EFFECTS OF DIFFERENT MODES OF CRYOTHERAPY ON POSTURAL CONTROL

by

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DEDICATION

I dedicate all my scholarly hard work to my father, Gary Edward Ashworth “Big Ed”. Without his love and hard work I would not be the young lady I am today. You will always be in my life, Rest In Peace Daddy.

“Finally, brethren, whatsoever things are true, whatsoever things are honest, whatsoever things are just, whatsoever things are pure, whatsoever things are lovely, whatsoever things are of good report; if there be any virtue, and if there be any praise, think on these things.” – Philippians 4:8 PPL

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CHAPTER I

Introduction

Introduction

Cryotherapy, meaning cold therapy, is a very common modality used over the years as a remedy for many chronic or acute injuries.[1,2] In sports medicine, cryotherapy is commonly used to help minimize the deleterious effects produced by the inflammatory process and aid in recovery with reductions in pain, swelling, muscle spasm, and the impact of secondary hypoxic injury after suffering an injury when it is paired with the use of rest, compression, and elevation.[1,3-5] Cryotherapy applied to an injured site decreases local temperature at the site constricting blood flow, resulting in a slowing metabolism and reducing the rate of inflammation that causes secondary hypoxic injury.[5] Cryotherapy also has an effect on nerve activity by impairing the function of the mechanoreceptors, plantar cutaneous, and intrinsic musculotendinous receptors.[6] Specifically cryotherapy slows the conduction velocity of the cutaneous thermoreceptors that are the primary afferent nerve fibers that send signals to the central nervous system and[7] are responsible for painful stimulation producing anesthesia[3,8]

Although cryotherapy is frequently used in the acute management of an injury, it is not commonly considered in rehabilitation because the use of ice decreases muscle function including: strength, vertical jump height, speed, agility, and postural stability.[1] The negative effects may arise from decreased activity of motor neurons following cryotherapy including activation and conduction velocity.[3,8] However, recent studies have reported inconsistent results that the use of cryotherapy could facilitate motor neurons or muscle activity, resulting in enhancing motor function.[2,9] Some recent

research findings have demonstrated that when an ice bag is placed specifically over a joint rather than a muscle belly increased muscle activation and strength of adjacent muscles occurs. This runs counter to research that demonstrates decrements in muscle function when the ice bag was placed over the muscle belly. Therefore, the placement of the cooling modality is important when considering cryotherapy and the effects it serves on muscle function.

Balance is an important factor when considering return to participation because it demonstrates the function of the limb. Generally, it is not recommended to return to play immediately after using cryotherapy due to the anesthetic effects of the modality. Researchers believe that a decrease in the somatosensory system will lead to a decrease in postural control.[3,10] Other authors have found no effect on postural control when an ice bag is applied to the ankle joint.[2,11] In a study conducted by Kernozek et al,[12] postural sway increased after a twenty-minute ice immersion and still had negative effects twenty minutes post treatment. On the contrary, other studies found no change in postural control with a twenty-minute treatment ice bag applied to the ankle joint.[2] These conflicting results indicate that focal joint cooling may have differential effects on postural control when compared with effects of general application of cryotherapy involving direct cooling of muscular structures.[1,13,14] In investigating dynamic postural control Miniello et al.[15] found no change after ice immersion. However, other authors found a diminishing effect in dynamic stability after ice immersion.[1,13]

Purpose

This study will help fill the gap in the literature concerning the effects of different modes of cryotherapy on postural control. The purpose of this study is to compare lower

leg ice immersion and ankle joint cooling on postural control (static and dynamic) in healthy subjects. Because cryotherapy is a common form of treatment in musculoskeletal injuries, this study is important in providing information on the effect of different modes of cryotherapy on postural control.

Significance of the Study

The research on the effects of cryotherapy on postural control has mixed findings and scientific backing. There has not been a single published study completed that compares both modes of cryotherapy applied to the lower leg including muscle cooling or only focal joint cooling. The outcomes of this study will provide significant contributions to the field of sports medicine by providing information on postural deficits after different modes of cryotherapy.

Research Questions

This study is designed to answer the following questions:

- Is postural control (static and dynamic) affected after focal ankle cooling in healthy subjects?
- Is postural control (static and synamic) affected after lower leg ice immersion in healthy subjects?

Hypothesis

- The hypothesis is that static and dynamic balance would be impaired following lower leg ice immersion, but would remain unchanged following ankle joint cooling.

Assumptions

- All subjects are honest with meeting the inclusion and exclusion criteria.

- All subjects will perform static and dynamic balance testing with their best efforts.
- Subjects are honest with their visual analog score on their perceived balance.
- Subjects will refrain from any other types of cryotherapy 24 hours before testing.

Delimitations

- Subjects are over the age of 18.
- Subjects have no lower leg or head injury within the past 6 months.
- Subjects have no circulatory conditions.
- Subjects have not been diagnosed with diabetes
- Subjects have no allergy to cold.
- Subjects are free from any neurological conditions

Limitations

- Difficulty with measuring temperature of the ankle joint rather than just the skin temperature over the ankle joint
- Unable to generalize to adolescents under the age of 18

Operational Definitions

- Postural Control: An ability to maintain static and/or dynamic balance among a base of support. This is calculated by center of pressure parameters.
- Center of Pressure (COP): Calculations from ground reaction forces from the body's movement and the base of support. Parameters include:
    - Velocity: Total distance traveled by COP over time.
    - Range: Absolute maximum and minimum displacement of COP from its mean.

    - Total Area: Total distance traveled by the COP over the course of the trial duration
    - Standard Deviation: average displacement around the mean COP.
- Static Balance: Balance maintained with no movement.
- Dynamic Balance: Balance maintained with functional movement.

CHAPTER II

Literature Review

Cryotherapy in Sports Medicine

Cryotherapy is a very common modality used over the years as a remedy for many chronic or acute injuries.[1,2] Cryotherapy, meaning cold therapy, has many different effects upon application.[8] Physiologically, cryotherapy decreases local temperature, nerve conduction velocity and frequency, muscle excitability, spindle depolarization, viscosity of fluids and tissues, and it also produces anesthesia.[3,8] Cryotherapy is used to reduce pain, swelling, and the impact of secondary hypoxic injury.[1,3,4] One of the most common ways cryotherapy is used is in the form of ice. When ice is paired with the use of rest, compression, and elevation it can reduce recovery time post-injury.[3]

Research has found that along with the physiological effects cryotherapy can decrease muscle strength, vertical jump height, speed, agility, and postural stability.[1] While other research found that the use of cryotherapy facilitates muscle activity and enhances motor function.[2,9] With the decrease of swelling and pain that limits movement, it has been accepted to return to participation after ice.[4] It has been stated that using ice immersion to the point of numbness can decrease injury time by increasing the tolerance for exercises.[12]

Types of Cryotherapy

There are different forms of cryotherapy including cold spray, ice cup, ice immersion, cold pack, and ice bag. [8] Cryokinetics is a form of rehabilitation that includes cryotherapy before to help reduce pain and swelling so the patient is able to perform exercises..[12] Cryokinetics has been found to be effective for rehabilitation for lateral

ankle sprains.[12] For this research the main focus will be on ice immersion and ice bag. There are various protocols for each form of cryotherapy.

Cold spray is chemically called liquid ethyl chloride and fluoromethane.[8] Cold spray is used for removing the heat from the surface of the skin, not reaching to the deep tissues.[8] The limitation of cold spray is that it is only a topical anesthesia rather than reaching to the deep tissues. Ice cup is commonly referred to as ice message due to its techniques. Ice cup is favorable because it is massaging while using ice to help with the indications of cryotherapy. However, to have the full effects of ice cup it is only recommended for a small area.

