

EFFECTS OF FOCAL KNEE JOINT COOLING ON DIFFERENT MODES OF  
QUADRICEPS STRENGTH ASSESSMENT

by

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## **DEDICATION**

This thesis is dedicated to God, who has always strengthened and guided me every single moment to finish this work.

## **ACKNOWLEDGEMENTS**

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## I. INTRODUCTION

### Introduction

Quadriceps strength is critical for knee function as it helps absorb shock placed on the knee during physical activity.<sup>1-3</sup> However, quadriceps weakness is common in patients with knee injuries.<sup>4-8</sup> Persistent muscle weakness that continues to occur despite rehabilitation efforts is caused by arthrogenic muscle inhibition (AMI).<sup>9</sup> AMI has been defined as an ongoing reflexive inhibition of the muscle surrounding a joint following an injury.<sup>10</sup> Persistent weakness of the quadriceps due to AMI has been shown to lead to poor functional outcomes<sup>11-12</sup> and promote an early onset of osteoarthritis.<sup>13</sup> It appears that traditional rehabilitation programs focusing on active exercise for quadriceps weakness have not been successful in counteracting AMI,<sup>10</sup> as traditional exercise does not seem to address the underlying neurophysiological origin of the weakness.

There are emerging studies focusing on developing an intervention aimed at AMI such as cryotherapy, transcutaneous electrical nerve stimulation, and neuromuscular electrical stimulation. Among various modalities, cryotherapy has been consistently found effective in relieving AMI by increasing peripheral sensory activity that is thought to override aberrant afferent activity responsible for AMI.<sup>14-20</sup> Specifically, Hart et al<sup>16</sup> reported that focal knee joint cooling (FKJC) which place the crushed ice bags on the knee joint, not on the quadriceps muscle was more effective in conjunction with exercise than exercise alone in gaining quadriceps strength for patients with anterior cruciate ligament reconstruction. This similar therapeutic effect was also found in individuals without joint pathology, indicating the joint cooling may be capable of increasing motor outputs in healthy individuals.<sup>15,18,21-25</sup> For example, Pietrosimone et al<sup>19</sup> reported 20



minutes of FKJC significantly increased quadriceps strength as well as voluntary activation.<sup>17</sup>

These improvements have been attributed to increases in motoneuron excitability following joint cooling.<sup>20,23,24,26,27</sup> Given the favorable outcomes associated with FKJC, the use of FKJC prior to therapeutic exercise has been recommended for patients with joint pathology in an effort to facilitate more complete muscle recruitment.<sup>7</sup> It should be noted that the promising results following FKJC<sup>14-20</sup> have only been investigated with an isometric mode of muscle contraction of the quadriceps. However, no studies have investigated functional modes of muscle contractions, such as concentric and eccentric modes, both of which are required to perform almost all types of physical activity.<sup>28</sup> In addition, muscles are often required to quickly generate force necessary for athletic and daily activities.<sup>29-31</sup> So, the isokinetic strength testing at various angular velocities in addition to isometric testing, would provide evidence on a comprehensive profile of muscle strength following FKJC, which would be more representative of knee function.

### **Purpose**

The purpose of study is to determine the effects of FKJC on different modes of quadriceps strength assessment.

### **Significance of the Study**

The study findings will provide evidence that FKJC can be an effective tool to maximize muscle function for both conditioning and rehabilitation settings. It is believed that cryotherapy is an effective modality not only to reduce pain, swelling, and secondary hypoxic injury during immediate care but also to induce analgesic effects during the early stages of rehabilitation allowing early active therapeutic exercise. In contrast, it has been

contraindicated in conditioning rehabilitation for muscle function when directly placed on a muscle due to detrimental effects such as decreases in motor nerve conduction velocity, muscle spindle sensitivity, and muscle strength. However, it is very important to note that these negative effects were found following direct muscle cooling while there is growing favorable evidence of improvements in muscle function following focal joint cooling.<sup>14-20,</sup>

<sup>21-25</sup> The current study finding in conjunction with previous promising findings associated with effects of FKJC on muscle function would support that joint cryotherapy is a safe and effective intervention to improve muscle function, and it should be indicated for individuals who want to further develop the quadriceps and patients with persistent muscle dysfunction as a recent study found that use of FKJC in combination with exercise was more effective than exercise alone in increasing quadriceps strength.

### **Research Question**

This study is designed to answer the following questions:

- Does FKJC increase isometric strength of the quadriceps?
- Does FKJC increase concentric strength of the quadriceps?
- Does FKJC increase eccentric strength of the quadriceps?

### **Hypothesis**

- FKJC will significantly improve isometric strength of the quadriceps, as determined by increases in peak torque, during maximal voluntary isometric contraction while the strength will remain unchanged following the sham treatment.

- FKJC will significantly improve concentric strength of the quadriceps, as assessed with increase in peak torque and total work, while the strength will remain unchanged following the sham treatment.
- FKJC will significantly improve eccentric strength of the quadriceps, as assessed with increase in peak torque and total work, while the strength will remain unchanged following the sham treatment.

### **Assumptions**

- All subjects were honest with meeting the inclusion and exclusion criteria.
- All subjects performed isometric and concentric/eccentric testing with their best efforts.
- Subjects were honest with their visual analog score on their perceived quadriceps strength.
- Subjects refrained from any other types of cryotherapy 72 hours before testing.

### **Delimitations**

- Ages of participants were limited from 18 to 40 years old.
- Subjects had no lower extremity within the past 6 months.
- Subjects had no history of knee surgery.
- Subjects had no impaired circulation.
- Subjects had no allergy to cold.
- Subjects were free from any neurological conditions

### **Limitations**

- Knee flexion angle during the isometric contraction was fixed at 80°.
- Testing time was different between first visit and second visit.

## **Operational Definitions**

- Quadriceps strength: An ability to produce isometric and isokinetic quadriceps strength.
- Isometric strength of quadriceps: An ability of maximal force production, while the muscle length and joint angle remain unchanged during quadriceps contraction.
- Concentric strength of quadriceps: An ability of resistive force production. The muscle length shortens and joint angle is changed during the phase of quadriceps extension.
- Eccentric strength of quadriceps: An ability of resistive force production. Muscles lengthen during the phase of quadriceps extension.
- Peak torque: Highest muscular force output at any moment during a repetition.
- Total work: The amount of work accomplished during a repetition which represents the muscle capability to maintain torque throughout the repetition.
- Focal knee joint cooling: Cryotherapy applied only to the knee joint.
- Sham: 1.5 L bags filled with candy corns mimicked focal knee joint cooling.

