THE EFFECTS OF ICE SLURRY INGESTION ON REPEATED-SPRINT ABILITY IN HEAT

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the Requirements for the Degree of Master of Science in Exercise Science
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ABSTRACT

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Title: The Effects of Ice Slurry Ingestion on Repeated-Sprint Ability in Heat

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Abstract

Introduction: Repeated-sprint ability is used to measure the physiological demands of stop-and-go activities. Athletes have a high physiological demand and environmental stress during high heat conditions. Precooling is where you preemptively lower core temperature to increase heat storage capacity. **Purpose:** The aim of this study was to examine the effect of ice slurry ingestion (0±1°C) vs. water (4°C) prior to the start of and during halftime of a simulated athletic competition in the heat on repeated-sprint cycling in recreationally active college-aged males. **Methodology:** The researchers used a precooling protocol of 7.5g/kg bodyweight of both water (control) and ice-slurry (experimental) over a 30-minute period prior to the exercise protocol. The participants participated in two, 10 minute halves. Including 5 second sprints, followed by 55 seconds of active recovery at 50 watts. Following the first half of the exercise protocol, participants ingested 2.5 g/kg of ice slurry in the 10 minute passive recovery period. Data collected: core temperature (degrees Celsius), mean power output, peak power output, rating of perceived exertion, heart rate (BPM). **Results:** There was no significant difference in core temperature, average mean and peak power, and fatigue within condition. There was a statistically significant difference in mean core temperature overall between groups ($F=18.36$, $p=0.00$) and fatigue by half within condition ($F=5.526$, $p=0.025$). **Conclusion:** The ice slurry was effective in lowering core temperature, there were no performance enhancements from precooling. Further research needs to be done.

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CHAPTER 1: INTRODUCTION

The ability to produce a high sprint speed or power output and the ability to maintain that sprint speed or power output during subsequent sprints is defined as repeated-sprint ability (Glaister, 2008). Repeated-sprint ability is one assessment used to measure the physiological demands of stop-and-go activity (Glaister, 2008). Many sports such as soccer, field hockey, and lacrosse require that athletes perform repeated sprints throughout competition. Repeated-sprint ability in sports has been researched heavily due to the technology to track the distances covered throughout a match. (Dobson & Keogh, 2017). Many different repeated sprint protocols are available in literature. Most protocols are designed to mimic the multiple short, maximal bouts of activity interspersed with rest periods in a competition. This is in an effort to translate research to practical application. The rest periods may be fixed or variable and active or passive. The sprint portion is usually a 4-8 second sprint, while the typical rest period is 20-30 seconds active recovery (Spencer et al., 2008). Although repeated-sprint athletes rely on anaerobic metabolic pathways for ATP synthesis, there is research to show that they also rely heavily on the aerobic system (Glaister, 2008). Relying heavily on the aerobic system is due to the incomplete rest time after the maximal sprint protocols. While the PCr-ATP system is the primary system to fuel athletes during the anaerobic portions of a game, the aerobic system also plays an important role to assist with PCr replenishment (Sanders., 2017). Due to the metabolic demands of repeated sprints these athletes endure high stress on the body during practice and competition without taking into account external environmental factors.

Although athletes in stop-and-go sports may be limited by metabolic factors, environmental heat poses another potential challenge to performance for these athletes. Many of these athletes have practice or competition for extended periods of time in the heat due to when their sport is in season. For example, the beginning of soccer and field hockey season during the fall or the end of lacrosse in the spring season. Thus, heat stress has the potential to become another limiting factor to performance, and the ability to mitigate heat stress presents an opportunity to enhance performance. The hypothalamus is a major component of the responses in the body's autonomic system to heat stressors. The effector response to maintain thermal homeostasis is determined by the relative amount of heat loss and gain within the body (Nagashima, K., 2015). In situations where heat gain exceeds heat loss, the body will initiate heat dissipation responses in order to protect core temperature. In most individuals their heart rate will increase with exposure to the heat secondary to a decreased blood pressure due to a reduction in plasma volume via sweating (Cheung, S. S., 2010). If these athletes continue to perform in these high heat environments it can lead to decreased in performance. This decrease in performance is due to the body protecting itself from the damage an increase in core temperature can do to the body by limiting exercise (Cheung, S. S., 2010; Cheung, S. S., & McLellan, T. M., 1998). When athletes train or compete in high heat conditions for an extended period of time, the possibility of heat illness increases due to the body's inability to rid the excess heat produced. Impaired exercise performance in heat has consistently been attributed to critically high core temperatures from the environment and exercise-related metabolic heat production (Brade, et al, 2013). Elevations in core temperature have been reported to affect metabolic, central nervous system, cardiovascular, and physiological responses to exercise (Hayes et al, 2014). These responses from the body are believed to occur once a certain core temperature set point has been reached; at that temperature the body will begin to shut down unnecessary energy expenditures and the individual fatigues (Cheung, S. S., 2010). This shut down will lead to the inability to continue with performance or competition.

There are many heat management strategies that have been used in research to lower core temperature prior to the start of and during exercise to cool the body to increase performance. Strategies include ice slurry ingestion, cool water immersion, ice vest, or a combination of these strategies. Cold water immersion is considered to be the gold standard for cooling the body as it is most effective as a post-activity treatment (Casa, D. J., 2007). However, cold water immersion for athletes is not practical for use prior to competition or during. Cooling vests are a more recent modality and can be worn under clothing for athletes. For this method it is important to try and cover as much skin surface area as possible for the best result because it uses air as a convective way to cool the body (Chinevere et al., 2008). This is also done as a pre or post exercise method (Faulkner,et al, 2019). Researchers have found the cooling vests to be an effective method in lowering core temperature (Chinevere et al., 2008, Faulkner., et al, 2019, Hadid et al., 2008). Many cooling strategies have been researched for endurance based events. For example researchers found that a cooling jacket and sleeves for 30 minutes prior to exercise benefited the time trials of cyclists in ambient temperatures of 24°C, 27°C, and 35°C (Faulkner,et al, 2019). One of the most recent precooling methods is ice ingestion as a practical method of precooling that has resulted in improved endurance performance in hot and humid conditions (Zimmerman et al, 2015). Ice ingestion is used a method prior to exercise to preemptively lower the individual's core temperature.

Precooling is done so that core temperature can be lowered in order to raise the individual's heat storage capacity (Siegel et al, 2010). Heat storage capacity is the amount of thermal energy being stored in the body. There has been research that shows how precooling is an effective way at lowering the individual's core temperature prior to exercise thereby effectively increasing their heat storage capacity and diminishing the detrimental effects of heat to performance or the body (Jones et al, 2016; Walker et al, 2014; Siegel et al, 2010; Zimmerman et al, 2015). This allows the individual to exercise or perform for a longer period of time before the body begins to limit movement to protect itself at a set point temperature. For highly fit individuals the body's temperature marker appears to be approximately 39.2°C (Cheung, S. S. 2010). Research supports the set point marker at which the body signals the system to shut down (Cheung, S. S., 2010). The use of an ice-slurry is highly practical because it can be administered to many people at a low cost.

There is limited research looking at the effects of precooling using only ice ingestion as opposed to multiple precooling techniques combined on repeated sprint athletes. Pre-cooling offers a cost-effective method at reducing core temperature. Utilizing precooling with repeated sprints may offer a possible solution to improve exercise performance in hot conditions and limit the added challenges of the environment on these athletes. This study looks to fill this gap in the literature for precooling in stop-and-go sports.

