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The Physiological Effects of Precooling Beverage Temperatures on Heat Strain in Collegiate Women Soccer Players

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by

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ABSTRACT

Precooling is a method used to decrease initial pre-exercise core temperature in order to facilitate a greater margin for heat production before a maximum core temperature is reached. The purpose of this study was to examine the differences in physiological and perceptual effects of precooling using beverages of three different temperatures: room temperature beverage (24.88 ± 1.13°C), cold beverage (6.15 ± 3.16°C) and ice slushy (-1.61 ± 0.45°C) in a hot environment (27.88 ± 0.72°C and 35.36 ± 0.83°C for wet globe bulb temperature and dry bulb temperature respectively). For all trials the environmental temperature was set to 35°C with 56% rh.

For this study, 10 physically active females (age= 23.7 ± 2.26 years, height=1.74 ± 0.23 m, weight=66.27 ± 0.92 kg, BMI=24.14 ± 2.63 kg/m^2, body fat= 22.99 ± 2.37% and VO_2 max= 43.61 ± 4.78 ml/kg/min) participated in the study. On three separate occasions participants precooled via beverage consumption over a 30-minute period with a 5-minute rest period before beginning a 45-minute interval treadmill protocol. Following exercise, participants then re-cooled for 15 minutes. Each subject precooled and re-cooled with all three beverages at their respective temperature. Treatments were randomized.

There were no significant differences found for T_{GI} during precooling, exercise or re-cooling Mean HR and mean T_{SK} during precooling were significantly lower in the ice slushy trial as compared to the room temperature trial (HR = 75.7 ± 15.7 and 80.1 ± 16.4 bpm; respectively, $p < 0.05$; T_{SK} = 34.47 ± 0.74 and 34.21 ± 0.92°C; respectively, $p < 0.05$). There was also a significant difference in thermal sensation during precooling among all three beverage temperatures (Thermal

sensation = 4.7 ± 0.7, 4.5 ± 0.7 and 4.0 ± 0.7; for room, cold, and ice slushy respectively, $p < 0.05$). Mean thirst sensation for ice slushy was also significantly lower during precooling when compared to cold ($p < 0.05$) and room temperature beverages($p < 0.05$). Mean thirst sensation was also significantly lower during exercise for ice slushy compared to cold ($p < 0.05$) and room temperature ($p < 0.05$) (precooling thirst sensation= 2.3 ± 1.0, 2.1 ± 1.1 and 1.6 ± 1.0; exercise 4.1 ± 2.0, 4.5 ± 1.7 and 3.2 ± 1.6 for room, cold and ice slushy respectively). During re-cooling mean thirst sensation was significantly lower for ice slush as compared to room temperature ($p < 0.05$).

Results from the current study suggest that precooling with an ice slushy as compared to a cold or room temperature beverage had little to no effect on T_{GI} and a small effect on HR and T_{SK} during precooling. Although, precooling with an ice slushy appeared to be effective at decreasing perceptual measurements.

CHAPTER 1: INTRODUCTION

Rationale

It has been shown that an increased core body temperature (TC) is a contributing factor to fatigue in endurance sports in hot environments (González-Alonso et al., 1999; Hasegawa, Takaori, Komura & Yamasaki, 2006; Hessemer, Langush & Brück,1984; Ihsan, Landers, Brearley & Peeling, 2010; Lee, Shirreffs & Maughan, 2008; Olschewski & Brück, 1988; Périard, Cramer, Chapman, Caillaud & Thompson, 2011; Siegel et al., 2010; Siegel, Mate, Watson, Nosaka & Laursen, 2012). González-Alonso et al. (1999) found that an increase in T_C is linked to a decrease in athletic performance (González-Alonso et al., 1999). In specific sports, such as soccer, athletes have a high level of metabolic heat production with approximately 80% of utilized energy appearing as heat (Maughan & Leiper, 1994). When coupling the high physiological demand of soccer and the potential for competition to take place in hot ambient temperatures, athletes may use various methods to prevent the negative physiological variables associated with high heat stress. Some of these methods may include but are not limited to cooling garments, chilled and iced beverages, cold tubs, air-cooling, reducing exercise intensity, and reducing exercise duration. Although reducing exercise intensity and duration can be effective methods they are not always an option for a competitive soccer player. Recently, researchers have explored precooling as a preventative measure to decrease the risk of heat stress (Bryne, Owen, Conefroy & Kai Wei Lee, 2011; Duffield & Marino, 2007; Hasegawa et al., 2006; Ihsan et al., 2010; Siegel et al., 2012; 2010; Stanley, Leveritt & Peake, 2010).

Precooling is a method used to decrease the initial T_C in order to increase the margin for metabolic heat production, which may lead to an increase in exercise time (Hasegawa et al., 2006; Lee et al., 2008; Marino, 2002; Olschewshi & Brück, 1988). Various precooling methods have been implicated to possibly reduce performance decrements in hot environments. External methods of precooling, such as cold-water immersion, cold air exposure, and wearing ice vests have been shown to be beneficial, but the practical application of these methods is limited due to the time and equipment that is required (Duffield et al., 2007; Hessemer et al., 1984; Marino, 2002; Marino, 2004; Olschewski & Brück, 1988). Therefore, the use of cold liquid and ice slushy ingestion may be a more practical method for team sports. Precooling could help to reduce or delay the negative physiological effects of exercising in the heat (Ihsan et al., 2010; Siegel et al., 2012; 2010).

In a recent study, Siegel et al. (2010) explains ingestion of a ice slushy beverage, as opposed to cold water alone, would result in a decreased T_C due to ice's increased heat sink capacity (Siegel et al., 2010). Heat sink is described as the thermodynamic characteristic of water to change into a solid state, creating a larger heat sink. The increased heat sink is caused by a decrease in specific heat capacity. Specific heat capacity is the amount of energy required to increase 1 g of any substance by 1ºK. The specific heat capacity of ice is 2.108 $kJ \cdot kg^{-1} \cdot K^{-1}$ where as liquid H2O is 4.204 $kJ \cdot kg^{-1} \cdot K^{-1}$. The combination of the solid and liquid form of H2O has the added benefit of the heat sink capacity of both forms (Merrick, Jutte & Smith 2003). The specific temperature of a beverage has been shown to have an influence on many factors such as: decreasing initial core temperature, decreasing physiological strain, increasing run time to exhaustion, and participants showing a decreased core temperature at specific time points when compared to warmer beverages (Bryne et al., 2011; Lee et al., 2008; Siegel et al. 2010; Stanley et al., 2010).

Problem Statement

The purpose of this study was to investigate the physiological effects of different temperatures of precooling beverages prior to one half of a simulated soccer match. There is limited research examining the effects of ice slushy beverage on precooling. Previous studies have shown significant improvement in run time to exhaustion and 40-km cycling time trial after ice slushy ingestion (Ihsan et al., 2010; Siegel et al., 2012; 2010). Some of the results concerning ice slushy ingestion are equivocal. In a study by Stanley et al. (2010), on two separate occasions ten trained men cycled for 75 minutes at 60% peak power output followed by 50 minutes of seated recovery followed by a performance trial at 75% peak power output for 30 minutes. The environmental conditions were set at 34°C, 60% relative humidity (rh). Participants were given 2.5 mL kg^{-1} of a cold liquid beverage (18.4 ± 0.5ºC) every 15 minutes during the 75 minutes of steady state cycling for both trials. During recovery, participants were given either the cold liquid beverage (CLB) (18.4 ± 0.5ºC) or ice slushy beverage (ISB) (-0.8 ± 0.1ºC) at the following time points: 5 min (400 mL), 15 min (200 mL), 25 min (200 mL) and 35 min (200 mL). Following ingestion participants then completed the performance trial. There was no difference in performance time between the two beverages (ISB 29.42 ± 2.07 min vs. CLB 29.98 ± 3.07 min). Although there was no difference between trials T_R, HR and PSI (based on T_R and HR) were significantly lower at the end of the recovery phase for the ISB than the CLB (T_R= 37.0 ± 0.3°C and 37.4 ± 0.2°C, respectively; HR= 87 ± 15 bpm and 91 ± 15 bpm respectively; PSI= 0.2 ± 0.6 and 1.1 ± 0.9 respectively) (Stanley et al., 2010). The conflicting findings show a decreased heat strain with no change in exercise time. This further implicates the present study's purpose, to advance research on the potential benefits of beverage temperature ingestion in decreasing the negative physiological effects of exercise in hot ambient temperatures, while possibly increasing performance by utilizing internal precooling methods. To date, there had been no studies focusing on liquid precooling during long duration interval treadmill running. The ability to determine the impact precooling would have on interval treadmill running would be beneficial to athletes such as soccer players who are often faced with hot ambient temperatures during competition. Hasegawa et al. (2006), examined the thermoregulatory response and exercise capacity of different precooling methods of cold-water immersion coupled with water ingestion for hydration purposes. Nine untrained men cycled for 60 minutes at 60% VO_{2max} (first exercise bout) followed by a time to exhaustion trial at 80% VO_{2max}. The environmental factors were set to 32°C and 80% rh. Conditions included no water intake, precooling with cold-water immersion (25°C) for 30 minutes, precooling for 30 minutes water ingestion (14-16°C) at 5-minute intervals, and a 30-minute precooling combination of the water immersion and water ingestion. The results of this study showed that the combination of the two methods allowed participants to exercise longer until exhaustion (no water 152 ± 16s; water 317 ± 50s; immersion 373 ± 17s; combine 481 ± 47s). Participants also had a decreased T_R through the first exercise bout in the combination trial (no water 39.1 ± 0.1°C; water 38.8 ± 0.1°C; immersion 38.7 ± 0.1°C; combine 38.5 ± 0.1°C)(Hasegawa et al., 2006). Therefore, increasing hydration levels and decreasing initial pre-exercise T_C, precooling with any beverage could serve as a more practical method of increasing performance. The purpose of this study was to examine the precooling effects of three different beverage temperatures on the physiological variables of collegiate women soccer players before and after exercising in the heat.

Study Variables

The present study included one independent variable (temperature of precooling beverage) with 3 levels (beverage temperature). The three temperatures of beverages were ice slushy (-1°C), cold liquid (4°C), and room temperature liquid (21.6°C). The dependent variables that were measured include gastrointestinal temperature (T_{GI}), skin temperatures (T_{SK}), heart rate (HR), rating of perceived exertion (RPE), thermal sensation, thirst sensation, and hydration levels via change in body mass (ΔBM), urine color (U_{COL}) and urine specific gravity (U_{SG}).

Hypothesises

H_{01}: There will be no differences in T_{GI} between the precooling beverages during a simulated soccer half.

H_{02}: There will be no differences in T_{SK} between precooling beverages during a simulated soccer half.

H_{03}: There will be no differences in HR between precooling beverages during a simulated soccer half.

H_{04}: There will be no differences in RPE between precooling beverages during a simulated soccer half.

H_{05}: There will be no differences in thermal sensation between precooling beverages during a simulated soccer half.

H_{06} There will be no differences in thirst sensation between precooling beverages during a simulated soccer half.

H_{07}: There will be no differences in pre/post hydrations levels between precooling following a simulated soccer half.

H_{R1}: Precooling with an ice slushy as compared to cold liquid or room temperature liquid ingestion will decrease T_{GI} during a submaximal interval treadmill protocol.

H_{R2}: Precooling with an ice slushy as compared to cold liquid or room temperature liquid ingestion will decrease S_K during a submaximal interval treadmill protocol.

H_{R3}: Precooling with an ice slushy as compared to cold liquid or room temperature liquid ingestion will decrease HR during a submaximal interval treadmill protocol.

H_{R4}: Precooling with an ice slushy as compared to cold liquid or room temperature liquid ingestion will decrease RPE during a submaximal interval treadmill protocol.

H_{R5}: Precooling with an ice slushy as compared to cold liquid or room temperature liquid ingestion will decrease thermal sensation during a submaximal interval treadmill protocol.

H_{R6}: Precooling with an ice slushy as compared to cold liquid or room temperature liquid ingestion will decrease thirst sensation during a submaximal interval treadmill protocol.

H_{R7}: Precooling with an ice slushy will lead to greater levels of hydration as compared to cold liquid or room temperature liquid ingestion following a submaximal interval treadmill protocol.

Conceptual Model

According to previous research precooling with a cold beverage reduces heat strain (Bryne et al., 2011; Lee et al., 2008; Siegel et al. 2010; Stanley et al., 2010). However, the ideal beverage temperature for successful precooling has not been determined. This study implemented three different beverage temperatures ice slushy (-1°C), cold liquid (4°C), and room temperature liquid (21.6°C) during the simulation of a 45 minute soccer half.

A 22.5-minute intermittent treadmill protocol was used by Davis et al. (2012), to simulate one half of a soccer match. Participants followed the protocol for two identical phases resembling a 45-minute soccer half. Total time spent in each locomotor category is respectively 17% standing, 40% walking, 30% low intensity running, 6% moderate intensity running, and 7% in sprinting (Davis et al., 2012). In an additional study by Mohr et al. (2008), observations of 34 elite women's soccer games yielded similar percentages of time spent in each locomotor category (Mohr, Krustrup, Andersson, Kirkendal & Bangsbo, 2008).

Operational Definitions

Precooling is defined as a specific method used to decrease T_C prior to an exercise bout allowing for a greater heat storage capacity (Marino, 2002). Gastrointestinal temperature (T_{GI}) refers to the temperature (ºC) of the gastrointestinal tract that reflects total T_C within a living body. Skin temperature (S_K) refers to the outer surface temperature of the body. Cooling rate refers to the difference in final temperature and initial temperature divided by the time in minutes. Total exercise time is the total amount of time in seconds that participants exercised. Ratings of perceived exertion (RPE) is the participant's perceived exertion using a 6-20 point Borg Scale of Perceived Exertion (Borg & Noble, 1974; Garber et al., 2011). Thermal sensation is defined as the participant's sense of temperature. Thirst sensation is defined as the psychological sensation to consume fluid. Urine specific gravity (U_{SG}) and urine color (U_C) refers to the bodies' hydration levels.

Assumptions

During this study it was assumed that all participants gave maximal effort. It was also assumed that participants followed the pre-trial hydration, dietary, and exercise guidelines. In order to account for menstrual status and cycle phase, we assumed that all women had a regular menstrual cycle and would report any irregularities. Menstrual cycle phase may play a role in thermoregulation. Inoue et al. (2005), observed that during heat exposure, mean body temperature of women is shown to be higher during the luteal phase than the follicular phase. (Inoue et al., 2005).

Limitations

One limitation present in this study was the fluctuation of the beverage temperature, which in turn could of affected its reliability through alteration of the specific heat capacity of the given beverage. Another limitation noted in this particular study refers to the selective gender focus. Only female participants were used, thus potentially limiting its application to men. But there was no reason to believe there would be any difference in men. This study also limits the generalizability to interval treadmill running. In addition to the interval running there is a limitation to the data received during exercise. The exercise intensity varied during the specified data collection points.