For ice immersion authors have conducted studies with ice water filled container to the tibial tuberosity while others have it five centimeters above the medial malleolus.[1,15] Book protocols suggest immersion of the limb that needs to be treated with no specific guidelines on what the ice water should cover.[8] Research protocols suggests a temperature under 4.4°C, while others have recommended a range from 12.8°C to 15.6°C. [1,15] Time limits have a wide range from 15 minutes to 20 minutes.[1,15] Other studies have been conducted with just the plantar aspect of the foot to be submerged. [16] If a larger portion of the body needs to be submerged it is then recommended for the patient to use a cold whirlpool.[8] A cold whirlpool is a larger version of an ice immersion; the only difference is that a cold whirlpool is consistently rotating the water to prevent warming of the water around the limb. Ice immersion is typically used when numbing of the muscle and joints are what the patient needs.

Ice bags and cold packs, specifically for joint cooling, have many different protocols. Ice packs are typically made out of gallon bags containing crushed, cubed, or

shaved ice. Whereas cold packs are commercially prepared packs that can be made up of gel or chemicals.[8] The gels and/or chemicals do not freeze but still have a very low temperature, allowing for possible frost bite.[8] The most common protocol is application for 20 minutes to efficiently provide cooling of the joint.[2,3,8] The main purpose for ice bag or cold pack is to create joint cooling for cryotherapy effects. Depending on where the location of application is, the effects of cryotherapy vary.

Cryotherapy on Proprioception

Proprioception is an integration of neural impulses from peripheral mechanoreceptors of the central nervous system.[17] These neural impulses come from muscle spindles and golgi tendon organs to relay information of the body's position in space. [3] Balance is a commonly used tool for measuring proprioception. Authors have found cryotherapy has no definite negative influence on proprioception while others have reported a decrease in proprioception.[1]

Elley[3] conducted a study to determine if a standard ice bag to the ankle joint affects one legged balance. Thirty participants were measured using an advanced mechanical technology incorporated force plate to measure the amount of sway. After application the participants were to stand on a single leg and focus on a spot on the wall. This research concluded that 56.67% of the subjects performance was significantly diminished while 43.33% of the subjects performance was improved.[3]

Nerve Conduction Velocity

Physiologic evidence has suggested that the use of cryotherapy has a negative effect on nerve conduction velocity. [4,11,17] The slowing of nerve conduction velocity compromises the neuromuscular system.[11,15] Nerve conduction velocity decreases as the

temperature decreases until nerve conduction in completely blocked.[8] Unmyelinated fibers are effected the same way myelinated fibers are in relation to cold.[8] Cold increases the duration of nerve action potentials that in turn decreases the number of fibers firing and slows the transmission rate.[8]

Herrera et al.[18] conducted a study with thirty six healthy participants to determine tibial nerve conduction following one of three cold interventions: ice cup, ice bag, or ice immersion. The ice cup and ice bag were over the calf where the ice immersion covered the calf along with the ankle and foot. This study concluded that ice immersion had the most detrimental effect on tibial nerve conduction velocity but the ice cup and ice bag also had a decrease in nerve conduction velocity.[18] Elley[3] recommends that due to the alterations in muscle performance, nerve conduction velocity, sensation, and connective tissue flexibility following cryotherapy application the subject should not return to participation. [3]

Reflex

Muscle spindles that are located in the muscle belly are responsible for sensing change in muscle length.[15] When muscle spindles are activated, it sends a reflex response in the muscle, this is known as monosynaptic stretch reflex.[15] Depending on the type of muscle fibers it is dependent on the temperature change to have a decrease in function.[8] Type I and IIa have no response to cold where Type IIb increase in activity until 30°C then a decrease in activity if temperature decreases.[8] Golgi tendon organs are not as affected by cold as other reflex's.[8] Authors have suggested that muscle spindles could be the primary mechanoreceptor in dynamic stability.[15] Therefore, a decrease of muscle spindles due to cryotherapy, decreases dynamic stability.

Muscle Strength/Power

Muscle strength is dependent on neuromuscular activity. Neuromuscular control is the interaction between the nervous and muscular systems. [15] The effects of cold on muscle strength depends on the deep muscle temperature.[8] During the cooling of the neuromuscular system this has a detrimental effect on muscle strength.[15] When an ice bag is placed over the joint it is researched to increase muscle activation and strength. [2]

Miniello et al.[15] measured muscle activation of the tibialis anterior and peroneus longus in seventeen healthy women after a twenty minute ice immersion of the lower leg to the tibial tuberosity. The results provided a significant decrease in muscle activity immediately after treatment.[15] Other authors have performed a study on the effects of ankle joint cooling on muscle function by using the Hoffmann reflex and plantar flexion torque.[19] Using a crushed ice bag over the ankle of fifteen subjects for thirty minutes, the H-reflex and torque measurements were collected immediately following. The results showed an increase in both H-reflex and peak plantar flexion torque at all testing times as compared to baseline.[19]

Cutaneous

Cutaneous receptors are mechanoreceptors located in the skin and provide information regarding awareness of position, touch, and movement.[3] A reduction in temperature to the cutaneous effects in the following order: tickle, cold, first pain, touch, second pain, warmth, then loss of sensation.[8] There have been mixed results on two point discrimination using tactile sense.[8] In a study done by Ingersoll et al, the researchers compared the effects of heat, ice, and no treatment on two point discrimination on the plantar aspect of the foot. The subjects were to immerse their foot and ankle in either cold

water at 4°C or hot water at 40°C. After the immersion they were instructed to differentiate between a one point and two points on the plantar surface of the foot. If there was a two point, the subjects had to draw how far the points were located. The study revealed that there was no significant difference between groups. Thus, indicating a return to play after cold or heat immersion is acceptable.[20]

Plantar cutaneous receptors supply information on maintaining postural control. [16,21] A decrease in these sensations increase postural sway and poor balance.[21] McKeon and Hertel[16] conducted a study to see the effect of plantar hypoesthesia on postural control. In their study the thirty-two participants immersed only the plantar aspect of the foot for ten minutes to reduce plantar cutaneous sensation. The researchers used Time to Boundary (TTB) in the single leg and double leg stance as the measurement tool and found that the TTB increased.[16] The TTB test measures the velocity of COP and where the foot went.[16] The higher the TTB, the greater the postural stability within the base of support.[16] Time to stabilization (TTS) is a measurement used for neuromuscular control. It includes the sensory and mechanical systems while the body is transitioning from a dynamic state to a static state.[15] This study implies that it is not safe for an athlete to return to activity after loss of sensation on the plantar aspect of the foot due to the decrease in postural control.

Postural Control

The vestibular, visual, and somatosensory systems are integrated to provide the nervous system with the information for postural control.[11,16,21] Components of the somatosensory system are: peripheral musculotendinous, articular, and cutaneous receptors. [16,21] Postural control can be affected by different systems including: afferent and efferent transmission, tendon-reflex, and propioceptors located in muscles, tendons,

and joints. [9]Authors believe that a decrease in somoatosensory system will lead to a decrease in postural control.[3,16] Other authors have found no effect on postural control when an ice bag is applied to the joint.[2,11]

Postural sway is analyzed following lateral ankle sprains in the medial-lateral directions due to the nature of the injury being a frontal plane injury.[12] In a study conducted by Kernozek et al.[12], after a twenty minute ice immersion postural sway increased and still had effects twenty minutes post treatment. Giemza[9] conducted a study on whole body cooling using twenty four healthy subjects at that moment placing them in a cold chamber for three and a half minutes at -60°C followed by three minutes at -130°C. The subjects were measured four times using the center of pressure at: just before whole body cooling, one minute after, six minutes after, and at eleven minutes after on a force plate. The medial to lateral directions decreased while the anterior to posterior directions remained similar to baseline.[9] This shows a decrease in postural control in the plane that ankle injuries occur.

