groups (a) cold compression (cryo/cuff) and (b) Robert Jones Bandage for 10 days. The study looked at effects of analgesic treatment and pain scores (Visual Analog Scale) during the patients hospital stay. There was no difference in analgesia treatment and pain scores between the two groups. However, there was a significant decrease in pain levels over the 10 day study for both groups. Gibbons et al. concluded that cold compression dressing and Robert Jones bandage help decrease patient’s pain levels over 10 days of treatment. This supports theories that cold treatments produce analgesia in soft tissue injuries.

Levy and Marmar (1993) evaluated the role of cold compression dressing in postoperation treatment of 80 subjects who underwent a total knee arthroplasty (TKA). Subjects were placed in one of two groups (a) Aircast cryo/cuff and (b) ace wrap. Pain levels were measured with the Visual Analog Scale and total injectable morphine per kilogram per day. Results revealed that cold compression subjects required less morphine and had lower pain levels than the ace wrap group. Levy and Marmar support the theory that a combination of cryotherapy and compression using an Aircast cryo/cuff is beneficial in decreasing pain levels in TKA patients than an ace wrap alone. This study shows the compression factor of decreasing swelling is not alone beneficial for
decreasing pain levels. The addition of a cold modality produces a decrease in pain levels that compression does not do alone.

However, Edwards et al. (1996) found that different techniques in cold therapy did not change the variables (blood loss, pain, and range of motion) measured in their study on postoperation management of 71 patients undergoing arthroscopic ACL reconstruction. This study consisted of three groups (a) cryo/cuff with ice water, (b) cryo/cuff with room temperature water, and (c) no cryo/cuff and was conducted over 3 days. There was no significant difference between the groups for all variables measured. Therefore, Edwards et al. did not find a reduction in pain levels with cold therapy.

Dervin et al. (1998) also researched 78 postoperative arthroscopic ACL surgery patients and studied total wound drainage, pain levels, and analgesic measurements. There were two groups within the study (a) cryo/cuff with ice water, and (b) cryo/cuff with room temperature water. There was no significant difference between the groups for pain levels. Although, the cryo/cuff group with ice water scored higher (30.1) than the group with room temperature water (24.8) on the Visual Analog Scale for pain. However, both groups did decrease in pain levels throughout the study. They concluded that the clinical effects of cryo/cuff did not have an influence on continuous ice water verses room temperature water. Therefore, in this study it must have been the compression factor alone that decreased the swelling which in return decreased the subject’s pain levels.

It is hard to determine an individual’s pain tolerance because the measurement is subjective. This can play a part in research findings that cryotherapy has different effects
on pain levels. The four previous studies show how pain levels can be subjective and may not necessarily be an objective factor to study.

*Effects on temperature.* Another area that cryotherapy has been studied is its effects on temperature. The temperature of tissue plays a key role in the healing process of an injury. A high tissue temperature can cause vasodilatation, which causes an increase in swelling. However, proper tissue temperature can promote tissue healing. Several studies have studied cryotherapy and its effects on tissue temperatures (Johnson et al., 1979; Jutte et al., 2001; Myrer et al., 1997; Otte et al., 2002).

Intramuscular temperatures control what physiological changes occur in the injured tissue and the speed of the injury progression. Optimal intramuscular temperature at which cold therapy is effective in helping soft tissue injuries in the acute phase is not yet known (Otte et al., 2002). However, studies have been conducted to observe the relationship between the length of a cold treatment and temperature changes at the skin and intramuscular level (Johnson et al., 1979; Jutte et al., 2001; Myrer et al., 1997; Otte et al., 2002).

A review of literature conducted by Mac Auley (2001a) revealed that out of 45 books in the medical field only 28 of the books addressed cold therapy for acute injury treatment. Among those, all the books gave specific information on the duration (minutes) of a cold therapy treatment, 21 books about the frequency, and 22 books on the length of time (days) treatment was conducted. Seventeen books did not give specific guidance on duration, frequency, or length of ice treatment. With such a lack in knowledge of the optimal tissue temperature for cold therapy to be effective, it is hard to state frequency, duration, and time of a cold therapy treatment. All the books that gave
specific information varied on the duration, frequency, and length of cryotherapy treatment. However, none of the books addressed optimal skin and intramuscular temperatures for acute soft tissue injuries. Therefore, more studies must be conducted to determine the optimal duration, frequency, length of time, and skin and intramuscular temperatures. This information is necessary for valuable physiological effects to benefit soft tissue trauma and prevent swelling, edema, pain, and inflammation (Mac Auley). The following studies will demonstrate the variety that exists among cold treatment parameters and temperature changes.

Myrer et al. (1997) studied subcutaneous and intramuscular temperatures during cryotherapy in the triceps surae muscle group of 32 subjects. Subjects were placed into one of two groups (a) 1.8 kg crushed ice and (b) cold whirlpool (10° C). The purpose of this study was to compare the cooling and rewarming effects of a 20 minute treatment on subcutaneous and intramuscular temperatures of the lower leg. Temperature measurements were taken with a 26-gauge hypodermic needle and the microprobes were inserted in left calf 1 cm below subcutaneous fat. They demonstrated that subcutaneous temperatures significantly differed between the ice pack group (-16.97 ± 3.81° C) and cold whirlpool group (-13.78 ± 2.97° C) groups greater than intramuscular temperatures after the first five minutes of cryotherapy in the triceps surae muscle group. However, there was no significant difference in intramuscular temperatures between the two groups (-7.09 ± 4.07° C ice pack and -5.13 ± 1.83° C cold whirlpool). Subcutaneous temperatures also significantly rewarmed more in the ice pack group (12.31 ± 3.28° C) than the cold whirlpool (7.43 ± 2.14° C). Myrer et al. found a significant difference in mean temperature increases over 5 minute intervals for 30 minutes between groups.
during the intramuscular rewarming period (1.96 ± 3.06° C for ice packs, -1.76 ± 1.36° C for cold whirlpool). Therefore, it is suggested for rapid and significant temperature decrease an ice pack is the best form of treatment. However, for a significant temperature decrease that will last for an extended period of time after treatment the cold whirlpool should be used (Myrer et al.). This study also shows that cryotherapy, regardless of the type of treatment, decreases subcutaneous and intramuscular tissue temperatures.

Johnson et al. (1979) examined 10 subject’s intramuscular temperature at 0.25 cm in the lateral head of the gastrocnemius during 30 minutes in a cold bath treatment and during a rewarming period. Measurements were taken over 5 hours: Pre treatment for 30 minutes, treatment for 30 minutes, and recovery for 4 hours. Pre treatment was measured at 30 minutes; treatment was measured every minute for the first 5 minutes and then every 5 minutes for the remaining 25 minutes; post treatment was measured every 30 minutes for 4 hours. Temperatures were taken with a 24-gauge hypodermic thermistor probe. It was found that intramuscular temperature significantly decreased from its pre treatment and post treatment readings (decrease of 12.0° C). However, the intramuscular rewarming temperature never reached the baseline temperature after 4 hours (no activity) of monitoring. Therefore, when treating soft tissue injuries, cold therapy will help decrease tissue temperature and prevent secondary tissue hypoxia. These physiological effects will help prevent further swelling and the temperature decrease will last for a couple of hours (Johnson et al.).

Knowing that cryotherapy decreases intramuscular tissue temperatures, Otte et al. (2002) studied how adipose tissue thickness may have an effect on those temperature changes. Forty-seven subjects were divided into one of four groups (a) 0-10 mm, (b) 11-
20 mm, (c) 21-30 mm, (d) 31-40 mm thigh skinfolds and were tested to see how long it took for cryotherapy treatment to reach 7º C from the baseline reading at 1 cm subadipose anterior thigh. A portable temperature data logger and type T thermocouples were used for all temperature measurements. They observed that thicker adipose tissue requires longer cold treatments in order for the intramuscular temperature to reach 7º C from baseline. Different adipose thickness resulted in significant differences in the allotted time for intramuscular temperature to reach 7º C from the baseline temperature (0-0.10 cm adipose tissue = 8.0 min., 0.11-0.20 cm = 23.3 min., 0.21-0.30 cm = 37.8 min., and 0.31-0.40 cm = 58.6 min.). It was theorized that the thickness of subcutaneous adipose tissue affects the rate of temperature changes in the human body. The thermal conduction and dispersion within the adipose tissue is low and adipose tissue has an insulating effect that is greater than other tissues. Therefore, when treating individuals with cryotherapy, adipose thickness needs to be addressed and treatment time needs to be altered for cryotherapy to be valuable in reducing swelling, temperature, metabolic rate, and blood volume (Otte et al.).

When determining the cryotherapy’s duration it is not optimal to take intramuscular temperature readings to obtain the correct decrease in temperature. However, skin temperature can be taken at the time of cryotherapy treatments. Therefore, Jutte et al. (2001) studied the relationship between intramuscular temperatures and skin temperature readings. They examined if skin temperature, room temperature, core temperature, time, and subcutaneous adipose fat explained changes in intramuscular temperature of 50 subjects right anterior midthigh skinfold (vertical) when an ice bag was applied for 30 minutes. Temperatures were taken during the 3 minute pre treatment, 30
minute treatment time, and 120 minute post treatment. They observed no single variable that adequately explained changes in intramuscular temperature (2 cm depth). All variables played a factor in explaining intramuscular temperature changes, but none could be isolated to explain intramuscular changes. Core temperature explained 4%, room temperature explained 23%, and skin temperature explained 21% of intramuscular temperature decrease. Skin temperature explained 50%, skin fold explained 7%, room temperature 4%, and core temperature 1% of the 120 minute intramuscular rewarming period. However, the intramuscular temperature did not return to its baseline values during the rewarming period. They observed skin temperature was not a good indicator of intramuscular temperature and should not be used alone to predict the efficiency of cryotherapy. Therefore, this study reveals that more than one factor needs to be considered when determining intramuscular temperature changes. However, Starkey (1993) review of literature on this area, states that there is a moderate correlation ($r = 0.65$) between skin temperature and intramuscular temperatures. More studies need to be conducted in this area to determine cryotherapy’s optimal duration to have an affect on temperature decreases.

Konrath and Lock (1996) studied the use of cold therapy after ACL reconstruction in 100 subjects. Subjects were placed in one of four groups (a) polar care device with cold water (4.4-10.0° C), (b) polar care device with lukewarm water (21.1-26.7° C), (c) 1.3-1.5 kg bag of crushed ice, and (d) no cold therapy. Skin temperature was taken every 4 hours, and measurements of drain output, amount of pain medication, range of motion, and length of hospital stay was recorded. Results from this study observed that the mean skin temperature of groups a and c was less than groups b and d but their results were not
significant. However, there was no significant difference between groups for drain output, range of motion, or length of hospital stay. They observed that cold therapy decreases skin temperature but did not find any objective benefits of cold therapy in early soft tissue injury treatment because the other three variables showed no significant differences between the groups.

In conclusion, the literature on cold therapy and temperature changes indicates that subcutaneous and intramuscular temperatures decrease with cold therapy (Johnson et al., 1979; Jutte et al., 2001; Konrath & Lock, 1996; Myrer et al., 1997; Otte et al., 2002). However, temperature changes differ depending on the type of treatment and thickness of the adipose tissue. All studies show a decrease in tissue temperature when cold therapy is applied to a soft tissue injury. Therefore, it can be stated that a decrease in intramuscular temperatures improves the treatment of soft tissue injury in the acute phase and prevents further swelling while reducing pain levels (Otte et al.).

Cryotherapy and Compression

It is accepted to treat an acute injury with RICE (rest, ice, compression, and elevation), which is often applied with an ice bag and ace wrap (Arnheim & Prentice, 2000; Prentice, 1999; Starkey, 1993). Studies have shown that cold therapy alone has beneficial effects in treating swelling (Coté et al., 1988, Stamford, 1996; Thompson et al., 2003; Weston et al., 1994), and compression alone helps decrease swelling. A combination of the two treatments, such as cryo/cuff, should produce similar effects if not more of a decrease in edema in an injured area.

Studies have shown that cold therapy and compression combined have a better effect than compression and cryotherapy alone (Levy & Marmar, 1993; Merrick et al.,
1993; Sloan et al., 1988). However, other studies have found no significant difference in cold therapy and compression compared to compression and cryotherapy alone (Dervin et al., 1998; Healy et al., 1994; Smith et al., 2002).

The Levy and Marmar (1993) study on total knee arthroplasty (TKA) was also conducted on blood loss, range of motion, and girth (swelling) measurements. Subjects were placed in one of two groups (a) Aircast cryo/cuff and (b) ace wrap and results revealed that cold compression decreased bleeding and swelling while increasing range of motion more than the ace wrap alone. Levy and Marmar support the combination of cryotherapy and compression using an Aircast cryo/cuff as more effective in reducing swelling in TKAs than an ace wrap (Levy & Marmar). This study shows that the combination of compression and cryotherapy is more beneficial than compression alone.