## **II. METHODS**

### **Research Design**

The study was a cross-over investigation with two independent variables including treatment condition (FKJC and sham) and time (pre-, immediately-, 20 minutes post-, and 40 minutes post-treatment). Primary outcomes included knee extension peak torque and total work calculated from 4 different tests of quadriceps strength: one isometric and two isokinetic tests (concentric and eccentric contractions) at two different angular velocities (60°/s and 180°/s). Secondary outcomes were scores on a visual analog scale for subject's perceived level of performance during the strength tests. Control variables were knee joint and quadriceps muscle surface temperatures at two different sites to monitor the delivery of FKJC along with the ambient air temperature.

### **Subjects**

Twenty-one subjects (12 males, 9 females, age:  $22.7 \pm 3.1$  years old, height:  $170.4 \pm 10.8$  cm, weight:  $74.2 \pm 16.4$  kg) without current pathology were recruited for the study, as FKJC has been shown to have similarly effectiveness in both individuals with and without joint pathology in increasing quadriceps strength.<sup>14-20</sup> It was important to determine how FKJC would affect all types of quadriceps strength in subjects without current pathology before considering its use for those with pathology. Subjects were excluded if they had a history of lower extremity injury within the past 6 months, neurological disease, any areas of impaired circulation, a fear of cryotherapy, and a history of knee surgery. The university's institutional review board approved the study protocol, and procedures were not performed until informed consents were obtained from all participants. Upon receipt of an informed consent a questionnaire were used to assess

the medical and health conditions of the potential subject to determine his/her eligibility to be enrolled in the study (Appendix A1-3).

### **Instrumentation**

A Biodex isokinetic dynamometer (Biodex System 4, Biodex Medical Systems, Shirley, NY) was used to test the different modes of quadriceps strength (Appendix A7). Biodex Advantage Software, Version 4.X (Biodex Medical Systems, Shirley, NY) with a Biofeedback Graphical User Interface (GUI) screen was used for computation of strength outcomes. PT-6 surface thermocouples and Physitemp Thermes USB electrothermometer (Physitemp Instruments Inc, Clifton, NJ) were used to record temperatures of skin at the patella tendon, mid-thigh, and ambient temperature at 4 different time intervals (pre-, immediately-, 20 minutes post-, and 40 minutes post-treatment). The temperature data were stored through the Measurement Computing Data Acquisition (MCC DAQ) Software (Measurement Computing <sup>TM</sup>, Norton, MA).

### **Procedures**

On the first day, subjects had an orientation session to practice and understand the testing procedures (Appendix A6) and to be familiarized with the strength tests. At least 72 hours of rest time were followed by the orientation session. Subjects underwent 3 tests of quadriceps strength including one isometric and two isokinetic tests (Appendix A5). Subjects received treatment sessions on two different test days which were at least 72 hours apart. The order of administering the treatment (cryotherapy versus sham) was randomized using randomly assigned envelopes (1:1 ratio) by the investigator. The isometric testing took place followed by isokinetic tests being performed at angular velocities of 60°/s and 180°/s in a random order. The baseline strength was assessed

before 20 minutes of treatment, and then the follow-up tests were repeated immediately-, 20 minutes post-, and 40 minutes post-treatment. The knee joint on the dominant side was tested, as determined by asking which leg they used to kick a ball. Subjects received verbal encouragement during each test, and the same examiner performed all testing procedures.

### **Isometric Testing of Quadriceps Strength**

Subjects were seated in the Biodex (Biodex System 4, Biodex Medical Systems, Shirley, NY) with the knee flexed 80° and the hip flexed 85°. The straps secured the ankle (superior to the malleoli), thigh (midline of thigh), waist (superior to the anterior superior iliac spine), and shoulders (diagonal from lateral surface of clavicle) as instructed by the manufacturer in order to limit extraneous movements. Subjects were instructed not to use the trunk and contralateral leg or hold the handle to produce force using compensatory strategies. After subjects were properly prepared, they had a practice session at 2 maximal voluntary isometric contraction (MVIC).<sup>6</sup> During the practice session, subjects were instructed to contract the quadriceps as fast and forcefully as possible to reach MVIC, and hold for at least 3 seconds.<sup>19</sup> After successful practice trials, at least 15 minutes of rest time was provided before the testing trials. Subjects were asked to perform 3 testing trials of MVIC with 5 seconds of rest between trials. Three successful trials of MVIC for 3 seconds were recorded at each time interval.

### **Isokinetic Testing of Quadriceps Strength**

After the isometric testing subjects remained seated in the Biodex (Biodex System 4, Biodex Medical Systems, Shirley, NY), but with the knee flexed 100° and the hip flexed 85° for 2 isokinetic tests (concentric and eccentric contractions) at different

angular velocities (60°/s and 180°/s).<sup>32</sup> The order of the angular velocities was randomly assigned to prevent order effects. Subjects had a practice session consisting of an isokinetic test at the 2 different angular velocities, involving alternating concentric and eccentric contractions with their maximal voluntary contraction effort. The concentric contraction of the quadriceps occurred during knee extension from 100° of knee flexion to 10° of extension while the eccentric repetition took place during knee flexion from 10° of extension to 100° of knee flexion. After successful practice trials, subjects were asked to perform 3 testing trials of an isokinetic test at each velocity with 5 seconds of rest between trials, and 120 seconds between tests (isokinetic at 60°/s or 180°/s). Three successful trials of each isokinetic test were recorded at each time interval.

### **Focal knee joint cooling**

Subjects were positioned supine on a table to receive a treatment. For FKJC two 1.5L plastic bags filled with crushed ice were used with one bag applied to the anterior knee (patella), and the other placed in the posterior knee (popliteal fossa), and they were secured with an elastic wrap throughout treatment (Appendix A7).<sup>19</sup> The sham treatment mimicked the FKJC with the same type of bag, but filled with candy corns to control potential effects of the compression that the elastic wrap might provide on the strength outcomes. All treatment conditions lasted for 20 minutes.