Delimitations

The delimitations of this study are that the study population was aerobically trained women ages 18-30 years. Therefore, results of this study may not pertain to other populations. Another delimitation was the environmental temperature that was used, consequently limiting the ability to apply this practice in other various environmental settings. In conjunction with the limited environmental controls, there was also a delimitation of temperature, with each beverage ice slushy beverage, cold beverage, and room temperature beverage.

Significance

Heat-related illness can be deadly and can occur in highly conditioned athletes. Therefore, the prevention of heat illness is an important factor in protecting an athlete's health. Heat-related deaths are among the top three causes of death among athletes (Casa et al., 2012). Internal beverage precooling could serve as a practical method that may aid in the prevention of heat related illnesses among athletes. Precooling is a specific method used to decrease T_{GI} prior to an exercise bout allowing for a greater heat storage capacity (Marino, 2002). If precooling with a beverage can significantly decrease the physiological variables associated with exercising in heat, its benefits would be valuable to any sport that takes place in a hot environment. There is limited evidence in the data concerning the various methods of precooling with a beverage during interval intermittent exercise.

CHAPTER 2: LITERATURE REVIEW

Hot ambient temperatures affect almost all outdoor sporting events in a warm climate. During prolonged exercise in hot environments the onset of fatigue is associated with the increase of T_C, which in turn, decreases performance (Lee et al., 2008). It has been shown that high ambient temperatures and high humidity have an unfavorable effect on athletic performance associated with an increase in many physiological variables including T_{GI}, HR, T_{SK}, and cardiac output (Périard et al.,2011; Quod, Martin & Laursen, 2006).

High intensity exercise in a hot environment causes reduced stroke volume, decreased central blood flow, and increased HR resulting in an increased cardiovascular strain (González-Alonso et al., 1999). In a study by Périard et al. (2011), eight endurance-trained cyclists performed two 40 km trials in hot (35ºC) and thermoneutral (20ºC) environments. Within the hot environment HR, RPE, and T_R were all increased when compared to the neutral environment (HR= 101.0 ± 5.0 and 98.8 ± 3.2% respectively; RPE= 16.8 ± 1.8 and 15.9 ± 1.9 respectively; T_R=39.8 ± 0.3 and 38.9 ± 0.2ºC respectively). Périard et al. (2011), also concluded that increasing cardiovascular strain parallels an increase in relative exercise intensity.

Cardiovascular strain can possibly be reduced by means of decreasing initial core temperature allowing an increase in the body's heat storage capacity. González-Alonso et al. (1999), reported that 30 minutes precooling with cold-water immersion at 17ºC resulted in a greater decrease in pre-exercise esophageal temperature (T_{ES}) as compared to water immersion in neutral 36ºC and preheating 40ºC tubs for 30 minutes (35.9 ± 0.2, 37.4 ± 0.1, and 38.2 ± 0.1 ºC, respectively). Results showed immersion in colder water allowed participants to increase time to exhaustion (time=17ºC 63 ± 3, 36ºC 46 ± 3 and 40ºC 26 ± 2 min). Despite the pre-exercise T_{ES} and time to exhaustion all participants fatigued at similar physiological values (T_{ES} 40.1- 40.2°C; T_{SK} 37.0-37.2°C; HR 196-198 beats/min; SV 19.9-20.8 l/min). González-Alonso et al. (1999), considered the increased exercise duration was due to increased internal capacity for heat, as well as the decrease in cardiovascular strain (González-Alonso et al., 1999).

Methods of Precooling

Precooling is a specific method used to decrease T_C prior to an exercise bout allowing for a greater heat storage capacity (Marino, 2004). Precooling is said to delay physiological fatigue by reducing the initial T_C allowing for an increased margin of heat production (Lee et al., 2008). Quod et al. (2006), stated that an increase in T_C is linked to an increase in physiological strain; therefore, reducing heat strain may allow an athlete to compete longer. Precooling can be used to reduce physiological strain and act as a safety implication to possibly prevent heat stress in outdoor sport settings where environmental factors pose the greatest threat. Studies have examined many various methods of precooling such as cold-water immersion, air-cooling, liquid-cooled suits, as well as ice jackets (Duffield & Marino, 2007; Hessemer et al., 1984; Hasegawa et al., 2006; Marino & Booth, 1998; Olschewski & Brück , 1988; Quod et al., 2006; Siegel et al., 2012). Researchers have been examining the body's response to cold-water baths since the 1930s, but it wasn't until the 1980s that whole-body cooling and sport performance began to be examined (Quod et al., 2006). Cold-water immersion has been studied in numerous experiments (Duffield & Marino, 2007; Hasegawa et al., 2006; Marino & Booth, 1998; Siegel et al., 2012). Marino and Booth (1998), found cold-water immersion to be effective in decreasing

T_C but it is uncomfortable and can take up to 60 minutes (if you want to minimize the bodies response to cold) to be an effective method. In order to avoid the initial stress and discomfort of being exposed to cold water temperature, Marino and Booth (1998), set the water temperature at 29ºC and reduced the temperature ~2ºC every 10 minutes over a 60 minute period to a temperature of ~17ºC. At the end of immersion T_R fell from 37.34 ± 0.36ºC to 36.64 ± 0.34ºC. T_{SK} was decreased from 33.23 ± 1.4 °C to 26.95 ± 1.8°C following immersion (Marino & Booth 1998). The practical application of cold-water immersion to a collegiate sports team could be limited due to the amount of time and resources (cold tubs) associated with this process.

Two separate studies Hessemer et al. (1984) and Olschewski & Brück (1988), investigated precooling with cold air exposure at temperatures of 5-10ºC for 15 minutes followed by rewarming periods that lasted up to 20 minutes. Rewarming periods were used to re-establish thermal comfort and reduce shivering. The effect of the cold air actually caused an initial increase in T_C during exposure, followed by a decrease in T_C likely. The initial increase in T_C is due to blood flow increasing to internal organs caused by vasoconstriction. In both studies, there was a benefit to precooling. Hessemer et al. (1984), reported an increase in work rate during a 60 min work rate test (control 172 W vs. cold air 161 W) following ~105 minutes of precooling (Hessemer et al.,(1984). Olschewski & Brück (1988), saw an increase in cycling time to exhaustion (control 18.5 ± 2.5 min vs. cold air 20.8 ± 2.3 min) following ~130 minutes of precooling (Olschewski & Brück 1988). Although precooling with cold air exposure could be effective, these methods have very little practical application due to the extended time needed to be effective (Marino, 2002).

Duffield & Marino (2007), researched the effect of precooling with an ice vest and a combination of cold-water immersion and an ice vest to improve maximal sprint and submaximal work during intermittent-sprint exercise. Nine competitive rugby players completed three trials of 2 x 30 minute intermittent sprint intervals which consisted of running 15-m sprint every minute separated by free-paced hard-running, jogging and walking. Environmental conditions were set at 32ºC and 30% rh. Precooling methods were implemented 15 minutes before exercise and for 10 minutes between bouts. One precooling method included wearing an ice vest before exercise as well as during the 10-minute half time. The second method included cold-water immersion (14 ± 1ºC) for the 15-minute pre exercise cooling and wearing an ice vest during the 10-minute halftime, a control was also used. They found that there was no significant difference in performance between the three conditions, although there were significant differences in $T_{C,}$ HR, T_{SK}, and thermal comfort with the ice vest/ ice bath method (no specific variables listed). This suggests there is a possible benefit to the physiological factors associated with exercise in the heat. (Duffield & Marino, 2007)

Cold beverage temperature ingestion is also a possible precooling method. Lee et al. (2008), examined the influence of beverage temperature on thermoregulatory responses during prolonged exercise. His findings support the belief that a decreased beverage temperature may have the ability to aid in thermoregulation during exercise. Eight men cycled to exhaustion in a hot and humid environment (35.0 ± 0.2ºC, 60 ± 1% rh). Participants consumed 300ml of either a cold (4ºC) or warm (37ºC) beverage 30 minutes before exercise and in 10-minute intervals during exercise. The cold beverage decreased T_R by 0.5 ± 0.1ºC more than the warm beverage. HR was lower following cold beverage as compared to warm beverage ingestion (HR=61±10 bpm and 69±9 bpm respectively). Participants exercised longer with the cold beverage as compared to the warm (time= 63.8 ± 4.3 minutes and 52.0 ± 4.1 minutes respectively). Perceived exertion and thermal sensation were lower with the cold beverage as opposed to the warm beverage during exercise (RPE=14±1 and 15±1 respectively; T_S 5±1 and 6±1 respectively) (Lee et al., 2008). In this study the influence of beverage temperature is implicated before and during exercise. Although the drink was consumed during exercise, the results still support the ability of the beverage temperature to significantly affect various thermoregulatory factors. This study adds to the potential benefit of beverage ingestion on precooling.

Byrne et al. (2011), examined the difference in cycling performance of seven men after consuming three servings of 300 mL of either cold (2ºC) or control (37ºC) flavored water during 35 minutes pre-exercise. Environmental conditions were set at 32ºC with 60% rh. In these trials, T_R had a greater decrease during the ingestion of cold vs. control (ΔT_C= 0.41 ± 0.16ºC and 0.17 ± 0.17ºC respectively). T_R remained lower (between 2.53-3.38ºC) until 5 minutes before the exercise and during the first 5-25 minutes of exercise. Those who ingested the cold beverage cycled a greater distance than those who ingested the control beverage (distance= 19.26 ± 2.91 and 18.72 ± 2.59 km respectively) (Bryne et al., 2011).

Precooling with cold beverage ingestion has been shown to be both effective and practical for decreasing various physiological stressors (Bryne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2012; 2010; Stanley et al., 2010). Siegel et al. (2010) compared run times to exhaustion in 10 men after ingestion $7.5 g \cdot kg^{-1}$ of either an ice slushy beverage (-1ºC) or cold beverage (4ºC) over a 30-minute period before exercise in a hot environment (34ºC, 54.9% rh). Run time to exhaustion was significantly longer after ingestion of the ice slushy as compared to cold water (time to exhaustion= 50.2 ± 8.5and 40.7 ± 7.2 minutes respectively). But at the same time point of exercise T_R was lower with ice slushy beverage. Pre-exercise T_R was decreased more with ingestion of the ice slushy as compared to that of cold water (beginning T_R=37.21 ± 0.19 and 37.13 ± 1.11ºC; ΔT_C 0.66 ± .14ºC and 0.25 ± .09ºC respectively). At the end of the trial,

T_R was greater in the ice slushy as compared to cold-water trial (T_R 39.36 ± .41ºC and 39.05 ± .37ºC respectively). Although T_R was higher at the completion of the exercise in the ice slushy trials, RPE and thermal sensation showed no significant differences at exhaustion (Siegel et al., 2010). Ihsan et al. (2010), compared physiological strain after crushed ice ingestion (1.4 ± 1.1º C) to tap water ingestion (26.8 ± 1.3ºC) as a precooling method during a 40-km cycling time-trial (1200kJ). Seven trained men consumed either crushed ice or tap water (6.8 $g \cdot kg^{-1}$ of body mass) 30 minutes before the trials. Results showed a significant difference in T_{GI} after ice ingestion until 200 kJ of work had been completed (T_R 36.74 ± .67ºC and 37.27 ± .24ºC respectively). The 40-km cycling times were 6.5% faster after crushed ice ingestion than tap water ingestion (time 5011 ± 810 and 5359 ± 820 s respectively) while there was no difference in mean power output (Ihsan et al., 2010).

Some of the research concerning ice slushy ingestion does not prove to be significant in improving performance but does decrease physiological strain, as shown by Stanley et al., (2010). In this study ten trained men were given either a cold liquid beverage (CLB) (18.4 ± 0.5ºC) or ice slushy beverage (ISB) (-0.8 ± 0.1ºC) as a method of precooling. On two separate occasions ten trained men cycled for 75 minutes at 60% peak power output followed by 50 minutes of seated recovery followed by a performance trial at 75% peak power output for 30 minutes. The environmental conditions were set at 34°C, 60% rh. Participants were given 2.5 $mL\ kg^{-1}$ of the CLB every 15 minutes during the 75 minutes of steady state cycling for both trials. During recovery, participants were given either the CLB or ISB at the following time points: 5 min (400 mL), 15 min (200 mL), 25 min (200 mL) and 35 min (200 mL). Following ingestion participants then completed the performance trial. There was no difference in performance time between the ISB and the CLB (time= 29.42 ± 2.07 and 29.98 ± 3.07 min respectively). Although there was no difference between trials T_R, HR and PSI (based on T_R and HR) were significantly lower at the end of the recovery phase for the ISB than the CLB (T_R= 37.0 ± 0.3°C and 37.4 ± 0.2°C, respectively; HR= 87 ± 15 bpm and 91 ± 15 bpm respectively; PSI= 0.2 ± 0.6 and 1.1 ± 0.9 respectively) (Stanley et al., 2010). The present study supports the potential physiological benefits of precooling with an ISB as compared to CLB.

Siegel et al. (2012), conducted a study looking at run time to exhaustion and physiological strain comparing precooling methods of a cold-water bath (24.0ºC) to an ice slushy ingestion (1.0ºC) and a control condition that used no precooling method. Eight men ran to exhaustion in a climate of 34ºC with 52% rh. Precooling methods took place for a 30-minute period. During the ice slushy trial participants ingested 7.5 $g \cdot kg^{-1}$ in 5-minute increments of 1.25 $g \cdot kg^{-1}$. At exhaustion T_R was significantly higher after ingestion of ice slushy as compared to cold water immersion and the control (T_R= 39.76 ± 0.36ºC, 39.48 ± 0.34ºC and 39.48 ± 0.36ºC respectively). Although it is important to note that at the same time point of exhaustion for the control T_R appears to be slightly lower for ice slushy when compared to the control. RPE was lower in ice slushy and cold water immersion as compared to control (RPE= 14.1 ± 3.0, 14.5 ± 2.3 and 15.1 ± 2.9 respectively) Participants' times to exhaustion were significantly greater with the use of both precooling techniques as compared to the control group (time 56.8 ± 5.6, 52.7 ± 8.4 and 46.7 ± 7.2 respectively) (Siegel et al., 2012).

There is evidence to show precooling with an ice slushy can be a practical method to possibly improve exercise performance (Ihsan et al., 2010; Siegel et al., 2012; 2010; Stanley et al., 2010). The thermodynamic characteristic of water to change into a solid state creates a larger heat sink. The increased heat sink is caused by a decrease in specific heat capacity. Specific heat capacity is the amount of energy required to increase 1 g of any substance by 1ºK. The specific heat capacity of ice is 2.108 $kJ \cdot kg^{-1} \cdot K^{-1}$ where as liquid H_2O is 4.204 $kJ \cdot kg^{-1} \cdot K^{-1}$. The combination of the solid and liquid form of H_2O has the added benefit of the heat sink capacity of both forms (Merrick et al., 2003). In the study by Siegel et al. (2010), the ice slushy (1ºC) facilitated a larger decrease in T_C than the cold liquid (4ºC) (Siegel et al., 2010).