Merrick et al. (1993) studied temperature decreases in the anterior thigh of 11 subjects. Skin and intramuscular temperatures (1 cm below the fat layer and 2 cm below the fat layer) were measured. All subjects were tested under four conditions (a) control, (b) compression only, (c) ice only, and (d) ice and compression. Subject’s protocol consisted of a 5 minute pre-application period, a 30 minute application period, and a 20 minute post-application period. Temperature measurements were recorded every 30 seconds for all three periods. Results revealed both the ice alone and ice and compression produced significantly lower temperatures at all three depth levels and temperatures did not return to their pre-application levels. However, the ice and compression produced significantly lower temperatures than ice alone. Therefore, Merrick et al. theorize that ice and compression is more effective than ice alone.
Sloan et al. (1988) studied the effects of cold therapy and compression as well but focused on studying artificially induced swelling (phosphate buffered saline) in the forearm. Their theory was that the combination treatment would cause a reduction in swelling. Eighty subjects were placed in one of four treatment groups (a) cooling in a water bath (21°, 10°, and 3° C), (b) controlled compression and cold cuff (30 mmHg), (c) cooling pressure bandage (10 mmHg), (d) pressure alone (sphygmomanometer at 20 mmHg). Treatments were conducted for 40 minutes and were measured at 2, 5, 10, 15, 20, 25, 30, 40, and 60 minutes by Wheal volume measurements. At 10 minutes all treated groups were significantly different from the control group. At 60 minutes the compression and cold cuff and cooling bandage were both significantly different from the other groups and from each other. Therefore, the addition of mild pressure (10 mmHg) to a mild cooling (15º-25º C) produced highly significant reduction in swelling in the forearm from 15 minutes onward. Pressure (20 mmHg) had a nonsignificant effect on the swelling. Sloan et al. theorize that the additional pressure with cold therapy treatments affects the capillaries which prevent gross fluid leakage that occurs with a soft tissue injury. This does not mean that cold and compression are effective in clinical situations because injuries are more complicated than the phosphate buffered saline that was injected into these subjects (Sloan et al.).

Healy et al. (1994) studied the efficacy of a cold compression dressing after TKA in 105 knees in 76 subjects and deduced very different conclusions from Levy and Marmar (1993), Merrick et al. (1993), and Sloan et al. (1988). Subjects were placed in one of two groups (a) cryo/cuff and (b) ace wrap and ice group. Range of motion, swelling (girth measurement), and wound drainage were measured on days 2-4, 7-14, and
4-6 weeks. Findings revealed there were no significant differences between the groups in all measurements taken. A slight increase in range of motion and decrease in swelling for the cryo/cuff group compared to the control group was noted, but results were not significant. Therefore, Healy et al. conclude that cold compression dressing does not provide a benefit over an ace wrap and ice in decreasing swelling for TKA patients.

Smith et al. (2002) examined the difference between compression and cold therapy in 84 patients with total knee replacement surgery. Subjects were randomly placed into one of two groups (a) compression bandaging and (b) Cryo-pad technology. Blood loss, pain score, range of motion, blood transfusion, opiate use, and swelling were the variables measured. There were no significant differences between the two groups for any of the variables measured. Therefore, Smith et al. does not support the theory that compression is more beneficial than cold therapy in reducing swelling.

Dervin et al. (1998) examined if the benefits of the cryo/cuff are attributable to its compressive effect rather than its cold application in postoperative arthroscopic ACL reconstruction. One group was treated with a cryo/cuff and ice water, while the other group was treated with cryo/cuff and room temperature water. Total wound drainage, swelling, pain, and analgesic measurements were analyzed. They found that there was no significant difference between groups for all variables tested. Therefore, Dervin et al. cannot conclude if the cryo/cuff is more effective due to its compressive component or its cold factor because the cryo/cuff was not influenced by the use of ice water versus room temperature water.

There is controversy about the effects of cryotherapy and compression in reducing edema compared to cryotherapy alone. Studies reveal positive and negative findings for
cryotherapy and compression (Dervin et al., 1998; Healy et al., 1994; Levy & Marmar, 1993; Merrick et al., 1993; Sloan et al., 1988; Smith et al., 2002). Further studies need to be conducted to determine the benefits of cryotherapy and compression on acute soft tissue trauma.

*Cryotherapy and Intermittent Compression*

Cold treatment alone and compression alone have been shown to decrease or maintain edema due to soft tissue injury (Coté et al., 1988; Hubbard et al., 2004; Ingersoll, 1991; Levy & Marmar, 1993; Merrick, 2002, 2004; Merrick et al., 1993; Prentice, 1999; Sloan et al., 1988; Stamford, 1996; Starkey & Ryan, 1996; Thompson et al., 2003; Weston et al., 2003). Cold therapy and compression combined is controversial in decreasing edema due to soft tissue injury (Dervin et al., 1998; Healy et al., 1994; Levy & Marmar, 1993; Sloan et al., 1988). Cryotherapy has been shown to lower soft tissue temperatures at the injury site and cause capillary constriction. Capillary constriction causes a decrease in cellular permeability, hemorrhage, tissue metabolism, musculoskeletal trauma, and inhibits pain and muscle spasm. Compression also causes capillary constriction and increases extracellular hydrostatic pressure which causes a decrease in edema formation. If a third component, intermittent compression is added it will help with venous and pedal lymph return which helps push debris within the injured area into the lymph system (Mora et al., 2002).

Therefore, a combination of cold therapy and intermittent compression in the lower extremity is theorized to be beneficial in reducing edema (Mora et al., 2002; Stockle et al., 1997). Studies have been conducted to show that intermittent compression with cold therapy is beneficial in decreasing swelling for an acute tissue injury.
Intermittent cold compression is very similar to the cryopress and the purpose of this study.

Several studies have investigated the effects of intermittent compression and cold treatment combinations in reducing edema in the lower extremity (Airaksinen et al., 1991; Mora et al., 2002; Stockle et al., 1997). These studies support the idea that intermittent cold compression helps decrease edema in the lower leg.

Mora et al. (2002) studied pulsatile cold compression in edema reduction following ankle fractures on 24 subjects. The subjects in this study were divided into two groups (a) cryo/cuff compression device with autochill pump, and (b) control group, which had no ice therapy but was required to be on bed rest and elevation. Subjects received treatment throughout the day but not at night. The intermittent cold compression group showed a 1.2 cm decrease in edema on day three compared to the control group (decreased 0.5 cm). Therefore, this study supports the use of cold intermittent compression to decrease edema in the ankle (Mora et al.).

Stockle et al. (1997) supports that intermittent cold compression helps reduce posttraumatic and postoperative edema in the ankle. This study examined 60 subjects that were placed in one of three groups (a) cool pack cryotherapy, (b) continuous cryotherapy, and (c) intermittent impulse compression. Girth measurements were taken to determine if ankle edema decreased over 6 days of treatment. The intermittent cold compression decreased ankle edema by 0.15 cm 24 hours postoperation, while continuous cryotherapy decreased edema 0.6 cm. Cool pack cryotherapy only decreased swelling in the ankle 0.3 cm postoperation. The average decrease in swelling 24 hours pre-operation was 53% for intermittent cold compression, 32% for continuous cryotherapy, and 10% for cool pack
cryotherapy. The average decrease of edema in the ankle 24 hours postoperation was
44%, 34%, and 20% respectively. Four days after surgery, swelling had decreased 74%,
70%, and 45% respectively. Therefore, this study showed that there was a significant
difference between all groups and intermittent cold compression decreased edema the
most (Stockle et al.).

Airaksinen et al. (1991) showed evidence that intermittent pneumatic compression
(IPC) (Ventipress device) in posttraumatic lower limb injuries was significant in reducing
edema. They studied 16 subjects with fractures of their lower legs who had been
immobilized for 6-12 weeks. All subjects received IPC treatment for 5 consecutive days
for 75 minutes on each day. Swelling was determined with CT console and leg
circumference measurements. Results revealed there was a decrease in edema, 23%-15.9%
for CT measurements and 23.5%-13.2% for circumference. This study shows that
intermittent compression has a positive effect on reducing edema. All the studies
mentioned previously found that intermittent cold compression has a positive effect on
reducing edema and should be considered for acute injury treatment.

Ankle Girth Measurements

Girth measurements overview. Girth measurements are a form of testing that
allows a clinician to determine the amount of swelling, edema, or inflammation present in
an injured hand, ankle, or foot (Arnheim & Prentice, 2000; Brijker, Heijdra, Van den
Elshout, Bosch, & Folgering, 2000; Ciotti, Bellisari, Bibi, Dolan, 2002; Martin, 1997;
Wilson et al., 1998). Girth measurements can be measured with a volumetric tank or a
flexible measuring tape using the figure 8 style (Arnheim & Prentice; Magee, 2002).
Advantages to figure 8 measurements are that it is a quicker way of measuring the girth
of an ankle. However, a disadvantage to figure 8 measurements is that often the measurement is done improperly and specific landmarks are not followed. Volumetric measurements are more accurate than figure 8 girth measurements but they take a greater amount of time to conduct (Arnheim & Prentice).

Many studies have been conducted to test the validity and reliability of figure 8 tape measurements and volumetric water displacement measurements in the ankle and foot (Brijker et al., 2000; Ciotti et al., 2002; Martin, 1997; Wilson et al., 1998).

Validity and reliability. Validity and reliability play a key role in research to determine if measurements are accurate and consistent within and between testers. Studies (Brijker et al., 2000; Ciotti et al., 2002; Martin, 1997; Wilson et al., 1998) have been conducted to study how valid and reliable the figure 8 girth measurement and volumetric tank measurements are for ankles.

Ciotti et al. (2002) tested the validity and intertester reliability of volumetric and figure 8 tape measurements of non-traumatized ankles. Two testers were used to test volumetric measurements and 20 subjects’ ankles were measured with both the figure 8 and volumetric techniques (measurements were taken 10 times). Results revealed that both the testers were significantly close to the actual volume of the ankle (1072 ml for tester 1, 1074 ml for tester 2, and 1079 ml for actual volume) and there was a high correlation \( r = 0.917 \) between the volumetric measurement and figure 8 measurement. Therefore, this study found that both the figure 8 method and volumetric method are valid and reliable techniques of measuring the girth of the ankle (Ciotti et al.).

Martin (1997) studied the inter and intra-observer variability of volumetric assessment using water displacement. Six experienced medical professions measured the
ankle 10 times on two subjects to determine the reliability of the volumetric measurements. Volumetric measurements were conducted with 1000 cc graduated cylinder and a single study monitor read. Results demonstrated that there was no significant difference in the graduated cylinder reading between the investigator and study monitor but there was a significant difference between volumes across the ten observations. The last five measurements were significantly greater than the first five measurements. Therefore, Martin suggests the intra-observation variability is low, while the repeated volumetric measurements of the ankle are highly variable.

Brijker et al. (2000) assessed the diurnal variability of leg volume in 10 patients with peripheral edema compared to ankle circumference and body weight measurements. This study found that volumetric measurements (3125 ml to 2715 ml = 13.1%) showed a greater decrease in edema after treatment than ankle circumference (26.7 cm to 24.8 cm = 7.1%) and body weight (71.0 kg to 66.8 kg = 5.9%) measurements. Brijker et al. show that volumetric water displacement is highly reproducible in the clinical setting and is an appropriate tool for monitoring peripheral edema.

Wilson et al. (1998) evaluated and compared the reliability and responsiveness of volumetric measurements of swelling in 13 athletes with grade one or two ankle sprains. Measurements were taken 3 days post injury and 1 week later. Each time measurements were conducted a total of 10 measurements were obtained. Results from Wilson et al. study observed volumetric measurements are consistent within the same occasion of measurement and the test-retest parameters have a low proportion of measurement error.
Summary of Related Literature

Ankle injuries are a common occurrence in sports. Generally, initial treatment for an ankle sprain consists of rest, ice, compression, and elevation (RICE). All four components of RICE are important in the treatment of an acute soft tissue injury. However, studies within this paper focus mainly on the cryotherapy and compression components of RICE and their effects on edema and pain (Côté et al., 1988; Levy & Marmar, 1993; Mac Auley, 2001a, 2001b; Sloan et al., 1988; Stamford, 1996; Thompson et al., 2003; Weston et al., 1994).

Cryotherapy is the therapeutic use of cold treatments that occurs through conduction (Arnheim & Prentice, 2000; Knight, 1995). Indications for the use of cryotherapy during the acute phase of an injury are to decrease inflammation, pain, muscle spasm, and restore range of motion (Prentice, 1999; Starkey, 1993). Cryotherapy and its effects on soft tissue injury have been studied for many years (Côté et al., 1988; Stamford, 1996; Thompson et al., 2003; Weston et al., 1994). Theses studies have been performed to determine how cold affects the physiological structures of the human body and aids in the healing process of an injury. All the studies stated above support cold therapy as the most beneficial modality to use during the acute phase of a soft tissue injury.

It is theorized that cryotherapy decreases cell metabolism which decreases secondary tissue hypoxia and prevents further tissue damage from occurring in the injured area. A decrease in secondary tissue hypoxia allows the injured ankle to isolate the injury and prevent healthy tissue from becoming damaged. Limiting the amount of tissue damage helps with the healing process of soft tissue. The smaller the injured area,
the quicker the athlete can return to participation. Therefore, if cryotherapy can prevent or reduce edema, the athlete’s injured ankle will heal faster and return to play will occur quicker.