On the contrary, other studies found no change in postural control with a twenty minute treatment ice bag applied to the ankle joint.[2] Dewhurst et al.[11] conducted a study using nine young and nine older females to assess the effects of heat or cold on postural stability. To alter muscle temperature 3°C the researchers used blankets that covered the lower limbs. To assess balance the subjects were to quiet stand in two positions; one with a large support of base (Romberg position), and the other with a narrow support of base (modified Tandem position). Both stances were tried under eyes open and eyes closed. The main findings of this study were that neither warming nor cooling affected postural stability.[11]

Center of Pressure (COP) is the three dimensional forces that monitors the interactions between the foot and the force plate that is used to measure postural control. [16]

Dynamic Balance

Dynamic balance can be measured by using the Biodex Balance System (BBS) with the force plate unlocked allowing medial/lateral and anterior/posterior directions; it is then measured by the degree of tilt about each axis. [1] Other ways dynamic balance can be measured is by is the star excursion balance test. [1,13]

Fullam et al.[13] conducted a study to see the effects of a fifteen minute ice immersion application on dynamic balance by using the star excursion balance test for pre- and post- ice application. The results showed there is a significant decrease in the anterior, posteriolateral, and posteriomedial reach distances.[13] This indicates that dynamic postural stability is affected immediately following cryotherapy application to the ankle joint. Another study conducted using a BBS found a significant increase in the medio-lateral direction after a fifteen minute ice immersion.[1]

Static Balance

Static balance is measured by force plates or the BBS that measure center of pressure.[1,14,22] Balance depends on afferent sensory input from peripheral receptors, these receptors were effected when a cold pack was applied around the knee of healthy subjects in a study by Surenkok et al.[17] Static balance was measured by using a one leg static balance position on a moveable plateform with eyes open.[17]

Saam et al.[14] conducted a study with thirty one healthy subjects with an application of ice to the ankle for ten minutes. Static balance was measured through thirty

second single leg stance on a PDM multifunction force plate that measured center of pressure.[14] The results concluded that the ice application did not affect static balance.[14] Douglas et al.[1] also measured the effects on static balance following a fifteen minute ice immersion. They found no differences in any direction using the BBS.[1]

Functional Task

Functional performance and agility tests provide an accurate assessment of the athletes' ability to perform. Functional and agility tests are developed to put stress on the joint and muscles simultaneously.[23] Some of these tests include: hop test, shuttle run, vertical jump test, co-contraction test, and carioca test.[23-25] To perform the hop test, the participant hops on one foot from one line to another six meters away while being timed.[23] The shuttle run is conducted by having two lines 6.1 meters apart and having the participant run at maximal velocity, touch the line with their foot and run back, repeating this task four times for a total of 24.4 meters while the observer timed the run.[23,24] The vertical jump test is administered by using one leg and having the participant jump as high as they could, that number was then subtracted from their standing reach distance.[23,25,26] The co-contraction test uses shuffle stepping around an arc while a band was placed around the subjects hips forcing the participant to be in a squat position. The participants went from center to the wall five times while being timed.[24] Carioca test was conducted over a 12.2 meter line going right to left then reversing back. Participants doing this test were timed and tested on ankle eversion and inversion.[24]

Evans et al.[24] found no adverse effect in healthy participants while conducting the shuttle run, carioca, and co-contraction tests after a twenty minute ice immersion eight centimeters above the lateral malleolus.[24] Williams et al.[26] also found adverse effect with

single-legged vertical hop test in healthy participants after ice crushed ice bag application around the ankle joint for twenty minutes with compression and without compression.[26]

Other studies have found have found a significant decrease in vertical jump after a twenty minute whirlpool immersion of the lower leg up to the fibular head.[23,25] Cross et al.[23] also found slower times after the whirlpool immersion during the hop test and shuttle run. Patterson et al.[25] found a slower time after the whirlpool immersion during the 40meter dash.

Clinical Implications

Since cryotherapy is used on acute and chronic ankle injuries it is important to know the effects of each cold therapy. There is mixed research on whether cryotherapy should be used before returning to activity. Due to the effects on proprioception it is not recommended for return to play, but other research states there are no effects on proprioception. The increase in muscle strength can be beneficial in protecting the ankle joint, but to what extent. It is still unknown how much the somatosensory system is incorporated in maintaining postural control..

When including functional tasks to evaluate an athlete's return to participation in an important step to consider. If the athlete is unable to perform simple functional tasks it is dangerous to have them return to activity where there are multiple functions they must execute. There is no definite answer due to the conflicting research on whether it is safe for an athlete or participant to return after any form of cryotherapy. The athletic trainer should be aware of the deficits and the additional effects of cryotherapy.

CHAPTER III

Methods

Research Design

A crossover design study was performed to investigate the effects of different cooling strategies on measures of postural control. Independent variables were treatment condition (Ice bag, Ice immersion, Sham, and Control) and time (pre-, immediately post-, 20 minutes post-, 40 minutes post-, and 60 minutes post-intervention). Primary outcomes were measures of center of pressure (COP) parameters to quantify static postural control and Star Excursion Balance Test (SEBT) reach distances in the anterior, posterior-lateral, and posterior-medial directions to estimate dynamic balance. Secondary outcomes were scores on a visual analog scale to represent subject's perceived level of postural control during a postural task and the number of failed trials of the task. Control variables were surface temperatures at the ankle and the soleus and the ambient air temperature. All subjects received all 4 treatments on separate days at least 24 hours apart in a random order. There were 4 different orders of treatments where the subjects were randomly selected for 1 of the 4 different orders of treatment. (Figure 1)

Subjects

Fifteen subjects (9 females, 6 males, age: 21.8±2.86years old, height: 171.37±9.05cm, weight: 74.25±22.61kg) were recruited from the Texas State University community to participate in the study. Subjects were included if they were over the age of 18. Subjects were excluded if they reported current lower extremity or head injuries within the past six months, neuropathology's, diabetes, balance disorders, Raynaud's disease, allergy or hypersensitivity to cold, or circulatory problems (A3). After inclusion

and exclusion criteria were verified, subjects were then asked for consent to participate in this study by signing the consent form (A1).The tested limb was randomly selected by flipping a coin allowing a 50% chance of determining a leg. The beginning of the order was also randomized to counterbalance the treatment effects. The order of reach directions during the SEBT was also randomized.

Instrumentation

Static balance was assessed using the Accusway Plus forceplate (AMTI, Watertown, MA). Center of Pressure data was collected at a rate of 50 Hz and a fourth-order low zero lag, low-pass filter with a cutoff frequency of 5 Hz was used to filter the COP data. Center of Pressure parameters was calculated using the Balance Clinic Software (AMTI, Watertown, MA). Skin and ambient air temperatures were collected using the Physitemp PT-6 surface thermocouples and computed using Physitemp Thermes USB electrothermometer (Physitemp Instruments, Inc., Clifton, NJ).