Summary

Heat illness, particularly exceptional heat stroke, can be a potentially deadly condition. Methods of precooling may be beneficial in the prevention of heat illness. Precooling through cold liquid ingestion has proven to be an effective method to reduce physiological strain and potentially decrease the detrimental effects of heat on performance. To date, there are no studies looking at precooling with an ice slushy while directly implementing interval exercise resembling sporting events such as a soccer match. Among other things, precooling with an ice slushy beverage could provide the benefit of decreasing physiological strain while assisting with hydration and combating heat stress. By means of liquid ingestion, precooling with an ice slushy has the potential ability to largely impact the performance of elite women's soccer players.

CHAPTER 3: METHODS

Participants

Ten recreational women's soccer players were recruited to participate in the study. Participants were current or previous members of the University of South Florida club team or active in intramural soccer. Please see Table 1 for participant characteristics. Participants were aerobically fit (VO_{2max}; M=43.61, SD= 4.78) and presumably heat acclimated. Participants were required to complete a medical history questionnaire that was reviewed by a physician. Potential participants were excluded if there was evidence of drug or alcohol abuse or they were taking the following classes of medication: alpha and beta (sympathetic) blocking agents, anticholinergics, antidepressants, lithium, antihistamines, calcium channel blockers, cocaine, diuretics, dopaminergics, ethanol, neuroleptics, and sympathomimetics. The physician excluded subjects he believed on history if the physician believed that an undiagnosed disease was present and that it could have interfered with the participant's ability to tolerate exercise in the heat. Exclusion criteria also included any subject that had a history of cardiovascular, metabolic, or respiratory disease, has fever or a current illness, had a history of a heat-related illness (heat exhaustion or heat stroke), had suspected obstructive disease of the gastrointestinal tract (including but not limited to diverticulitis and inflammatory bowel disease), exhibited or had a history of disorders or impairment of the gag reflex, had previous gastrointestinal surgery, could have underwent Magnetic Resonance Imaging (MRI) scanning during the period that the Cor-Temp™ Disposable Temperature Sensor was within the body (36 hour maximum), or had hypomotility disorders of the gastrointestinal tract including but not limited to the ileus. Any person who had a current musculoskeletal injury was excluded. Participants who could not communicate in English were not recruited. Participants were required to sign a consent form in compliance with guidelines set by the University of South Florida Institutional Review Board. Please refer to Table 1 for participant characteristics

Table 1: Participant Characteristics

	N	Mean ± SD
Age (years)	10	23.7 ± 2.26
Height (m)	10	1.74 ± 0.23
Weight (kg)	10	66.27 ± 0.92
Body Mass Index (kg/m^2)	10	24.14 ± 2.63
Body Fat (%)	7	22.99 ± 2.37
VO_2 max (ml/kg/min)	10	43.61 ± 4.78

Study Location. This study took place in the University of South Florida Heat Stress Lab. VO_{2max} trials took place at the University of South Florida REC 004.

Instrumentation

Three perceptual measurements were utilized in this study: rating of perceived exertion scale (RPE), thermal sensation scale, and thirst sensation. For RPE the 15-point Borg scale was utilized (Borg, 1982) (appendix C). Thermal sensation scale ranged from 0-7 and corresponded to the following sensation: 0-unbearably cold, 1-very cold, 2-cold, 3-cool, 4-comfortable, 5-warm, 6-hot, and 7-very hot (Davis et al., 2012) (appendix E). Thirst sensation scale ranged from 1-9 with 1- not thirsty at all, 3- a little thirsty, 5- moderately thirsty, 7-very thirsty, and 9- very, very thirsty (Engell et al., 1987; Riebe et al., 1997) (appendix: D).

Equipment

All precooling, exercise, and re-cooling took place in an environmental chamber that allowed temperature and humidity to be controlled. Heart rate was assessed using a Polar heart rate monitor. A Stairmaster Club 510 treadmill was used for the exercise protocol. VO_{2max} was assessed using a Vacuumed Vista Mini CPX. Skin temperature was measured using YSI 409A thermistors at 4 sites: chest, arm, thigh and calf. Average Tsk was computed as T_{SK} = 0.3Tchest + 0.3Tarm + 0.2Tthigh + 0.2Tcalf (Ramanathan, 1964). Telemetric gastrointestinal (GI) CorTemp™ pills were used to measure core temperature. Urine specific gravity was measured with a urine refractometer and a urine color chart was used to assess hydration (Armstrong, Soto, Hacker, Casa, Kavouras, and Maresh, 1998). Body composition was measured at 3 sites using a skinfold caliper. A standard fluid replacement beverage was used for all beverages. A standard kitchen blender was used to create an ice slushy from the frozen fluid replacement beverage.

Procedures

Participants were required to pass a medical screening and sign an informed consent before participation in the study.

For all trials participants were asked to wear clothing similar to that of a typical soccer uniform. This included comfortable shorts, a polyester blend top, sports bra, shin guards, socks, and running shoes. All trials were separated by a minimum of 48 hours and a maximum of 14 days and were scheduled for the same time of day. Before arrival, participants were asked to follow specific diet and exercise limitations for a period of 24 hours. Participants were asked to refrain from caffeine, alcohol, non- steroidal anti-inflammatory drugs, dietary supplements, and high intensity exercise for 24 hours prior to experimental trials. Participants were instructed to consume 16 ounces of water before going to bed, also in the morning/afternoon on the day of each trial to ensure euhydration upon arrival. Euhydration was confirmed upon arrival with a urine specific gravity of $\leq$1.020.

There was a total of five sessions: one $Vo_{2max,}$ one familiarization trial, and three experimental trials.

VO_{2max} Trial. Participants were asked to report to the Health and Exercise Science Lab for VO_{2max} testing. They were asked to follow the same guidelines as stated above. A modified Bruce protocol was followed (Appendix B). VO_{2max} and HR_{max} were obtained during these trials.

Familiarization Trial. Guidelines for the familiarization trials matched that of the experimental trials with a few slight variations. The familiarization trials took place in a thermoneutral environment and participants did not ingest the CorTemp pill. Also, the participants only completed one half (22.5 minutes) of the given exercise protocol. There was no emphasis on specific beverage temperature. The beverages were administrated in the same increments as they were in the experimental trials before exercise. Participants were provided with a sports drink to serve as a hydration beverage and they drink ad libitum during and after exercise. The main focus of the familiarization trial was to ensure participants were comfortable with the exercise protocol.

Experimental Trials. On the day of experimental trials participants swallowed an ingestible thermal sensor pill with 8 oz. ounces of water 8 hours prior to reporting to the Heat Stress Lab. Upon arrival to the laboratory, participants were asked to give a urine sample to confirm euhydration via analysis of urine specific gravity ($U_{SG} \leq 1.020$) and urine color was also assessed. Also a semi-nude (shorts and sports bra) body weight was recorded. Participants then dressed in the appropriate clothing (comfortable shorts, a polyester blend top, sports bra, shin guards, socks, and running shoes). A HR monitor was then positioned on the participant's chest. Four skin thermistors were then affixed to each participant on the right quadriceps, right gastrocnemius, chest, and right tricep or upper arm.

Participants then entered the environmental chamber which was set at 35° C and 56% rh. Participants were asked to rest in a seated position for 15 minutes in order to collect baseline data ($T_{SK,}$ HR, and T_{GI}). Over the next 30 minutes, participants consumed 7.5 $g \cdot kg^{-1}$ (for a 65 kg person this would be ~17.2 oz.) of either the ice slushy (1.0°C), cold liquid (4.0°C), or room temperature liquid (21.6°C). A sports drink fluid replacement beverage was used for all beverages. Participants were given 1.25 $g \cdot kg^{-1}$ of the specified beverage every 5 minutes to facilitate a standardized ingestion rate, also to avoid sphenopalatine ganglioneuralgia (brain freeze). Once participants finished the final ingestion they then rested for a 5-minute period before beginning the exercise protocol. Participants then completed two identical phases of the given exercise protocol (appendix: B) for a total of 45-minutes, which simulated the first half of a soccer match. During all exercise trials participants had access to 3.75 $g \cdot kg^{-1}$ of a room temperature beverage in which they consumed during the 45 minutes of exercise. Following the exercise bout, participants rested for 15 minutes in the environmental chamber, while consuming, 3.75 $g \cdot kg^{-1}$ of the same assigned beverage used pre-exercise, 1.25 $g \cdot kg^{-1}$ of the specific beverage was given every 5 minutes. While in the environmental chamber, participants reported RPE, thermal sensation, and thirst sensation every 5 minutes. The researcher also collected data in 5-minute intervals including $T_{SK,}$ HR, and T_{GI}. Environmental data was recorded every 15 minutes.

Upon exiting the chamber, participants removed the HR monitor and skin thermistors, toweled dry, and took a post exercise semi-nude body weight and provided a post-exercise urine sample. They then reported session RPE, session thirst sensation, and session thermal sensation.

Participants followed the exercise protocol unless one of the following termination criteria was met: T_{GI} of 39.5°C, a state of exhaustion, HR within 95% of maximal heart rate, once the trial protocol was completed, or if the participant wished to stop at which time they ceased exercise and exited the environmental chamber. If a participant did not complete the full protocol the researcher recorded total duration of exercise and completed the post-exercise protocol.

Laboratory protocol for experimental trials.

1. Upon arrival a urine sample was given.
2. Subject took a semi-nude body weight.
3. HR monitor and skin thermistors were affixed.
4. Subjects dressed and entered the chamber.
5. Subjects rested for 15 minutes inside the chamber.
6. Precooling began marking the 0 time point of the protocol.
7. Every 5 minutes participants were given 1.25 $g \cdot kg^{-1}$ of the assigned beverage.
8. Participants drank until the 30-minute time point.
9. Participants then rested for 5 minutes.
10. The exercise protocol began this was the 35-minute time point.
11. Participants completed the exercise protocol, which lasted 45 minutes. Unless participant willingly stopped early or was stopped early.
12. Following exercise re-cooling began. This was at the 80-minute time point.

13. For 15 minutes up until the 95-minute time point the participants re-cooled using the same beverage type and amount as precooling.
14. They then exited the chamber removed HR monitor and skin thermistors.
15. Participants towel dried and took a semi-nude body weight.
16. A post urine sample was then collected.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences, Version 22.0™ (SPSS). There was one independent variable (beverage temperature) with three levels room, cold and ice slushy. Dependent variables included T_{GI}, H_R, T_{SK}, RPE, thermal sensation, thirst sensation, semi-nude body weight, U_{SG}, Urine color, total exercise time. All experimental trials were completed in a randomized counterbalanced order to limit order of effects. A repeated measures ANOVA was performed on three levels of drink temperature (room temperature, cold and ice slushy) and the dependent variables of gastrointestinal temperature (T_{GI}), skin temperature (T_{SK}), heart rate (HR), thirst sensation, thermal sensation, and ratings of perceived exertion (RPE). The results were analyzed by the phase of the research protocol (precooling, exercise and re-cooling). The precooling phase took place from 0-30 minutes. The exercise portion began at minute 45, which was when the participants completed the interval running exercise bout. The re-cooling phase consisted of the 15 minutes following exercise. For pre and post measurements urine specific gravity (U_{SG}), urine color (U_C) and semi-nude body weight (BW) a paired t-test was performed comparing the difference of pre and post for each condition. The significance was set at $P < 0.05$ for all comparisons. Data was presented using means and standard deviations.

CHAPTER 4: RESULTS

Gastrointestinal Temperature (T_{GI})

Mean T_{GI} by time point is presented in Figure 1, and mean T_{GI} by phase is present in Figure 2, 3 and 4. (Mean T_{GI} for each time point is presented in Appendix H in Tables 1A, 2A and 3A.) There were no differences among conditions for T_{GI} within the pre-cooling, exercise or re-cooling phases ($p > 0.05$) (See Table 2). Cooling rate is presented in Table 3. For pre-exercise cooling rate, there was no significant difference found in T_{GI} between the three treatments ($p>0.05$). There was also no significant between-treatment difference found during re-cooling ($p>0.05$). Also effect sizes for T_{GI} by treatment were low and are shown in Table 4.