Studies have shown that cold therapy alone has beneficial effects in treating edema and compression alone helps decrease edema (Dervin et al., 1998; Gibbons et al., 2001; Healy et al., 1994; Levy & Marmar, 1993; Sloan et al., 1988; Smith et al., 2002; Stockle et al., 1997). A combination of the two treatments, such as cryo/cuff, has been shown to reduce edema more effectively than cold therapy alone. Studies that have been conducted on cryotherapy and compression have found the combination to be more effective than just ice (Levy & Marmar, 1993; Merrick et al., 1993; Sloan et al., 1988; Stockle et al., 1997). It is theorized that the compression component of the cryotherapy and compression treatment helps with cellular permeability, prevents fluid leakage from cells, and helps with the removal of debris from the injured area. These physiological effects along with the effects from cryotherapy, as stated previously, help increase the healing process and remove debris from the injured area. When considering a treatment for acute soft tissue injury, consider adding compression to the cryotherapy treatment to decrease edema which may allow the athlete to return to participation quicker.

Studies have also shown cryotherapy to be beneficial in decreasing pain and temperature (Gibbons et al., 2001; Jutte et al., 2001; Levy & Marmar, 1993; Myrer et al., 1997; Otte et al., 2002). It is theorized that the anesthetic effects of local cooling is due primarily to slowing or elimination of pain signal transmission. Cold therapy affects pain perception by interrupting pain transmission and decreasing nerve conduction velocity. Gibbons et al. and Levy and Marmar found that pain levels were reduced in total knee
replacement patients. Pain levels decrease because there is a decrease in temperature which slows down the nerve conduction velocity. Myrer et al., and Otte et al. support the decrease in skin and intramuscular temperatures due to cryotherapy. Therefore, cryotherapy should be considered when treating pain because the combination of a reduction in skin and intramuscular temperatures has a positive effect on pain levels.

Cryotherapy’s effects on edema, pain, and temperature help a clinician treat patients with the proper modalities. One more area of research that may improve acute soft tissue injury treatment is the addition of intermittent compression to cryotherapy. Airaksinen et al. (1991), Mora et al. (2002), and Stockle et al. (1997) studied intermittent compression and its role in decreasing edema during cold treatments in acute soft tissue injury. All three studies support that intermittent compression helps decrease ankle edema. The decrease in edema is theorized to be due to a weight bearing stimulus that is caused by intermittent compression. The weight bearing stimulus causes an increase in arterial flow which causes more capillaries to open and an increase in osmotic reabsorption. An increase in osmotic reabsorption increases lymph flow which helps increase the healing process of soft tissue injury and remove debris from the injured area.

The cryopress is similar to the cryotherapy and intermittent compression modalities. However, the cryopress is unique because it also incorporates sequential compression to the injured limb. The sequential feature to the cryopress may be more beneficial in the prevention or reduction of edema and pain in soft tissue injuries. However, no study has specifically examined the cryopress and its involvement in preventing or reducing current edema and pain in grade 1 ankle sprains. Therefore, the purpose of this study was to compare the effects of the cryopress and cryo/cuff treatments
on ankle edema and pain after 3 consecutive days of treatment in Division I varsity athletes.
Chapter 3

Methods

This chapter will be presented in the following sections: Selection of Subjects, Instrumentation, Testing Procedures, and Analysis of Data.

Selection of Subjects

The subjects in this investigation were 16 male and female NCAA Division I varsity athletes between the ages of 18-22 years old (172.71-205.74 ± 10.46 cm.; 76.05-104.40 ± 10.30 kg.). Subjects were selected for this study by meeting the following criteria: (a) member of OU varsity sports team, (b) had a grade 1 ankle sprain within the past 24 hours, (c) had to of been initially evaluated by a certified athletic trainer and then evaluated by the Ohio University’s team physician, and (d) completed the consent form. Eligible subjects were divided into two groups, cryopress (CP) and cryo/cuff (CC) treatment. Subjects were placed in either CP or CC group based on the following:

1. First female with grade 1 ankle sprain → CC
2. Second female with grade 1 ankle sprain → CP
3. First male with grade 1 ankle sprain → CP
4. Second male with grade 1 ankle sprain → CC

Rotation continued to alternate as subjects came in.

Participation in this study was voluntary and all subjects signed an Informed Consent Form approved by the Institutional Review Board (IRB) (see Appendix A).

Instrumentation

A Grimm Cryopress (Marietta, OH) and Aircast Cryo/cuff (Wichita, KA) were used for 3 consecutive days to promote a reduction in ankle edema and pain. The
cryopress is a machine that combines cold therapy, sequential intermittent pressure (sequential cryocompression sleeve), and elevation (20°) for the lower extremity. The temperature (4.4° C-15.5° C), pressure (0-100 mmHg), gradient (off-20%), and time (2-20 min.) can be changed depending on the purpose of the treatment. The cryo/cuff is a combination of cold therapy and compression through a cooler and cuff. The temperature, pressure, and time can be controlled by the clinician applying the cryo/cuff. Prior to cryotherapy treatment, subjects filled out a questionnaire about the mechanism of injury, past history with ankle injuries, taping or bracing, and treatment (see Appendix B) and were questioned to determine any contraindication to cold therapy (see Appendix C).

Before and after cryopress and cryo/cuff treatments each day, girth measurements (volumetric and figure 8) were measured and recorded. Each subject’s injured ankle was measured for 3 days post injury pre and post each cryopress or cryo/cuff treatment. Testing took place over 3 consecutive days after the initial injury with one treatment per day and results were recorded immediately pre and post treatment. Subjects were instructed not to apply compression, ice, or elevation to their injured ankle while they were a subject of this study.

Testing Procedure

Participants were asked to sign a consent form prior to participation in the study. Prior to cold therapy treatment, the injured and non-injured ankle was measured using a figure 8 technique and volumetric measurements.

Volumetric measurements were conducted as follows: the patient was seated in a chair with hip and ankle at 90° flexion with the volumetric tank level on the floor. The tank was filled with water (33.5° C) until the water started to drain out of the tube. Once
the water had stopped draining, the subject’s foot was cleaned and wiped dry. The subject then placed his or her limb on the bottom of the tank and against the back wall of the tank. The subject was instructed to keep still so the water level equalized throughout the draining procedure. Water was collected in a container until the water stopped draining from the tube. The water collected in the container was then measured in a graduated cylinder and the measurements (ml) were recorded (Arnheim & Prentice, 2000). This procedure was conducted on both the injured and non-injured limb pre-treatment on the first day of the treatment. However, only the injured ankle was measured post-treatment on day one and pre and post-treatment on days two and three.

Figure 8 measurements were conducted as follows: the ankle was placed in 90º dorsiflexion or as far as the swelling would allow the joint to dorsiflex. The tape measure was started midway between the tibialis anterior tendon and the lateral malleolus and moved medially across the instep of the foot just distal to the navicular tuberosity. Then the tape was pulled across the arch of the foot just proximal to the base of the fifth metatarsal (styloid process) and across the tibialis anterior tendon. The tape measure was brought around the ankle joint distal to the tip of the medial malleolus and across the achilles tendon, and then distal to the lateral malleolus. The figure 8 measurement was finished by returning to the tape measure to the starting position between the tibialis anterior tendon and lateral malleolus (Magee, 2002). Girth measurements were taken three times and the means of those three numbers were used as the final girth measurement pre and post treatment. Girth measurements were taken on both the injured and non-injured ankle on day one of treatment to determine the amount of edema present
in the injured ankle. However, only the injured ankle was measured post-treatment on
day one and pre and post-treatment on day two and three.

The figure 8 and volumetric measurements were alternated to counter balance the
order of testing. Therefore, one subject received figure 8 measurements and then
volumetric measurements during their 3 days of testing. Then the next subject received
the reverse order to ensure that the order of the figure 8 and volumetric measurements did
not have an effect on the results of this study. Once figure 8 and volumetric
measurements were conducted the athlete was situated in the supine position on a
standard treatment table. The injured limb was placed in the cryopress or cryo/cuff for 20
minutes. For the cryopress, the athlete’s foot was placed in the cryopress boot, located at
the end of the treatment table. The athlete’s foot was placed completely in the boot so the
subject’s foot was touching the distal end of the cryopress boot and the boot was closed
and clipped to secure the limb in place. The un-injured leg was placed next to the
cryopress. The cryopress parameters were set as follows: temperature to 9° C, pressure to
50 mmHg, and gradient ratio to 20%. The gradient automatically factors the pressure
ratio and reduces the compression pressure of the mid and proximal chambers
proportionally. After the pressure, gradient, and water temperature were set, the
investigator pressed the fill button on the machine. The cryopress then filled to the set
amount of pressure. At this point, the machine was drained for 5 seconds. Then the time
(20 minutes) was set and the start button was pressed. The cryopress then filled for a
minute and a half and drained for 30 seconds for 2 minute cycles until the allotted time
had expired. During treatment, the athlete was instructed to wiggle his or her toes during
the 30 seconds when the pressure was decreasing. The athlete was also given an
emergency button that he or she could use if he or she felt as though there was too much pressure being placed on his or her limb. This switch would start draining the cryopress and release the pressure on the athlete’s limb. However, if the athlete used this switch, he or she was disqualified from the study.

The cryo/cuff is a vinyl bladder that fits over the ankle like a boot with an open toe box. The cuff is attached by Velcro straps making the boot completely surround the ankle. The cuff is filled with ice water by means of a portable cooler and tubing. For this study, the tubing was connected to the cuff and the cooler was filled with water to the line marked in the cooler and then ice was added to reach a temperature of 9° C. To fill the bladder, the air vent on the cooler was opened and the cooler was held directly over the ankle and as high as the hose allowed the cooler to go above the cuff. Then the air vent was closed and the tube was disconnected from the cuff by pressing the quick-disconnect on the tube (Starkey, 1993). The cryo/cuff was full when the bladder was filled and pressure (50 mmHg) was applied to the ankle. When filled, the cryo/cuff delivered compression and cooling to the ankle. The water in the cooler was changed at 10 minutes to make sure the water temperature was consistent and treatment time was 20 minutes. Water temperature was determined using a Healthteam digital thermometer (Hauppauge, NY) and the ankle was elevated 20° (measured with large goniometer) using a bolster.

The same procedure was followed for the CC group as the CP group.

The athlete’s pain level was also recorded pre and post-treatment on all 3 days using the Visual Analog Scale (see Appendix D). The athlete was given a 10 cm line with one centimeter markings perpendicular to the 10 cm line extending across the line. One end of the 10 cm line was labeled “no pain” and the other end was labeled “severe pain.”
The athlete was asked to mark the line to indicate where his or her pain level was pre
and post treatment. Pain levels were scaled on a 0-10 scale. Zero was the equivalent of no
pain at all and 10 was the worst pain the athlete has ever felt and he or she needed to go
to the hospital right away (Arnheim & Prentice, 2000).

Analysis of Data

The data that was collected from the outcome variables were:

1. Figure 8 girth measurements (average in cm) measured with a flexible
measuring tape.

2. Volumetric (ml) measurements measured with the volumetric tank.

3. Pain levels measured with Visual Analog Scale (0-10).

Statistical reports were conducted as follows:

1. The variables (figure 8 and volumetric measurements) were
analyzed by using a 2x3 (group x day) Factorial Analysis of Variance (ANOVA)
(Statistical Package for Social Sciences (SPSS), Ohio University) to determine if the
dependant variables (amount of edema and pain levels) were significantly different
between pre and post cryopress and cryo/cuff treatments and over time for 3 consecutive
days of treatment post injury.

2. A pairwise comparison analyses was performed on mean difference figure 8
and pain data and pre and post figure 8, volumetric, and pain over time data to determine
significant differences between group and day interactions and day main effects.

3. Independent t-test analysis was performed post hoc for figure 8 and pain
measurements to identify significant differences between the two groups.
4. Pearson product-moment correlation was performed for figure 8 and volumetric measurements to determine if a significant relationship between the two measurements was present.

4. Means and standard deviations were calculated.

5. A $p < .05$ was used to test for statistical significance.
Chapter 4

Results

This chapter is presented under the following sections: Purpose of the Study, Null Hypothesis, Subject Data from the Questionnaire, Analysis of Variance Results, Relationship Between Figure 8 and Volumetric Measurements, and Summary of Results.

Purpose of the Study

The purpose of this study was to compare the effects of the cryopress and cryo/cuff treatments on ankle edema and pain after 3 consecutive days of treatment in Division I varsity athletes. This study was conducted to observe how a combination of intermittent sequential compression and cold therapy treatment prevents further or decreases current edema and pain in the ankle compared to a common technique, the cryo/cuff, which is frequently utilized. The results of this study suggest that both the cryopress and cryo/cuff decrease ankle edema and pain levels in first degree inversion ankle sprains.

Null Hypothesis

The following null hypotheses were considered:

H₀₁: There will be no significant difference in edema reduction in the ankle joint in athletes receiving 3 consecutive days of cryopress treatment compared to athletes receiving cryo/cuff treatment.

H₀₂: There will be no significant difference in pain levels in athletes receiving 3 consecutive days of cryopress treatment compared to athletes receiving cryo/cuff treatment.
H₀₃: There will be no significant difference in edema reduction in the ankle joint between pre and post measurements on days 1, 2, and 3 in athletes receiving cryopress treatment compared to athletes receiving cryo/cuff treatment.

H₀₄: There will be no significant difference in pain levels between pre and post measurements on days 1, 2, and 3 in athletes receiving cryopress treatment compared to athletes receiving cryo/cuff treatment.