Postural Control Assessment

Subjects were instructed to perform three successful trials with eyes open then eyes closed of unipedal stance for 10 seconds on the Accusway Plus forceplate (AMTI, Watertown, MA). Subjects were instructed to hold an upright stance with hands on hip (Figure 3).[2] A failed trial was indicated when the subject touches down with non-testing leg, opening of eyes when they are supposed to be closed, and moving the planted foot. The number of failed trials was recorded (Table 6). For the functional test to measure dynamic balance subjects were instructed to perform the SEBT in the anterior, posterior-medial, and posterior-lateral directions.[26] These directions were selected based on previous research's validity as opposed to all eight directions. [27] Subjects were instructed

to maintain an upright stance with hands on hips while reaching out as far as they could reach and touching as far as they could with just their toes (Figures 7-9).[26] Six practice trials were given before testing begins, during testing three trials will be measured in centimeters and averaged in each direction. Each subjects leg length were measured to normalize reach distance with leg length.[26] Specific foot positions and balance assessment are consistent with a previously reported manner.[2]

Visual Analog Scales

A subjective level of balance performance were quantified with Visual Analog Scales (VAS).[2] After each of the postural tasks, subjects were to rate the level of their performance by marking over a 100 mm horizontal line ranging from 0 to100 with 0 representing ‘‘worst balance’’ and 100 indicating ‘‘best balance’’ (A4).

Temperatures

Three PT-6 surface thermocouples were placed over the skin of the anterior portion over the sinus tarsi, on the skin over the soleus muscle belly, and another to measure ambient air.[2] These thermocouples remained in place throughout the duration of testing to ensure cooling was effective. The temperatures were measured at baseline, immediately post, 20-mins post, 40-mins post, and 60-mins post treatment.

Treatments

Focal ankle joint cooling (FAJC) treatment consisted of one plastic bag filled with 1.5L of crushed ice applied to the anterior aspect of the ankle with compression wrap and elevated for 20 minutes (Figure 10).[2,3] Sham treatment mimics the FAJC, but with the same plastic bag filled with room temperature candy corn (Figure 11). Ice immersion treatment involved the tested leg immersed in an ice bucket set at 10°C up to the fibular

head for 20 minutes (Figure 12).[23] Lastly, subjects were instructed to set quietly for the control session.

Data Processing

Center of Pressure parameters include the mean velocity, area, standard deviation, and percent of available range. A larger value indicates a decrease in static balance or an increase in postural instability. Star Excursion Balance Test measures were calculated by reach distances in centimeters by taking the average of the three trials in anterior, posterior-lateral, and posterior-medial directions. A larger value indicates a greater dynamic balance and more functional movement.

Statistical Analysis

For each of postural control measures, a two-way ANOVA (Treatment and Time) with repeated measures were performed to determine the effects of cryotherapy on postural control. For VAS scores, another two-way ANOVA was conducted to assess subjective effects on balance performance. Post hoc simple contrasts were conducted to identify specific differences in the presence of significant interactions or main effects. For the control variable of temperature, a one-way ANOVA was performed for differences in temperature measurements between pre- and post-intervention. Alpha level was set a priori at 0.05. All statistical analyses will be performed using SPSS 20.0 statistical software (SPSS Incorporated, Chicago, IL, USA).

CHAPTER IV

Results

Descriptive statistics for all measures are presented in Tables 1-5. There were no significant interactions (all p values>0.05) found for any of the COP, VAS, and SEBT measurements. There was a significant difference found in temperature during the focal ankle cooling treatment at the ankle skin surface ($F(15)=69.027$, $p<.001$) that decreased immediately post treatment then raised closer to baseline and the soleus skin surface ($F(15)=35.975$, $p<.001$) that increased immediately post treatment then decreased closer to baseline (Table 5). During lower leg immersion treatment there was a significant difference found in temperature at the ankle skin surface ($F(15)=217.969$, $p<.001$) and the soleus skin surface ($F(15)=215.232$, $p<.001$), both locations decreased immediately post treatment then raised closer to baseline. The soleus skin surface temperature during the sham showed significance ($F(15)=3.431$, $p=0.014$) along with ankle skin surface temperature during the control session ($F(15)=3.572$, $p=0.012$).

CHAPTER V

Discussion

The purpose of this study was to compare lower leg ice immersion and ankle joint cooling on postural control (static and dynamic) in healthy subjects. The hypothesis that static and dynamic balance would be impaired after cooling of the lower leg is rejected. The hypothesis that static and dynamic balance would remain unchanged following ankle cooling is accepted. Static and dynamic balance was not significantly impaired following either ankle joint or lower leg ice immersion. The findings were consistent with an absence of perceptional changes found in the VAS scores. The method used to create a hypothermal effect was found to significantly decrease the skin surface temperatures at the ankle and soleus during leg immersion and decrease at the ankle and increase at the soleus during ankle cooling treatment. The results showed that cryotherapy did not negatively affect postural control. This evidence is consistent with other studies done with ankle cooling.[2,14,15]

Although unexpected, leg immersion had no effects on balance. One study has reported these same findings.[15] Other studies have recorded significant differences only in the ML direction using COP measurements and the Biodex system.[1,12] Other studies have found postural control impairments following ice water immersion in healthy participants.[22,28] The previous report that found no differences have hypothesized that the ankle and surrounding muscles work harder due to anesthesia effects of cryotherapy.[15] The muscle spindles sense change in muscle length causing them to fire for a reflex contraction possibly causing unknown better balance. There

could also be compensation from other joint activation along with core stabilization.

During this study, the ice immersion the subject placed their foot on the bottom of the bucket possibly causing interference in cooling and impairing the plantar cutaneous sensation nerves. Some researchers have shown significance on cooling the plantar aspect of the foot impairing the plantar cutaneous sensation nerves.[10,29] The temperatures that were measured in this study were of the skin surface; therefore we cannot conclude that the muscle belly and deep structures were significantly cooled.

Ankle cooling had no significant difference on balance. This is concurrent with other research.[2,3,26] Postural control was not effected after a 20-minute ice bag applied to the ankle according to COP measurements in two studies using healthy subjects and subjects with chronic ankle instability.[2,26] Another study showed a 56.67% decrease in balance but a 43.33% increase or no change in balance after ice bag application over the ankle in healthy participants.[3] This study had similar methodology as the previously reported studies in regards to ankle cooling treatment. It has been hypothesized that since ankle cooling only effects the structures around the joint and not the muscular structures, the soleus compensates to make up for ankle structures to produce postural control.

The data suggests that ice immersion and focal ankle joint cooling had no effect on postural control along with the sham and control groups. Cryotherapy is still a commonly used modality in sports medicine. The results from this study show a decrease in skin temperature that accepts the benefits of cryotherapy but contradicts that balance is impaired. Therefore, including cryotherapy before balance activities can be done. The benefits of decreased swelling and pain with the potential gains in balance activities can be made in the rehabilitation settings.

This study had limitations that were not considered when beginning. The examiner gave verbal cues such as “good job” or “you can do better”. This could have affected the subject into trying harder and being more focused on balancing. This could also be the reason the VAS scores showed no significance since the examiner gave positive reviews. The testing was done in two different areas during some testing days but it did not affect all subjects, due to room conflicts. This study also used a healthy population that had no interruptions in balance prior to testing.

This study compared two common modes of cryotherapy with a sham and control group, for future studies it is recommended to compare the use of the two different modes along with a cryotherapy just cooling the plantar aspect of the foot. This will give better insight and can locally pinpoint where the disruption is in balance. I would also recommend the use of EMG to note the activation of the soleus muscle, this gives a clear output of how much the soleus is compensating during balance. This study used a uni-pedal stance, for future studies I would recommend testing bi-pedal stance or sports specific functional activities.