Figure 1 Mean Gastrointestinal Temperature by time point

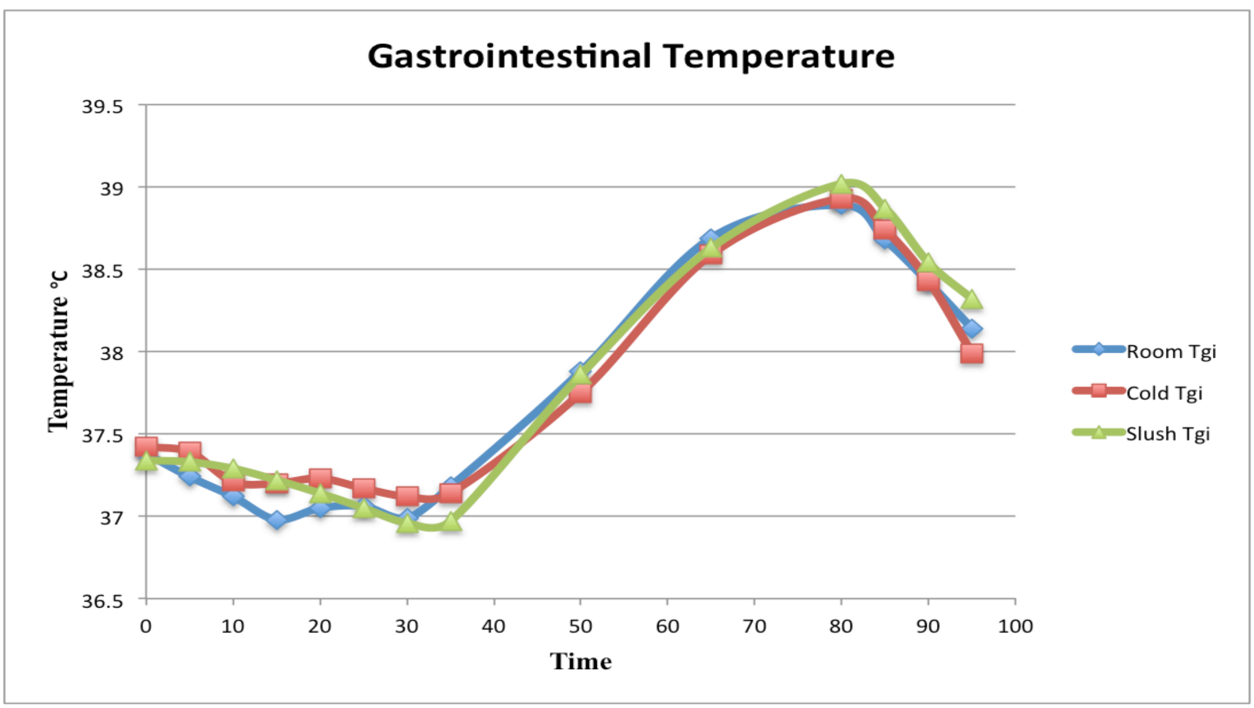

Figure 2 Mean Precooling Gastrointestinal Temperature

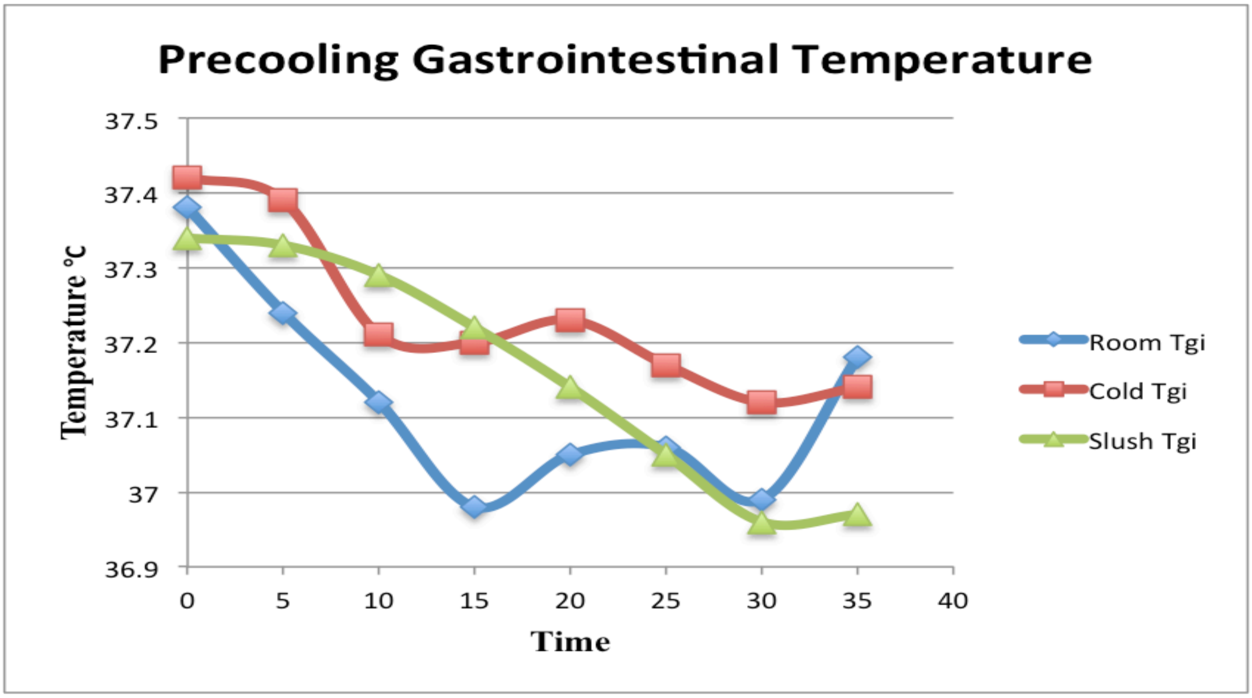

Figure 3 Mean Exercise Gastrointestinal Temperature

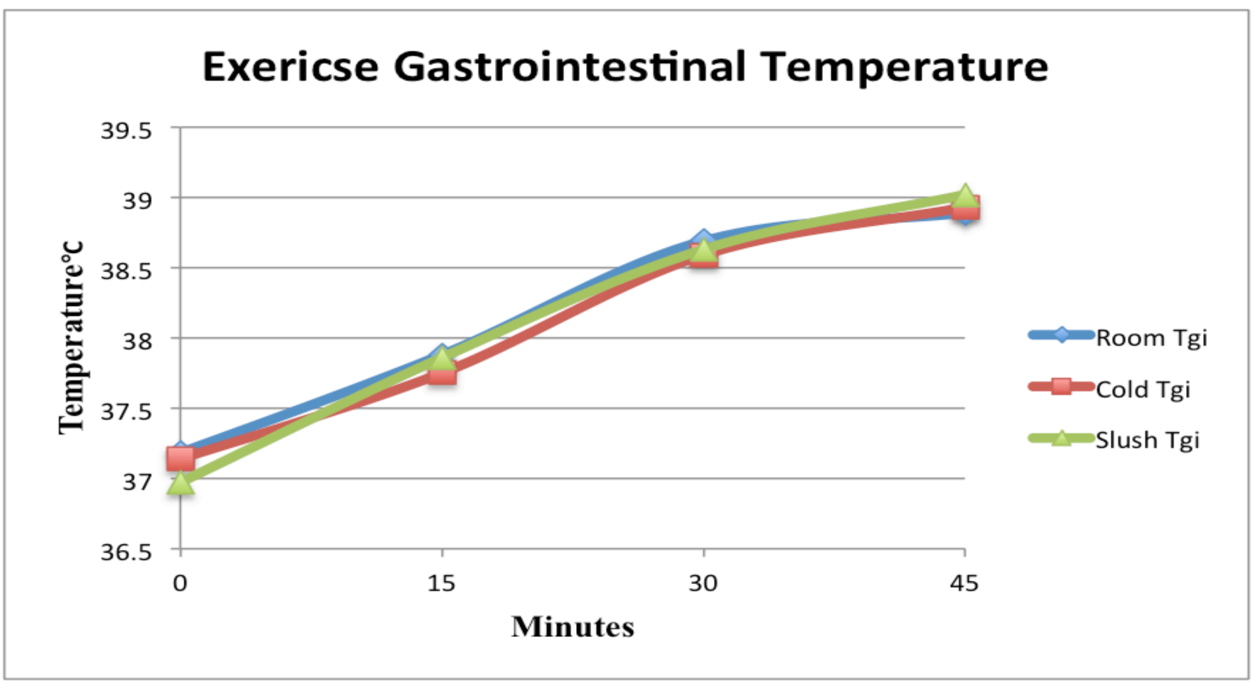

Figure 4 Mean Re-cooling Gastrointestinal Temperature

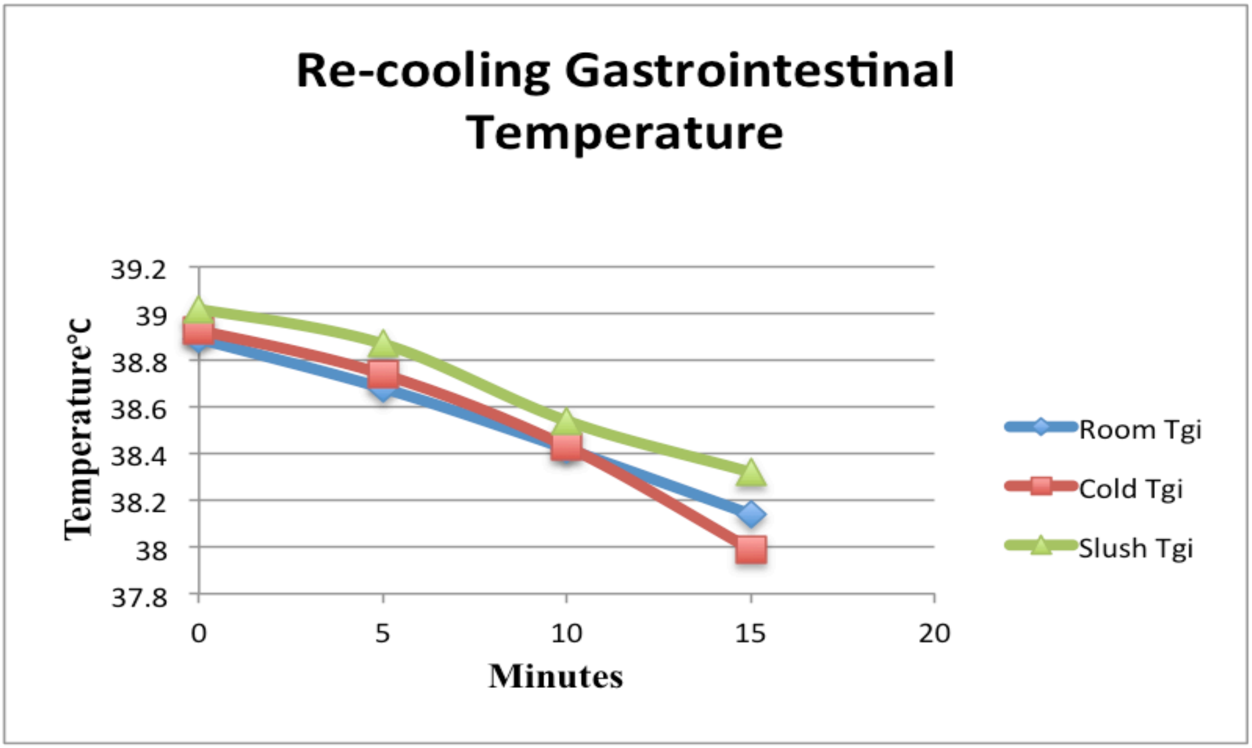

Table 2 T_{GI} by treatment (mean ± standard deviation)

	Room T_{GI} (°C)	Cold T_{GI} (°C)	Slush T_{GI} (°C)	p-value
Precooling	37.13 ± .074	37.23 ± 0.51	37.16 ± 0.47	0.559
Exercise	38.41 ± 0.68	38.28 ± 0.58	38.68 ± 0.6	0.445
Re cooling	38.42 ± 0.59	38.27 ± 0.6	38.52 ± 0.56	0.317

Table 3 T_{GI} Cooling Rate (mean ± standard deviation)

	Room (°C)	Cold (°C)	Slush (°C)	p-value
Precooling	0.0055 ± 0.0119	0.0095 ± 0.0128	0.0105 ± 0.0049	0.488
Re cooling	0.0453 ± 0.0425	0.0608 ± 0.0457	0.0419 ± 0.0131	0.685

Table 4 T_{GI} Effect Size

	Trial Phase		
Treatments	Precooling	Exercise	Re-cooling
Room vs. Cold	.16	.21	.25
Cold vs. Slush	.14	.14	.43
Slush vs. Room	.05	.08	.17

Skin Temperature (T_{SK})

Mean T_{SK} by time point is presented in Figure 5, and mean T_{SK} by phase is present in Figure 6, 7 and 8. Skin temperature by phase is shown in Table 5. During the precooling phase, mean T_{SK} was significantly lower for the room temperature condition when compared to the ice slushy condition (T_{SK}= 34.21 ± 0.93°C, 34.22 ± 1.5°C and 34.47 ± 0.74°C for room, cold and ice slushy, respectively; p= 0.015). (Mean T_{SK} by time point is shown in Appendix H Tables 4A, 5A, and 6A). During the exercise and re-cooling phases, there were no significant differences in T_{SK} presented in Table 5. Effect sizes for T_{SK} are low to moderate and are shown in Table 6.