Purpose

The purpose of this study is to examine the effect of ice slurry ingestion vs. placebo prior to the start of and during halftime of a simulated athletic competition in the heat on repeated-sprint cycling in recreationally active college-aged males.

Null Hypotheses

There will be no difference in core temperature between ingestion of ice slurry and a placebo post precooling protocol.

There will be no difference in core temperature between ingestion of ice slurry and a placebo during exercise protocol.

There will be no difference in average mean power output between ingestion of ice slurry and a placebo during exercise protocol.

There will be no difference in average peak power output between ingestion of ice slurry and a placebo during exercise protocol.

There will be no difference in fatigue between the ingestion of ice slurry and a placebo during exercise protocol.

There will be no difference in heart rate between ingestion of ice slurry and a placebo during exercise protocol.

There will be no difference in rating of perceived exertion between ingestion of ice slurry and a placebo during exercise protocol.

Delimitations

1) Participants were recreationally active individuals from a university in northeastern Pennsylvania.

2) Participants were males aged from 18-35 years.

3) Participants were physically active at least three times per week following ACSM guidelines, 20-60 minutes of activity, 3-5 times per week (Garber et al., 2011).

4) Participants were apparently healthy with no prior history of heat illness.

5) Participants were apparently healthy with no lower extremity injuries in the past year.

Limitations

1) Participant dropout due to illness or injury.

2) Participants giving maximal effort each sprint.

3) Participants' adherences to pre-conditions.

4) Participants' level of heat acclimatization.

Operational Definitions

Average Mean Power Output – Average power output (in watts) per 5 second cycle sprint, averaged across all sprints

Average Peak Power Output – Maximum power output (in Watts) per 5 second cycle sprint, averaged across all sprints

Ice slurry – 7.5 g/kg of ice slurry (-1 or 0°c) for precooling, equal amounts for every 5 minutes in a 30 minute precooling, 10 minute half time with slurry ingestion of 2.5g/kg (Siegel et al, 2010).

Control condition – Water kept at 4 degrees Celsius (Siegel et al., 2010).

Heat conditions – A tent heated to 33 degrees Celsius with electric heaters (Zimmerman et al., 2015)

Termination criteria – Core temperature greater than or equal to 39.5ºC, HR greater than 10 bpm over age predicted max heart rate using the formula "220-Age" (Physical Activity Basics – CDC, 2018) or the participant requests to end the test (Hailes et al, 2016).

Recreationally active – Physically active at least three times per week following ACSM guidelines, 20-60 minutes of activity, 3-5 times per week (Garber et al., 2011).

Fatigue – Percent Decrement Method is fatigue = 100 – [(total power output/ideal power output) x 100] where total power output is the sum of all mean power values from all sprints. Ideal power output is the number of sprints multiplied by the maximum mean power (Glaister, 2008).

Repeated-sprint protocol – 5 second, maximal sprint each minute, followed by 55 seconds of active recovery at 50 watts on the cycle. The 5 second sprint was performed at a resistance of 0.07 Nm/kg bodyweight of each participant (Duffield, et al,. 2003) on an electromagnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands). The protocol ended with the participant completing a final 55 second active recovery.

CHAPTER 2: LITERATURE REVIEW

Repeated Sprints

The ability to produce a high sprint speed or power output and the ability to maintain that sprint speed or power output during subsequent sprints is defined as repeated-sprint ability (RSA) (Glaister, 2008). This ability is viewed as a key factor when performing in field sports such as field hockey, soccer, or lacrosse. (Spencer et al., 2005). The sprint portion is usually a 4-8 second sprint, while the rest period it typically 20-30 seconds (Spencer et al., 2005). Most protocols are designed to mimic multiple short, maximal bouts of activity with fixed rest periods in a competition.

Analyzing repeated sprints has progressed greatly with modern technology. The most current technique is using GPS to track an individual's movement throughout a match or a game, which allows for the researcher to track velocities and distances covered by the athlete (Dobson & Keogh, 2007; Spencer et al., 2005). GPS tracking and time-motion analysis have shown that sprinting accounts for 1-10% of the total distance covered by an athlete and 1-3% of total playing time (Buchheit, Mendez-Villanueva, Simpson & Bourdon, 2010; Spencer et al., 2004). Although technology can provide a great amount of information, the movements performed can vary. These movements can be categorized into sprinting and striding or a combination of the two (Spencer et al., 2004). It has been demonstrated that the combination of striding and sprinting as one category resulted in a 3.7 – 4.4 seconds of sprinting with 40 – 56 seconds of recovery in between the high intensity bouts for soccer athletes (Withers et al., 1982). When sprinting was placed in its own category research showed the sprint duration as 2 – 3 seconds (Barros et al., 1999). There is a wide range of sprints performed throughout the game/match of these field sports. The average number of sprints performed are 19-62 per match in soccer (Mohr et al., 2003; Yamanaka et al., 1988), field hockey (Spencer et al., 2004), and rugby (Duthie, Pyne, & Hooper, 2005). This wide range in sprints could be due to the different positions of the athletes and the different sports being played. It was reported that strikers in field hockey performed about twice as many sprints as fullbacks did throughout a single match (Lothian & Farrally, 1994).

When evaluating repeated-sprint performance, the most likely contributors to fatigue in the individual is the buildup of inorganic phosphate or lactate (Girard et al., 2011). Looking at a protocol including ten, six second sprints, at the beginning of the exercise the participants use approximately 92% of ATP from the immediate energy system, or by anaerobic glycolysis (Girard et al., 2011). For example on sprint ten in the protocol, 60% of the ATP is still being supplied through the anaerobic metabolism (Girard et al., 2011). This reliance on anaerobic pathways due to the intensity of the exercise will increase the concentration of both inorganic phosphate and lactate in the muscle cell (Girard et al., 2011). As the competition goes on and the sprints progress, the reliance on the aerobic metabolism and subsequent manifestation of fatigue increase (Girard et al., 2011).

Research showed that by sprint ten in a repeated-sprint protocol of a 6 second sprint with 30 second passive recovery about 40% of ATP is being produced aerobically (Girard et al., 2011). This study has shown that by the 10th sprint with the same protocol the PCr stores have dropped about 51% from resting (Girard et al., 2011). This is important to keep in mind for the present study because of the added detrimental effect the environment can have on an athlete in addition to the already existing fatigue. Performance of the athlete would unlikely compromised if the rest time between the sprints were two minutes. This is due to the almost full recovery between these sprints (Spencer et al., 2005). However, it is important to keep in mind that rest periods between sprints in competition are usually an active recovery. This may affect the recovery of the athlete as the competition continues. Sprinting is a key aspect to many of these stop and go sports, however there are other movements or factors throughout the competition that may cause fatigue. Elements such as jogging, jumping, changing direction and environmental factors can cause added fatigue on the athletes in competition.

Performance in the Heat

The hypothalamus (specifically the preoptic area) plays a major role in the autonomic responses to heat stressors. Once the body drifts from its core temperature set point, research has shown the body begins to show symptoms (Cheung, S. S. 2010; Nagashima, K., 2015). It was theorized that this occurs to protect the body's system integrity. When the body experiences a high heat environment the autonomic response will cause a few things to happen. There are three ways the body will try to lower its core temperature and release heat; convection, conduction and evaporation (Nagashima, K., 2015). The body's superficial vessels will dilate causing blood to flow from the core body parts to the skin.