CHAPTER VI

Conclusion

In conclusion, the results of the current study demonstrated that cryotherapy had no effect on static and dynamic balance. Based on these results the immediate effects of cryotherapy is not detrimental to postural control. Ankle joint cooling and ice immersion had no differences after a twenty minute treatment session on static and dynamic balance.

APPENDIX SECTION

Appendix A

Additional Methods

A1: Consent Form

Consent of an Adult to be in a Research Study

In this form "you" means a person 18 years of age or older who is volunteering to participate in this study. In this form "we" means the researchers and staff involved in running this study at Texas State University.

Principal Investigator: Sarah Ashworth, ATC, LAT, CES
Texas State Graduate Student
Sea50@txstate.edu
740-646-9776

Purpose of form

This form will help you decide if you want to be in this research study. You need to be informed about the study before you can decide if you want to participate. You should have all your questions answered before you give your permission or consent to be in this study.

Please read this form carefully. If you want to participate in the study, you will need to sign this form. A signed copy of this form will be provided for you.

Purpose of the study

The purpose of this study is to compare and see the effects of lower leg cooling and ankle joint cooling on postural control. You are asked to participate in this study because you meet the inclusion and exclusion criteria.

Duration of study

Your participation in this study will require four visits at least twenty-four hours apart to the Biomechanics/Sports Medicine Laboratory at Texas State University. It will take approximately 1.5 to 2 hours each visit to complete the study.

Participation in the study

If you agree to participate, you will sign this consent form before any study procedures take place. You will be screened for your current health status to determine whether you qualify for participating in the study. The screening involves filling out health questionnaires. You may choose not to answer any questions for any reason.

Once you are found to be eligible, you will be prepared for lower leg static and dynamic balance tests. You will then be prepared for one of the four treatment conditions and reassessed in static and dynamic balance.

Static Balance Testing: This testing provides information on how well you maintain an upright posture for ten seconds after each treatment conditions. The following procedures will be performed in the following order:

1. You will be positioned on a force plate to measure your balance
2. You will be asked to stand on one foot with eyes open and closed for ten seconds each
3. If you touch down with the opposite limb, make contact with the stance limb, lift up or move your planted foot, or unable to maintain standing posture for ten seconds, the trial will be terminated and repeated
4. Three successful trial of each balance condition will be measured
5. One of the four treatment conditions will then be applied during one session
    a. Ice bag- one ice bag applied to the front aspect of the ankle with compression wrap for 20 minutes.
    b. Sham- one candy corn filled bag applied to the front aspect of the ankle with compression wrap for 20 minutes.
    c. Control- remain seated for 20 minutes.
    d. Ice Immersion- ice bucket set at 10°C to the fibular head for 20 minutes.
6. Tests and measurements of static balance will be repeated immediately after, 20min. after, 40mins. After, and 60min. after.
7. You will then return at least 24 hours between treatments repeating the procedures until all four different treatment conditions have been completed.

Dynamic Balance Testing: This testing provides information on how well you maintain an upright posture while reaching in three different directions. The following procedures will be performed in the following order:

1. You will be positioned on the center of the Star Excursion Balance Test
2. You will be asked to stand on one foot while reaching in the front, back-lateral, and back-medial directions with the opposite foot reaching as far as possible
3. If you touch down with the opposite limb other than to touch the tape for measurement, make contact with the stance limb, lift up or move your planted foot, or unable to maintain standing posture during the test the trial will be terminated and repeated
4. Three successful trial in each direction will be measured
5. One of four treatment conditions will then be applied during one session
    a. Ice bag- one ice bag applied to the front aspect of the ankle for 20 minutes.
    b. Sham- one candy corn filled bag applied to the front aspect of the ankle for 20 minutes.
    c. Control- remain seated for 20 minutes.
    d. Ice Immersion- ice bucket set at 10°C to the fibular head for 20 minutes.
6. Tests and measurements of dynamic balance will be repeated immediately after, 20min. after, 40min. after, and 60min. after.
7. You will then return at least 24 hours between treatments repeating the procedures until all four different treatment conditions have been completed.

Risks of this study

There are a few discomforts associated with this study. There is a small chance that you will lose balance during the test and fall. You may also experience some mild levels of discomfort with the balance activity and with the treatment of cryotherapy. We will take every precaution to minimize the risks and discomfort s by making sure that

pain/discomfort levels are minimal prior to participating in the study. If at any time you are uncomfortable with participating in the study you may withdraw from the study with no fear of repercussions.

You may have cryotherapy side effects that can include temporary numbness. We will make sure that full function/feeling has returned to your comfort level before leaving the testing room. Call us if you have any symptoms or problems that you feel are related to the study.

If you are pregnant now, or get pregnant during the study inform us so that we can ensure the safety of your unborn baby and you will then be withdrawn from the study. If you meet any of the exclusion criteria you will be withdrawn from the study.

If you are hurt in this study
Please be advised that medical treatment is available upon the event of physical injury resulting from this study. Medical treatment will be limited to first aid and ice. If further medical attention is needed the subject will have to seek the appropriate medical attention. Texas State University-San Marcos students may choose to go to the Student Health Center free of charge. Please call 512-245-2161 to schedule an appointment or speak to a health care provider at the Student Health Center. We will report an adverse events per institutional policy. In the event that you believe you have suffered injury not apparent immediately after testing, please contact the IRB chairperson Dr. Jon Lesser ate 512-245-3413, who will review the matter with you and identify any other resources that may be available.

Compensating for being in the study
You will be paid $25 if you complete the study including all four different forms of treatment. You will not get paid at all if you do not complete all parts of the study.

In addition to the compensation for your time being in the study, your participation will contribute to expanding the body of knowledge to understand the effects of different modes of cryotherapy.

Confidentiality of your participation
Your participation in this study is confidential. Only the investigators will have access to your personal identifiers and to any information that may be linked with your identity. All information that you complete will have an identification number rather than your name to ensure you confidentiality. All data will be stored in a locked cabinet in the Biomechanics Sports Medicine Lab for seven years. In the event of this study being published, none of your personal identifying information will be disclosed.

Knowing the results before publishing
We will inform you during the study of any results that are important to your health. That information is important for you to know, because it may help you decide whether you want to continue being in this study. We cannot tell you any other information until the results have been studied when the research is completed in August. At that time you

can ask for more information by contacting the investigators listed below.

Please contact the researchers listed below if you want to:

- Obtain more information about the study
- Ask a question about the study procedures or treatments
- Report an illness, injury, or other problem (you may also need to tell your regular doctors)
- Leave the study before it is finished
- Express a concern about the study

Principal Investigator: Sarah Ashworth, ATC, LAT, CES
Sea50@txstate.edu
740-646-9776

Faculty Chair Investigator: Kyung Min Kim, PhD, ATC, LAT
Department of Health and Human Performance
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San Marcos, TX 78666
Kmk102@txstate.edu
512-245-4373

Concerns about this study

This project 2015X2361 was approved by the Texas State IRB on 04/20/15. Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB chair, Dr. Jon Lasser (512-245-3413 - lasser@txstate.edu) and to Becky Northcut, Director, Research Integrity & Compliance (512-245-2314 - bnorthcut@txstate.edu).

Signing this consent form

Before you sign this form, please ask questions about any part of this study that is not clear to you. Your signature below means that you understand the information given to you about the study and in this form. If you sign this form it means that you agree to join the study.

Voluntary Participation

Your participation in this study is completely voluntary. You may withdraw from this study at any time without any negative consequences from anyone associated with the study.