Figure 5 Mean Skin Temperature by time point

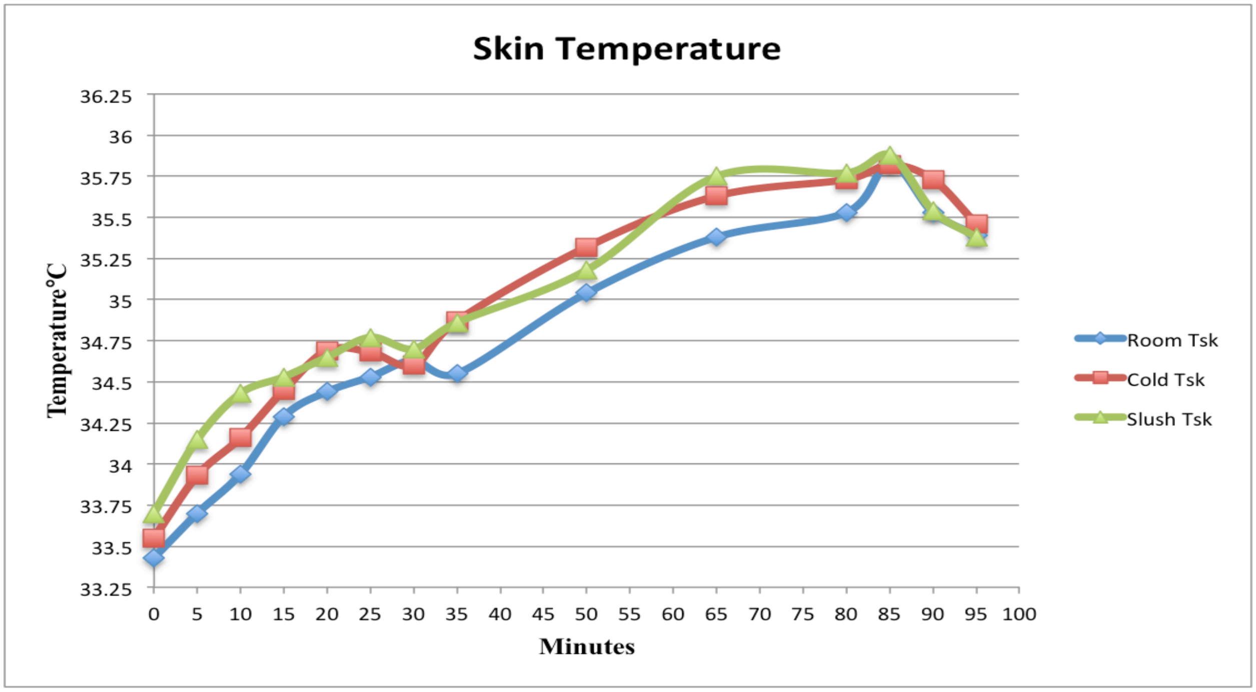

Figure 6 Mean Precooling Skin Temperature by time point

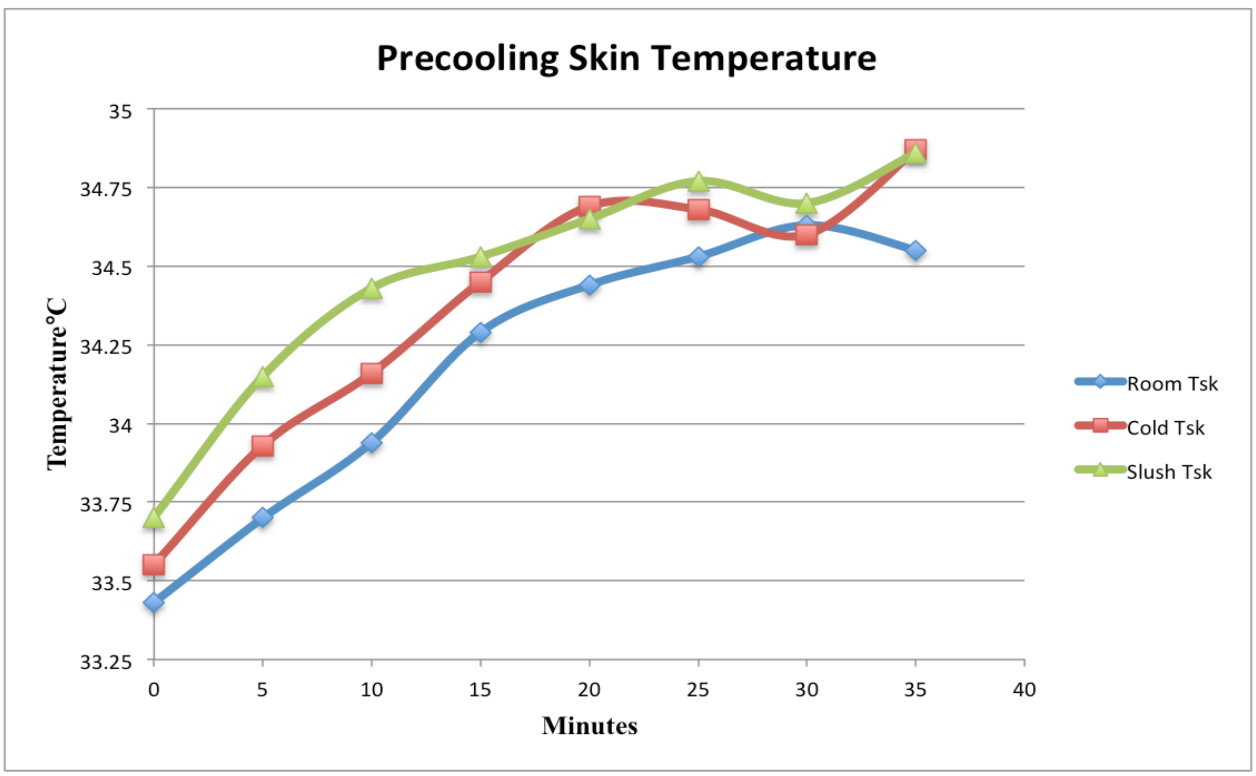

Figure 7 Mean Exercise Skin Temperature by time point

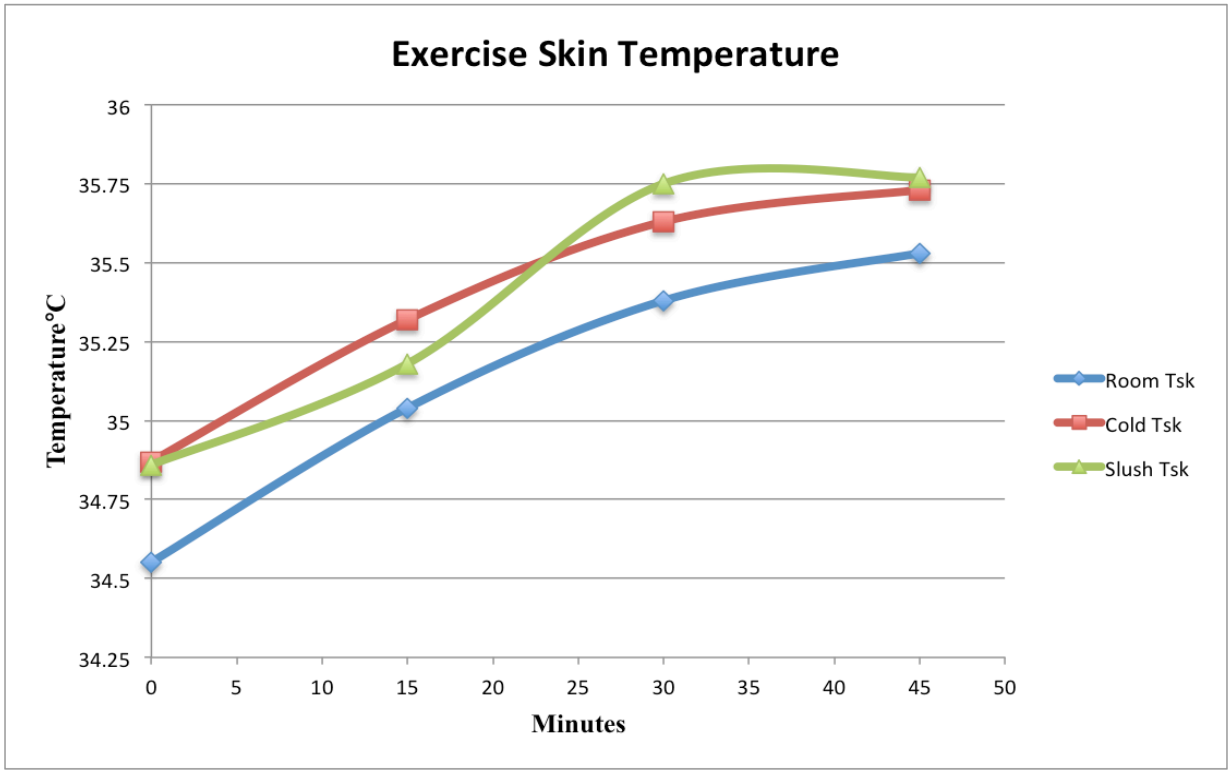

Figure 8 Mean Re-cooling Skin Temperature by time point

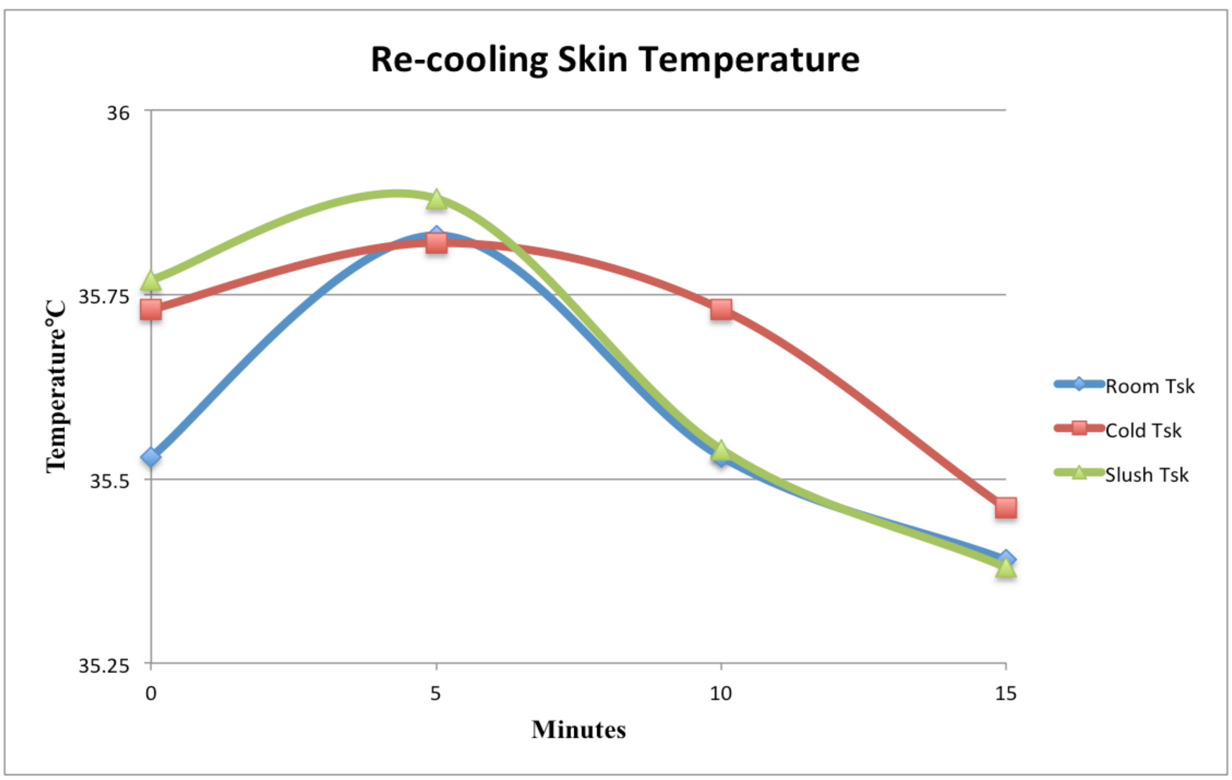

Table 5 T_{SK} by treatment (mean ± standard deviation)

	Room T_{SK} (°C)	Cold T_{SK} (°C)	Slush T_{SK} (°C)	p-value
Precooling (n=30)	34.21 ± 0.93*	34.22 ± 1.5*	34.47 ± 0.74	0.013
Exercise (n=24)	35.24 ± 0.59	35.53 ± 0.51	35.49 ± 0.73	0.14
Re-cooling (n=20)	35.57 ± 0.59	35.57 ± 0.61	35.59 ± 0.78	0.988

*Significantly different from ice slushy ($p < 0.05$)

Table 6 T_{SK} Effect Size

	Trial Phase		
Treatments	Precooling	Exercise	Re-cooling
Room vs. Cold	.01	.53	.00
Cold vs. Slush	.21	.06	.03
Slush vs. Room	.31	.38	.03

Heart Rate (HR)

Mean heart rate (HR) for each phase by treatment is shown in Table 7. Mean HR by time point is presented in Figure 9, and mean T_{GI} by phase is present in Figure 10, 11 and 12. During the precooling phase, HR with ice slushy treatment was significantly lower than the room temperature treatment (HR= 80.1 ± 16.4, 78.7 ± 13.5 and 75.7 ± 15.7 bpm for room, cold and ice slushy, respectively; p= 0.006). There was no significant difference in HR during exercise (HR=165.4 ± 16.2, 164.3 ± 16.1 and 166.4 ± 12.8 bpm, for room, cold and ice slushy, respectively; p= 0.726). During the re-cooling phase there was also no significant difference among the treatments for mean HR during the re-cooling phase (HR= 117.3 ± 10.9, 114.1 ± 15.1 and 112.9 ± 10.6 bpm; p= 0.08 for room, cold and ice slushy, respectively). However, when each time point was analyzed, there was a significant difference in HR between the cold and room temperature beverage fifteen-minute time point at the end of re-cooling (HR= 115.9 ± 13.1 and 106.9 ± 12.7 bpm, for room and cold respectively; p= 0.045). Effects sizes were low and are shown in Table 8. (Mean HR by time point is shown in Appendix H Tables 7A, 8A, and 9A).