This movement is the body's way to try and release heat by convection or conduction from the core to the environment. In some situations, especially athletic competitions the body will sweat to lose heat via evaporation from the skin (Nagashima, K., 2015). These autonomic responses depend on the amount of heat gained vs. the amount of heat loss within a system. Heat gain can be from basal metabolic rate, muscular activity, or the environment in which the activity is performed; while heat loss is mainly influenced by the individuals' perspiration and evaporation (Cheung, S. S., 2010; Nagashima, K., 2015). If too much heat is gained or not enough heat is lost, exertional heat illness can occur.

There are three classifications of exertional heat illnesses; heat cramps, heat exhaustion, and heat stroke. Once the hypothalamus has been damaged from either heat exhaustion or heat stroke, it will not work at the same capacity it once did (Cheung, S. S., 2010; Nagashima, K., 2015). The body's thermoregulatory system becomes compromised due to excessive heated conditions or because of too much physical exertion; or from a combination of the both (Phinney et al., 2001). Heat illnesses are more prevalent in certain populations (children, elderly, overweight individuals), in certain environments (hot/humid environments), while exercising for extended periods of time, and as a result of impairment to sweating. Therefore, it seems that athletes, specifically stop and go athletes competing in the summer or high heat environments, should be concerned with keeping their body temperature normal or lower. Exertional heat illness poses a serious threat to athletes who is participate in high intensity sports in hot environment. Athletes with a higher amount of gear worn such as football are at an even further likelihood of having an exertional heat illness (Phinney et al., 2001).

Impaired exercise performance in heat has consistently been attributed to critically high core temperatures from the environment and exercise related metabolic heat production (Brade, et al., 2013). Elevations in core temperature have been reported to affect metabolic, central nervous system, cardiovascular and physiological responses to exercise (Hayes et al., 2014). Fatigue during repeated-sprint activity seems likely to be exacerbated with the addition of heat stress onto the significant metabolic demands that are placed on participants. It stands to reason that the ability to mitigate the physiological impact of the heat stress may confer benefits both to performance and in reduction of the risk of exertional heat illness.

Cooling Methods

There are three methods of cooling the body shown in the research investigated. These methods include ice slurries, cold water immersions, and convective cooling vests. Some protocols used a combination of these methods.

Walker et al. (2014) investigated the effects of cold water immersion and ice slurry ingestion on 74 participants. There were three groups including a cold water immersion, control, and ice slurry ingestion group. This study was based on the occupation of firefighters, simulating a search and rescue in a heat chamber. The participants performed 2x20 minute searches/halves in a 40.5°C heat chamber During the half time the participants would exit the chamber, take off their jackets, and change breathing apparatus. Unlike the ice slurries which were used as a precooling method, cold water immersion is mostly seen as a post exercise protocol to assist in bringing core temperature back to normal. After the entire exercise protocol the participants would enter the cold water immersion tank which was 15°C for up to 15 minutes (Walker et al., 2014). Cold water immersion is known as the gold standard to lower core temperature or return core temperature to normal post exercise. However, there are some limitations. Cold water immersion is not practical for prior to an athletic event. There is also a concern that if the individual remains immersed too long they could be at risk for hypothermia.

Cooling vests/sleeves are used to cover as much as the body surface as possible. It is also the newest method to enter the research field. This form of cooling can be worn under uniforms/clothing. One study looked at twelve male team sport players. The participants completed four experimental conditions, initially involving a 30-min precooling period consisting of either a cooling jacket, ingestion of an ice slushy, combination of cooling jacket and ice ingestion, or control group. This was followed by 70 minutes of repeat sprint cycling in 35ºC, 60% relative humidity (Brade et al., 2014). The exercise protocol consisted of 2x30-min halves, separated by a 10-min half-time period where the same cooling method was used. Each half was comprised of 30x4 second maximal sprints. The researchers concluded, a combination of cooling jacket and ice ingestion (external and internal) body cooling techniques may enhance repeated sprint performance in the heat compared to individual cooling methods (Brade et al., 2014).

Ice slurries have been found to be a practical and low cost method in cooling the body prior to exercise. There has been research done to support the claims that precooling with a slurry has preemptively lowered core temperature and in turn increased an individual's heat storage capacity (Siegel et al., 2010). However, there is also research that demonstrates the ice-slurry ingestion influenced heat storage capacity but did not improve physical performance (Zimmerman et al., 2015). It is still being used and researched as a method of precooling to try and lower core body temperature.

The precooling protocol employed in the present study was based on that of Siegel et al. (2011) who found that the ingestion of 7.5 g/kg of ice slurry (1°C), ingested at 1.25 g/kg every five minutes, reduced rectal temperature significantly by 0.66 ± 0.14°C. There were 10 male participants who either ingested a control cold water 4°C or an experimental 0°C ice slurry before running a ventilatory threshold test in a heat chamber (34°C) (Siegel et al., 2010). These results were associated with prolonged run time to exhaustion by 19 ± 6%, compared to cold fluid (4°C) ingestion. Ice slurry ingestion has been compared to the other methods listed earlier.

In another study that researched ice slurries, 9 moderately trained females performed 2, 36 minute halves on a cycle ergometer (Zimmerman et al., 2015). The cycling protocol mimicked stop and go sports such as soccer and field hockey similar to the present study. There was a control group where water was used as the precooling protocol and an experimental group where precooling included crushed ice ingestion. The crushed ice ingestion protocol did lower core body temperature significantly before exercise, compared to the control water protocol, and it also lowered the perception of thermal stress (Zimmerman et al., 2015). However, there was no improvement in performance (Zimmerman et al., 2015). Ishan et al. (2010) found 40 km cycling time trail performances to be improved by 6.5% in endurance trained males. These males regularly competed in triathlons and cycling while ingesting 6.8 g/kg (1.4 ± 1.1°C) of crushed ice. This reduced GI temperature by 1.1 ± 0.6 °C compared to tap water (26.8 ±

1.3°C). These athletes did the precooling thirty minutes prior to the event (Ishan et al., 2010).

A study suggested that an ice slurry has been used based on the law of enthalpy of fusion. This says that ice requires increased heat absorption to change from a solid to a liquid, enabling ice to absorb more heat than water of a similar temperature (Merrick et al., 2003). Performance benefits of precooling with an ice slurry ingestion may be due to the proximity to the brain's blood supply, potentially leading to the increase of brain cooling as opposed to the core. The brain cooling may be due to the proximity of the mouth and esophagus to the carotid arteries, potentially resulting in the cooling of the blood flowing to the brain (Mariak et al., 1999). This would increase the time required for the brain to reach a critically high temperature. Thus, ice slurry ingestion would potentially increase exercise time to exhaustion and allow for greater metabolic heat production/storage (Siegel & Laursen, 2011).

Precooling by ice-slurry ingestion seems to be a reliable method to lower core temperature prior to exercise, however, it is not clear if it will uniformly improve performance in sports and occupational fields such as firefighting. Ice slurries may be a practical application to combat heat related illnesses and mitigate the detrimental effects of heat on performance in repeated-sprint athletes.

CHAPTER 3: METHODOLOGY

Participants

The participants consisted of recreationally active males aged 18-30 years. Participant participation was voluntary, and each participant had no history of heat illness or heat injury. Participants were apparently healthy and recreationally active at least three times per week for a minimum of thirty days following ACSM guidelines (Garber et. al, 2011). Before the start of the experiment the participants completed an informed consent (Appendix A), heat illnesses and injuries questionnaire (Appendix B), and a PAR-Q (Appendix C). The design of the study was a randomized, counter-balanced crossover experiment. Approval from the East Stroudsburg University Institutional Review Board (IRB) was obtained for this study (Appendix D).