### **Skin temperature**

Two surface thermocouples were used for the measurement of skin surface temperatures at two sites over the center of patellar tendon and midthigh. Ambient air temperature in the laboratory was measured using another surface thermocouple. Three measurements of temperatures at each site before and after 4 different tests of quadriceps



strength: one isometric and two isokinetic tests (concentric and eccentric contractions) at two different angular velocities (60°/s and 180°/s) were recorded at each time point (pre-, immediately-, 20 minutes post-, and 40 minutes post-treatment) to ensure the delivery of FKJC to the knee joint, not the quadriceps.<sup>22</sup>

### **Visual analog scale**

Visual analog scales were used to quantify a perceived level of strength performance.(Appendix A5) After successful 3 trials of each test, subjects were asked to draw a vertical line across a 100 mm horizontal line. Scores ranged from 0 to 100 with 0 representing “least strength” and 100 indicating “highest strength”.

### **Data Processing**

Peak torque was calculated from all 3 strength tests (one isometric and 2 isokinetic tests) and total work was calculated from the 2 isokinetic strength tests (concentric and eccentric contractions) at two different angular velocities (60°/s and 180°/s) as previously suggested.<sup>19,32</sup> These variables have been commonly reported in the literature to capture different aspects of the quadriceps strength.<sup>32</sup> The mean of 3 trials for each variable in each contraction (isometric, concentric, and eccentric) was used for statistical analysis.

### **Power Analysis**

Sample size was determined for the primary aims by using means and standard deviations from the previous study assessing effects of FKJC on quadriceps strength during maximal voluntary isometric contraction.<sup>19</sup> Given an alpha of 0.05 and a 1-beta level of .80 the moderate effect size (d=0.6) was used to calculate sample size. A

minimum of 18 participants was estimated as needed to find significant differences.

However, 21 subjects were included in the current.

### **Statistical Analysis**

Separate 2 (treatment condition) by 4 (time) ANOVA with repeated measures were conducted to determine effects of FKJC on each of the strength outcomes and visual analogue scales (VAS) scores. Post hoc simple contrasts were used to locate specific differences in the presence of significant interactions or main effects. For skin surface temperature, planned pairwise comparisons were conducted between baseline and any of follow-ups at each site. Alpha level was set *a priori* at  $p \leq 0.05$ . All statistical analyses were conducted with Statistical Package for Social Sciences (version 22, IBM, Armonk, NY) software.

### **III. RESULTS**

Descriptive statistics of all outcomes are presented in Table 1-4. There were no significant interactions for strength outcomes for any of the modes of muscle contractions. However, significant time main effects were found for all isokinetic outcomes except for the isometric mode (Table 1-2), indicating quadriceps strength declined over time during isokinetic tests regardless of treatment conditions. There were no significant interactions or time main effects for all visual analogue scale (VAS) scores that represent subjective levels of quadriceps strength (Table 3). The skin surface temperature over the knee joint significantly decreased immediately after removal of the 20-min FKJC, and the cooling effect remained for 40 minutes (Table 4). In contrast to the temperature over the knee joint, the skin surface temperature over rectus femoris significantly increased up to 20 minutes after removal of the 20-min FKJC (Table 4).

#### IV. DISCUSSION

The current study revealed that 20 minutes of focally cooling the knee joint with 2 bags of crushed ice did not change quadriceps strength, measured by either peak torque or total work during isometric, concentric, and eccentric modes of muscle contractions. The lack of significant changes was also consistent with no alterations in participants' perceived quadriceps strength, quantified with visual analogue scale (VAS) scores. As expected, our cooling method significantly decreased skin surface temperature over the patellar ligament up to 40 minutes after the joint cooling was removed. However, the skin surface temperature over the rectus femoris significantly increased up to 20 minutes after removal of FKJC. This temperature change over the rectus femoris might be caused by warming effects on quadriceps from the isometric and isokinetic quadriceps contraction tests. Subjects performed a total of 9 repetitions of quadriceps contractions (3 isometric, 3 isokinetic at 60° / seconds, and 3 isokinetic at 180° / seconds) at each time points (baseline, immediately, 20 minutes, and 40 minutes post FKJC application).

This is the first study to investigate effects of FKJC on isokinetic strength of the quadriceps. However, the lack of significant increases in isometric contraction of the quadriceps conflicts with previous findings.<sup>16,19,25</sup> A previous study<sup>19</sup> suggested that knee extension maximal isometric contractions were significantly higher following FKJC at 20 minutes post-application, and the trend lasted 30 minutes post-application. These immediate strength gains have been attributed to increased motor output of the knee extensors by facilitating the central nervous system.<sup>19</sup> There are several factors that may explain the conflicting findings on effects of FKJC on isometric contraction of quadriceps. The different findings from the previous study<sup>19</sup> could be explained by a small sample

size. Eleven healthy subjects participated in the prior study<sup>19</sup> when compared to the current study sample size with 21 healthy subjects.<sup>19</sup> Another factor could be that a different knee flexion angle was used during the muscle contraction tests. Isometric contraction tests at 70° of knee flexion was performed in a previous study while the test in the current study was conducted at 80°, which had been determined by pilot experiment, showing that several participants had produced higher peak torque at 80° than at 60°, 70°, and 90° of knee flexion. The previous study<sup>19</sup> found that FKJC increased peak torque 25 Nm in healthy subjects after 20 minutes of FKJC treatment ( $263.84 \pm 88.78\text{Nm}$  at Baseline,  $288.84 \pm 91.29\text{Nm}$  at 20 minutes-post treatment). Our results also had observed a 6Nm increase in peak torque (Table 1) when compared to the sham group, although it did not reach statistical significance. Therefore, it is unclear whether a 20 Nm increase of maximal voluntary muscle contraction can be contributed to a favorable outcome of motor function and strength gain. Previous studies<sup>16,25</sup> which found the increase of force output during the quadriceps contraction following FKJC were conducted on patients with anterior cruciate ligament injury or experimental knee swelling. A previous study<sup>16</sup> with anterior cruciate ligament reconstructed patients found a significantly higher normalized isometric contraction torque than cryotherapy and exercise alone after 2 weeks of combined treatment of FKJC and rehabilitation exercises. Another previous study<sup>25</sup> used experimental knee joint infusion. Fifteen ml of dextrose saline was injected into the knee joint space, showing that 20 minutes of FKJC with 3 ice bags around knee joint significantly increased quadriceps peak torque in subjects with saline injected knee immediately after removing FKJC. From the results of previous studies,<sup>16,19,25</sup> we could assume that FKJC might be an effective tool to help recover

quadriceps strength as 20 minutes of FKJC treatment is believed to manipulate altered spinal reflexive and cortical motor pathways, which is led to increase in neuromuscular function<sup>33,34,35</sup> in patients with arthrogenic muscle inhibition. However, our results showed that knee joint cooling in healthy conditions is not supported and inconclusive. It is possible that FKJC might not be strong enough to induce a facilitative effect on healthy quadriceps, indicating that there seems to be no room available for neurological function improvement in healthy individuals.