Figure 9 Mean Heart Rate by time point

Figure 10 Mean Precooling Heart Rate by time point

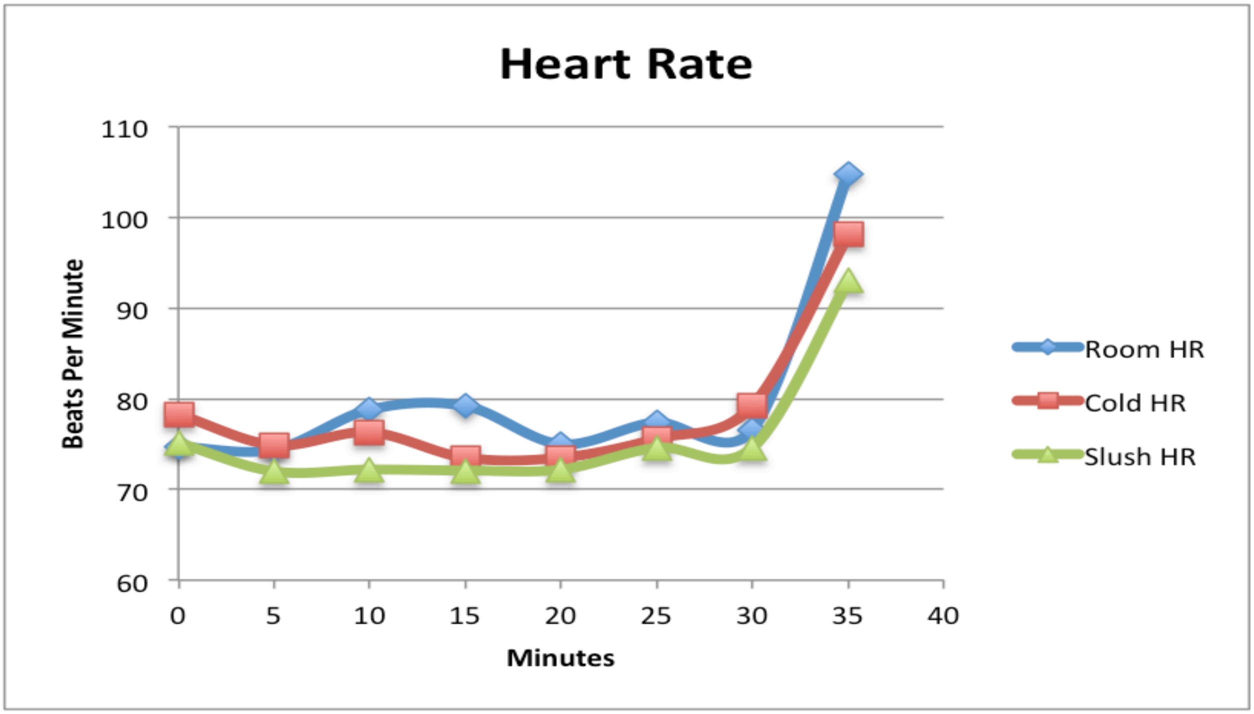

Figure 11 Mean Exercise Heart Rate by time point

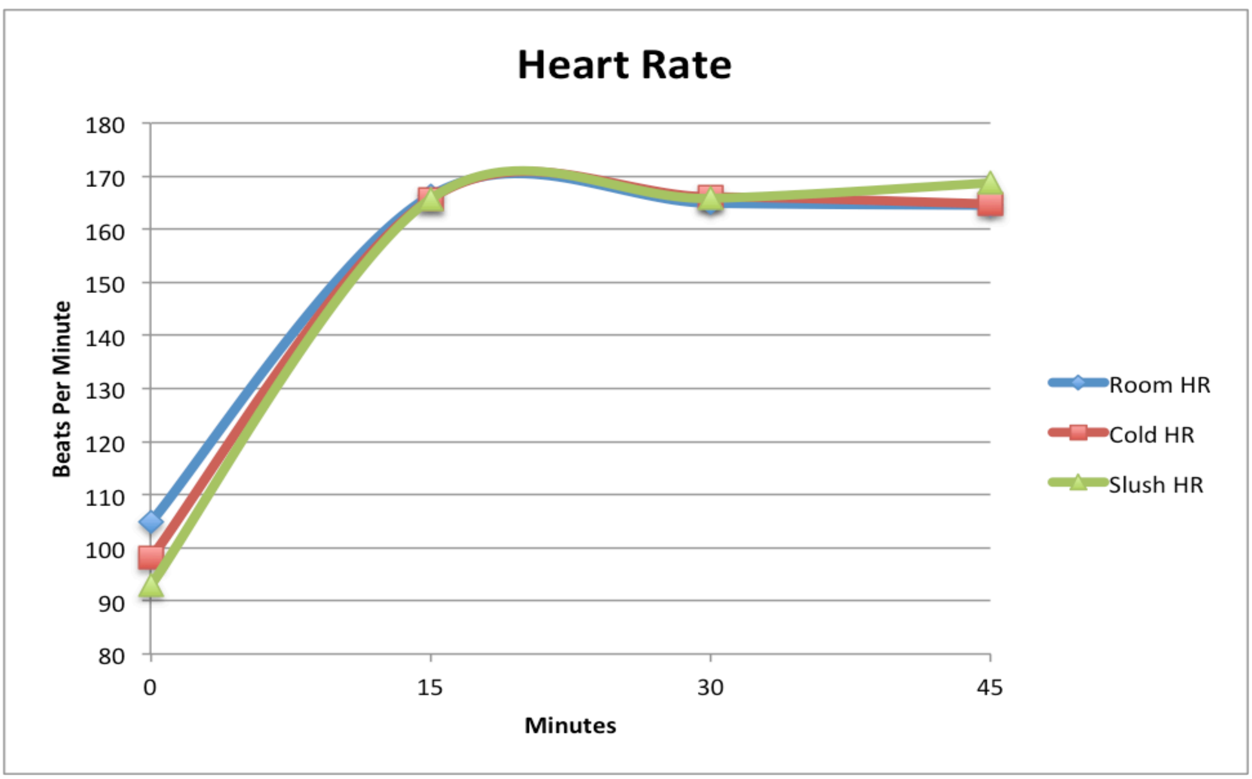

Figure 12 Mean Re-cooling Heart Rate by time point

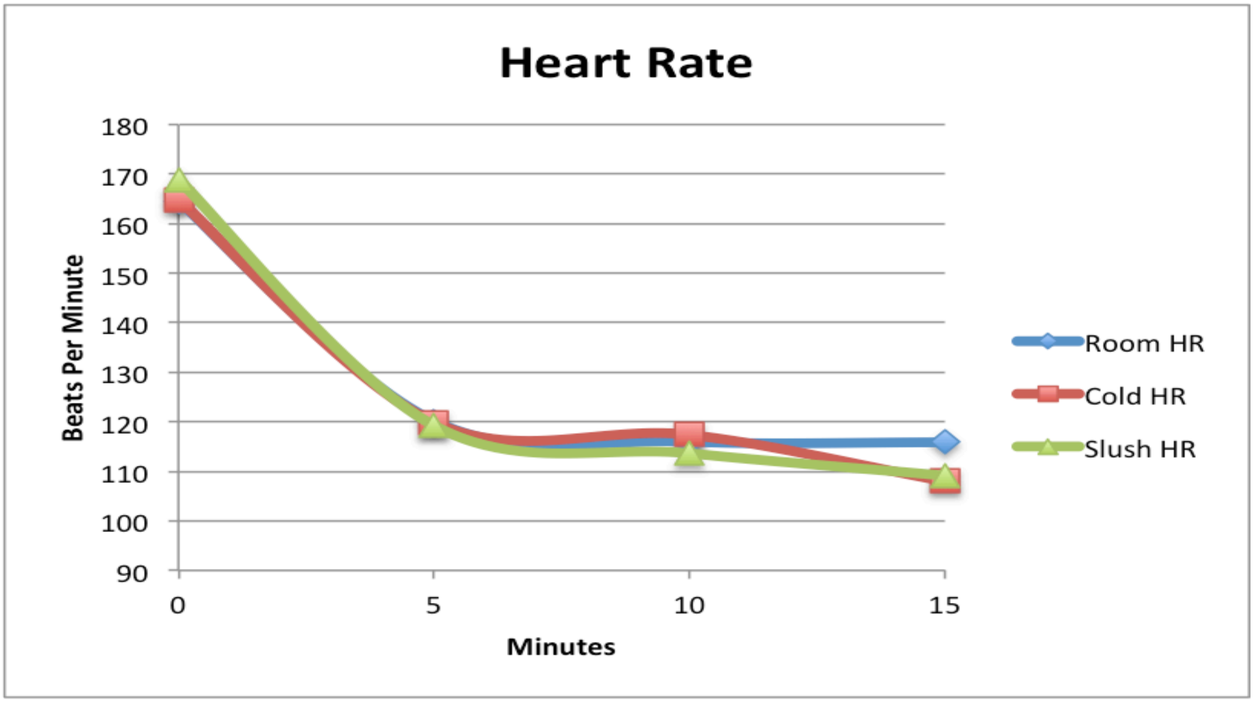

Table 7 HR by treatment (mean ± standard deviation)

	Room HR (bpm)	Cold HR (bpm)	Slush HR (bpm)	p-value
Precooling (n=80)	80.1 ± 16.4*	78.7 ± 13.5	75.7 ± 15.9*	0.022
Exercise (n=25)	165.4 ± 16.2	164.3 ± 16.1	166.4 ± 12.8	0.726
Re-cooling (n=21)	117.3 ± 10.9	114.1 ± 15.1	112.9 ± 10.6	0.08

*Significantly different, room temperature > ice slushy ($p < 0.05$)

Table 8 HR Effect Size

	Trial Phase		
Treatments	Precooling	Exercise	Re-cooling
Room vs. Cold	.1	.07	.25
Cold vs. Slush	.2	.15	.09
Slush vs. Room	.27	.07	.41

Thirst Sensation

Mean thirst sensation for each time point by treatment is shown in Figure 13. During the precooling phase there was a significantly lower thirst sensation in the ice slushy condition when compared to the room temperature and the cold beverage condition (thirst sensation= 2.3 ± 1.04, 2.1 ± 1.09 and 1.6 ± 1.03; for room, cold and ice slushy, respectively; p=0.01). During exercise, thirst sensation during the ice slushy condition was also significantly lower than the room temperature and cold beverage conditions (thirst sensation = 4.08 ± 1.95, 4.54 ± 1.86 and 3.21 ± 1.61; for room, cold and ice slush, respectively; p=0.001). In the re-cooling phase there was a significantly lower thirst sensation in the ice slushy compared to the room temperature condition (thirst sensation = 3.4 ± 1.9, 2.9 ± 1.6 and 2.2 ± 2.2 for room, cold and ice slushy, respectively; p= 0.016). (Mean thirst sensation by time point is shown in Appendix H Tables 10A, 11A and 12A). Effect sizes were medium to high and are shown in Table 10. For total session thirst sensation there was a significantly lower thirst sensation for the slushy compared to the cold beverage (thirst sensation= 4.8 ± 2.3,4.6 ± 1.96 and 3.4 ± 1.9 for room, cold and ice slushy, respectively; p=0.031).

Figure 13 Mean Thirst Sensation by time point

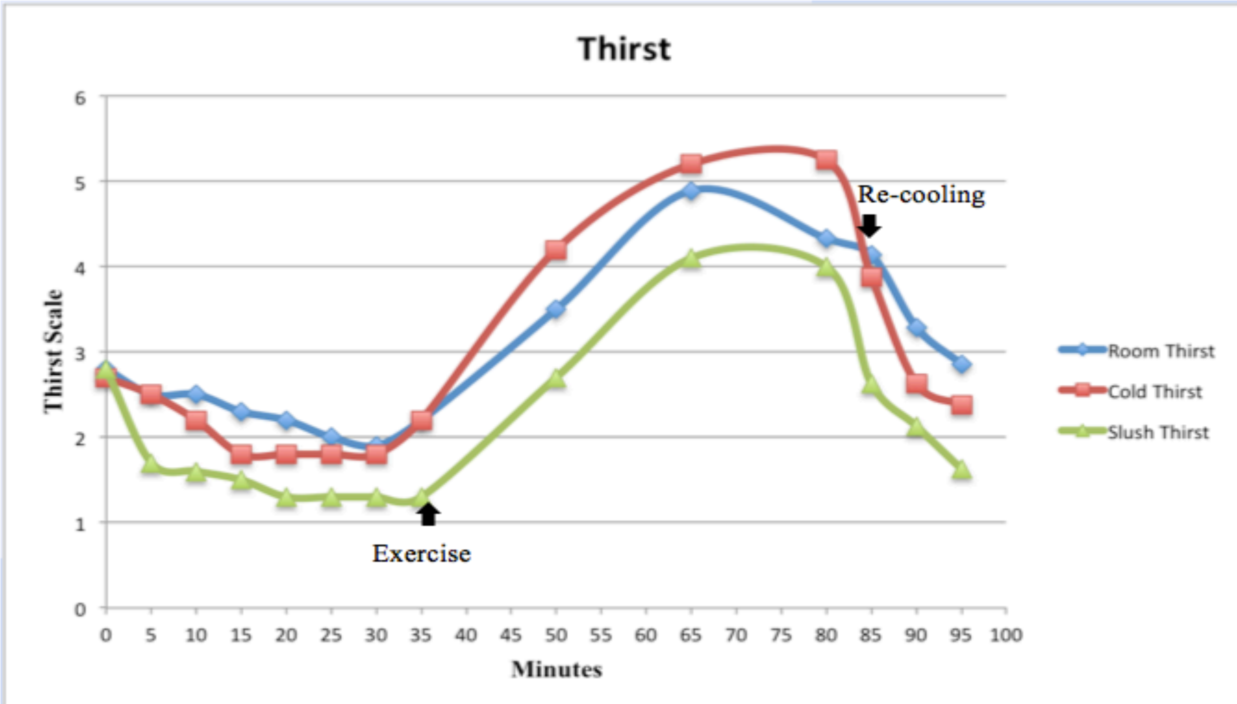

Table 9 Thirst Sensation by treatment (mean ± standard deviation)

	Room Thirst	Cold Thirst	Slush Thirst	p-value
Precooling* (n=80)	2.3 ± 1.0	2.1 ± 1.1	1.6 ± 1.0	0.01
Exercise* (n=24)	4.1 ± 2.0	4.5 ± 1.9	3.2 ± 1.6	0.001
Re-cooling* (n=21)	3.4 ± 1.9	2.9 ± 1.6	2.2 ± 2.2	0.02

*Significantly different; slushy < cold and/or room ($p < 0.05$)

Table 10 Thirst Sensation Effect Size

	Trial Phase		
Treatments	Precooling	Exercise	Re-cooling
Room vs. Cold	.19	.24	.33
Cold vs. Slush	.47	.76	.33
Slush vs. Room	.68	.49	.58

Thermal

Mean thermal sensation for each phase by time point is shown in Figure 14. During precooling the ice slushy thermal sensation was significantly lower then the room temperature and cold beverage treatments, for the cold beverage thermal sensation was significantly lower then the room temperature beverage (thermal sensation = 4.7 ± 0.7, 4.5 ± 0.7 and 4.0 ± 0.7 for room, cold and ice slushy, respectively; $p < 0.05$). During exercise there were no significant differences for thermal sensation (thermal sensation = 6.1 ± 1.0, 6.1 ± 1.0 and 4.0 ± 0.7,for room, cold and ice slushy, respectively; $p = 0.077$). In the re-cooling phase, there were also no significant differences found among conditions (thermal sensation = 5.2 ± 1.3, 5.2 ± 1.1 and 5.2 ± 1.4, for room, cold and ice slushy, respectively; $p = 1.0$). Effect sizes were low and are shown in Table 12. (Mean thermal sensation by time point is shown in Appendix H Tables 13A, 14A and 15A).

Following exercise, subjects reported total thermal sensation for the session. There were no significant differences among conditions for session thermal sensation (thermal sensation= 6.2 ± 1.1, 6.1 ± 1.2 and 5.8 ± 1.1, for room, cold and ice slushy, respectively; $p= 0.142$).

Figure 14 Mean Thermal Sensation by time point

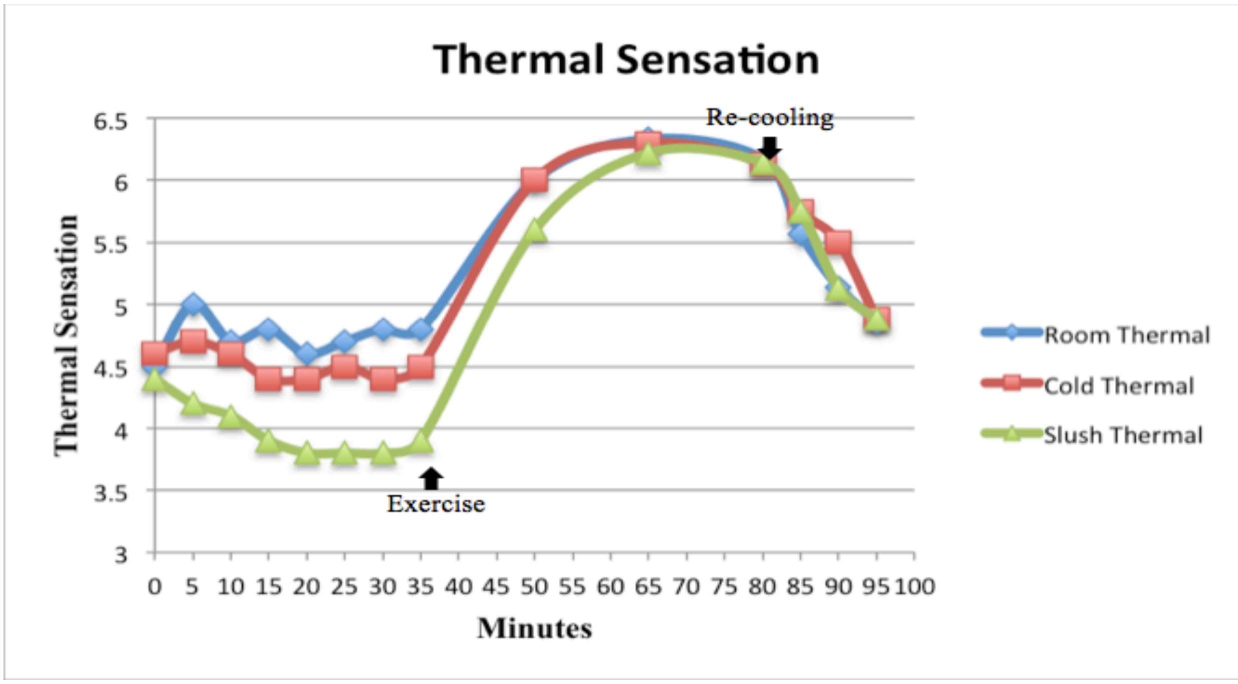

Table 11 Thermal Sensation by treatment (mean ± standard deviation)

	Room Thermal	Cold Thermal	Slush Thermal	p-value
Precooling (n=80)	4.7 ± 0.7*	4.5 ± 0.7*	4.0 ± 0.7*	0.00
Exercise (n=24)	6.1 ± 1.0	6.1 ± 1.0	5.9 ± 1.0	0.077
Re-cooling (n=21)	5.2 ± 1.3	5.2 ± 1.1	5.2 ± 1.4	1.00

*All significantly different ($p < 0.05$)

Table 12 Thermal Sensation Effect Size

	Trial Phase		
Treatments	Precooling	Exercise	Re-cooling
Room vs. Cold	.33	.05	.00
Cold vs. Slush	.75	.20	.00
Slush vs. Room	.32	.26	.00

Ratings of Perceived Exertion (RPE)

The RPE during exercise revealed a significant difference between the conditions. The RPE during the ice slushy condition was significantly lower than the room temperature condition and the cold condition (RPE= 13.2 ± 3.7, 13.0 ± 3.6 and 12.1 ± 3.7 for room, cold and ice slushy, respectively; $p < 0.001$). Effects sizes were medium to low and are shown in Table 13. (Mean RPE by time point is shown in Appendix H Table 16A).