Demographic Data

Table 1. Subject Characteristics

Subjects	**Height (cm)**	**Weight (kg)**	**Age (years)**
1	178	85	23
2	176	84.2	25
3	213	96.2	26
4	177	87.3	24
5	163	78.7	22
6	178	98	24
7	178	80.6	21
8	174	77.5	23
9	173	94	25
Mean	178.89	86.83	23.67
SD (±)	13.64	7.64	1.58

Note. Table 1 describes all subject demographics which include height (cm), weight (kg), and age (years).

Procedures

Participants were asked to visit the laboratory a total of three times consisting of orientation / familiarization, and two experimental visits: precooling and control. Each session was separated by a minimum of seven days for a washout period (Duffield, et al., 2003).

Session one included an introduction to the experiment and explanation of the protocol where participants were free to ask any questions regarding the study, followed by completion of the informed consent. Participants were then asked to complete the forms discussed earlier (Informed consent, heat illness questionnaire, and PAR-Q). It was explained that prior to arriving at the laboratory for testing, the participants needed to refrain from any vigorous exercise for 24 hours, and to avoid food, drink, cigarettes, or caffeinated products two hours prior to the testing session (Duffield, et al,. 2003). Demographic data were then collected including height (m), mass (kg), and body mass index (BMI) (kg/m^2). Each participant's bike seat height was obtained and remained constant throughout the all sessions. The final part of the orientation session was the familiarization protocol. Participants completed one half of the repeated-sprint protocol (see below) and were able to ingest water ad libitum.

Sessions two and three included the full repeated-sprint protocol, one with the experimental trial and the other with the placebo. Visits began with pre-exercise urine refractometry to determine the hydration status of the participant. The protocol for urine refractometry is described in detail below. Following confirmation of euhydration status, the participant entered the heat chamber 30 minutes prior to the warm-up and remained in the heat chamber for the remainder of the protocol. The heat chamber was maintained at 33 degrees Celsius. During the 30 minute pre-exercise period instructions were provided, including informing the participant as to the experimental or control protocol to be followed (protocols are described in detail below). At the end of the 30 minutes the participant began the warm-up protocol. This included a 5 minute warm-up, with 3 minutes of cycling at 75 watts and then increasing to 100 watts for two minutes (Duffield, et al,. 2003). There was a 5 minute passive recovery period following the warm-up, with the subject seated on the cycle, before continuing on to the exercise protocol.

The exercise bout was a repeated-sprint cycling protocol, consisting of two 10 minute halves. This exercise protocol was designed to mimic a full contest of a stop and go sport. Each half was separated by a 10 minute break which included a passive recovery with the participant seated on the cycle. Participants ingested either ice slurry (experimental) or cool water (control) both prior to the exercise and again at half time, as described in detail below. The exercise protocol consisted of one 5 second, maximal sprint each minute, followed by 55 seconds of active recovery at 50 watts on the cycle. The 5 second sprint was performed at a resistance of 0.07 Nm/kg bodyweight of each participant (Duffield, et al,. 2003) on an electromagnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands). The protocol ended with the participant completing a final 55 second active recovery. Following the active recovery, each participant got off of the cycle and remained in the heat chamber until their heart rate returned to within ten beats per minute of the resting measurement of that testing session. The last step of the experiment was to do a post exercise urine refractometry and core temperature to insure that participants were adequately hydrated prior to leaving the laboratory.

Each of the following measurements was recorded after every five second sprint throughout the protocol. The data collected from each sprint was core temperature (degrees Celsius), rating of perceived exertion (RPE) was taken using the Borg's six to twenty scale (RPE, Borg, 1998) (Appendix E), mean power output (W), peak power output (W), heart rate (BPM), and work (KJ). Mean power output, peak power output, and work were collected by a computer running LEM software directly interfaced with the electromagnetically braked cycle ergometer. Core temperature was collected using the rectal thermistor (Measurement Specialties, Andover, Minnesota). Heart rate was monitored throughout the testing sessions using a Polar Heart Rate Monitor (Polar Accurex Plus; Polar Electro Oy, Kempele, Finland). Fatigue was calculated using the percent decrement score, which has been reported to be valid and reliable in determining fatigue (Glaister, 2008):

$$\text{Fatigue} = 100 - [(\text{Total power output} \div \text{Ideal power output}) \times 100]$$

Where total power output is the sum of all mean power values from all sprints. Ideal power output is the number of sprints multiplied by the maximum mean power (Glaister, 2008).

Ice Slurry Ingestion

The same exercise protocol was followed for both experimental and control sessions. During the 30 minutes prior to the warm-up while the participant was in the heat conditions, they ingested 7.5 g/kg bodyweight of ice slurry in equal amounts every 5 minutes over the 30 minute time period. The ice slurry was plain ice. After the precooling protocol, the individual continued to their 5 minute warm-up period as discussed earlier. Following the first 10 minute half of the exercise protocol, the participant ingested 2.5 g/kg bodyweight of ice slurry in the 10 minute recovery half time period. Following the recovery time there was the final 10 minute half of repeated-sprints (Siegel et al., 2010), which replicated the first half of the exercise. The control condition consisted of the ingestion of water in an amount equivalent to the ice slurry condition (Brade, et al,. 2013). The water was 4 degrees Celsius due to the typical temperature of drinks found in a conventional refrigeration unit (Siegel et al., 2010). All exercise protocols were followed exactly in both conditions.

Urine Refractometry

Hydration status was assessed using urine refractometry (Atago Hand-held Refractometer, Japan). The procedures for urine refractometry remained constant for pre and post exercise in both conditions. Participants were instructed in the procedures to secure a clean catch urine sample and then provide the sample in a double sealed cup. The sealed container was opened while maintaining hand placement on the container throughout the entire test. Using a pipette the researcher placed a small drop onto the refractometer. Using the same pipette the sample was returned to the sample cup. Taking clean water with that pipette the researcher discarded the water into a different waste cup to clean the pipette. This was repeated two more times to ensure cleaning. The sample was viewed, looking on the left side of the reader, the blue line will determine the value. The participants could continue with the protocol if they had a specific urine gravity of 1.020 or below which was an indication of euhydration (How to Maximize Performance Hydration, NCAA., 2013). However, if the sample measurement was 1.021 or greater the participant was dehydrated and the researchers gave the participant 16 ounces of water to drink within 30 minutes on site of the experiment. A second urine refractometry test was then administered after an additional 30 minutes (How to Maximize Performance Hydration, NCAA, 2013). To ensure hydration, participants were told to drink 16 ounces 2-3 hours before the session, they were advised to drink another 8 ounces of water 15 minutes before the session (How to Maximize Performance Hydration, NCAA., 2013).

Statistical analysis

Statistical analysis was performed using SPSS 20.0 (IBM Corporation) (SSPS., Chicago, IL). Descriptive data (means, standard deviations) were calculated for all demographic (age, height, weight, BMI) data. In addition, descriptive data was calculated for all dependent variables (percent decrement, average mean power output, average peak power output, core temperature, RPE, and heart rate). A one way ANOVA was used to establish significant difference between groups (control, experimental) for baseline core temperature (pre slurry ingestion) and for pre exercise temperature (post ice slurry/placebo ingestion). A two-way ANOVA (groups [2-levels]; time [2-levels]) was used to establish significant differences in all other dependent variables across supplement and placebo conditions. The study had two levels (halves) by two conditions (control and experimental). If significant F values were observed, post hoc analysis of the data was performed by application of a pairwise comparisons with Bonferroni correction. An alpha of 0.05 was used for all analyses.