Consent from adult

PARTICIPANT	**PARTICIPANT**	**DATE**
(PRINT NAME)	(SIGNATURE)	

To be completed by participant if 18 years of age or older

Person Obtaining Consent

By signing below you confirm that you have fully explained this study to the potential subject, allowed them time to read the consent or have the consent read to them, and have answered all their questions.

PERSON OBTAINING CONSENT (PRINT NAME)	PERSON OBTAINING CONSENT DATE (SIGNATURE)

A2: General Health Questionnaire

General Health Questionnaire

Subject ID:_____ IRB#_____

HEIGHT	WEIGHT	SEX	AGE	DOB

Which leg would you use to kick a ball? Right Left

Have you consumed any of the following stimulants or depressants in the last 12 hours?

○Caffeine ○Alcohol

○Tobacco

○Other _____

If yes, please explain_____

Do you exercise regularly? ○Yes ○No

If yes, what type, how often, and how long? _____

Please check below if you have or had any of the following:

General

○Allergies (latex, heat, cold, medication, etc)
○Cancer
○Biomedical Devices (implants, pacemaker)
○Currently pregnant or nursing
○Current illness (infection, cold, etc)
○Diabetes
○Asthma
○Surgery
○Taking over the counter medications (last 24hrs)
○Other: _____

Please explain any checked items: _____

_____

Date of last physical exam: _____

Neurological

○Epilepsy/seizures
○Anxiety disorders
○ADHD
○Diabetic Neuropathy
○Concussion or traumatic brain injury
○Cerebral palsy
○Balance Disorder
○Vertigo
○Parkinson's Disease
○Multiple Sclerosis
○Other _____

Please explain any checked items: _____

_____

Cardiovascular

○Stroke
○High Blood Pressure
○Heart Attack
○Shortness of Breath
○Sickle Cell Trait
○Heart Murmur
○Heart Disease
○Thrombosis or Embolism

○Marfan's Syndrome ○Cardiac Arrythmia
○Other: _____
Please explain any checked items: _____
_____

General Orthopedic
○Rheumatoid arthritis ○Surgery
○Osteoarthritis ○Gout
○Osteoporosis/Osteopenia ○Assistive Devices (crutches, braces)
○Previous Fracture ○Lower Extremity sprain/strain
○Other: _____
Please explain any checked items: _____
_____

A3: Subject Screening Form

Subject Screening Form

IRB #:
Subject ID# _____. DATE:_____.

Inclusion Criteria:

YES

- Subjects over the age of 18

Exclusion Criteria:

NO

- Subjects that have been diagnosed with neurological injury
- Subjects that have been diagnosed with diabetes
- Subjects who have a history of balance disorders
- Subjects that have Raynaud's disease
- Subjects that have an allergy or hypersensitivity to cold
- Subjects who have circulatory problems
- Subjects who have a history of head or lower extremity injury within the past 6 months

This subject was **INCLUDED / EXCLUDED** in this study

A4: Visual Analog Scale (VAS)

Subject ID#:_____ Test side: Right Left

Timeline: Baseline ( ) Immediately post ( ) 20 min post ( ) 40 min post ( ) 60 min post ( )

Set Up

Test Leg length:_____cm

Foot Length: _____cm Foot Width: _____cm

Force Plate Coordinates

Stance	Coordinate (cm) (+X, -X)	Coordinate (cm) (+Y, -Y)
Double		
Single		

Single leg stance

Eyes Open : Trial 1 2 3 4 5 6 7 8 9 10 Failed trial #____

Eyes Closed: Trial 1 2 3 4 5 6 7 8 9 10 Failed trial #____

Please rate your balance you just performed with eye **OPEN** by marking the line below:

Worst Imaginable Balance _____ *Best Imaginable Balance* ____*cm*

Please rate your balance you just performed with eye **CLOSED** by marking the line below:

Worst Imaginable Balance _____ *Best Imaginable Balance* ____*cm*

SEBT

Anterior: Trial 1 2 3 4 5 6 7 8 9 10 Failed trial #____

Posterior-Medial: Trial 1 2 3 4 5 6 7 8 9 10 Failed trial #____

Posterior-Lateral: Trial 1 2 3 4 5 6 7 8 9 10 Failed trial #____

Please rate your balance you just performed in the **ANTERIOR** direction by marking the line below:

Worst Imaginable Balance _____ *Best Imaginable Balance* ____*cm*

Please rate your balance you just performed in the **POSTERIOR-MEDIAL** direction by marking the line below:

Worst Imaginable Balance _____ *Best Imaginable Balance* ____*cm*

Please rate your balance you just performed in the **POSTERIOR-LATERAL** direction by marking the line below:

Worst Imaginable Balance _____ *Best Imaginable Balance* ____*cm*

A5: Procedures for Static and Dynamic Balance and Skin Temperature

1. Turn on the computer & Physitemp Thermes USB electrothermometer.
2. Place Accusway Plus forceplate safely on the ground making sure it is level for static balance testing.
3. Hook up USB and power cables from the Accusway Plus forceplate and Physitemp Thermes USB electrothermometer to computer.
4. Hook up PT-6 surface thermocouples to Phyitemp Thermes USB electrothermometer.
5. Have subject remove appropriate clothing and shoes to expose the lower extremities.
6. Open balance Clinic.
7. Select thesis protocol.
8. Create a new file for the subject.
9. Zero Calibrate Accusway Plus forceplate.
10. Apply PT-6 surface thermocouples to:
    a. Anterior aspect of ankle over talus
    b. Muscle belly of soleus muscle
    c. Open exposed to room air
11. Have the subject stand on the Accusway Plus forceplate.
12. Testing Position (Figure 1&2)
    a. Align the medial malleolus to the center horizontal line (x-axis)
    b. Align the calcaneus to the vertical line (y-axis)
    c. With the rear foot positioned as above, you may allow the subject to splay to comfort
13. Instruct patient position to maintain throughout balance test.
14. Allow patient to practice static balance on selected limb.
15. Start Static Balance testing
    a. 3 trials of single leg standing with eyes opened (Figure 3)
    b. 3 trials of single leg standing with eyes closed (Figure 4)
16. Save data and mark any failed attempts.
17. Have patient mark the visual analog scale on how well their balance was.
18. Align patient's foot as instructed in step 12 along tape. (Figure 5&6)
19. Have patient practice the Star Excursion Balance Test six times in each direction
    a. Anterior (Figure 7)
    b. Posterior-medial (Figure 8)
    c. Posterior-lateral (Figure 9)
20. Have patient perform Star Excursion Balance Test three times in each direction while marking distance.
21. Record reach distances
22. Measure patients leg length

23. Have patient seated during treatment for 20 minutes
    a. Ice bag- one ice bag applied to the anterior aspect of the ankle with compression wrap. (Figure 10)
    b. Sham- one candy corn filled bag applied to the anterior aspect of the ankle and with compression wrap. (Figure 11)
    c. Control- remain seated
    d. Ice Immersion- ice water set at 10°C to the fibular head. (Figure 12)
24. Repeat steps 8-13, 15-18, and 20-21 immediately post, 20 mins post, 40 mins post, and 6- mins post treatment
25. Print out the data
26. Shut down the computer

Table 1. Center of pressure (COP) measures taken during unipedal stance for 10 seconds (mean and standard deviation)