Subject Data from Questionnaire

There were sixteen subjects (9 females and 7 males) that participated in this study. Eight subjects were in the CP group and eight subjects were in the CC group. CP group consisted of four females and four males and CC consisted of five females and three males. Demographics for subjects in this study are presented in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (M)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>19.63</td>
<td>174.96</td>
<td>79.59</td>
</tr>
<tr>
<td></td>
<td>1.60</td>
<td>9.55</td>
<td>15.70</td>
</tr>
<tr>
<td>CC</td>
<td>20.63</td>
<td>185.12</td>
<td>85.05</td>
</tr>
<tr>
<td></td>
<td>1.41</td>
<td>10.46</td>
<td>10.29</td>
</tr>
</tbody>
</table>

*Note.* cm = centimeters; kg = kilograms.

*₂n = 8.*
The CP group consisted of a male football player, a male diver, a male wrestler, a male baseball player, a female field hockey player, a female softball player, a female volleyball player, and a female track and field athlete, Table 2. All of the subjects inverted their ankle and were diagnosed with a grade 1 ankle sprain. Fifty percent of the subjects injured their right ankle and 50% of the subjects injured their left ankle. Twenty-five percent of the subjects injured their ankle between 7:00 a.m.-11:00 a.m., 25% subjects injured their ankle between 11:30 a.m.-3:00 p.m., and 50% of the subjects injured their ankle between 3:30 p.m.-7:00 p.m. Seventy-five percent of the subjects received a bag of ice within the first 24 hours of the injury and 25% of the subject’s first treatment was the cryopress. All of the subjects received treatment between 11:00 a.m.-3:00 p.m. Twenty-five percent of the subjects had never injured their ankle before, 37.5% of the subjects sprained their ankle 12 months ago, one of the subjects sprained their ankle 24 months ago, 12.5% of the subjects sprained their ankle three years ago, and another 12.5% of the subjects sprained their ankle seven years ago. All of the subjects reported no surgery on their ankle prior to their injury date. Twenty-five percent of the subjects reported having their ankles taped, 12.5% of the subjects reported getting their ankle either taped on some days or using their braces on other days, another 12.5% of the subjects reported getting their ankle taped but not on a daily basis, and 50% of the subjects reported no form of taping or bracing.
### Table 2

<table>
<thead>
<tr>
<th>Athlete’s Sport and Group Classification</th>
<th>CP</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseball</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Basketball, female</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Basketball, male</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Diver, male</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Field Hockey</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Football</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Lacrosse, female</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Softball</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Track &amp; Field, female</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Volleyball, female</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Wrestling, male</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

The CC group consisted of three male basketball players, two female volleyball players, a female basketball player, a lacrosse player, and a female track and field athlete, Table 2. All of the subjects inverted their ankle and were diagnosed with a grade 1 ankle sprain. One of the subjects injured their right ankle and 87.5% of the subjects injured their left ankle. Thirty-seven and a half percent of the subjects injured their ankle between 7:00 a.m.-11:00 a.m., 37.5% of the subjects injured their ankle between 11:30 a.m.-3:00 p.m., and 12.5% of the subjects injured their ankle between 3:30 p.m.-7:00
p.m. Seventy-five percent of the subjects received a bag of ice within 24 hours of the injury and 25% of the subject’s first treatment was the cryo/cuff. All of the subjects received treatment between 11:00 a.m.-3:00 p.m. Thirty-seven and a half percent of the subjects had never injured their ankle before, 12.5% of the subjects sprained their ankle one year ago, 12.5% of the subjects sprained their ankle two years ago, another 12.5% of the subject sprained their ankle three years ago, and 25% of the subjects sprained their ankle four years ago. All of the subjects reported no surgery on their ankle prior to their injury date. Fifty percent of the subjects reported having their ankles taped, 12.5% of the subjects reported having their ankles braced, and 37.5% of the subjects reported no form of taping or bracing.

**Analysis of Variance Results**

**Pre/post mean differences figure 8 measurements.** Descriptive statistics for mean differences figure 8 measurements are presented in Table 3 and graphically in Figure 1. A Factorial ANOVA summary is presented in Table E1 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated a significant group by day interaction for mean differences figure 8 measurements ($F_{2, 28} = 4.72, p = .02$). Pairwise comparisons revealed a significant day x group interaction between day 1 and day 2 ($F_{1, 14} = 8.93, p = .01$) and no significant day x group interaction between day 1 and day 3 ($F_{1, 14} = 3.28, p = .09$) and day 2 and day 3 ($F_{1, 14} = 1.29, p = .31$) for mean differences. A complete pairwise comparison is presented in Table E2 (see Appendix E). The data also indicated a significant between-subjects main effect ($F_{1, 14} = 13.25, p = .00$). A complete between-subject summary is presented in Table E3 (see Appendix E). A $t$-tests identified no significant difference on day 1 between groups ($t_{14} = 0.34, p = .74$) but did reveal a
significant difference on day 2 between groups ($t_{14} = 4.30, p = .00$) and on day 3 ($t_{14} = 3.37, p = .00$).

Table 3

Pre/Post Mean Differences Figure 8 Measurements (cm)

<table>
<thead>
<tr>
<th>Day</th>
<th>M</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CP</td>
<td>CC</td>
<td>CP</td>
</tr>
<tr>
<td>1</td>
<td>-.39</td>
<td>-.44</td>
<td>0.23</td>
</tr>
<tr>
<td>2</td>
<td>-.52</td>
<td>-.07</td>
<td>0.24</td>
</tr>
<tr>
<td>3</td>
<td>-.47</td>
<td>-.16</td>
<td>0.15</td>
</tr>
</tbody>
</table>

*Note. cm = centimeters*
Figure 1. Pre/post mean differences figure 8 measurements for CP ($N = 8$) and CC ($N = 8$) groups on days 1, 2, and 3 of treatment. * $p < .05$ between groups.

**Pre treatment figure 8 measurements over time.** Descriptive statistics for pre treatment figure 8 measurements are presented in Table 4 and graphically in Figure 2. A Factorial ANOVA summary is presented in Table E4 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated a significant group by day interaction ($F_{2, 28} = 4.04, p = .03$) and day main effect ($F_{2, 28} = 49.62, p = .00$) for pre treatment figure 8 measurements. Pairwise comparisons revealed a significant day main effect between day 1 and day 2 ($F_{1, 14} = 10.24, p = .01$), between day 1 and day 3 ($F_{1, 14} = 121.93, p = .00$),
and between day 2 and day 3 ($F_{1,14} = 36.73, p = .00$). A significant day x group interaction occurred between day 2 and day 3 ($F_{1,14} = 6.39, p = .02$) but no significant day x group interaction between day 1 and day 2 ($F_{1,14} = 4.17, p = .06$) and day 1 and day 3 ($F_{1,14} = 0.45, p = .52$) for pre treatment figure 8 measurements. A complete pairwise comparison is presented in Table E5 (see Appendix E). The data also indicated no significant between-subjects main effect ($F_{1,14} = 1.83, p = .20$). A complete between-subject summary is presented in Table E6 (see Appendix E).

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>CP</td>
<td>CC</td>
<td>CP</td>
</tr>
<tr>
<td>1</td>
<td>53.29</td>
<td>55.88</td>
<td>4.28</td>
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<tr>
<td>2</td>
<td>53.17</td>
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</tr>
<tr>
<td>3</td>
<td>52.29</td>
<td>54.99</td>
<td>4.30</td>
</tr>
</tbody>
</table>

*Note.* cm = centimeters
Figure 2. Pre treatment figure 8 measurements across time for CP \((N = 8)\) and CC \((N = 8)\) groups on days 1, 2, and 3 of treatment. ** \(p < .05\) between day 1 and 3, ++ \(p < .05\) between day 2 and 3, ^^ \(p < .05\) between day 1 and 2.

Post treatment figure 8 measurements over time. Descriptive statistics for post treatment figure 8 measurements are presented in Table 5 and graphically in Figure 3. A Factorial ANOVA summary is presented in Table E7 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated a significant group by day interaction \((F_{2,28} = 7.43, p = .00)\) and day main effect \((F_{2,28} = 57.95, p = .00)\) for post treatment figure 8 measurements. Pairwise comparisons revealed a significant day main effect.
between day 1 and day 2 ($F_{1, 14} = 9.72, p = .01$), between day 1 and day 3 ($F_{1, 14} = 127.57, p = .00$), and between day 2 and day 3 ($F_{1, 14} = 44.11, p = .00$). A significant day x group interaction occurred between day 2 and day 3 ($F_{1, 14} = 5.01, p = .04$) and between day 1 and day 3 ($F_{1, 14} = 16.78, p = .00$) but no significant day x group interaction between day 1 and day 2 ($F_{1, 14} = 1.80, p = .20$) for post treatment figure 8 measurements. A complete pairwise comparison is presented in Table E8 (see Appendix E). The data also indicated no significant between-subjects main effect ($F_{1, 14} = 2.12, p = .17$). A complete between-subject summary is presented in Table E9 (see Appendix E).

The CP group had a greater reduction in ankle edema (0.52 ± 0.08 cm, $SD = 0.24$) compared to the CC group (0.07 ± 0.63 cm, $SD = 0.18$) over the 3 day treatment period.

Table 5

<table>
<thead>
<tr>
<th></th>
<th>$M$</th>
<th>$SD$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>CP</td>
<td>CC</td>
<td>CP</td>
</tr>
<tr>
<td>1</td>
<td>53.02</td>
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<td>2</td>
<td>52.66</td>
<td>55.29</td>
<td>4.37</td>
</tr>
<tr>
<td>3</td>
<td>51.76</td>
<td>54.85</td>
<td>4.28</td>
</tr>
</tbody>
</table>

*Note. cm = centimeters*
Figure 3. Post treatment figure 8 measurements across time for CP ($N = 8$) and CC ($N = 8$) groups on days 1, 2, and 3 of treatment. ** $p < .05$ between day 1 and 3, ++ $p < .05$ between day 2 and 3, ^^ $p < .05$ between day 1 and 2.

Pre/post mean differences volumetric measurements. Descriptive statistics for mean differences volumetric measurements are presented in Table 6 and graphically in Figure 4. A Factorial ANOVA summary is presented in Table E10 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated no significant group by day interaction for volumetric measurements ($F_{2, 28} = 0.19, p = .83$). The data also
indicate no significant differences between-subjects main effect ($F_{1, 14} = 2.27, p = .15$), Table E11 (see Appendix E).

Table 6

Pre/Post Mean Differences Volumetric Measurements (ml)

<table>
<thead>
<tr>
<th>Day</th>
<th>CP</th>
<th>CC</th>
<th>CP</th>
<th>CC</th>
<th>CP</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-31.00</td>
<td>-28.75</td>
<td>18.88</td>
<td>17.06</td>
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<td>8</td>
</tr>
<tr>
<td>2</td>
<td>-25.63</td>
<td>-16.88</td>
<td>20.78</td>
<td>10.67</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>-28.13</td>
<td>-21.25</td>
<td>7.99</td>
<td>7.44</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

*Note:* ml = millimeters
Figure 4. Pre/post mean differences volumetric measurements for CP (N = 8) and CC (N = 8) groups on days 1, 2, and 3 of treatment.

*Pre treatment volumetric measurements over time.* Descriptive statistics for pre treatment volumetric measurements are presented in Table 7 and graphically in Figure 5. A Factorial ANOVA summary is presented in Table E12 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated no significant group by day interaction ($F_{2,28} = 0.67, p = .52$) and a significant day main effect ($F_{2,28} = 10.53, p = .00$) for pre treatment volumetric measurements. Pairwise comparisons revealed a significant day main effect between day 1 and day 2 ($F_{1,14} = 6.80, p = .02$), between day 1 and day 3
(\(F_{1,14} = 35.03, p = .00\)), but no significance between day 2 and day 3 \((F_{1,14} = 2.54, p = .13\)). A complete pairwise comparison is presented in Table E13 (see Appendix E). The data also indicated no significant between-subjects main effect \((F_{1,14} = 1.08, p = .32\)). A complete between-subject summary is presented in Table E14 (see Appendix E).

### Table 7

<table>
<thead>
<tr>
<th></th>
<th>Pre Treatment Volumetric Measurements (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(M)</td>
</tr>
<tr>
<td>Day</td>
<td>CP</td>
</tr>
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<td>2</td>
<td>1310.63</td>
</tr>
<tr>
<td>3</td>
<td>1290.63</td>
</tr>
</tbody>
</table>

*Note.* ml = millimeters
Figure 5. Pre treatment volumetric measurements across time for CP (N = 8) and CC (N = 8) groups on days 1, 2, and 3 of treatment. ** p < .05 between day 1 and 3, ^^ p < .05 between day 1 and 2.

*Post treatment volumetric measurements over time.* Descriptive statistics for post treatment volumetric measurements are presented in Table 8 and graphically in Figure 6. A Factorial ANOVA summary is presented in Table E15 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated no significant group by day interaction (\(F_{2,28} = 1.28, p = .29\)) and a significant day main effect (\(F_{2,28} = 14.39, p = .00\)) for post volumetric measurements. Pairwise comparisons revealed a significant day main
effect between day 1 and day 3 \((F_{1, 14} = 36.75, p = .00)\) and between day 2 and day 3 \((F_{1, 14} = 8.70, p = .01)\) but no significant day main effect between day 1 and day 2 \((F_{1, 14} = 4.34, p = .06)\). A complete pairwise comparison is presented in Table E16 (see Appendix E). The data also indicated no significant between-subjects main effect \((F_{1, 14} = 1.28, p = .28)\). A complete between-subject summary is presented in Table E17 (see Appendix E).