Following exercise, subjects reported total RPE for the session. There were no significant differences in overall session RPE. (RPE= 14.1 ± 3.3, 14.1 ± 3.2 and 13.3 ± 3.8; for room, cold and ice slushy, respectively; p= 0.214).

Figure 15 Mean Ratings of Perceived Exertion by time point

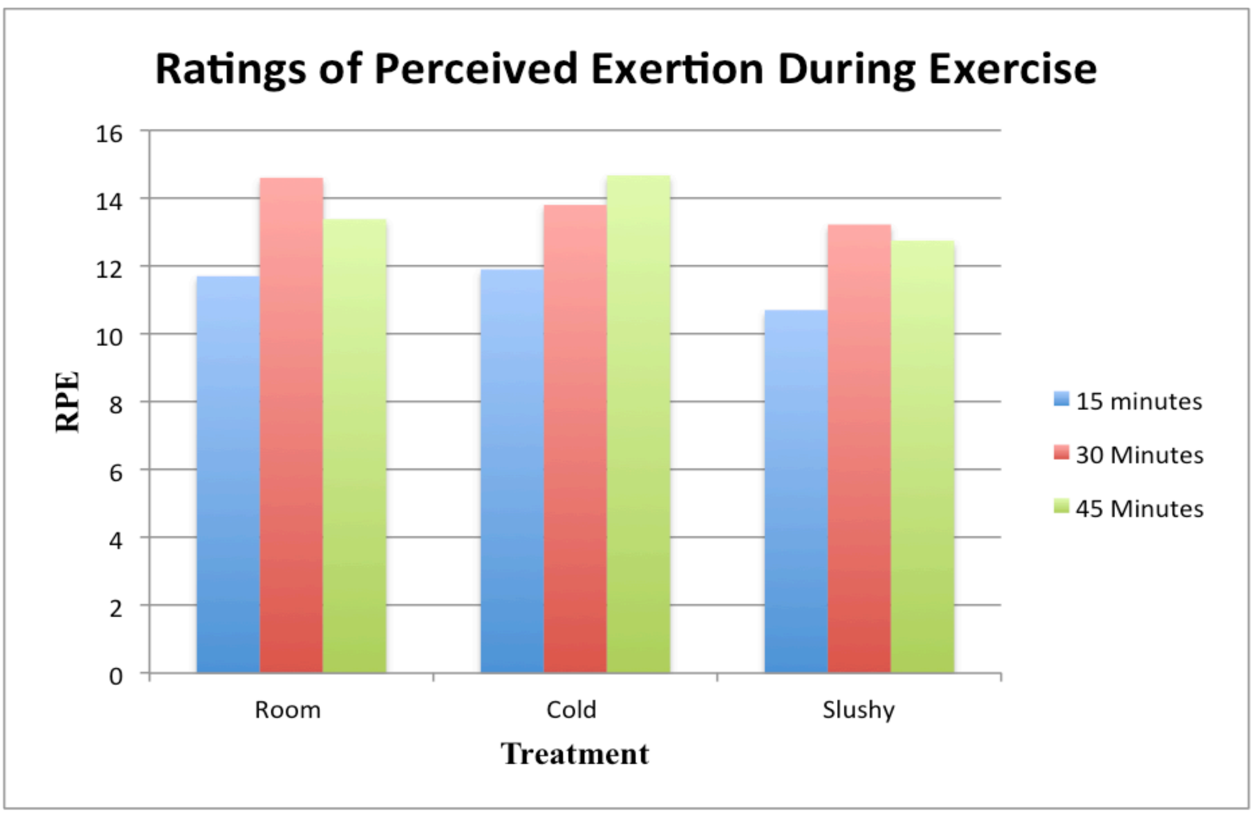

Table 13 RPE Effect Size

	Trial Phase
Treatment	Exercise
Room vs. Cold	.06
Cold vs. Slush	.24
Slush vs. Room	.29

Total Exercise Time

Total exercise time for each condition is shown below in table 14. There were no significant differences among conditions for total exercise time.

Table 14 Total Exercise time (mean ± standard deviation)

	Room	Cold	Slushy	p-value
Exercise time (seconds)	2401.2 ± 460.11	2597 ± 241.66	2513.2 ± 370.39	0.161

Beverage Temperature

Mean beverage temperature for each condition is shown below in table 15. Beverage temperatures were significantly different ($p < 0.001$) for all conditions table 15.

Table 15 Beverage Temperature between conditions (mean ± standard deviation)

	Room (°C)	Cold (°C)	Slush (°C)	p-value
Pre	24.88 ± 1.12*	6.15 ± 3.16*	-1.61 ± .45*	0.00
Post	25.04 ± 1.12*	6.94 ± 2.84*	-1.44 ± .535*	0.00

*Significantly different for all conditions; ($p < 0.05$)

Environmental Conditions

Mean environmental temperature for each condition is shown below in table 16. There were no significant differences in environmental temperature among the trials. The dry average bulb temperature for all trials was 35.36 ± 0.83 °C with a WBGT of 27.88 ± 0.72 °C. The environmental chamber was set to 35°C and 56% rh.

Table 16 Environmental Temperature between conditions (mean ± standard deviation)

	Room (°C)	Cold (°C)	Slush (°C)	p-value
Dry Bulb Temperature	35.35 ± 0.78	35.38 ± 0.81	35.37 ± 0.93	0.975
Wet Bulb Globe Temperature	27.75 ± 0.7	28.0 ± 0.73	27.87 ± 0.7	NA

*Significant difference ($p < 0.05$)

Urine Specific Gravity (USG)

Pre and post mean U_{SG} for all conditions is shown below in table 17. There were no significant differences present for pre or post U_{SG} between any of the conditions.

Table 17 Urine Specific Gravity U_{SG} (mean ± standard deviation)

Condition	Pre	Post	p-value
Room U_{SG}	1.012 ± 0.009	1.011 ± 0.008	0.341
Cold U_{SG}	1.001± 0.008	1.009 ± 0.006	0.863
Slush U_{SG}	1.014 ± 0.012	1.014 ± 0.011	0.662

Urine Color (U_C)

Pre and post mean U_C for all conditions is shown below in table 18. There were no significant differences present for pre or post U_C between any of the conditions.

Table 18 Urine Color U_C (mean ± standard deviation)

Condition	Pre	Post	p-value
Room U_C	3.0 ± 1.7 (9)	3.3 ± 1.7	0.563
Cold U_C	2.6 ± 1.7	2.8 ± 0.9	0.85
Slush U_C	3.6 ± 2.4	3.6 ± 2.1	1.0

Body Weight (BW)

Pre and post mean BW for all conditions is shown below in table 19. There were no significant differences present for pre or post BW for the room temperature and cold beverage conditions. There was a significant difference in pre and post body weight seen for the ice slushy (BW 148.6 ± 20.5, 147.4 ± 20.0 kg for pre and post respectively; p=0.042). There was no significance between all three conditions for the mean pre (p= 0.4) or mean post (p= 0.8) body weights.

Table 19 Body Weight BW (mean ± standard deviation)

Condition	Pre	Post	p-value
Room BW (kg)	67.3 ± 9.9	67.1 ± 9.9	0.183
Cold BW (kg)	66.9 ± 9.9	66.9 ± 9.8	0.8
Slush BW (kg)*	67.4 ± 9.3	66.9 ± 9.1	0.042

*Significant difference ($p < 0.05$)

CHAPTER 5: DISCUSSION

Previous research suggests that internal precooling via cold beverage ingestion may help to decrease various physiological variables commonly associated with heat stress (Bryne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2012; 2010; Stanley et al., 2010). Moreover, precooling using an ice slushy has previously been shown to be a more effective method of decreasing T_C precooling as compared to a cold beverage in a liquid state (Ihsan et al., 2010; Siegel et al., 2012; 2010; Stanley et al., 2010).

Physiological Variables

Gastrointestinal Temperature (T_{GI}) & Skin Temperature (T_{SK})

In the current study it was hypothesized that precooling with an ice slushy as compared to a cold or room temperature beverage would facilitate a greater decrease in T_{GI} and T_{SK}. The current study found no significant differences in T_{GI} among the three beverage conditions. Previous studies that also explored precooling with drinks at various temperatures found that the colder beverages were able to create greater decreases in internal core temperature (T_C) during precooling than that of the warmer beverages (Bryne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010). When looking at T_{SK} during precooling the ice slushy beverage provided greater cooling than the room temperature beverage. This finding is not surprising and is in line with the results of Siegel et al. (2010). During precooling, Siegel et al. (2010) reported a lower T_{SK} at the end of ice slushy ingestion as compared to the cold beverage. Differences in results of T_C and T_{SK} could be due to a number of different factors. Other studies using beverage precooling compared only two beverage temperatures such as cold (2°C and 4°C) vs. warm (37°C) (Bryne et al., 2011;Lee et al., 2008); crushed ice (1.4°C) vs. control (26.8°C) (Ihsan et al., 2010); and cold (4°C) vs. ice slushy (-1°C) (Siegel et al., 2010). In the present study cold and ice slushy beverage temperatures (beverage temperature= 24.88 ± 1.15, 6.15 ± 3.16, -1.61 ± 0.45°C for room, cold and ice slushy respectively) closely match the temperatures of Siegel et al. (2010). In fact, the cold beverage temperature was slightly higher and the ice slushy temperature was slightly lower for the present study. There were still no differences observed between the conditions in the present study, but Siegel et al. (2010) saw a significantly lower T_R with the ice slushy beverage. Moreover, the previously mentioned studies that used various beverage temperatures found T_C was significantly lower for the coldest beverage during precooling, although the present study did not find similar results (Bryne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010).

Differences in results may be caused by precooling time, amount of beverage, and the environmental conditions in which subjects precooled. Three of the previous studies pre-cooled for 30 minutes (Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010) and one precooled for 35 minutes (Bryne et al., 2011). Standardized ingestions rates were used in all studies. Ihsan et al. (2010), and Siegel et al. (2010) drank every 5 minutes as in the current study; Lee et al. (2008), drank every 10 minutes; and Bryne et al. (2011), drank every 15 minutes. The beverage amount was also standardized for all trials. In two previous studies participants ingested a total of 900mL over 30 and 35; not taking body weight into account (Bryne et al., 2011; Lee et al., 2008), while in the other two studies, participants consumed either 6.8 $g \cdot kg^{-1}$ (Ihsan et al. 2010) or 7.5 $g \cdot kg^{-1}$

(Siegel et al. 2010) over 30 minutes during the precooling phase. In the present study precooling lasted for 30 minutes and participants consumed 7.5 $g \cdot kg^{-1}$ of the assigned beverage every 5 min. Based upon previous research and the current study the effect caused by the amount and timing of the precooling beverage does not seem to have a great effect on T_C (Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010). The present study's precooling time and beverage allotment matched that of Siegel et al. (2010), but T_{GI} was not decreased in the present study.

Other differences in T_{GI} and T_{SK} could be related to a difference in precooling environmental temperature. All previous studies had participants precool in a cooler environment (environmental conditions= 21°C, 60% rh; 30°C, 75% rh; 27°C, 27% rh and 24°C) (Bryne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010) compared to the 35°C, 56% rh used in the present study. All previous studies found a decrease in T_C during precooling. This appears to be the biggest factor in the differing results during precooling because it was the only factor that was dramatically different during precooling between the present study and that of Siegel et al. (2010). Precooling in a cooler temperature would presumably result in greater cooling. A cooler environmental temperature would decrease the physiological strain associated with hot temperatures. The increase in environmental conditions could have caused an increase in the bodies' physiological response to heat resulting in a potentially higher T_C, HR and T_{SK} (Quod et al., 2006). If an increase T_C could be associated with the warmer environmental condition then it would decrease the potential heat storage capacity that could have been provided by the various precooling methods.

During exercise there were no significant differences found between the three conditions for T_{GI} or T_{SK} in the present study. When looking at exercise T_{SK} in previous research, there were also no significant differences in T_{SK} found during exercise. There were significant differences during exercise found for T_C in previous research (Byrne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010). Both Bryne et al. (2011) and Ihsan et al. (2010) saw a significant difference in T_C the first part of exercise with a colder (2°C & 1.4 ± 1.1°C) beverage as compared to a warmer (37°C & 26.8 ± 1.3°C) beverage. Differences were seen during the 5-25 minute time points for Bryne et al. (2011) and Ihsan et al. (2010) who reported a difference in T_C until 200kJ of work was completed. Differences in T_C when compared to the present study could be due to the differences in exercise modality in which Bryne et al. (2011) and Ihsan et al. (2010) cycled while in the present study participants ran. Additional differences in T_C could be caused by the differences in the exercise protocol. Performance was measured by cycle time to completion (Ihsan et al., 2010) or distance in a given time (Bryne et al., 2011) as compared to the interval treadmill run where speed and time were controlled as in the present study. Furthermore the environmental conditions differed between studies. A different environmental temperature was used in both studies (30°C, 75% rh and 32°C, 60% rh) compared to the 35°C and 56% rh used in the present study (Byrne et al., 2011; Ihsan et al., 2010). Siegel et al. (2010) also reported a decreased T_R for the ice slushy as compared to the cold beverage for first 30 minutes of exercise. Differences between the present study and that of Siegel et al. (2010) include the exercise protocol in which a run to exhaustion protocol was used (Siegel et al., 2010). The results from the present study when compared to that of Siegel et al. (2010) are hard to compare due to the lack of a decreased precooling T_{GI} in the present study. Lee et al. (2008) reported a significantly lower mean T_R for the cold beverage (4°C) cycling trial as compared to the warm beverage (37°C) cycling trial. Lee's study may have prevented a greater increase in T_R because the environmental conditions were much lower than that of the present study (27°C, 20% rh vs. 35°C, and 56%rh). Also Lee's study used cycle time to exhaustion for the exercise portion of the trial (Lee et al., 2008), which could cause potential differences in T_C. All previous studies showed a decrease in T_C during precooling which could have also lead to significant differences found for the colder beverage during exercise (Byrne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010). Therefore, without a significantly lower T_{GI} between conditions during precooling in the present study, the difference in exercise T_{GI} could have been diminished. Because T_C was not decreased prior to exercise there was in increase in the bodies' heat storage capacity between the three conditions (Marino, 2002).