The current study was focused on isometric and isokinetic maximal strength following FKJC with outcome of peak torque and total work. However, using other neuromuscular measurement techniques such as Electromyography (EMG) and central activation ratio (CAR) may help understand quadriceps muscle function after FKJC better. Thus, measures of quadriceps voluntary activation and CAR during isokinetic contraction after FKJC are recommended for future studies.

Traditionally, cryotherapy is frequently used in sports medicine primarily to decrease pain, acute inflammation, metabolic rate, and edema.<sup>36</sup> In contrast to popular use of cryotherapy in managements of acute injuries, sports medicine practitioners tend to discourage cryotherapy in rehabilitation because they believe it has detrimental effects on neuromuscular function, including muscle stiffness caused by inhibition of actin and myosin interaction and decreased tension of both fast and slow twitch fibers,<sup>37,38</sup> decreased nerve impulse transmissions,<sup>39</sup> spindle activity, receptor firing rate, and decreased afferent fiber conduction velocity.<sup>40-46</sup> Previous researches<sup>47,48</sup> reported strength decreased after cooling on the muscle. It is noted that location of cooling (muscle versus joint) may matter as our findings in conjunction with previous reports<sup>17,21</sup> suggest no

harmful effects on muscle strength following locally cooling a joint where the muscle belly is not typically located. This helps us expand utilization of FKJC for patients and athletes. Cryokinetics (combination of cryotherapy and exercise) by use of FKJC may be alternative method with potential benefits for patients with knee joint injuries because it may help increase range of motion and maintain quadriceps strength while decreasing pain, swelling, and inflammation.<sup>47</sup>

## **V. CONCLUSION**

The current study demonstrated that 20 minutes of FKJC did not change quadriceps strength during isometric, concentric, and eccentric modes of muscle contractions. These results indicate that FKJC may not be harmful to muscle strength, and suggests that knee joint cooling could be used in rehabilitation for its analgesic effects prior to exercise for patients with acute or chronic injuries.



## **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 between 18 years of age and 40 years of age 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:** Joosung Kim, MS, ATC, LAT.  
Texas State Graduate Student  
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###### **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 study is to determine effects of Focal Knee Joint Cooling (FKJC) on different modes of the quadriceps strength assessment. 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 two visits at least forty-eight hours apart between the visits to the Biomechanics/Sports Medicine Laboratory at Texas State University. It will take approximately 1 to 1.5 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 quadriceps strength test. You will then be prepared for one of the two treatment conditions and reassessed in quadriceps strength test.

**Quadriceps Strength Measurement:** This testing provides information on how well you can produce your thigh muscle strength (quadriceps peak torque). The following procedures will be performed in the following order:

1. You will be positioned seated in the Biodex.
2. Your ankle (superior to the malleoli), thigh (midline of thigh), waist (superior to the anterior superior iliac spine), and shoulder (diagonal from lateral surface of clavicle) will be secured with the straps in order to limit extraneous movements.
3. You will be asked to push and resist against the Biodex arm as hard as you can at 90° of knee flexion.
4. You will be asked to perform 3 testing trials of maximum voluntary isometric contraction (MVIC) with 60 seconds of rest between trials.
5. Three successful 3 trials of MVIC for 3 seconds will be recorded at each time interval.
6. After the isometric testing subjects will remain seated in the Biodex (Biodex System 4, Biodex Medical Systems, Shirley, NY), but with the knee flexed 90° and the hip flexed 85° for 2 isokinetic tests at different angular velocities (60°/s and 180°/s).
7. The order of the angular velocities will be randomly assigned to prevent order effects.
8. You will have a practice session consisting of an isokinetic test at the 2 different angular velocities, involving alternating concentric and eccentric contractions.
9. The concentric contraction of the quadriceps will occur during knee extension from 90° of knee flexion to full extension while the eccentric one will take place during knee flexion from full extension to 90° of the knee flexion.
10. After successful practice trials, you will be asked to perform 3 testing trials of an isokinetic test at each velocity with 60 seconds of rest between trials, and 120 seconds between tests. Three successful trials of each isokinetic test will be recorded at each time interval.
11. One of the two treatment conditions will then be applied
  - a. Ice bag- one ice bag will be applied to the anterior aspect of the knee and one applied to the posterior aspect of the knee with compression wrap.
  - b. Sham- one candy corn filled bag will be applied to the anterior aspect of the knee and one applied to the posterior aspect of the knee with compression wrap.
12. Tests and measurements of isometric measurement of quadriceps strength will be repeated immediately, 20min and 40mins post treatment.

### **Risks of this study**

There are a few discomforts associated with this study. You may experience some mild levels of discomfort with the maximal voluntary isometric and isokinetic quadriceps contraction and with the treatment of cryotherapy (ice treatment). We will take every precaution to minimize the risks and discomforts 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 (ice treatment) 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 safety of your unborn baby.

**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 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 at 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 compensated \$30 if you complete the study including all two different forms of treatment. You will not get compensated at all if you do not complete all parts of the study.

**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 your 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. At that time you can ask for more information.