		Eyes Open				Eyes Closed			
		X-Average (in.)	X-SD(in.)	Y-Average(in)	Y-SD(in.)	X-Average (in.)	X-SD(in.)	Y-Average(in.)	Y-SD(in.)
Ankle Cooling	Baseline	-.07±.29	.20±.04	-.44±.41	.32±.09	-.06±.25	.41±.07	-.25±.62	.59±.16
	Immediately Post Treatment	.02±.25	.22±.04	-.28±.55	.30±.07	-.02±.31	.39±.06	-.21±.51	.52±.11
	20-Mins. Post Treatment	-.03±.35	.21±.21	-.51±.45	.32±.06	.03±.33	.39±.06	-.17±.56	.59±.16
	40-Mins. Post Treatment	-.07±.28	.22±.05	-.47±.50	.33±.08	-.002±.25	.39±.05	-.19±.46	.59±.16
	60-Mins. Post Treatment	-.06±.29	.22±.05	-.51±.43	.36±.10	.002±.29	.38±.06	-.23±.42	.53±.12
Lower Leg Immersion	Baseline	.005±.18	.21±.05	-.21±.40	.31±.07	.005±.15	.39±.06	-.09±.55	.53±.13
	Immediately Post Treatment	.05±.22	.24±.05	-.16±.40	.38±.11	.06±.26	.37±.11	.17±.66	.60±.13
	20-Mins. Post Treatment	-.07±.26	.23±.04	-.19±.51	.37±.14	-.04±.28	.38±.08	.03±.71	.57±.17
	40-Mins. Post Treatment	-.06±.20	.22±.06	-.31±.45	.35±.07	-.05±.16	.39±.07	-.16±.43	.54±.12
	60-Mins. Post Treatment	-.06±.22	.22±.05	-.51±.49	.33±.07	-.06±.25	.38±.07	-.07±.52	.54±.13
Sham	Baseline	-.11±.18	.21±.04	-.38±.50	.30±.08	-.04±.26	.41±.08	-.13±.42	.60±.15
	Immediately Post Treatment	-.05±.21	.21±.05	-.47±.52	.39±.16	-.002±.20	.41±.07	-.09±.33	.56±.14
	20-Mins. Post Treatment	-.10±.26	.20±.04	-.50±.54	.34±.12	-.03±.29	.39±.05	-.08±.48	.56±.13
	40-Mins. Post Treatment	-.07±.23	.21±.04	-.44±.53	.32±.08	-.003±.17	.40±.07	-.10±.45	.57±.15
	60-Mins. Post Treatment	-.06±.25	.22±.04	-.38±.57	.37±.11	-.02±.25	.38±.05	-.06±.60	.50±.15
Control	Baseline	-.001±.37	.20±.04	-.47±.48	.29±.08	.001±.35	.40±.06	-.22±.46	.56±.14
	Immediately Post Treatment	-.06±.37	.21±.04	-.62±.38	.33±.09	.04±.35	.39±.05	-.29±.42	.55±.10
	20-Mins. Post Treatment	-.08±.39	.19±.05	-.48±.56	.31±.08	-.006±.35	.36±.06	-.08±.53	.50±.10
	40-Mins. Post Treatment	.01±.38	.21±.05	-.58±.30	.35±.12	.02±.35	.37±.06	-.19±.37	.52±.10
	60-Mins. Post Treatment	-.05±.32	.21±.04	-.57±.30	.34±.11	-.007±.33	.38±.08	-.11±.47	.55±.13

Table 2. Visual analog scale scores (cm) of subjective levels of postural control during unipedial stance for 10 seconds (mean and standard deviation).

VAS						
		Baseline	Immediately post Treatment	20-min. post Treatment	40-min post Treatment	60-min post Treatment
Ankle Cooling	Eyes open	7.88±1.50	7.84±1.68	8.14±1.44	8.33±1.51	8.54±1.27
	Eyes closed	5.39±2.63	5.31±2.68	6.39±1.74	6.53±2.05	6.75±1.80
Lower Leg Immersion	Eyes open	7.95±1.59	7.64±1.87	8.05±1.73	8.07±1.50	8.27±1.48
	Eyes closed	5.79±2.36	4.57±2.48	5.63±6.69	6.69±1.85	6.49±2.12
Sham	Eyes open	7.13±2.67	7.25±2.78	7.67±2.48	7.42±2.73	7.70±2.67
	Eyes closed	5.01±2.88	5.43±2.65	5.32±2.56	6.01±2.35	6.30±2.84
Control	Eyes open	7.11±2.67	6.90±2.62	7.36±2.50	7.41±2.57	7.52±2.61
	Eyes closed	4.62±2.83	4.97±2.46	6.08±2.78	6.69±1.92	6.10±2.52

Table 3 Normalized reach distance (cm) during modified Star Excursion Balance Test

		Anterior	Posterior-medial	Posterior-lateral	Composite
Ankle Cooling	Baseline	86.97±8.18	94.93±8.55	83.71±11.84	88.54±8.34
	Immediately Post Treatment	85.77±8.37	92.01±9.03	82.93±12.49	86.90±8.42
	20-Mins. Post Treatment	86.37±9.31	95.29±8.65	86.91±13.79	89.52±8.78
	40-Mins. Post Treatment	86.84±9.20	94.71±8.48	86.44±10.54	89.33±8.16
	60-Mins. Post Treatment	86.61±8.94	93.70±9.43	85.73±10.31	88.68±8.52
Lower Leg Immersion	Baseline	86.94±9.67	91.38±9.58	81.98±15.60	86.77±9.93
	Immediately Post Treatment	87.50±9.15	91.70±9.63	81.92±18.96	87.04±11.02
	20-Mins. Post Treatment	87.71±10.15	93.70±10.32	84.18±12.03	88.53±9.14
	40-Mins. Post Treatment	87.54±12.19	93.12±11.43	85.74±13.14	88.80±10.56
	60-Mins. Post Treatment	87.83±10.21	93.80±11.81	86.07±12.56	89.23±10.09
Sham	Baseline	87.53±8.49	93.26±8.30	86.31±10.13	89.03±7.61
	Immediately Post Treatment	85.79±9.02	91.82±11.67	82.90±12.10	86.84±9.03
	20-Mins. Post Treatment	86.63±7.55	93.67±10.46	84.60±13.11	88.30±9.47
	40-Mins. Post Treatment	87.23±9.55	92.94±10.98	83.67±12.74	87.95±9.71
	60-Mins. Post Treatment	87.77±8.64	94.78±9.50	84.16±12.17	88.90±9.62
Control	Baseline	87.54±9.71	95.26±10.60	85.01±13.11	89.27±10.04
	Immediately Post Treatment	87.03±9.51	90.46±11.96	84.31±14.29	87.27±10.53
	20-Mins. Post Treatment	85.76±9.32	93.58±10.99	85.35±13.91	88.23±10.15
	40-Mins. Post Treatment	87.12±8.86	95.04±10.08	87.30±12.00	89.82±8.91
	60-Mins. Post Treatment	86.79±10.72	94.33±10.75	86.92±11.76	89.25±9.84

Table 4. Visual analog scale scores (cm) of subjective levels of postural control during modified Star Excursion Balance Test (mean and standard deviation).