Table 8

Post Treatment Volumetric Measurements (ml)

<table>
<thead>
<tr>
<th>Day</th>
<th>CP</th>
<th>CC</th>
<th>CP</th>
<th>CC</th>
<th>N</th>
<th>N</th>
</tr>
</thead>
<tbody>
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<tr>
<td>2</td>
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<td>1393.13</td>
<td>263.37</td>
<td>167.95</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

*Note. ml = millimeters*
Figure 6. Post treatment volumetric measurements across time for CP ($N = 8$) and CC ($N = 8$) groups on days 1, 2, and 3 of treatment. ** $p < .05$ between day 1 and 3, ++ $p < .05$ between day 2 and 3.

Pre/post mean differences pain measurements. Descriptive statistics for mean differences pain measurements are presented in Table 9 and graphically in Figure 7. A Factorial ANOVA summary is presented in Table E18 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated a significant group by day interaction for mean differences pain measurements ($F_{2, 28} = 10.80, p = .00$) and day main effect ($F_{2, 28} = 9.37, p = .00$). Pairwise comparisons revealed a significant day x group interaction
between day 1 and day 2 ($F_{1,14} = 16.61, p = .00$), day 1 and day 3 ($F_{1,14} = 5.73, p = .03$), and day 2 and day 3 ($F_{1,14} = 7.60, p = .02$) for mean differences. Pairwise comparison also revealed a significant day main effect between day 1 and day 2 ($F_{1,14} = 6.73, p = .02$), between day 1 and day 3 ($F_{1,14} = 15.90, p = .00$), but no significant day main effect between day 2 and day 3 ($F_{1,14} = 2.74, p = .12$). A complete pairwise comparison is presented in Table E19 (see Appendix E). The data indicated no significant between-subjects main effect ($F_{1,14} = 0.12, p = .74$). A complete between-subject summary is presented in Table E20 (see Appendix E). A $t$-test identified no significant difference on day 1 between groups ($t_{14} = 3.18, p = .10$) but did reveal a significant difference on day 2 between groups ($t_{14} = 5.73, p = .03$).

Table 9

Pre/Post Mean Differences Pain Measurements (VAS)

<table>
<thead>
<tr>
<th>Day</th>
<th>$M$</th>
<th>$SD$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CP</td>
<td>CC</td>
<td>CP</td>
</tr>
<tr>
<td>1</td>
<td>0.50</td>
<td>1.13</td>
<td>0.76</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>0.00</td>
<td>0.89</td>
</tr>
<tr>
<td>3</td>
<td>0.25</td>
<td>0.13</td>
<td>0.46</td>
</tr>
</tbody>
</table>
Figure 7. Pre/post mean differences pain measurements (VAS) for CP ($N = 8$) and CC ($N = 8$) groups on days 1, 2, and 3 of treatment. * $p < .05$ between groups, + = CC mean difference pain measurements = 0.

**Pre treatment pain measurements over time.** Descriptive statistics for pre treatment pain measurements are presented in Table 10 and graphically in Figure 8. A Factorial ANOVA summary is presented in Table E21 (see Appendix E). Results of the 2(Groups) x 3(Days) Factorial ANOVA indicated a significant group by day interaction ($F_{2, 28} = 3.48, p = .04$) and a significant day main effect ($F_{2, 28} = 43.72, p = .00$) for pre treatment pain measurements. Pairwise comparisons revealed a significant day main
effect between day 1 and day 2 ($F_{1,14} = 18.29, p = .00$), between day 1 and day 3 ($F_{1,14} = 66.96, p = .00$), and between day 2 and day 3 ($F_{1,14} = 37.19, p = .00$). There was a significant day x group interaction between day 1 and day 2 ($F_{1,14} = 5.65, p = .03$) and between day 2 and day 3 ($F_{1,14} = 6.83, p = .02$), but no significant day main effect between day 1 and day 3 ($F_{1,14} = 0.04, p = .84$) for pre treatment pain measurements. A complete pairwise comparison is presented in Table E22 (see Appendix E). The data also indicated no significant between-subjects main effect ($F_{1,14} = 0.23, p = .64$). A complete between-subject summary is presented in Table E23 (see Appendix E).

Table 10

Pre Treatment Pain Measurements (VAS)

<table>
<thead>
<tr>
<th>Day</th>
<th>M</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CP</td>
<td>CC</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5.56</td>
<td>5.63</td>
<td>1.84</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>3.19</td>
<td>3.13</td>
<td>2.00</td>
</tr>
</tbody>
</table>
Figure 8. Pre treatment pain measurements (VAS) across time for CP ($N = 8$) and CC ($N = 8$) groups on days 1, 2, and 3 of treatment. ** $p < .05$ between day 1 and 3, ++ $p < .05$ between day 2 and 3, ^^ $p < .05$ between day 1 and 2.

Post treatment pain measurements over time. Descriptive statistics for post treatment pain measurements are presented in Table 11 and graphically in Figure 9. A Factorial ANOVA summary is presented in Table E24 (see Appendix E). Results of the 2 (Groups) x 3 (Days) Factorial ANOVA indicated a significant day main effect for pain measurements ($F_{2, 28} = 22.96, p = .00$) but no significant day x group interaction ($F_{2, 28} = 0.75, p = .48$). Pairwise comparison revealed a significant day main effect between day 1
and day 2 ($F_{1, 14} = 5.47, p = .04$), between day 1 and day 3 ($F_{1, 14} = 35.25, p = .00$), and day 2 and day 3 ($F_{1, 14} = 32.40, p = .00$), Table E25 (see Appendix E). The data indicated no significant difference between-subjects main effect ($F_{1, 14} = 0.14, p = .72$), Table E26 (see Appendix E).

Table 11

<table>
<thead>
<tr>
<th>Post Treatment Pain Measurements (VAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>M</strong></td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>Day 1</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>
Figure 9. Post treatment pain measurements (VAS) across time for CP ($N = 8$) and CC ($N = 8$) groups on days 1, 2, and 3 of treatment. ** $p < .05$ between day 1 and 3, ++ $p < .05$ between day 2 and 3, ^^ $p < .05$ between day 1 and 2.

Relationship Between Figure 8 and Volumetric Measurements

A Pearson product-moment correlation was conducted to determine the overall relationship between figure 8 and volumetric measurements. Results of the Pearson correlation indicated a high correlation between figure 8 and volumetric measurements ($r = .93$).
Summary of Results

A 2x3 (group x day) Factorial ANOVA was performed on group data for each of the variables (edema and pain) for mean differences and overall pre and post measurements. The alpha level was set at 0.05 ($p < .05$). Results of the repeated measures ANOVA indicated a significant group x day interaction and between-subject main effect for mean differences figure 8 measurements. Data also indicated a significant group x day pre and post treatment figure 8 measurements, and pre treatment pain measurements. A significant day main effect for was observed with pre and post treatment figure 8 measurements, pre and post treatment volumetric measurements and pre and post treatment pain measurements. However, the data indicated no significant group x day interaction for mean differences volumetric measurements on each day, for pre and post treatment volumetric measurements, or for post treatment pain measurements. The data also revealed no significant between-subject main effect for mean differences volumetric measurements, for pre and post treatment volumetric measurements, pre and post treatment figure 8 measurements and for post treatment pain measurements. However, the data indicated a significant between-subject main effect for pre treatment pain measurements.

A pairwise comparison analyses was performed on mean differences figure 8 and pain data and pre and post treatment figure 8, volumetric, and pain data to determine significant differences between group and day interactions and day main effects. Results for mean differences figure 8 measurements revealed a significant day x group interaction between day 1 and day 2 and no significant day x group interaction between day 1 and day 3 and day 2 and day 3. Results for the pre and post treatment figure 8 measurements
revealed a significant day main effect between day 1 and 2, day 1 and 3, and day 2 and 3. A significant group x day interaction occurred between day 2 and 3 for pre treatment figure 8 measurements and day 1 and 3 and day 2 and 3 for post treatment figure 8 measurements. Results for pre treatment volumetric measurements revealed a significant day main effect between day 1 and 2 and day 1 and 3. Results for post treatment volumetric measurements revealed a significant day main effect between day 1 and 3 and day 2 and 3. Results for the pre treatment pain measurements revealed a significant day x group interaction between day 1 and 2 and day 2 and 3. Results also revealed a significant day main effect for pre treatment pain measurements to occur between day 1 and 2, day 1 and 3, and day 2 and 3. Results for post treatment pain measurements revealed there was no significant day main effect between day 1 and day 2 but there was a significant day main effect between day 1 and day 3.

Independent t-test analyses were also performed post hoc on figure 8 and pain data to determine significant differences between the two groups for figure 8 and pain measurements. Results revealed there was no significant difference on day 1 for figure 8 measurements. However, there was a significant difference between groups on day 2 and day 3 of the figure 8 measurements. Results also revealed there was no significant difference on day 1 for pain measurements. However, there was a significant difference between groups on day 2 of pain measurements.

Data was also normalized to a percentage of day one to see how the volumetric and figure 8 measurement percentages differed. The results indicated there was a 22% greater difference in measurements with the volumetric method measuring greater. A Pearson product-moment correlation was also conducted to observe the relationship
between figure 8 and volumetric measurements. Data revealed there is a high correlation ($r = .93$) between figure 8 and volumetric measurements.
Chapter 5

Discussion

The purpose of this study was to compare the effects of the cryopress and cryo/cuff treatments on ankle edema and pain after 3 consecutive days of treatment in Division I varsity athletes. The results of this study suggest that both the cryopress and cryo/cuff decrease ankle edema and pain levels in first degree inversion ankle sprains.

When an injury occurs, changes take place in the injured tissue. Damaged tissue becomes debris that needs to be removed from the area for new cells to replace the damaged ones. The presence of cellular debris releases chemical mediators (histamine, leucotaxin, necrosin) that informs the body that an injury has occurred. Blood hemorrhages from the broken vessels and leaks into the extravascular spaces, causing swelling (Houglum, 1992; Knight, 1995; Merrick, 2002; Starkey, 1993; Prentice & Voight, 2001). These events occur within the first hours of a soft tissue injury.

However, hemorrhaging occurs for a short period of time and then edema starts to form. To stop an increase in edema, the body responds by plugging the injured area with fibrin causing a hematoma to form. This is followed by the four phases of inflammatory response: hemodynamic changes, permeability changes, leukocyte migration and phagocytosis (Houglum, 1992; Knight, 1995; Merrick, 2002; Starkey, 1993). It is at this point that the inflammation response may be having an effect on the results of the present study. It is also at this time, that leukocytes are being released into the injured tissue. Leukocytes breakdown the debris (free protein) of damaged tissues and the hematoma and send it through the lymphatic system. Once the debris is removed, wound healing can take place (Houglum; Knight; Merrick; Starkey; Prentice & Voight, 2001). The cryopress
and cryo/cuff are observed to be beneficial in treating acute soft tissue damage and decreasing ankle edema over 3 treatments and during each individual treatment in the present study. The cryopress and cryo/cuff are theorized to decrease ankle edema due to their compression and cryotherapy components.

Knight (1995) states that cryotherapy’s ability to decrease temperature, metabolism, and cell permeability causes vasoconstriction of the blood vessels, which prevents edema from forming and decreases current edema in an injury site (Arnheim & Prentice, 2000; Jutte et al., 2001; Knight; Prentice, 1999; Starkey, 1993). A decrease in edema reduction is supported in the present study for both figure 8 and volumetric measurements. Results of this study revealed that the least amount of edema was present in the ankle for both the CP and CC groups on day 3 compared to day 1 and day 2. These results are theorized to be due to cryotherapy’s effects on the inflammation process and its role in controlling and preventing further edema. Smith (2003) supports the theory that cryotherapy has an effect on the inflammation process of ankle edema. Therefore, the cryopress and cryo/cuff are useful modalities for decreasing acute ankle edema in the clinical setting.

Results from the present study show that there is a gradual decrease in edema over time for figure 8 measurements. The cryopress is observed to decrease the amount of edema in the ankle more than the cryocuff over time for figure 8 measurements between all 3 testing days. This may be due to the sequential intermittent component of the cryopress that is increasing the function of the venous and lymphatic system. The greatest difference between days is occurring between day 2 and day 3 for the CP group. However, the CC group is significantly different between day 1 and day 3 meaning that
the cryo/cuff is reducing ankle edema over the 3 days of treatment. Therefore, both the cryopress and cryo/cuff are beneficial in decreasing ankle edema.

Volumetric measurements over time are observed to have similar results for both groups and that the day is a factor in the decrease in edema. Pre treatment volumetric measurements show that between day 1 and day 3 there is a decrease in ankle edema and between day 2 and day 3. This may be due to the cryotherapy’s effects on secondary injury and prevention of further edema from accruing or the reduction in current edema. Post treatment volumetric measurements show that the difference in ankle edema was occurring between day 1 and day 3 and between day 1 and day 2 for both groups. Again, edema is being reduced over the total time of the treatment, revealing that cryotherapy is beneficial in the acute care of ankle sprains. However, there is also a significant difference between day 1 and day 2. This may be caused by the inflammation process and how cryotherapy and compression are affecting edema. Possible reasons for similar volumetric measurements between the groups can be due to the fact that the cryo/cuff may be displacing the edema to another area of the lower leg other than the ankle joint. It is possible the volumetric measurements are not significant between the groups because the fluid is still in the lower leg but not the ankle joint for the CC group. Edema displacement for the cryopress may be farther down the leg than the cryo/cuff due to its sequential component and compression form the foot to the upper thigh.