CHAPTER 4: RESULTS

The purpose of this study was to examine the effect of ice slurry ingestion prior to the start of and during halftime of a simulated athletic competition in the heat utilizing repeated-sprint cycling protocol in recreationally active college-aged males.

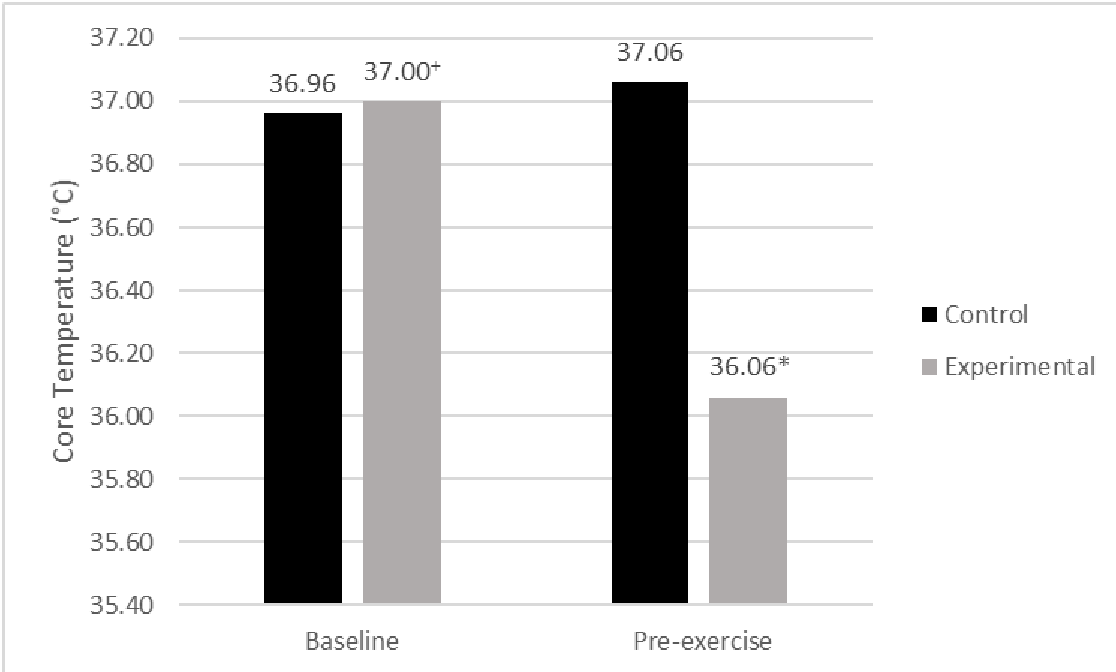

Figure 1. Core temperature baseline vs. pre-exercise by condition

Figure 1 depicts there was no significant difference between control group and experimental group for core temperature at baseline+ (Control = 36.96 ± 0.09°C, experimental = 37.0 ± 0.07°C, F = 1.39, p = 0.255). There was a significant difference between control group and experimental group for core temperature pre-exercise* (Control = 37.06 ± 0.11°C, experimental = 36.06 ± 0.69°C, F = 18.16, p = 0.00).

Table 2. Mean core temperature of all participants per half by condition

Group	Core Temperature (ºC) Half 1	Core Temperature (ºC) Half 2	Core Temperature (ºC) Overall
Control Group	37.14 ± 0.14	37.24 ± 0.33	37.19 ± 0.25
Experimental Group	36.31 ± 0.70	36.44 ± 0.82	36.38 ± 0.75
Mean	36.72 ± 0.65	36.84 ± 0.73	36.78 ± 0.69

Note. Values are mean ± standard deviation.

Table 2 depicts there was no main effect of core temperature for group by half ($F = 0.003$, $p = 0.954$) nor was there a main effect revealed from the ANOVA for half ($F = 0.378$, $p = 0.543$). Furthermore, there was not a significant difference through interaction.

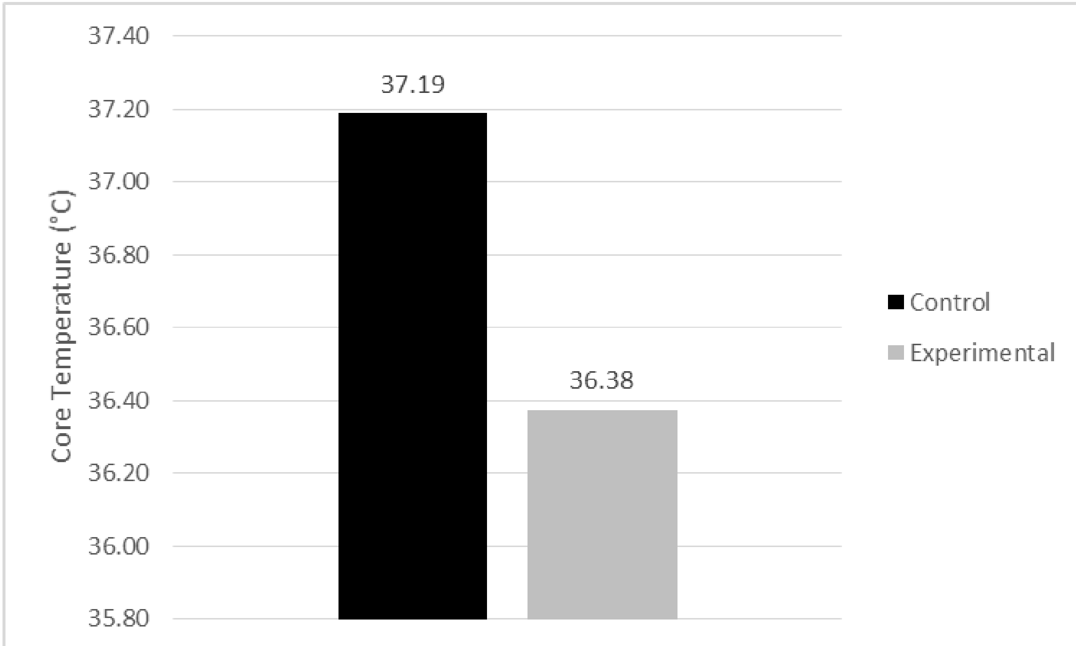

Figure 2. Mean core temperature of all participants overall

Figure 2 depicts there was a main effect for group ($F=18.365$, $p <0.01$) The control group overall mean core temperature was 37.19 ± 0.25ºC and the experimental group overall mean core temperature was 36.38 ± 0.75 ºC. Demonstrating the ice slurry is effective throughout the exercise protocol.