**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:**

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**Concerns about this study**

This project [2015F6191] was approved by the Texas State IRB on [02/02/16]. 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**

**DATE**

(PRINT NAME)

**PARTICIPANT**

(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**

**DATE**

(PRINT NAME)

**PERSON OBTAINING CONSENT**

(SIGNATURE)

## Appendix A2: General Health Questionnaire

Biomechanics/Sports Medicine Lab				
Health Questionnaire: General				
Subject ID: _____				
HEIGHT	WEIGHT	SEX	AGE	DATE OF BIRTH
				/ /
Which leg would you use to kick a ball?			Right <input type="checkbox"/>	Left <input type="checkbox"/>
Which leg would you use to jump from?			Right <input type="checkbox"/>	Left <input type="checkbox"/>
<b>Please check below if you have or have had any of the following:</b>				
<b>General Medical</b>				
<input type="checkbox"/> Allergies (latex, heat, cold, electricity, medications, etc)		<input type="checkbox"/> Recent illness (upper respiratory infection, cold, infections)		
<input type="checkbox"/> Cancer		<input type="checkbox"/> Diabetes		
<input type="checkbox"/> Biomedical Devices (implants, pacemaker)		<input type="checkbox"/> Asthma		
<input type="checkbox"/> Currently pregnant or nursing		<input type="checkbox"/> Surgery		
		<input type="checkbox"/> Other: _____		
<b>Please explain any checked items:</b> _____				
_____				
<b>Please provide date of last physical exam:</b> _____				
<b>Neurological</b>				
<input type="checkbox"/> Epilepsy/seizures		<input type="checkbox"/> Cerebral Palsy		
<input type="checkbox"/> Anxiety disorders		<input type="checkbox"/> Balance Disorder		
<input type="checkbox"/> ADHD		<input type="checkbox"/> Vertigo		
<input type="checkbox"/> Diabetic Neuropathy		<input type="checkbox"/> Parkinson's Disease		
<input type="checkbox"/> Concussion OR Traumatic Brain Injury		<input type="checkbox"/> Multiple Sclerosis		
		<input type="checkbox"/> Other: _____		
<b>Please explain any checked items:</b> _____				
_____				
<b>Cardiovascular</b>				
<input type="checkbox"/> Stroke		<input type="checkbox"/> Marfan's Syndrome		
<input type="checkbox"/> High Blood Pressure		<input type="checkbox"/> Cardiac Arrhythmia (Irregular Heart Beat)		
<input type="checkbox"/> Heart Attack		<input type="checkbox"/> Other: _____		
<input type="checkbox"/> Shortness of Breath				
<input type="checkbox"/> Sickle Cell Trait				
<input type="checkbox"/> Heart Murmur				
<input type="checkbox"/> Heart Disease (Coronary Heart Disease, Arteriosclerosis)				
<input type="checkbox"/> Thrombosis or Embolism				

## Appendix A2: Continued

### Biomechanics/Sports Medicine Lab

#### Health Questionnaire: General

*Please explain any checked items:* \_\_\_\_\_

#### General Orthopedic

- |  |   |
|--|---|
| <input type="checkbox"/> Rheumatoid Arthritis    | <input type="checkbox"/> Surgery                              |
| <input type="checkbox"/> Osteoarthritis          | <input type="checkbox"/> Gout                                 |
| <input type="checkbox"/> Osteoporosis/Osteopenia | <input type="checkbox"/> Assistive Devices (crutches, braces) |
| <input type="checkbox"/> Previous Fracture       | <input type="checkbox"/> Other: _____                         |

*Please explain any checked items:* \_\_\_\_\_

#### Other

Have you taken any prescription or over the counter medications within the last 24 hours?

<i>Yes</i>	<i>No</i>
<input type="checkbox"/>	<input type="checkbox"/>

*If yes, please list:* \_\_\_\_\_

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

- |                                   |                                       |
|-----------------------------------|---------------------------------------|
| <input type="checkbox"/> Caffeine | <input type="checkbox"/> Alcohol      |
| <input type="checkbox"/> Tobacco  | <input type="checkbox"/> Other: _____ |

*If yes, please explain:*

\_\_\_\_\_  
\_\_\_\_\_

Do you exercise regularly?

<i>Yes</i>	<i>No</i>
<input type="checkbox"/>	<input type="checkbox"/>

*If yes, how often, what type and for how long? Complete the ankle activity score form*

\_\_\_\_\_  
\_\_\_\_\_

Are you currently on an athletic team?

<i>Yes</i>	<i>No</i>
<input type="checkbox"/>	<input type="checkbox"/>

*If yes, at what level?* \_\_\_\_\_

*If yes, for what sport?* \_\_\_\_\_

## Appendix A3: Lower Extremity Health Questionnaire

### Biomechanics/Sports Medicine Lab

#### Health Questionnaire: Lower Extremity

##### **Orthopedic**

Regarding your lower extremity (hips, thighs, knees, shins, ankles, feet) please answer the following questions:

Do you have a history of any broken bones?

*Please explain the extent of the injury including the date and severity:*

---

---

Do you have a history of any dislocations?

*Please explain the extent of the injury including the date and severity:*

---

---

Do you have a history of any muscle or tendon strains or tears?

*Please explain the extent of the injury including the date and severity:*

---

---

Do you have a history of any torn or sprained ligaments?

*Please explain the extent of the injury including the date and severity:*

---

---

If the injury is a lateral ankle sprain, how many times have you sprained in your entire life? How long since your last ankle sprain?

---

---

#### A4: 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 lower extremity injury within the past 6 months

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



## Appendix A5: Strength Test Sheet

Subject ID#: _____	Test Side (Dominant): R / L	Testing: B / 0 / 20 / 40	Treatment: Ice / Sham
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Isometric Maximal Voluntary Contraction (MVC):	Trial	1	2	3
(Fold for VAS)				
<p>Please rate your <b><u>MVC</u></b> strength you just performed by marking the line below:</p> <div style="display: flex; align-items: center; justify-content: space-between;"> <div style="flex-grow: 1; border-bottom: 1px solid black; position: relative;"> <span style="position: absolute; left: -20px; bottom: -5px;">Lowest</span> <span style="position: absolute; right: -20px; bottom: -5px;">Highest</span> </div> <div style="text-align: right; margin-right: 20px;">CM _____</div> </div>				

---

Isokinetic Concentric Voluntary Contraction (CON) at 60°/s:	Trial	1	2	3
Isokinetic Eccentric Voluntary Contraction (EXC) at 60°/s:	Trial	1	2	3
(Fold for VAS)				
<p>Please rate your <b><u>CON</u></b> strength you just performed by marking the line below:</p> <div style="display: flex; align-items: center; justify-content: space-between;"> <div style="flex-grow: 1; border-bottom: 1px solid black; position: relative;"> <span style="position: absolute; left: -20px; bottom: -5px;">Lowest</span> <span style="position: absolute; right: -20px; bottom: -5px;">Highest</span> </div> <div style="text-align: right; margin-right: 20px;">CM _____</div> </div>				
<p>Please rate your <b><u>EXC</u></b> strength you just performed by marking the line below:</p> <div style="display: flex; align-items: center; justify-content: space-between;"> <div style="flex-grow: 1; border-bottom: 1px solid black; position: relative;"> <span style="position: absolute; left: -20px; bottom: -5px;">Lowest</span> <span style="position: absolute; right: -20px; bottom: -5px;">Highest</span> </div> <div style="text-align: right; margin-right: 20px;">CM _____</div> </div>				