Mean differences figure 8 measurements showed there was a significant day x group interaction occurring as well as a between subjects main effect, specifically on day 2 and day 3 (Figure 10). Possible reasons for the difference between the two groups’ mean differences measurements could be the sequential intermittent component of the
cryopress. Results from this study show that the cryopress had a greater difference in pre and post measurements for individual treatments for ankle edema reduction than the cryo/cuff. Intermittent compression’s role in decreasing edema is theorized to increase the venous and lymphatic system. The lymphatic system is the movement of fluids out of an extremity due to a formation of two pressure gradients.

Figure 10: Edema differences between days for figure 8 measurements (cm) for CP group \((N = 8)\) and CC group \((N = 8)\) between days 1, 2, and 3.

The first gradient is between tissues and capillaries. When compression is applied, the hydrostatic pressure of the capillaries decreases and encourages reabsorption of interstitial fluids through the lymph system. Since the lymphatic system is passive,
external forces (muscular contraction) are needed to promote fluid movement (Knight, 1995). The intermittent aspect of the cryopress is similar to exercise and muscle contractions that aid in the activation of the lymphatic system. Mora et al. (2002) studied pulsatile cold compression on ankle fractures and concluded that intermittent cold compression stimulates weight bearing. Weight bearing activates the lymphatic system by increasing arterial flow which causes capillaries to open and increase osmotic reabsorption. The osmotic reabsorption causes lymph flow and removal of debris from the injury site. The removal of debris promotes tissue healing and recovery from the injury (Knight). The second gradient is between the distal and proximal movement of the fluid due to elevation of the sequential intermittent compression. Gravity helps move the fluid from higher pressure (ankle) to lower pressure (thigh). The force of gravity assists with the return of fluid back to the heart via the venous and lymphatic system and decreases the hydrostatic pressure by resisting flow into the elevated peripheral vessels. The sequential component of the cryopress may be helping with this process by applying pressure throughout the leg and greater amounts of pressure distally than proximally.

Another reason why there may be differences between the two groups for figure 8 measurements may be the accuracy of the figure 8 measurements. The proper way to conduct a figure 8 measurement of the ankle is to place the ankle in 90° of dorsiflexion. However, when edema is present in an ankle, subjects are not able to dorsiflex their ankle to 90°. The lack of consistency in the ankle angle may be affecting the results of the figure 8 measurements in this study causing the difference between the subject’s pre and post measurements.
Figure 8 measurements are a quick way to test girth measurements and are useful in the clinical setting. However, they are not as accurate as volumetric measurements because they are often done incorrectly and landmarks are not followed (Arnheim & Prentice, 2000). Brijker et al. (2000) studied both volumetric and figure 8 measurements and found that volumetric measurements showed a greater decrease in edema than figure 8 measurements. It is possible that the present study revealed significant results for figure 8 measurements because they are not as accurate a measurement as volumetry and can have high variability.

Mean differences volumetric measurements for this study showed no significant day x group interaction or between groups main effect. However, results of this study show that the CP groups had a greater decrease in ankle edema for individual treatment measurements than the CC group for volumetric measurements. A possible reason why there may be a difference between the CP and CC groups on each individual treatment day could be the intermittent compression component of the cryopress, which was discussed earlier. However, possible reasons for a lack of significance can be that the volumetric measurements are more accurate than figure 8 measurements. Martin (1997), Ciotti et al. (2002), and Wilson et al. (1998) studied the validity and reliability of volumetric measurements. They all found that volumetric measurements are valid and reliable techniques for girth measurements. Ciotti et al. tested intertester reliability of volumetric measurements and found them to be valid and reliable. Martin conducted a similar study of inter and intra-observer variability and found variability to be low. While, Wilson et al. found that the same occasion of measurements and test-retest parameters have low proportion of measurements error with volumetric measurements.
Therefore, there is less variability within the measurements. This can be why there is a difference in results between figure 8 and volumetric measurements for each individual treatment day.

Another reason may be that to test volumetric measurements the ankle is placed in a gravity-dependent position. By placing the ankle in a gravity-dependent position the effects of the compression treatment are being reversed. The hydrostatic pressures of the capillaries that were decreased during treatment due to compression are increasing once the ankle is placed in a gravity-dependent position. The gravity-dependent position causes the volume of the ankle to increase. Tsang et al. (2003) conducted a study on elevation and intermittent compression and how long the effects of those two treatments lasted in injured ankles. They found that the injured ankle returned to its baseline measurements within less than 5 minutes after the ankle was returned to a gravity-dependent position. Subjects within the present study had to walk from the cryopress area to the testing area due to the set up of the athletic training room. The subject’s ankle was not only placed in a gravity-dependent position it was also being walked on. These actions may have allowed edema to begin to move back into the ankle and affected volumetric measurements for the cryopress.

Looking at volumetric measurements closer, it is apparent that both groups showed a similar decrease in ankle edema for each individual treatment. Both groups were observed to have a smaller decrease in ankle edema on day 2 and a greater decrease in ankle edema on day 1 and day 3 (Figure 11). Possible reasons for this observation may be the compression component of the modalities rather than the cold function of the
modal. It is theorized that compression plays more of a role in decreasing edema than cold alone.

Knight (1995) states that cold therapy alone does not remove edema but that a modality with compression is responsible for removing edema. It is theorized that the compression retards or causes reabsorption of swelling by decreasing the pressure gradient between blood vessels and tissue (Houglum, 1992; Knight; Starkey, 1993). Both the cryopress and cryo/cuff function as a compression modality. Levy and Marmar

![Graph showing edema differences between days for volumetric measurements (ml) for CP group (N = 8) and CC group (N = 8) between days 1, 2, and 3.](image-url)
(1993) studied cold compression in post-operation total knee arthroplasty (TKA) patients and theorized that the additional pressure of compression affects the capillaries. Pressure on the capillaries prevents gross fluid leakage from occurring within the soft tissue injury site and reduces edema. Compression plays an important part in the lymphatic system and its role in removing debris from the injury site.

Knight (1995) also states that once edema forms it is not able to be prevented. Therefore, once edema is present, modalities can only remove it and/or prevent further edema from forming. Subjects within this study were in-season and out-season athletes. In-season athletes have a certified athletic trainer present at practices and games. Out-season athletes do not always have a certified athletic trainer present at practices. This affects this study because the in-season athletes will receive initial treatment of an ice bag earlier than the out-season athletes. This can affect when primary and secondary injury ends and begins. It is theorized that cryotherapy retards secondary injury. The sooner cryotherapy is applied, the sooner the metabolic rate is decreased and the less secondary injury occurs. Therefore, some subjects within this study may have retarded his or her secondary injury earlier than other subjects. This can have an affect on the amount of edema present in the ankle and affect the results of this study.

An interesting aspect of this study is the fluctuation in mean differences measurements on each individual day of treatment for figure 8 and volumetric measurements. The greatest amount of edema reduction for mean differences measurements occurs on day 1 for all groups and forms of measurement except for the CP group for figure 8 measurements. It is possible that on day 1 of this study there was the most amount of edema present to be removed during treatment. However, day 2
shows a smaller amount of decrease in edema between pre and post measurements than
day 1 and day 3 except for CP group for figure 8 measurements. The differences in the
amount of mean differences measurements on each day can be due to when primary and
secondary injury is occurring and what the chemical mediators and leukocytes are doing
in the injured area. Secondary injury causes edema to form within an injured area. It is
possible that in this study secondary injury has already started on day 1 and then had an
affect on day 2 and 3 measurement results. However, chemical mediators and leukocytes,
such as neutrophils, basophils, and macrophages may be more prominent on one day of
treatment compared to another day. Macrophages and neutrophils not only help the
injured tissue but they are also capable of giving off chemical mediators that continue the
inflammation process. It is possible that chemical mediators where in greater amounts on
day 1 and day 3 than day 2. Therefore, there was more edema present, which caused a
greater difference in mean differences measurements to occur on day 1 and day 3.

The final variable studied in the present study was pain. The results from the
present study show that post treatment pain measurements were significantly decreased
over the 3 day treatment period (Figure 12). Levy and Marmar (1993) observed cold
compression dressing decreased pain levels of total knee arthroplasty patients. Similarly,
Gibbons et al. (2001) observed that pain was significantly decreased after using a cold
compression (cryo/cuff) for 10 days on total knee replacement patients. Dervin et al.
(1998) also studied pain levels and found that pain levels were reduced in arthroscopic
ACL surgeries when using a cold compression modality. Data from the present study
agrees with Levy and Marmar, Gibbons et al., and Dervin et al. and supports the theory
that cryotherapy may play a role in decreasing pain levels after an acute soft tissue injury.
Results from the mean differences pain measurements observed that the CP group had a greater decrease in pain levels for individual treatments on day 2 than days 1 and 3 compared to the CC group. The CC group had its smallest decrease in pain levels on day 2 compared to day 1 and day 3. The decrease in pain may be due to how effectively these modalities are staying at a consistent temperature and pressure throughout the treatment. The cryopress regulates itself to stay at the parameters it is set at. However, the cryo/cuff’s pressure depends on the clinician applying the modality and the size of the foot it is being applied too. The temperature of the cryo/cuff can vary throughout treatment as well. Compression has an affect on tissue temperatures and temperature has an affect on nerve conduction velocity. The lower the temperature the slower the nerve
conduction velocity and the less pain the subject feels. Therefore, the cryopress may be having a greater decrease in pain levels for individual treatments than the cryo/cuff due to its ability to self regulate its parameters.

It is theorized that anesthetic effects of local cooling is due primarily to slowing or elimination of pain signal transmission. Cold therapy affects pain perception and transmission by interrupting pain transmission and decreasing nerve conduction velocity. Cold therapy stimulates the large-diameter neurons, preventing pain transmission from occurring by acting as a counterirritant and decreasing the speed of nerve conduction by slowing communication at the synapse (Starkey, 1993). It is also theorized that the cooling effect acts on peripheral nerves to increase pain thresholds (Smith et al., 2002).

When considering what modality to use for an acute soft tissue injury, the purpose of the treatment needs to be considered. Immediately after an injury cold therapy is used to prevent swelling, edema, and pain. However, if treatment is occurring hours or days past the initial injury, removal of edema becomes the purpose of the treatment. Knight (1995) states that compression is needed to remove edema. The present study supports that theory and revealed that both the cryopress and cryo/cuff decrease ankle edema over a 3 day treatment period.

However, determining significant results for mean differences in edema reduction for the present study depends on the modality used to measure ankle edema. For significant results, figure 8 measurements are to be conducted and for non-significant results, volumetric measurements are to be conducted. However, a continuous decrease in ankle edema was observed in this study for both modalities. There is variance in the amount of edema reduced on each individual day of treatment. This variation leaves
questions as to why some days decrease more edema than others. The inflammation and healing phases is theorized to play a role in causing the changes in edema reduction and need to be taken into consideration when observing ankle edema.

The present study also showed that both groups decreased in their pain levels over time. There was no difference between the CP and CC group for pain measurements. Therefore, if pain reduction is a goal of an ankle sprain treatment protocol, either the cryopress or cryo/cuff can be used.

**Conclusions**

Within the limitations of this study, the results suggest the following conclusions:

1. There was a significant day x group interaction for pre treatment figure 8 measurements meaning that there was a decrease in ankle edema for both groups over the entire treatment time.

2. There was a significant day main effect between day 1 and day 2, day 1 and day 3, and day 2 and day 3 for pre treatment figure 8 measurements meaning there was a significant difference in ankle edema between days.

3. There was a significant day x group interaction for post treatment figure 8 measurements meaning there was a decrease in ankle edema for both groups over the entire treatment time.

4. There was a significant day main effect between day 1 and day 2, day 1 and day 3, and day 2 and day 3 for post treatment figure 8 measurements meaning that ankle edema decreased significantly between the days.
5. There was no significant between subject main effect for pre or post treatment figure 8 measurements over time meaning that there is no difference in ankle edema due to which treatment the subject received.

6. There was a significant group by day interaction for mean differences figure 8 measurements meaning both the cryopress and cryo/cuff effects ankle edema during the cryotherapy treatment.

7. Significance was found between day 1 and day 2 for mean differences figure 8 measurements meaning between day 1 and day 2 the cryo/cuff had a greater effect on ankle edema on day 1 than day 2.

8. There was a significant difference between-subject main effect for mean difference figure 8 measurements meaning a difference existed between the CP and CC groups for figure 8 measurements.

9. The CP group had a greater reduction in ankle edema on day 2 than day 1 and day 3 for mean difference figure 8 measurements.

10. There was no significant day x group interaction for pre or post treatment volumetric measurements meaning that there is no difference between the groups or day of the cryotherapy treatment over the entire treatment time.