		Baseline	Immediately Post Treatment	20-min. post Treatment	40-min post Treatment	60-min post Treatment
Ankle Cooling	Anterior	6.63±2.09	7.12±1.79	7.50±1.47	7.49±1.68	7.60±1.68
	Posterior Medial	7.37±1.80	7.71±1.77	7.86±1.53	7.69±1.72	7.99±1.55
	Posterior Lateral	6.71±1.99	7.12±2.11	7.9±1.39	7.44±1.79	7.81±1.47
Lower Leg Immersion	Anterior	6.53±1.88	7.00±1.64	7.57±1.45	7.71±1.49	7.79±1.52
	Posterior Medial	7.45±1.97	7.41±1.72	8.13±1.34	7.90±1.9	8.05±1.43
	Posterior Lateral	6.64±2.00	7.11±1.62	7.53±1.2	7.73±1.43	7.77±1.39
Sham	Anterior	7.2±2.06	7.14±2.03	7.21±1.72	7.45±1.88	7.41±2.11
	Posterior Medial	7.47±2.00	7.67±1.90	7.93±1.61	7.95±1.64	7.91±1.98
	Posterior Lateral	7.27±2.09	7.33±2.12	7.39±1.88	7.87±1.84	7.71±2.06
Control	Anterior	6.49±2.31	7.02±1.76	7.68±1.49	7.79±1.29	7.46±1.85
	Posterior Medial	7.35±1.69	7.43±1.54	7.69±1.63	7.95±1.17	7.96±1.77
	Posterior Lateral	6.98±2.17	7.17±1.90	7.50±1.60	7.89±1.23	7.39±1.93

Table 5. Skin surface temperatures (˚C, mean and standard deviation)

Temperatures (˚C)						
Condition	Site	Baseline	Immediately Post Treatment	20-min. post Treatment	40-min post Treatment	60-min post Treatment
Ankle Cooling	Ankle	31.06±1.47*	21.04±4.52*	26.59±2.58*	27.95±2.37*	28.35±2.26*
	Muscle	30.59±1.17*	32.64±.93*	30.208±.85	29.89±.80*	29.85±1.29
	Ambient Air	23.08±.35	23.00±.21	22.99±.20	23.00±.23	23.05±.23
Lower Leg Immersion	Ankle	31.01±1.20*	16.65±1.10*	23.74±2.22*	25.83±2.67*	26.81±2.38*
	Muscle	30.19±1.74*	17.29±1.24*	24.82±1.22*	26.80±.88*	27.49±1.59*
	Ambient Air	22.92±.43	22.84±.37	22.87±.33	23.22±1.44	22.96±.35
Sham	Ankle	30.34±1.35	30.12±1.21	29.77±1.24	27.81±7.76	29.45±1.40
	Muscle	30.00±1.22	31.97±.82	30.26±1.03	29.74±.98	29.36±2.07
	Ambient Air	22.85±.33	22.86±.33	22.80±.33	22.80±.33	22.86±.35
Control	Ankle	31.04±1.36	30.60±1.12	30.33±1.42	29.53±1.69	29.42±1.60
	Muscle	30.36±1.25	30.04±1.06	31.82±8.25	29.62±1.12	29.62±1.11
	Ambient Air	22.87±.28	22.93±.40	22.86±.37	22.87±.38	22.87±.40

*Denotes significant difference ($p<.050$) between baseline and after treatment

Table 6. Failed trials during the static balance (mean and standard deviation)

		Ankle Cooling	Lower Leg Immersion	Sham	Control
Eyes Open	Baseline	.13±.35	0.13±.35	.07±.26	.13±.35
	Immediately Post Treatment	0±0	.13±.52	0±0	.07±.26
	20-min. Post Treatment	0±0	0±0	.07±.26	0±0
	40-min. Post Treatment	0±0	0±0	0±0	.2±.56
	60-min. Post Treatment	.13±.35	.07±.26	.07±.26	.13±.35
Eyes Closed	Baseline	3.13±4.90	1.27±1.67	2.2±2.4	1.8±1.37
	Immediately Post Treatment	4±4.81	4.2±3.34	1.4±1.24	1.47±1.51
	20-min. Post Treatment	1.6±2.32	2.07±2.44	1.87±2.77	.73±1.39
	40-min. Post Treatment	2.4±3.68	1.33±2.44	1.07±1.03	1.47±2.39
	60-min. Post Treatment	1.8±2.83	1.27±1.75	.93±1.79	.93±1.49

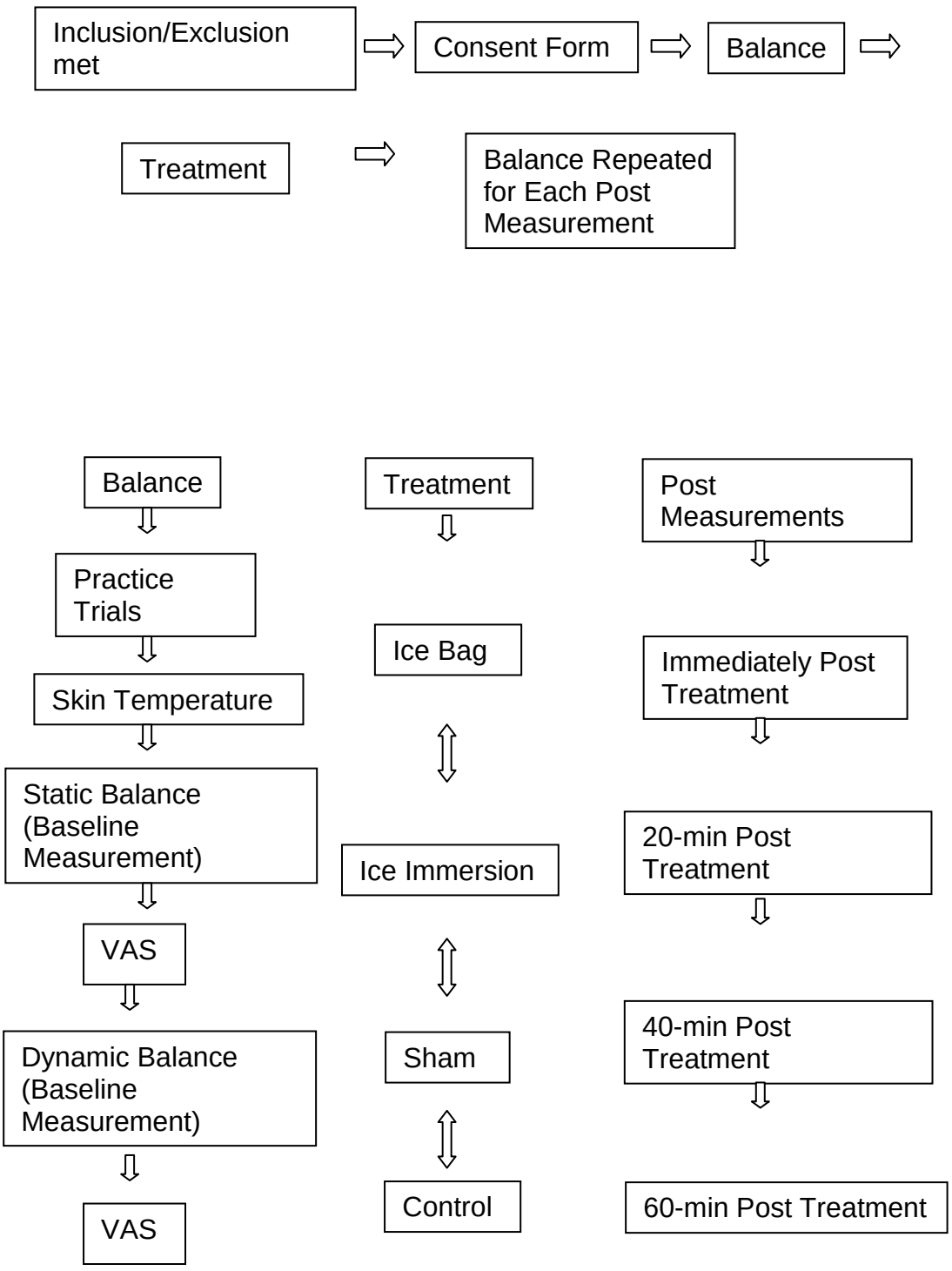

Figure 1
Diagram of Study Procedures

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