---

Isokinetic Concentric Voluntary Contraction (CON) at 180°/s:	Trial	1	2	3
Isokinetic Eccentric Voluntary Contraction (EXC) at 180°/s:	Trial	1	2	3
(Fold for VAS)				
<p>Please rate your <b><u>CON</u></b> strength you just performed by marking the line below:</p> <div style="display: flex; align-items: center; justify-content: space-between;"> <div style="flex-grow: 1; border-bottom: 1px solid black; position: relative;"> <span style="position: absolute; left: -20px; bottom: -5px;">Lowest</span> <span style="position: absolute; right: -20px; bottom: -5px;">Highest</span> </div> <div style="text-align: right; margin-right: 20px;">CM _____</div> </div>				
<p>Please rate your <b><u>EXC</u></b> strength you just performed by marking the line below:</p> <div style="display: flex; align-items: center; justify-content: space-between;"> <div style="flex-grow: 1; border-bottom: 1px solid black; position: relative;"> <span style="position: absolute; left: -20px; bottom: -5px;">Lowest</span> <span style="position: absolute; right: -20px; bottom: -5px;">Highest</span> </div> <div style="text-align: right; margin-right: 20px;">CM _____</div> </div>				

## Appendix A6: Procedures for Strength Testing and Skin Temperature

1. Consent form
2. Health Question form
3. Introduction of testing
4. Orientation session at the first day
5. Randomization of Treatment (Ice or Sham) / Isokinetic contraction angular velocities (60°/s or 180°/s)
6. Strength Testing at the second day: Before – Immediately - 20 minutes after - 40 minutes after
7. Strength Testing at the third day: Before – Immediately - 20 minutes after - 40 minutes after

# 1<sup>ST</sup> VISIT

## 1. Orientation

Strength testing (1 trial = 1 max repetition)

### 1) Isometric (3 seconds of resistance)

- *Orientation session (warm up)*
  - Trial 1 with 25%
  - Trial 2 with 50%
  - Trial 3 with 75%
  - Trial 4 with 100%
  - Trial 5 with 100%
- *Orientation session with 100%*
  - Trial 1
  - 60 sec rest
  - Trial 2
  - 60 sec rest
  - Trial 3

### Isometric Encouragement

**Give me maximal effort you have!**

**Three, Two, One, Go!**

**Contract as fast forcefully as possible and hold until I tell**

### 2) Isokinetic (60°/s or 180°/s)

- *Orientation session (warm up)*
  - Trial 1 with 25%
  - Trial 2 with 50%
  - Trial 3 with 75%
  - Trial 4 with 100%
  - Trial 5 with 100%
- *Orientation session with 100%*
  - Trial 1 CON-ECON
  - 60 sec rest
  - Trial 2 CON-ECON
  - 60 sec rest
  - Trial 3 CON-ECON

- 120 sec rest between angular velocities

### 3) Isokinetic (60°/s or 180°/s)

- *Orientation session (warm up)*
  - Trial 1 with 25%
  - Trial 2 with 50%
  - Trial 3 with 75%
  - Trial 4 with 100%
  - Trial 5 with 100%
- *Orientation session with 100%*
  - Trial 1 CON-ECON  
5 sec rest
  - Trial 2 CON-ECON  
5 sec rest
  - Trial 3 CON-ECON
- At least 30 minutes rest before real testing begins

## 2<sup>ND</sup> VISIT

### 1. Before treatment Testing

- *Practice session with 100%*
  - Trial 1 (Isometric)  
5 seconds rest
  - Trial 2 (Isometric)  
120 seconds rest
  - Trial 1 (Isokinetic 60°/s)  
5 seconds rest
  - Trial 2 (Isokinetic 60°/s)  
120 seconds rest
  - Trial 1 (Isokinetic 180°/s)  
5 seconds rest
  - Trial 2 (Isokinetic 180°/s)
- At least 20 minutes of rest
- temperature measurement (patella and mid-thigh)

#### 1) Isometric (3 seconds of resistance)

- *Testing session with 100%*
  - Trial 1  
5 seconds rest
  - Trial 2  
5 seconds rest
  - Trail 3
  - VAS
- temperature measurement (patella and mid-thigh)
- 120 sec rest between angular velocities

## **2) Isokinetic (60°/s or 180°/s)**

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest
  - Trial 3 CON-ECON
  - **VAS**
- temperature measurement (patella and mid-thigh)
- 120 sec rest between angular velocities

## **3) Isokinetic (60°/s or 180°/s)**

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest
  - Trial 3 CON-ECON
  - **VAS**
- temperature measurement (patella and mid-thigh)

## **2. Treatment (Ice or Sham) 20 minutes lying down on the treatment table**

- temperature measurement (patella and mid-thigh)

## **3. Immediately after treatment Testing**

### **1) Isometric (3 seconds of resistance)**

- *Testing session with 100%*
  - Trial 1  
5 seconds rest
  - Trial 2  
5 seconds rest
  - Trail 3
  - **VAS**
- **temperature measurement (patella and mid-thigh)**
- 120 sec rest between angular velocities

### **2) Isokinetic (60°/s or 180°/s)**

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest
  - Trial 3 CON-ECON
  - VAS
- temperature measurement (patella and mid-thigh)
- 120 sec rest between angular velocities

### **3) Isokinetic (60°/s or 180°/s)**

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest
  - Trial 3 CON-ECON
  - VAS
- temperature measurement (patella and mid-thigh)

## **4. 20 minutes after treatment Testing**

- temperature measurement (patella and mid-thigh)
- ### **1) Isometric (3 seconds of resistance)**

- *Testing session with 100%*
  - Trial 1  
5 seconds rest
  - Trial 2  
5 seconds rest
  - Trail 3
  - VAS
- temperature measurement (patella and mid-thigh)
- 120 sec rest between angular velocities

### **2) Isokinetic (60°/s or 180°/s)**

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest
  - Trial 3 CON-ECON
  - VAS
- temperature measurement (patella and mid-thigh)

- 120 sec rest between angular velocities

### 3) Isokinetic (60°/s or 180°/s)

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest
  - Trial 3 CON-ECON
  - **VAS**