11. There was a significant day main effect for pre treatment volumetric measurements between day 1 and day 2 and day 1 and day 3 meaning that over time ankle edema decreased and that there was a significant decrease in edema between day 1 and day 2 as well.
12. Significant day main effect for post treatment volumetric measurements was found between day 1 and day 3, and day 2 and day 3 meaning ankle edema decreased over time for volumetric measurements and between day 2 an day 3.

13. There was no significant difference between subjects for both the pre and post treatment volumetric measurements meaning the type of modality used to decrease ankle edema over time can be either the cryopress or cryo/cuff.

14. There was no significant group by day interaction for mean differences volumetric measurements meaning both groups demonstrated similar ankle edema reduction during individual treatments of cryotherapy.

15. There was no significant differences between-subject main effect for mean differences volumetric measurements meaning both groups were similar with their ankle edema reduction.

16. There was a significant day x group interaction for pre treatment pain measurements between day 1 and day 3 and day 2 and day 3 meaning that pain measurements decreased over time with cryotherapy treatments and between day 2 and day 3.

17. Significant day main effects were found between day 1 and day 2, day 1 and day 3, and day 2 and day 3 for pre treatment pain measurements meaning that pain levels were lowered as the treatment continued.

18. Significant between subjects was found for pre treatment pain measurements meaning that the two groups had different effects on pain measurements.

19. Significant difference between groups occurred on day 2 when CP group had a greater pain level for pre treatment pain measurements than CC group.
20. There was a significant day effect for post treatment pain measurements meaning there was a difference in pain measurements over the 3 treatment days.

21. There was a significant day main effect for post treatment pain measurements between day 1 and day 3 and day 2 and day 3 meaning between day 1 and day 3 and day 2 and day 3 the pain measurements for both the cryopress and cryo/cuff groups decreased over the 3 days of treatment.

22. There was no significant differences between-subject main effect for post treatment pain measurements meaning both groups demonstrated similar pain levels throughout the treatment period.

23. There was a significant day x group interaction for mean differences pain measurements between day 1 and day 2, day 1 and day 3, and day 2 and day 3 meaning that pain decreased between the groups and days on individual treatments.

24. There was a significant day main effect for mean differences pain measurements between day 1 and day 2, and day 1 and day 3 meaning that pain was decreased between day 1 and day 2, and day 1 and day 3.

25. There was no significant between subjects main effect for mean differences pain measurements meaning there is no differences in pain between the groups.

Recommendations

The following recommendations for further study seem appropriate:

1. Enlarge the sample size of subjects.

2. Repeat the same study but decrease the distance between the cryopress area and post treatment testing area.

3. Repeat the same study and look at the rewarming period for both modalities.
4. Repeat the same study and look at the athlete’s time for return to play status.

5. Conduct a study where the cryo/cuff is stimulated to work like the cryopress and look at ankle edema and pain.

6. Repeat the same study but examine skin and intramuscular temperature changes for each modality.


APPENDIX A

INFORMED CONSENT FORM
Ohio University Consent Form

Title of Research: A comparison of the Effects of the Cryopress and Cryo/cuff on Ankle Edema and Pain after Three Treatments in Division I Varsity Athletes

Principal Investigator: Meredith L. Ruck
Co-Investigator:
Department: Recreation and Sports Sciences

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form.

Explanation of Study

I, Meredith Ruck, a graduate assistant and certified athletic trainer at Ohio University, will be conducting a research study to complete my Master’s Degree. You are being asked to participate in a research study, which is examining the effects of the cryopress and cryo/cuff on ankle edema and pain. Before agreeing to be part of this study, please read and listen to the following information carefully. Feel free to ask questions if you do not understand something.

In order to decide whether or not you wish to be a participant of this study you should know about its risks and benefits to make an informed judgment. This consent form provides you with detailed information about the research study. I will discuss any aspects of the study with you that you do not understand. You should be aware of all aspects of the study, its purpose, the procedures to be used and any risks or benefits. Once you understand the study, you will be asked if you wish to participate, if you do, you will be asked to sign this form. If you decide to volunteer, the procedure will be as follows: Prior to cold therapy treatment, you will be questioned about contraindications to cold treatments. If you present with any of the following signs or symptoms you will be disqualified from the study. Contraindications include:

- cardiac or respiratory complications,
- circulatory insufficiency (lack of blood flow to the extremities; blue color in fingernails while in the cold or during cold treatments, do not tolerate the cold very well),
- cold allergy (hypersensitivity to cold),
- anesthetic skin,
- advanced diabetes (lack of blood flow, ulcers, and/or death of bone or skin to the lower extremities),
- raynaud’s phenomenon (white, blue, or red discoloration of the extremities due to cold treatment),
- peripheral vascular disease, infections. If no contraindications are present, the next step is to measure your injured and non-injured ankle. Your injured and non-injured ankle will be measured using a volumetric tank and figure eight measurements. Testing will be conducted for three days straight with one treatment each day.

You will be asked to clean and dry your foot and ankle prior to testing. Then you will be asked to be seated in a chair with your hip and ankle at 90° flexion with the volumetric tank level on the floor and your foot is to be placed into a tank of water (33.5°C) that is on the floor. You will be instructed to keep still so the water level evens
out. Measurements of the limbs volume (ml) will be conducted. This procedure will be conducted on both your injured and non-injured limb pre and post each cold therapy treatment for three days straight.

Then figure eight measurements will be conducted. Figure eight measurements consist of landmarks (between the tibialis anterior tendon and the lateral malleolus, distal to the navicular tuberosity, proximal to the base of the fifth metatarsal, distal to the tip of the medial malleolus, distal to the lateral malleolus) being marked on your foot and leg. These marks are being used as reference points for the investigator for girth measurements of the ankle. Figure eight measurements will be taken three times and the average of those three numbers will be used as the final girth measurement before and after treatment. Girth measurements will be taken bilaterally to determine the amount of edema present in the injured limb.

Once figure eight and volumetric measurements are conducted you will be situated in the supine position on a standard treatment table. The injured limb will be placed in either the cryopress or cryo/cuff for twenty minutes. For the cryopress, located at the end of the treatment table, your foot will be placed in the cryopress boot and the un-injured leg will be placed next to the cryopress. The cryopress parameters (time- 20 minutes, temperature- 8.9°C, pressure- 70mmHg, and gradient- 20%) will be set. The cryopress will begin its filling for one and a half minutes and will drain for 30 seconds. During treatment, you will be instructed to wiggle your toes during the 30 seconds when the pressure has decreased to get your blood flow flowing again in the lower extremity. You will also be given an emergency button that you can use if you feel as though there is too much pressure being placed on your limb. This switch will start draining the cryopress and release the pressure on your limb.

For the cryo/cuff a vinyl bladder will be placed over your ankle like a boot with an open toe box. The cuff is filled with ice water (8.9°C) by means of a portable cooler and tubing. When filled, the cryo/cuff delivers compression and cooling to the ankle. The water in the cooler will be changed at ten minutes to make sure the water temperature is consistent and treatment time is twenty minutes. Water temperature will be determined using a Healthteam digital thermometer (Hauppauge, NY) and the ankle will be elevated 20° (measured with large goniometer) using a bolster. The same procedures will be followed for the cryo/cuff group as the cryopress group. In addition, a Bat-10 Therometer (Physytemp Instruments Inc.) will be placed on your ankle to record your skin temperature during and after the cold treatment.

Your pain levels will also be recorded pre and post each day’s treatment using the visual analog scale. You will be given a 10cm line with one end labeled “no pain” and the other end is labeled “severe pain.” You will be asked to mark a line perpendicular to the 10cm line to indicate where their pain level is. They will also be asked to write down the numerical value to where their line is placed. Pain levels will be scaled on a 0-10 scale. Zero will be the equivalent of no pain at all and ten is the worst pain the athlete has ever felt and they need to go to the hospital right now.

**Risks and Discomforts**

Risks involved with this study include possible minor discomfort during cryopress and cryo/cuff treatments due to the pressure that is being applied to the injured leg.
However, there is a very low chance of this occurring. Another possible risk would be peripheral nerve damage to the common peroneal nerve since there is compression and cold treatment over the nerve. However, there is a very low risk (.001%) that this will occur because in both the cryopress and cryo/cuff there is vinyl material that is in-between the skin and cold water. Therefore, the chances of nerve damage are very minimal.

**Benefits**

Benefits of this study include potentially beneficial treatment for your injured ankle; however, you are in no way required to participate in the study to receive treatment for your ankle. With this treatment you may return to your sport faster than receiving no treatment. This research will also help with appropriate cold therapy techniques by helping sports medicine professionals and athletes target a particular method of reducing edema and pain after a grade 1 or 2 ankle sprain.

This study will help athletic trainers and athletes determine how affective the cryopress and cryo/cuff are in reducing edema and pain after grade 1 and 2 ankle sprains. This study will also help athletes, coaches, athletic trainers, and sports medicine professionals determine whether the cryopress or cryo/cuff is better for treating edema and pain. This study will also provide Ohio University athletes and athletic trainers with the knowledge needed to treat edema in the most appropriate manner. Results from this study will provide another technique that can be utilized by athletic trainers and sports medicine professionals to treat edema and pain in grade one and two ankle sprains.

**Alternative Treatment**

If you decide not to participate in this study, you will be referred to your certified athletic trainer for your initial injury treatment. Treatment that you may receive from your certified athletic trainer may be RICE (Rest, Ice, Compression, and Elevation). Your ankle will be treated with an ice bag for 20 minutes while it elevated to help reduce swelling in the ankle joint. An ace wrap will be placed on the ankle after cold treatment. This treatment will be conducted at the discretion of your athletic trainer.

**Confidentiality and Records**

Any and all information obtained from you will be confidential. Your privacy will be protected at all times. You will not be identified individually in any way as a result of your participation in this research. The data collected however may be used as part of publications and paper related to cryotherapy. Your participation will be reported in the aggregate and no identifying information will be provided in any reports during or after this study.
**Contact Information**
If you have any questions regarding this study, please contact (Researcher/Advisor & email/phone number).

Researcher:  
Meredith Ruck  
ruck@ohio.edu  
593-3656

Advisor:  
Jeff Seegmiller  
seegmill@ohio.edu  
593-4656

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

I certify that I have read and understand this consent form and agree to participate as a subject in the research described. I agree that known risks to me have been explained to my satisfaction and I understand that no compensation is available from Ohio University and its employees for any injury resulting from my participation in this research. I certify that I am 18 years of age or older. My participation in this research is given voluntarily. I understand that I may discontinue participation at any time without penalty or loss of any benefits to which I may otherwise be entitled. I certify that I have been given a copy of this consent form to take with me.

Signature_________________________ Date______________

Printed Name_________________________
APPENDIX B

PRE-PARTICIPATION QUESTIONNAIRE
Pre-participation Questionnaire

Name: _____________________   Subject Number:______

Age:____   Phone Number:______________

Year of School:_____   Position:____________________

Sport:______________________

How did the Injury occur:

What time of day did the injury occur:

Did you Invert (INV) or evert (EV) your ankle:  INV   EV

Have you injured this ankle before:
If YES, how long ago did it happen:
If YES, how many times:

Have you had surgery on your ankle before:
If YES, when:

Do you get your ankle(s) taped or braced: If YES which one

What type of treatment have you received up to this point:
APPENDIX C

CONTRAINDICATIONS TO COLD TREATMENTS
Contraindications to Cold Treatments

Do you (the subject) have any:

Cardiac or respiratory complications

Circulatory insufficiency (lack of blood flow to the extremities; blue color in
fingernails while in the cold or during cold treatments, do not tolerate the
cold very well)

Cold allergy (hypersensitivity to cold)

Anesthetic skin

Advanced diabetes

Raynaud’s phenomenon (white, blue, or red discoloration of the extremities due
to cold treatment)

Peripheral vascular disease

Infections

(Prentice, 1999; & Starkey, 1993)
APPENDIX D

VISUAL ANALOG SCALE
Visual Analog Scale

Please rate your pain level using the line below. Mark a line perpendicular to the present line. That number will represent the amount of pain you are in based on a scale from 0-10 with zero being no pain at all to ten being the worst pain you have ever felt; take me to the hospital right now. This procedure will be done pre and post cold therapy treatment.