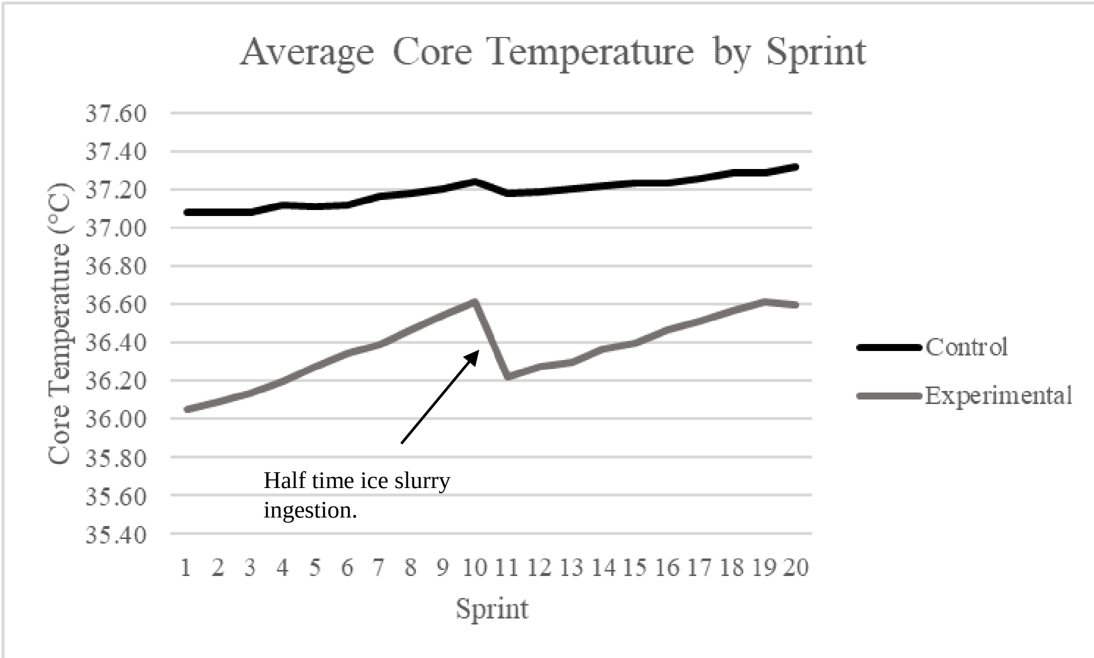

Figure 3. Average core temperature by sprint

Figure 3 depicts average core temperature by sprint, clearly demonstrates the effect of the ice slurry on core temperature at both pre exercise and at half time.

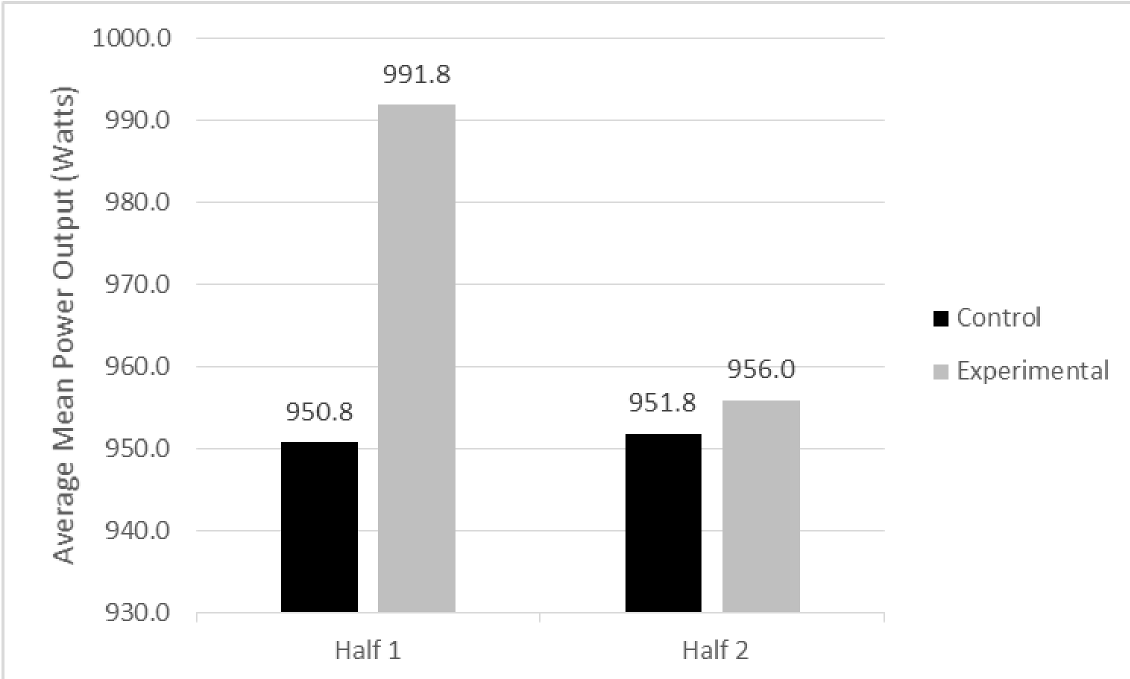

Figure 4. Average mean power output of all participants by condition

There was no significant difference in average mean power output by group (Control = 956.60 ± 159.68 watts, experimental = 973.88 ± 149.23 watts, F=0.067, p=0.798). There was no significant difference in average mean power output by half (Half 1 = 976.58 ± 156.27 watts, half 2 = 953.90 ± 153.44 watts, F = 0.352, p = 0.557). The average mean power output for the control group, first half was 950.8 ± 162.6 watts. The average mean power output for the experimental group, first half was 991.8 ± 148.9 watts. The average mean power output for the control group, second half was 951.8 ± 157.4 watts. The average mean power output for the experimental group, second half was 956.0 ± 148.1 watts.

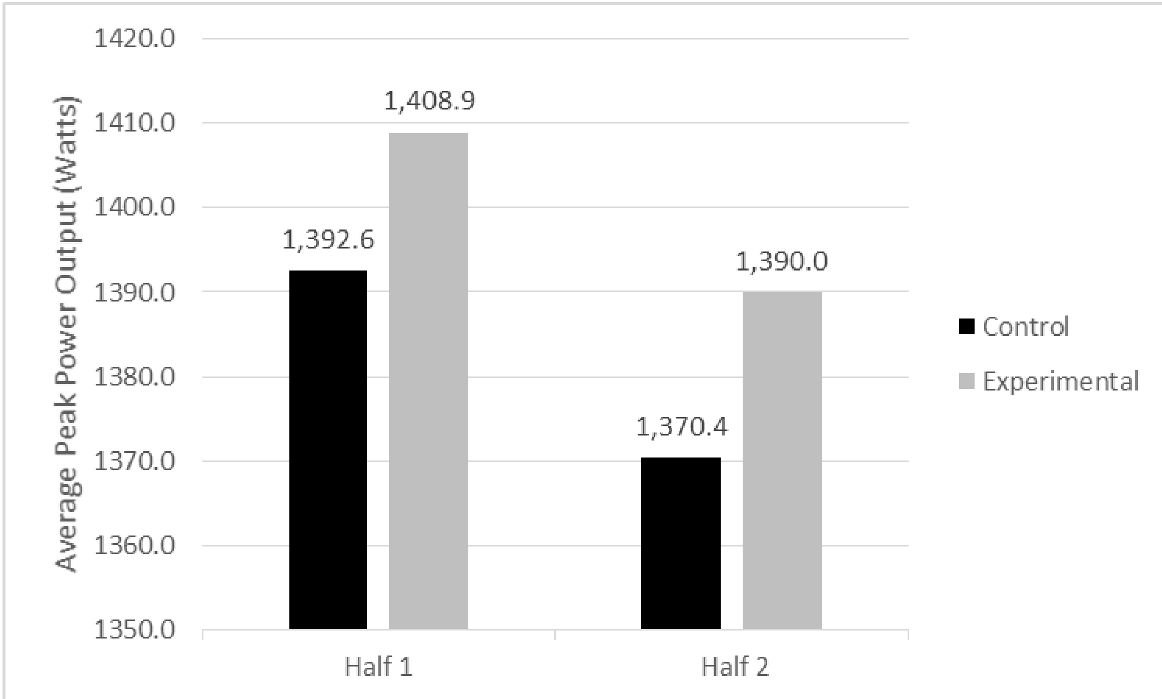

Figure 5. Average peak power output of all participants by condition

There was no significant difference in average peak power by group (Control = 1381.47 ± 215.36 watts, experimental = 1399.46 ± 208.20 watts, F=0.027, p = 0.871). There was no significant difference between average peak power output by half (Half 1 = 1400.75 ± 215.97 watts, half 2 = 1380.18 ± 207.45 watts, F = 0.172, p = 0.681). The average peak power output for the control group, first half was 1392.53 ± 27.55 watts. The average peak power output for the experimental group, first half was 1408.92 ± 20.95 watts. The average peak power output for the control group, second half was 1370.36 ± 82.61 watts. The average peak power output for the experimental group, second half was 1390.00 ± 66.49 watts.