- **temperature measurement (patella and mid-thigh)**

## 5. 40 minutes after treatment Testing

- **Temperature measurement**
- 1) **Isometric (3 seconds of resistance)**

- *Testing session with 100%*
  - Trial 1  
5 seconds rest
  - Trial 2  
5 seconds rest
  - Trail 3
  - **VAS**

- **temperature measurement (patella and mid-thigh)**
- 120 sec rest between angular velocities

### 2) Isokinetic (60°/s or 180°/s)

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest
  - Trial 3 CON-ECON
  - **VAS**

- **temperature measurement (patella and mid-thigh)**
- 120 sec rest between angular velocities

### 3) Isokinetic (60°/s or 180°/s)

- *Testing session with 100%*
  - Trial 1 CON-ECON  
5 seconds rest
  - Trial 2 CON-ECON  
5 seconds rest

- Trial 3 CON-ECON
- *VAS*
- temperature measurement (patella and mid-thigh)

## **3<sup>RD</sup> VISIT**

- Same procedure as 2<sup>nd</sup> Visit except treatment

## **Appendix A7: Focal Knee Joint Cooling Treatment**





**Table 1 Descriptive summary of peak torque (PQ) during isometric and isokinetic contractions.**

Treatment	Contraction	RANOVA	Baseline	Immediately	20 minutes	40 minutes	Effect Size <sup>a</sup>	Effect Size <sup>b</sup>	Effect Size <sup>c</sup>
FKJC	Isometric	F3, 60=1.5, P =0.211 <sup>†</sup>	234.0±67.5	237.5±72.1	240.0±71.2	241.8±69.9	-0.05 (-0.66, 0.55)	-0.09 (-0.69, 0.52)	-0.11 (-0.72, 0.49)
	Concentric* 60°/s (Nm)	F3, 60=0.6, P =0.639 <sup>†</sup>	188.5±58.1	185.1±58.1	184.1±58.4	182.8±54.9	0.06 (-0.55, 0.66)	0.08 (-0.53, 0.68)	0.10 (-0.50, 0.71)
	Eccentric* 60°/s (Nm)	F3, 60=2.3, P =0.089 <sup>†</sup>	246.5±88.8	250.1±85.0	242.9±80.2	238.1±73.6	-0.04 (-0.65, 0.56)	0.04 (-0.56, 0.65)	0.10 (-0.50, 0.71)
	Concentric 180°/s (Nm)	F3, 60=0.8, P =0.499 <sup>†</sup>	170.6±50.5	169.2±53.5	165.8±53.6	169.4±52.6	0.03 (-0.58, 0.63)	0.09 (-0.51, 0.70)	0.02 (-0.58, 0.63)
	Eccentric* 180°/s (Nm)	F3, 60=0.2, P =0.872 <sup>†</sup>	224.8±75.0	223.8±76.2	214.7±69.9	213.0±66.8	0.01 (-0.59, 0.62)	0.14 (-0.47, 0.74)	0.17 (-0.44, 0.77)
	Isometric	F3, 60=0.3, P =0.854 <sup>‡</sup>	242.0±70.5	236.3±67.2	237.7±72.1	237.2±71.6	0.08 (-0.52, 0.69)	0.06 (-0.54, 0.67)	0.07 (-0.54, 0.67)
	Concentric* 60°/s (Nm)	F3, 60=2.9, P =0.044 <sup>‡</sup>	188.7±59.8	182.5±59.4	179.1±60.3	177.9±50.1	0.10 (-0.50, 0.71)	0.16 (-0.45, 0.77)	0.20 (-0.41, 0.80)
	Eccentric* 60°/s (Nm)	F3, 60=4.5, P =0.006 <sup>‡</sup>	248.4±79.6	238.5±77.5	230.9±73.6	224.3±69.1	0.13 (-0.48, 0.73)	0.23 (-0.38, 0.84)	0.32 (-0.29, 0.93)
	Concentric 180°/s (Nm)	F3, 60=2.3, P =0.087 <sup>‡</sup>	173.8±57.1	170.0±55.7	168.2±56.3	165.8±45.5	0.07 (-0.54, 0.67)	0.10 (-0.51, 0.71)	0.16 (-0.45, 0.76)
	Eccentric* 180°/s (Nm)	F3, 60=8.3, P =0.001 <sup>‡</sup>	229.4±66.3	222.8±69.1	215.9±65.8	214.3±59.8	0.10 (-0.51, 0.70)	0.20 (-0.40, 0.81)	0.24 (-0.37, 0.85)
Sham									

Abbreviation: FKJC: Focal Knee Joint Cooling. RANOVA: repeated measures analysis of variance.

<sup>a,b,c</sup> indicates Cohen *d* estimate of effect size was calculated between baseline and 20-min measurements using pooled standard deviation along with its associated 95% confidence interval. Positive values indicate increased peak torque after treatment.

<sup>a</sup>: Baseline vs. Immediately, <sup>b</sup>: Baseline vs. 20 minutes post treatment, <sup>c</sup>: Baseline vs. 40 minutes post treatment.

<sup>†</sup> indicates Treatment and Time interaction report, <sup>‡</sup> indicates Time main effect report, \* indicates significant time main effect between baseline and post follow ups,  $P \leq 0.05$ .