Pre cold therapy treatment:

Post cold therapy treatment:
APPENDIX E

ANOVA SUMMARIES
Table E1

Summary of ANOVA Within Subjects for Mean Differences Figure 8 Measurements (cm)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
<th>$1 - \beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>0.14</td>
<td>2</td>
<td>0.07</td>
<td>1.21</td>
<td>0.31</td>
<td>0.08</td>
<td>0.24</td>
</tr>
<tr>
<td>Days*Group</td>
<td>0.53</td>
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<td>0.27</td>
<td>4.72</td>
<td>0.02*</td>
<td>0.25</td>
<td>0.74</td>
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<tr>
<td>Error (Days)</td>
<td>1.58</td>
<td>28</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. cm = centimeters

*p < .05
### Table E2

Summary of Pairwise Comparison Within Subjects for Mean Differences Figure 8 Measurements (cm)

<table>
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<tr>
<th>Source</th>
<th>1 vs. 2</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>η²</th>
<th>1 - β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>0.25</td>
<td>1</td>
<td>0.25</td>
<td>2.19</td>
<td>0.16</td>
<td>0.14</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>1 vs. 3</td>
<td>1</td>
<td>0.15</td>
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<td>0.34</td>
<td>0.07</td>
<td>0.15</td>
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<td></td>
<td>2 vs. 3</td>
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<td>0.01</td>
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<td>1 vs. 2</td>
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<td>1.00</td>
<td>8.93</td>
<td>0.01*</td>
<td>0.39</td>
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<tr>
<td></td>
<td>1 vs. 3</td>
<td>0.52</td>
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<td>0.52</td>
<td>3.28</td>
<td>0.09</td>
<td>0.19</td>
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<tr>
<td></td>
<td>2 vs. 3</td>
<td>0.08</td>
<td>1</td>
<td>0.08</td>
<td>1.13</td>
<td>0.31</td>
<td>0.08</td>
</tr>
<tr>
<td>Error (Days)</td>
<td>1 vs. 2</td>
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<td>14</td>
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<td></td>
<td>1 vs. 3</td>
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<td>14</td>
<td>0.16</td>
<td></td>
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<td></td>
<td>2 vs. 3</td>
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</tbody>
</table>

*Note.* cm = centimeters

*p < .05
Table E3

Summary of Between Subjects for Mean Differences Figure 8 Measurements (cm)

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<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>η²</th>
<th>1 - β</th>
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<td>0.23</td>
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<td>Error</td>
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<td>14</td>
<td>0.02</td>
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<td></td>
</tr>
</tbody>
</table>

*Note.* cm = centimeters

*p < .05*
### Table E4

Summary of ANOVA Within Subjects for Pre Treatment Figure 8 Measurements (cm)

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<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>η²</th>
<th>1 - β</th>
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<td>Error (Days)</td>
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<td>28</td>
<td>0.07</td>
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<td></td>
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</tbody>
</table>

*Note.* cm = centimeters

*p < .05
Table E5

Summary of Pairwise Comparison Within Subjects for Pre Treatment Figure 8 Measurements (cm)

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<th>Source</th>
<th>SS</th>
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<th>MS</th>
<th>F</th>
<th>p</th>
<th>η²</th>
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</thead>
<tbody>
<tr>
<td>Days 1 vs. 2</td>
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<tr>
<td>Days*Group 1 vs. 2</td>
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<td>2 vs. 3</td>
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<td>1.08</td>
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<td>0.65</td>
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<tr>
<td>Error (Days) 1 vs. 2</td>
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<tr>
<td>1 vs. 3</td>
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</tr>
<tr>
<td>2 vs. 3</td>
<td>2.36</td>
<td>14</td>
<td>0.17</td>
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<td></td>
</tr>
</tbody>
</table>

*Note. cm = centimeters

*p < .05
Table E6

Summary of Between Subjects for Pre Treatment Figure 8 Measurements (cm)

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<tr>
<th>Source</th>
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<th>MS</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
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<td>1.00</td>
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<td>Error</td>
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</table>

*Note.* cm = centimeters
Table E7

Summary of ANOVA Within Subjects for Post Treatment Figure 8 Measurements (cm)

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<th>p</th>
<th>η²</th>
<th>1 - β</th>
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<tbody>
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<td>Days</td>
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<td>3.64</td>
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<td>0.00*</td>
<td>0.81</td>
<td>1.00</td>
</tr>
<tr>
<td>Days*Group</td>
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<td>2</td>
<td>0.47</td>
<td>7.43</td>
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<td>0.92</td>
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<td>Error (Days)</td>
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*Note.* cm = centimeters

*p < .05
Table E8

Summary of Pairwise Comparison Within Subjects for Post Treatment Figure 8 Measurements (cm)

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<th>η²</th>
<th>1 - β</th>
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<td>Days 1 vs. 2</td>
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<td>1.05</td>
<td>9.72</td>
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<td>0.83</td>
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<td>Days 1 vs. 3</td>
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<td>0.90</td>
<td>1.00</td>
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<td>Days 2 vs. 3</td>
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<td>1</td>
<td>7.13</td>
<td>44.11</td>
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<td>1.00</td>
</tr>
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<td>0.19</td>
<td>1.80</td>
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<tr>
<td>Days*Group 1 vs. 3</td>
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<td>1</td>
<td>1.80</td>
<td>16.78</td>
<td>0.00*</td>
<td>0.55</td>
<td>0.97</td>
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<tr>
<td>Days*Group 2 vs. 3</td>
<td>0.81</td>
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<td>0.55</td>
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<td></td>
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<tr>
<td>Error (Days) 2 vs. 3</td>
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*Note. cm = centimeters

*p < .05
Table E9

Summary of Between Subjects for Post Treatment Figure 8 Measurements (cm)

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<th>1 - β</th>
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<td>46373.11</td>
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<td>1.00</td>
</tr>
<tr>
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<td>2.12</td>
<td>0.17</td>
<td>0.13</td>
<td>0.27</td>
</tr>
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*Note. cm = centimeters*
Table E10

Summary of ANOVA Within Subjects for Mean Differences Volumetric Measurements (ml)

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<th>p</th>
<th>η²</th>
<th>1 - β</th>
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<tbody>
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<td>Days</td>
<td>603.29</td>
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<td>0.29</td>
<td>0.08</td>
<td>0.26</td>
</tr>
<tr>
<td>Days*Group</td>
<td>89.54</td>
<td>2</td>
<td>44.77</td>
<td>0.19</td>
<td>0.83</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>Error (Days)</td>
<td>6556.50</td>
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<td></td>
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</tr>
</tbody>
</table>

*Note.* ml = millimeters
Table E11

Summary of Between Subjects for Mean Differences Volumetric Measurements (ml)

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<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
<th>$1 - \beta$</th>
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<tbody>
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<td>Intercept</td>
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<td>10217.84</td>
<td>163.17</td>
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<tr>
<td>Group</td>
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<td>142.01</td>
<td>2.27</td>
<td>0.15</td>
<td>0.14</td>
<td>0.29</td>
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<tr>
<td>Error</td>
<td>876.71</td>
<td>14</td>
<td>62.62</td>
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</tr>
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</table>

*Note.* ml = millimeters
### Table E12

Summary of ANOVA Within Subjects for Pre Treatment Volumetric Measurements (ml)

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<th>F</th>
<th>p</th>
<th>η²</th>
<th>1 - β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>9202.54</td>
<td>2</td>
<td>4601.27</td>
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<td>0.00*</td>
<td>0.43</td>
<td>0.98</td>
</tr>
<tr>
<td>Days*Group</td>
<td>588.38</td>
<td>2</td>
<td>294.19</td>
<td>0.67</td>
<td>0.52</td>
<td>0.05</td>
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<td>Error (Days)</td>
<td>12235.75</td>
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*Note.* ml = millimeters

*p < .05
Table E13

Summary of Pairwise Comparison Within Subjects for Pre Treatment Volumetric Measurements (ml)

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<th>p</th>
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<th>$I - \beta$</th>
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<tr>
<td>Days</td>
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<td>6561.00</td>
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<td>0.02*</td>
<td>0.33</td>
<td>0.68</td>
</tr>
<tr>
<td>Days*Group</td>
<td>36.00</td>
<td>1</td>
<td>36.00</td>
<td>0.04</td>
<td>0.85</td>
<td>0.00</td>
<td>0.05</td>
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<tr>
<td>Error (Days)</td>
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<td>964.50</td>
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</table>

Note. ml = millimeters

*p < .05
Table E14
Summary of Between Subjects for Pre Treatment Volumetric Measurements (ml)

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<th>p</th>
<th>η²</th>
<th>1 - β</th>
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<tbody>
<tr>
<td>Intercept</td>
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<td>2992456.78</td>
<td>634.99</td>
<td>0.00</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td>Group</td>
<td>50850.25</td>
<td>1</td>
<td>50850.25</td>
<td>1.08</td>
<td>0.07</td>
<td>0.07</td>
<td>0.16</td>
</tr>
<tr>
<td>Error</td>
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<td>14</td>
<td>47126.01</td>
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</tbody>
</table>

*Note.* ml = millimeters
Table E15

Summary of ANOVA Within Subjects for Post Treatment Volumetric Measurements (ml)

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<th>F</th>
<th>p</th>
<th>η²</th>
<th>I - β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
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<td>2994.27</td>
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<td>1.00</td>
</tr>
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<td>2</td>
<td>267.27</td>
<td>1.28</td>
<td>0.29</td>
<td>0.08</td>
<td>0.26</td>
</tr>
<tr>
<td>Error (Days)</td>
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<td>208.15</td>
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</table>

*Note:* ml = millimeters

*p < .05
Table E16

Summary of Pairwise Comparison Within Subjects for Post Treatment Volumetric Measurements (ml)

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<th>Source</th>
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<th>MS</th>
<th>F</th>
<th>p</th>
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<th>1 - β</th>
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<tr>
<td>Days</td>
<td>1 vs. 2</td>
<td>1914.06</td>
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<td>1914.06</td>
<td>4.34</td>
<td>0.06</td>
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<tr>
<td></td>
<td>1 vs. 3</td>
<td>11826.56</td>
<td>1</td>
<td>11826.56</td>
<td>36.75</td>
<td>0.00*</td>
<td>0.72</td>
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<td></td>
<td>2 vs. 3</td>
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<td>4225.00</td>
<td>8.70</td>
<td>0.01*</td>
<td>0.38</td>
<td>0.78</td>
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<td>Days*Group</td>
<td>1 vs. 2</td>
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<td>1</td>
<td>33.06</td>
<td>0.08</td>
<td>0.79</td>
<td>0.01</td>
<td>0.06</td>
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<tr>
<td></td>
<td>1 vs. 3</td>
<td>945.56</td>
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<td>945.56</td>
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<td>625.00</td>
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<td>0.28</td>
<td>0.08</td>
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<td>1 vs. 3</td>
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<td>321.78</td>
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*Note.* ml = millimeters

*p < .05
### Table E17

Summary of Between Subjects for Post Treatment Volumetric Measurements (ml)

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<td>28827950.70</td>
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<td>0.98</td>
<td>1.00</td>
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<td>58887.11</td>
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*Note.* ml = millimeters
### Table E18

Summary of ANOVA Within Subjects for Mean Differences Pain Measurements

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<th>p</th>
<th>$\eta^2$</th>
<th>$1 - \beta$</th>
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</thead>
<tbody>
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<td>2</td>
<td>1.65</td>
<td>9.37</td>
<td>0.00*</td>
<td>0.40</td>
<td>0.97</td>
</tr>
<tr>
<td>Days*Group</td>
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<td>2</td>
<td>1.90</td>
<td>10.80</td>
<td>0.00*</td>
<td>0.44</td>
<td>0.98</td>
</tr>
<tr>
<td>Error (Days)</td>
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*p < .05
Table E19

Summary of Pairwise Comparison Within Subjects for Mean Differences Pain Measurements

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<th>F</th>
<th>p</th>
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<td>Days</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 vs. 2</td>
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<td>1</td>
<td>3.06</td>
<td>6.73</td>
<td>0.02*</td>
<td>0.33</td>
<td>0.68</td>
</tr>
<tr>
<td>1 vs. 3</td>
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<td>1</td>
<td>6.25</td>
<td>15.91</td>
<td>0.00*</td>
<td>0.53</td>
<td>0.96</td>
</tr>
<tr>
<td>2 vs. 3</td>
<td>0.56</td>
<td>1</td>
<td>0.56</td>
<td>2.74</td>
<td>0.12</td>
<td>0.16</td>
<td>0.34</td>
</tr>
<tr>
<td>Days*Group</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 vs. 2</td>
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<td>1</td>
<td>7.56</td>
<td>16.61</td>
<td>0.00*</td>
<td>0.54</td>
<td>0.97</td>
</tr>
<tr>
<td>1 vs. 3</td>
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<td>2.25</td>
<td>5.73</td>
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<td>0.61</td>
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<td>1.56</td>
<td>7.61</td>
<td>0.02*</td>
<td>0.35</td>
<td>0.73</td>
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<td>0.39</td>
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<td>2 vs. 3</td>
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*p < .05
Table 20

Summary of ANOVA Between Subjects for Mean Difference Pain Measurements

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<th>1 - ( \beta )</th>
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<tbody>
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<td>3.36</td>
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<td>0.51</td>
<td>0.94</td>
</tr>
<tr>
<td>Group</td>
<td>0.03</td>
<td>1</td>
<td>0.03</td>
<td>0.12</td>
<td>0.74</td>
<td>0.01</td>
<td>0.06</td>
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<td>Error</td>
<td>3.28</td>
<td>14</td>
<td>0.23</td>
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### Table 21

Summary of ANOVA Within Subjects for Pre Treatment Pain Measurements

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<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
<th>$1 - \beta$</th>
</tr>
</thead>
<tbody>
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<td>Days</td>
<td>47.63</td>
<td>2</td>
<td>23.81</td>
<td>43.72</td>
<td>0.00*</td>
<td>0.76</td>
<td>1.00</td>
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* $p < .05$
Table E22

Summary of Pairwise Comparison Within Subjects for Pre Treatment Pain Measurements

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*p < .05
Table E23

Summary of Between Subjects for Pre Treatment Pain Measurements

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Table E24

Summary of ANOVA Within Subjects for Post Treatment Pain Measurements

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*\( p < .05 \)
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* $p < .05$
Table E25

Summary of Between Subjects for Post Treatment Pain Measurements

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