Table 3. Fatigue, calculated by percent decrement, of all participants per half by condition

Group	Fatigue (%) Half 1	Fatigue (%) Half 2	Fatigue (%) Overall
Control Group	54.51 ± 1.24	56.81 ± 2.20	55.66 ± 2.09*
Experimental Group	54.63 ± 1.65	56.45 ± 4.30^{s}	55.54 ± 3.30
Mean	54.57 ± 1.42^{+}	56.63 ± 3.32	55.60 ± 2.72

Note. Values are mean ± standard deviation for fatigue.

As can be seen in table 3 there was no significant difference for fatigue by group* ($F = 0.019$, $p = 0.891$) nor a main effect for group by half^{+} ($F = 0.71$, $p = 0.79$). However, there was a significant difference for fatigue by half^{s} ($F = 5.526$, $p = 0.025$).

Table 4. Heart rate of all participants per half by condition

Group	**Heart rate (BPM) Half 1**	**Heart rate (BPM) Half 2**	**Heart rate (BPM) Overall**
Control Group	150.06 ± 16.68	158.26 ± 17.39	154.16 ± 12.91
Experimental Group	140.93 ± 19.70	150.99 ± 17.35	145.96 ± 12.91
Mean	145.49 ± 12.88	154.62 ± 13.04	150.06 ± 13.59

Note. Values are mean ± standard deviation for heart rate.

As can be seen in table 4 there was no significant difference between heart rate by group ($F = 3.792$, $p = 0.060$), heart rate by half ($F = 4.705$, $p = 0.038$), nor heart rate group by half ($F = 0.049$, $p = 0.827$).

Table 5. Rating of Perceived Exertion (RPE) of all participants per half by condition

Group	RPE Half 1	RPE Half 2	RPE Overall
Control Group	13.84 ± 1.70	14.87 ± 1.39	14.36 ± 2.48
Experimental Group	13.33 ± 1.69	14.23 ± 1.63	13.75 ± 2.47
Mean	13.59 ± 1.67	14.55 ± 1.50	14.07 ± 1.64

Note. Values are mean ± standard deviation for RPE.

As can be seen in table 5 there was no significant difference in RPE by group ($F = 1.143$, $p = 0.293$). There was no significant difference in RPE by half ($F = 3.224$, $p = 0.082$), nor was there a main effect for RPE for group by half ($F = 0.13$, $p =0.910$).

CHAPTER 5: DISCUSSION & CONCLUSION

The purpose of this study is to examine the effect of ice slurry ingestion prior to the start of and during halftime of a simulated athletic competition in the heat utilizing a repeated-sprint cycling protocol with recreationally active college-aged males. The results of this study indicated that there were no significant differences in average mean power output, average peak power output, and fatigue. However, there was a significant finding in core temperature by conditions.

The current investigation found no significant difference ($p > 0.05$) between conditions for average mean power output and average peak power output. In a similar study, Brade et al., (2012) looked at 12 male team sport players completing four different conditions, including a combination of a cooling jacket and ice ingestion, control group, cooling jacket alone, and ice ingestion alone. The precooling was administered 30 minutes prior to exercise with an ice jacket and ice slushy. The exercise was repeated-sprints on the cycle including 2 x 30 minute halves, separated by a 10 minute half-time period. Each half was comprised of 30 × 4 second maximal sprints on 60 second marks, interspersed with 56 seconds of sub-maximal exercise at varying intensities for an active recovery. The data suggested that there was a better performance in the cooling jacket alone and the combination groups compared to ice slushy by itself for all performance variables at every stage, except for peak power. The data suggested better performance in the cooling jacket group compared to ice slushy alone for peak power.

Similar to the results of the present study, Brade et al. (2012) found no statistically significant difference in the ice slushy alone precooling group for RPE, mean and peak power outputs. It was found that repeated sprint performance in the heat may be enhanced using a combination of precooling methods involving internal and external, not a singular precooling method such as an ice slushy (Brade et al., 2012). It is suggested by Brade et al. (2012) that using a cooling jacket may have had an insulating effect, by impairing heat flow along a temperature gradient from body core to skin, perhaps accounting for the difference in core temperature returning to baseline throughout the exercise of the current study. Therefore, potentially due to the lack of insulation of the individuals as the exercise protocol continued, their core temperature began to rise.

Minetts et al. (2011) looked at precooling, with ten male team-sport athletes. These athletes performed 85-minutes of free-paced intermittent-sprint running after 20 minutes of precooling via cooling jacket. Researchers looked at distances covered, heart rate, perceptual exertion, and thermal stress. The results of this study showed that exercise heart rate was reduced with whole body precooling prior to the exercise (Minetts et al., 2011). Heart rate had shown to be lower in the experimental trials for all subjects in both halves (Minetts et al., 2011). Whereas, in the present study we would expect to see a change in heart rate due to precooling, vasodilation of the vessels. We did not see this response potentially due to not lowering the core temperature low enough or the participants not elevating their core temperature close to the critical value. Their blood pressure was not threatened enough through the environment or the ice slurry to observe a change in heart rate.

In contrast to Minetts et al. (2011), the present study demonstrated that there was no statistical significant difference for fatigue by conditions ($p = 0.891$). However, there was a an expected statistical significant difference for fatigue by half, demonstrating increase in culamative fatigue as participants progressed through the sprint protocol ($p = 0.025$). Fatigue was not significantly different between the groups. Although fatigue was not different between groups, the core temperature of the participants was significantly lower in the experimental group. This shows the ice slurry was effective at lowering core temperature and increasing heat storage capacity. Although the critical value is 39.2°C for core temperature, the increase in the participants' core temperature may not have been of a significant magnitude to elicit additional increases in fatigue (Brade et al., 2012).

The results from the current study demonstrated a statistically significant difference in the core temperature between the participants' baseline core temperature and post precooling protocol (pre-exercise) ($p < 0.05$). This indicates that the precooling protocol used was effective in lowering the participant's core temperature prior to exercise. It's been speculated by Siegel et al. (2010) a decrease in core temperature may enable more blood to be directed to working muscles to aid in waste removal and delivery of oxygen and nutrients, both of which would aid performance. This finding is similar to the results Siegel et al. (2010) found when investigating the effects of precooling with an ice slurry on running performance in the heat. The researcher found that the precooling protocol with an ice slurry was an effective means to decrease the core temperature. As demonstrated in the present study, one of the potential theories was that the precooling protocol could increase heat storage capacity for the individual. However, in the present study the precooling may not have had an effect on participants due to the fact that their core temperature did not approach the critical value (39.2°C) in the placebo condition. Siegel et al. (2010) mentioned by lowering core temperature before exercise, rectal temperature could increase over a longer period of time allowing the participant to terminate exercise at a similar temperature, thereby potentially improving performance by increasing heat storage capacity.