**Table 2 Descriptive summary of total work (TW) during isokinetic contraction at 60°/s and 180°/s**

Treatment	Contraction	RANOVA	Baseline	Immediately	20 minutes	40 minutes	Effect Size <sup>a</sup>	Effect Size <sup>b</sup>	Effect Size <sup>c</sup>
FKJC	Concentric* 60°/s (J)	F3, 60=1.3, P =0.296 <sup>†</sup>	204.2±64.0	205.4±65.4	202.4±63.9	199.0±62.0	-0.02 (-0.62, 0.59)	0.03 (-0.58, 0.63)	0.08 (-0.52, 0.69)
	Eccentric* 60°/s (J)	F3, 60=1.4, P =0.265 <sup>†</sup>	252.6±86.7	252.8±84.6	243.5±87.5	239.0±77.9	0.00 (-0.61, 0.60)	0.10 (-0.50, 0.71)	0.17 (-0.44, 0.77)
	Concentric* 180°/s (J)	F3, 60=0.2, P =0.873 <sup>†</sup>	181.5±56.6	181.9±60.7	176.3±61.1	174.4±57.5	-0.01 (-0.61, 0.60)	0.09 (-0.52, 0.69)	0.13 (-0.48, 0.73)
	Eccentric* 180°/s (J)	F3, 60=0.5, P =0.716 <sup>†</sup>	242.7±78.0	237.1±78.9	229.1±78.0	225.2±74.3	0.07 (-0.53, 0.68)	0.18 (-0.43, 0.78)	0.23 (-0.38, 0.84)
Sham	Concentric* 60°/s (J)	F3, 60=3.5, P =0.022 <sup>‡</sup>	205.3±71.0	199.9±66.3	193.5±69.9	193.6±61.5	0.08 (-0.53, 0.68)	0.17 (-0.44, 0.77)	0.18 (-0.43, 0.78)
	Eccentric* 60°/s (J)	F3, 60=11.7, P =0.001 <sup>‡</sup>	249.8±76.6	241.3±77.9	229.1±73.0	222.4±72.6	0.11 (-0.49, 0.72)	0.28 (-0.33, 0.88)	0.37 (-0.24, 0.98)
	Concentric* 180°/s (J)	F3, 60=4.6, P =0.006 <sup>‡</sup>	182.5±64.0	178.5±62.7	174.2±63.7	171.8±53.8	0.06 (-0.54, 0.67)	0.13 (-0.48, 0.74)	0.18 (-0.43, 0.79)
	Eccentric* 180°/s (J)	F3, 60=12.1, P =0.001 <sup>‡</sup>	243.4±73.0	229.4±69.4	223.4±63.0	219.8±56.7	0.20 (-0.41, 0.80)	0.29 (-0.31, 0.90)	0.36 (-0.25, 0.97)

Abbreviation: FKJC: Focal Knee Joint Cooling. RANOVA: repeated measures analysis of variance.

<sup>a,b,c</sup> indicates Cohen *d* estimate of effect size was calculated between baseline and 20-min measurements using pooled standard deviation along with its associated 95% confidence interval. Positive values indicate increased total work after treatment.

<sup>a</sup>: Baseline vs. Immediately, <sup>b</sup>: Baseline vs. 20 minutes post treatment, <sup>c</sup>: Baseline vs. 40 minutes post treatment.

\* indicates significant time main effect between baseline and post follow ups,  $P \leq 0.05$ .

<sup>†</sup> indicates Treatment and Time interaction report

<sup>‡</sup> indicates Time main effect report

**Table 3. Descriptive summary of visual analogue scale (VAS) measures (mm) for a perceived level of quadriceps strength during isometric and isokinetic contractions**

Treatment	Contraction	Baseline	Immediately	20 minutes-post	40 minutes-post	Effect Size <sup>a</sup>	Effect Size <sup>b</sup>	Effect Size <sup>c</sup>
FKJC	Isometric	90.2±8	89.0±10	90.0±9	89.1±10	0.13 (-0.47, 0.74)	0.02 (-0.58, 0.63)	0.12 (-0.48, 0.73)
	Concentric 60°/s	87.2±11	86.0±11	87.2±9	86.5±13	0.11 (-0.50, 0.71)	0.00 (-0.60, 0.60)	0.06 (-0.55, 0.66)
	Eccentric 60°/s	88.3±12	88.1±09	89.2±6	87.5±12	0.02 (-0.59, 0.62)	-0.09 (-0.70, 0.51)	0.07 (-0.54, 0.67)
	Concentric 180°/s	85.0±15	83.2±15	83.9±12	82.2±13	0.12 (-0.49, 0.73)	0.08 (-0.52, 0.69)	0.20 (-0.41, 0.81)
	Eccentric 180°/s	82.5±16	79.3±16	82.8±13	82.5±11	0.20 (-0.41, 0.81)	-0.02 (-0.63, 0.58)	0.00 (-0.60, 0.60)
	Isometric	90.9±8	91.3±07	87.9±12	87.5±13	-0.05 (-0.66, 0.55)	0.29 (-0.31, 0.90)	0.32 (-0.29, 0.92)
	Concentric 60°/s	86.0±13	84.7±15	83.2±14	78.8±19	0.09 (-0.51, 0.70)	0.21 (-0.40, 0.81)	0.44 (-0.17, 1.05)
	Eccentric 60°/s	88.0±10	85.6±13	85.0±13	80.8±18	0.21 (-0.40, 0.81)	0.26 (-0.35, 0.87)	0.49 (-0.12, 1.11)
	Concentric 180°/s	83.9±12	82.4±15	83.0±16	80.8±15	0.11 (-0.49, 0.72)	0.06 (-0.54, 0.67)	0.23 (-0.38, 0.84)
	Eccentric 180°/s	83.2±13	82.5±15	82.2±15	79.7±17	0.05 (-0.56, 0.65)	0.07 (-0.53, 0.68)	0.22 (-0.39, 0.82)

<sup>a,b,c</sup> indicates Cohen *d* estimate of effect size was calculated between baseline and 20-min measurements using pooled standard deviation along with its associated 95% confidence interval. Positive values indicate increased perceived strength level after treatment.

<sup>a</sup>: Baseline vs. Immediately, <sup>b</sup>: Baseline vs. 20 minutes post treatment, <sup>c</sup>: Baseline vs. 40 minutes post treatment.

**Table.4 Descriptive summary of Skin-Surface Temperatures (°C)**

Treatment	Site	Baseline	Immediately	20 minutes-post	40 minutes-post
FKJC	Patellar ligament	28.76±1.15	12.21±3.25*	19.58±1.92*	22.57±1.61*
	Rectus Femoris	31.12±1.01	31.49±1.16 <sup>†</sup>	31.51±1.23 <sup>†</sup>	31.36±1.14
	Ambient	20.83±0.51	20.93±0.42	20.99±0.43 <sup>†</sup>	21.00±0.44
Sham	Patellar ligament	28.79±1.08	28.31±0.76*	28.29±0.91*	27.99±1.92
	Rectus Femoris	31.25±1.13	31.58±1.27 <sup>†</sup>	31.72±1.20 <sup>†</sup>	31.67±1.14 <sup>†</sup>
	Ambient	20.99±0.41	21.05±0.39 <sup>†</sup>	21.05±0.40	21.05±0.43

\*Significant decrease in temperature from the baseline,  $P \leq 0.05$ .

<sup>†</sup>Significant increase in temperature from the baseline,  $P \leq 0.05$ .

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