In another study (Zimmerman et al., 2015), it was shown that the ingestion of ice effectively lowered the core temperature of women cycling in same temperature as the present study. Although the results did not improve performance measures, the researchers suggest there was not improvement due to the physiological differences in the participants' gender (Zimmerman et al., 2015). Zimmerman argued that Ice ingestion alone may not be an effective way to maintain a lower core temperature throughout exercise. Although the methodology demonstrated the ability to lower core temperature directly after ice ingestion, this lowered core temperature was not maintained throughout exercise. Notably, the female participants in Zimmerman's study did not reach the critical value of core temperature similar to the present study.

The lack in difference in RPE by half hints that pacing may have been an issue for some participants. While this cannot be definitively determined, it is worth noting as a potential contributor to the lack of effect of the precool protocol.

Future Considerations

Some things to consider for future works would to try and use a combination of precooling methods to maintain the lowered core temperature throughout the exercise protocol. While participant numbers in this study (n = 9) were similar to other studies that have researched precooling methods (Castle et al., 2008 & Duffield & Marino., 2012) a larger group of participants may have provided more conclusive results. Another area to keep in mind for future considerations is inducing more heat stress to increase the participants' core temperature to induce fatigue greater capacity.

Conclusion

The results suggest that ice ingestion does not provide more of a performance benefit than ingesting water prior to repeated-sprint exercise bouts in the heat (33°C). Ice ingestion did however, improve heat storage capacity by lowering core temperature after ingestion. There needs to be further research done to explore the potential avenues to increase heat storage capacity in repeated-sprint athletes and the effects on performance.

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Appendices

Appendix A

200 Prospect Street
East Stroudsburg, PA
18301-2999

East Stroudsburg University Institutional Review Board
Human Research Review
Protocol # ESU-IRB-066-1819

Date: **May 24, 2019**
To: **Jenna Rose Bilancia**
From: **Shala E. Davis, Ph.D., IRB Chair**
Proposal Title: **"The effects of an Ice Slurry for Precooling and Cooling During Repeated Sprint Exercise in Heat Conditions**

Review Requested:	Exempted	Expedited X	Full Review
Review Approved:	Exempted	Expedited X	Full Review

FULL RESEARCH

____ Your full review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your full review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your full review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit.

EXEMPTED RESEARCH

____ Your exempted review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your exempted review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your exempted review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

EXPEDITED RESEARCH

__X__ Your expedited review research proposal has been approved by the University IRB (12months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your expedited review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

Your expedited review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

Please revise or submit the following:

East Stroudsburg University of Pennsylvania
A Member of Pennsylvania's State System of Higher Education
An Equal Opportunity/Affirmative Action Employer

Appendix B

Informed Consent

Title of Investigation: THE EFFECTS OF AN ICE SLURRY FOR PRECOOLING AND COOLING DURING EXERCISE ON REPEATED SPRINTS IN HEAT CONDITIONS

EAST STROUDSBURG UNIVERSITY Exercise Science

<u>Principal Investigator</u>: **Jenna Rose Bilancia**

Overview of the study

Repeated sprints are one assessment used to measure the physiological demands of stop-and-go activity (Glaister et al, 2004). The sprint portion is usually a 4-8 second sprint, while the rest period usually is about 20-30 seconds (Spencer et al, 2008). There are detrimental effects to the athletes when performing in high heat environments (Hayes et al, 2014). There are many heat management strategies that have been used in research to lower core temperature prior to the start of the exercise and in a short break to also cool the body to increase performance. The task at hand was to identify a cost-effective method which can lower core temperature in hot conditions as to ascertain a way to delay detrimental effects on performance.

Testing Sessions

Visit one will consist of orientation, written informed consent, par-q, and heat illness questionnaire. Demographic data will be collected, along with a 10-minute familiarization trial. The trial will orient the subjects with the equipment being used and the exercise protocol. Session two and three will be the experimental protocol. Subject will begin with 30 minutes in the heat conditions (34 ˚C) where they will either ingest 7.5g/kg of body weight of water (4 ˚C) or ice-slurry (0 or 1˚C). Following the precooling part, subjects will have a 5 minute warm-up, following the warm-up there will be a 10 minute half. This will include 10, 5 second sprints at 0.07N/kg and a 55 second active recovery at 50 watts. There will then be a 10 minute recovery phase, where the subject will ingest 2.5 g/kg of ice slurry or water depending on the session. Followed by a second 10 minute half following the same protocol. Heart rate, core temperature, RPE, percent decrement average mean and peak power outputs will be collected following each 5 second sprint. . Heart rate and core temperature will be monitored continuously for safety purposes. Urine refractometry will be used to ensure hydration status pre and post-testing; if hydration was not achieved before the trial, the researchers would hydrate the subjects on site.

Although be it slight, there are still some risks involved. Any individual information obtained from this study will remain confidential. Non-identifiable data will be used for scientific presentations. You may withdraw from the study at any time. If you have any questions you may contact the principal investigator at jbilancia@live.esu.edu; or by telephone at 973-876-3784. If you feel you were put at risk, or have any further concerns, you can contact Dr. Chad Witmer.

cwitmer@po-box.esu.edu Tel: (570)-422-3362

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE READ THE INFORMATION PROVIDED AND YOU HAVE DECIDED TO PARTICPIATE IN THE STUDY.

I have read and understood the above explanation of the purpose and procedures for this study and agree to participate. I also understand that I am free to withdraw my consent at any time.

<u>Participant</u>

____________________ ____________________ ____________________

Print Name **Signature** **Date**

<u>Principal Investigator</u>

____________________ ____________________ ____________________

Print Name **Signature** **Date**

____

Witness Signature

Appendix C

Heat Illness Questionnaire

Title of Investigation: THE EFFECTS OF AN ICE SLURRY FOR PRECOOLING AND COOLING DURING EXERCISE ON REPEATED SPRINTS IN HEAT CONDITIONS

Principal Investigator: Jenna Rose Bilancia

Please circle if you have ever experienced any of the following problems in the past:

Heat cramps	Heat exhaustion
Heat stroke	Heat rash

Please circle if you have ever experienced any of the following problems in a hot environment in the past:

Confusion

Fainting

Seizures

Very high body temperature

I have not experienced any illness, symptoms, or health problems related to heat in the past. I understand the purpose and procedures for this study. I also understand that I am free to withdraw my consent at any time.

Participant

____________________ ____________________ ____________________

Print Name Signature Date

Principal Investigator

____________________ ____________________ ____________________

Print Name Signature Date

____

Witness Signature

Appendix D

Physical Activity Readiness Questionnaire (PAR-Q) and You

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly:

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of any other reason why you should not do physical activity?
☐	☐	8.	Have you ever suffered a heat illness/injury? If yes, please list below.

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active

If or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

you You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk

answered: with your doctor about the kinds of activities you wish to participate in and follow his/her advice.

- Find out which community programs are safe and helpful for you.

Delay becoming much more active:

- If you are not feeling well because of a temporary If you answered NO honestly to all PAR-Q illness such as a cold or a fever – wait until you feel questions, you can be reasonably sure that you can: better; or