It is also important to note the different methods used to measure T_C. In the present study and in Ihsan et al. (2010) T_C was measured by way of gastrointestinal temperature (T_{GI}). Bryne et al. (2011), Lee et al. (2008) and Siegel et al. (2010) recorded T_C via rectal temperature (T_R). The difference in methods of collecting T_C could potentially be a factor leading to different results.

Another difference in the presents study was the type of participants used. In the present study all participants were all women. In the beverage precooling studies all participants were men (Byrne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010). Some variables of women's physiology, such as body water regulation and various hormone levels, differ from men. Additionally, anthropometric characteristics, body composition, and social behaviors (daily activity) could also be a contributing factor of variance between men and women (Kaciuba-Uscilko & Grucza, 2001). Burse (1979) summarized that morphological differences (~20% smaller body mass, ~14% more body fat, ~33% less lean body mass, but only ~18% less surface area then men) are a limiting factor for women, leaving them more vulnerable to the effects of hot and cold temperatures (Burse, 1979). Additionally, there are fluctuations in mean body temperature throughout the various phases of the menstrual cycle.

During heat exposure, mean body temperature of women is shown to be higher during the luteal phase then during the follicular phase. (Inoue, Tanaka, Omoria, Kuwahara, Ogura & Ueda, 2005). Hirata et al.(1986) studied the relationship between finger blood flow and T_{ES} in four women at 40% and 70% Vo_{2max} at a ambient temperature of 20°C. As found in Inoue et al (2005), resting T_{ES} was higher in luteal phase then in the follicular phase but there was no difference in finger blood flow between the two phases. This study concluded that despite the differences in menstrual cycle phase, thermoregulatory responses were the same (Hirata, Nagasaka, Hirai, Hirashita, Takahata & Nunomura, 1986). In the present study participants' menstrual cycle was no controlled, however this was intended to simulate a realistic athletic setting. The increased core temperature throughout various phases on menstruation cannot be controlled by the athlete leaving them subjective to having to compete during a phase of increased T_{GI}.

The present study also incorporated a re-cooling phase post exercise that was not seen in previous studies. There were no differences in mean T_{GI} or T_{SK} for the re-cooling phase.

Heart Rate (HR)

It was hypothesized that the ice slushy beverage would result in a lower HR when compared to the cold and room temperature beverage trials. In the present study, mean HR during precooling was significantly lower for the ice slushy as compared to the room, but not the cold, temperature beverage. In other beverage precooling studies there were no significant differences reported for precooling HR (Byrne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010). This difference could be due to the environmental conditions of other researchers (mentioned above) during precooling which were lower than the conditions in the present study. The increased room temperature can cause an increase in heat strain (Quod et al., 2006). The increased heat strain caused by the warm environment could increase the ability of the beverage temperature to affect heart rate since the other studies did not experience the same type of heat exposure during precooling.

During exercise, HR was similar for each condition in the present study. Lee et al. (2008) reported a decreased HR during the first 35-minutes of exercise in the cold beverage trial as compared to the warm beverage (Lee et al., 2008). The difference in a decreased HR for the cold beverage when compared to the present study could be due to a decreased environmental temperature present in the Lee et al. (2008) study (35°C, and 56%rh vs. 27°C, 20% rh). Additionally there were differences in exercise mode and protocol of cycling to exhaustion vs. interval treadmill running. The lower environmental temperature of Lee et al. (2008) would not create the same heat stress present in the current study. The increased environmental temperature in the present study could have caused an increased HR across all conditions and decreased the effectiveness of the beverages. The interval running exercise protocol in the present study could have also affected the average HR for exercise because subjects were not running at a constant speed and thus HR fluctuated throughout the trial. Therefore the reported HR was dependent upon the phase of the exercise protocol.

In the re-cooling phase of the experimental trials there were no differences in mean HR. No other studies comparing beverage precooling used a re-cooling phase. The re-cooling phase was used in this study to potentially gain insight into re-cooling between exercise bouts like during half time of a soccer game.

Perceptual Variables

Thirst Sensation

It was hypothesized that thirst sensation would be lower with the ice slushy trials as compared to the room temperature and cold beverage trials. In the present study, participants had a lower thirst sensation for the ice slushy condition as compared to the room temperature and cold condition for the precooling and exercise phase of the trials. During the re-cooling phase the ice slushy beverage resulted in a lower thirst sensation than the room temperature beverage. To date, there appears to be no beverage precooling study that incorporates thirst sensation. The decreased thirst sensation could increase the comfort of the participant.

Thermal Sensation

It was hypothesised that thermal sensation would be lower in the ice slushy trials as compared to the other conditions. During precooling participants reported decreased thermal sensation for ice slushy compared to the room temperature and the cold beverage, as well as the cold compared to the room temperature. The decreased thermal sensation for the colder beverages suggests that that the colder beverage increased the ability to decrease the thermal sensation of the participant.

During exercise, thermal sensation was similar for all beverages. These results differ from that found in a previous study by Lee et al. (2008) that observed significantly lower thermal sensation for the whole trial after ingestion of the cold as compared to the warm beverage. Siegel et al. (2010) also saw decreased thermal sensation in the ice slushy beverage as compared to the warm beverage throughout precooling and 30 minutes into exercise. The present study thermal sensation results are similar to that of Ihsan et al. (2010) who found a significant difference only during the precooling phase with a thermal sensation that was lower for the crushed ice (1.4 ± 1.1°C) compared to the control (26.8 ± 1.3°C). When Bryne et al. (2011) compared a cold beverage to a warm beverage there was no difference in thermal sensation during exercise.

In the re-cooling phase of the trial there were no significant differences found in thermal sensation among the conditions. The participants were still exposed to the hot humid environment during re-cooling, with a T_{GI} that was increased during exercise and higher then what was seen in precooling. This suggests that the thermal sensation is not decreased during re-cooling and may be due to the high T_{GI}.

Ratings of Perceived Exertion (RPE)

In the current study it was hypothesized that RPE would be lower in the ice slushy trial when compared to the cold and room temperature trials. When comparing the mean exercise session RPE the ice slushy beverage resulted in a lower RPE than both the cold and room temperature beverage trials. Lee et al. (2008) also observed a decreased RPE for the cold beverage as compared to the warm beverage (Lee et al., 2008). Siegel et al. (2010) saw a significantly lower RPE through the first 30 minutes of exercise, however, at the end of exercise there was no difference in RPE. This could be due to the fact that participants exercised to exhaustion in their study. Other beverage precooling studies revealed no differences in RPE between the conditions (Byrne et al., 2011; Ihsan et al., 2010). The difference in RPE for the present study when compared to previous research could be due to the type of exercise. All other studies were measuring performance either maximum distance or to exhaustion. The current study used an interval protocol with a set speed and duration. Therefore, the actual speed and time was not relative to the participant's fitness.

Exercise Time

Between conditions there was no significant difference in exercise time. The complete exercise protocol lasted 45 minutes. Six subjects completed the exercise protocol for all 3 conditions. Out of the other four participants only one was stopped in each trial each time for a maximal T_{GI} of 39.5^{o}C (time= 1954, 2410 and 2382 seconds for room, cold and ice slushy respectively). One participant reached maximal T_{GI} in the ice slushy trial (time= 1550 seconds) and for the room temperature trial this same participant voluntary stopped during the protocol (time= 1999 seconds). There was one participant who was stopped for maximal T_{GI} in the room temperature trial but completed the cold and ice slushy trials. The final participant voluntary stopped due to feeling fatigued in all three trials. The room temperature beverage saw the biggest drop out rate with four drop outs, there were three drop outs in the slushy, and two for the cold beverage condition. The exercise protocol could have limited the effects of the beverages because the study was not a test to exhaustion or a distance for time we cannot measure performance. If performance was measured to exhaustion we may have seen differences between the three conditions. The purpose of this study protocol was to look at the effects of precooling in a way that could replicate a soccer match to increase its application to soccer players.

Study Weaknesses

Some weaknesses found in the present study include the use of the gastrointestinal CorTemp pill for measuring T_C. The issue with the pills is the exact time the participant took the pill is unknown. The subjects were instructed to take the pill at a specific time but there was no way to control for the exact time in which the pill was taken. Because this was a study looking at beverage temperatures effect on T_C the actual beverage temperature may have affected the pill with potentially limiting a true T_{GI} reading. Another weakness in the present study was that menstrual cycle was not controlled. However, this was not controlled due to the nature of competitive sports in which participants must compete no matter what phase of the menstrual cycle they were in.

Study Strengths

Strengths of the present study include the exercise protocol. The protocol used increased the practical application of the present study to soccer players. Another strength of the present study is the environment in which participants precooled and re-cooled. Although, it appears that the precooling environment may have decreased the effects of precooling with a beverage, it seems more practical to have participants precool in the same type of environment that a soccer player would typically have to precool in before a game.

Conclusion

It was hypothesized that the ice slushy would facilitate a greater decrease in physiological and perceptual variables as compared to the cold and room temperature beverages. There was not a large amount of significant data found in the present study. There were no observed differences in T_{GI} at any time point between the three conditions. T_{SK} and HR were both significantly ($p < 0.05$) lower for the precooling phase for the ice slushy as compared to both the cold and room temperature beverage conditions. Thirst sensation was significantly ($p < 0.05$) lower across all phases for the ice slushy when compared to the other beverages. During precooling thermal sensation was significantly ($p < 0.05$) decreased for the ice slushy as compared to the room and cold temperature beverage and the cold was also significantly ($p < 0.05$) lower then that of the room temperature beverage. RPE was also significantly ($p < 0.05$) lower during exercise for the ice slushy as compared to the other beverages. Considering, there were no differences found for T_{GI} through all phases of the trials and no difference in HR or T_{SK} during exercise and re-cooling, there seems to be a greater impact of an ice slushy on perceptual variables. One of the biggest differences between the present study and previous studies (Byrne et al., 2011; Ihsan et al., 2010; Lee et al., 2008; Siegel et al., 2010) was the environment in which precooling took place. Further investigation looking at beverage precooling in warm environment could give a better insight to the effect the precooling environment played on all variables. If the environment is too hot to facilitate a significant decrease in T_C using an ice slushy or a cold beverage then the potential benefits could be limited to sports or activities that have the ability to precool in a cold environment.

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Appendix A: Medical History Questionnaire

MEDICAL HISTORY

Name ________________________________ Date_________________

Date of Birth ____ / ____ / ____

Family History

Does anyone in your family have a history of medical problems? Y / N
If yes, explain: ____
Mother: ____Living: Y / N
Age of Death: __________ Cause of Death: _____________________________________
Father: ____ Living: Y / N
Age of Death: __________ Cause of Death: ____________________________________
Brother(s): ____Living: Y / N
Age of Death: __________ Cause of Death: ____________________________________
Sister(s): ____Living: Y / N
Age of Death: __________ Cause of Death: _____________________________________
Has anyone in your family ever been diagnosed with:
Y / N Sudden unexplained death Relationship: _____________________________
Explain: ____
Y /N Alcohol/Substance Abuse Relationship: _____________________________
Explain: ____
Y/N Asthma Relationship: _____________________________
Explain: ____
Y/N Cancer Relationship: _____________________________
Explain: ____
Y/N Diabetes Relationship: _____________________________
Explain: ____
Y/N Heart Disease (of any kind) Relationship: _____________________________
Explain: ____
Y/N High Blood Pressure Relationship: _____________________________
Explain: ____
Y/N Marfan Syndrome Relationship: _____________________________
Explain: ____
Y/N Migraines/Severe Headaches Relationship: _____________________________
Explain: ____
Y/N Osteoporosis/Bone Disorder Relationship: _____________________________
Explain: ____
Y/N Seizures/Epilepsy Relationship: _____________________________

Explain: ___
Y/N Sickle Cell Disease/Trait Relationship: ___
Explain: ___

Current Medical Conditions:

Y/N Are you currently under medical supervision for an injury/illness?
If yes, explain: ___
Y/N Do you have a current ongoing or chronic illness?
If yes, explain: ___
Y/N Do you have any gastrointestinal tract issues?
If yes, explain: ___

Surgery/Hospitalization:

Y/N Have you ever had surgery?

Date: ___ Surgery: ___

Date: ___ Surgery: ___

Date: ___ Surgery: ___

Y/N Have you ever been hospitalized for a reason other than surgery?

Date: ___ Reason: ___

Date: ___ Reason: ___

Medications:

Y/N Do you regularly use any prescription medication?
If yes, explain: ___
Y/N Do you regularly use non-prescription medication?
If yes, explain: ___
Y/N Do you regularly take any dietary supplements?
If yes, explain: ___

Allergies:

Are you allergic to any of the following:
Y/N Aspirin
Y/N Food (specify) ___
Y/N Dust/pollen
Y/N Insect stings (specify) ___
Y/N Penicillin
Y/N Sulfa Drugs
Y/N Novocaine
Y/N Soy
Y/N Other Drugs (specify) ___

Cardiovascular System:

Y/N Do you get more fatigued (tired) during exercise, or get fatigued earlier during exercise than your teammates?
Y/N Do you become more short of breath during exercise than your teammates?
Y/N Have you ever fainted or passed out during or after exercise?
Y/N Have you ever had chest pains during or after exercise?
Y/N Have you ever been told that you have high blood pressure (hypertension)?
Y/N Have you ever been told that you have a heart murmur?
Y/N Have you ever been told that you had high cholesterol (hyperlipidemia)?
Y/N Has a physician ever ordered heart testing (for example: EKG, Echo, stress test, holter monitor)? If yes, please explain:____
Y/N Have you ever been diagnosed with any type of heart disease (hypertrophic cardio coronary artery abnormality, heart infection, heart valve disease, Marfan's Syndrome, ect)?

If you answered yes to any of the above questions, please explain:
____
____
____

Respiratory System:

Y/N Do you cough, wheeze, have difficulty breathing, or get short of breath during exercise? If yes, how often?____
Y/N Have you ever been diagnosed with asthma?
Y/N If so, is your asthma well controlled?
Please check one: I have symptoms from my asthma: daily_____ More than twice per week_____ Less than twice per week _____ Hardly ever _____
Y/N Do you use an inhaler?
If yes, what kind? ____
Y/N Do you have seasonal allergies that require medical treatment or medication?

Neurological System:

Y/N Have you ever had a head injury or a concussion? Date: ___________________ Explain:
____
If so, how many concussions? ___________
Y/N Have you ever been knocked out, unconscious, or lost your memory?
Date: ___________________ Explain:
____
Y/N Have you ever had a seizure? Date: ___________________
Explain:
____
Y/N Have you ever had a stinger, burner, or pinched nerve? Date: ______________ Explain:
____

Heat Illnesses:
Y/N Have you ever had heat stroke or heat exhaustion?
If so, please explain: ____
Y/N Have you ever had muscle cramps caused be the heat?

How often? ________________________

Y/N Have you ever been dizzy or fainted in the heat?
How often? _____________________________

Y/N Have you ever been confused in the heat?
How often? __________________________________

Y/N Have you ever been hospitalized for a heat related condition?

Women Only:

What was the date of your last menstrual period? _______________________________________
When was your first menstrual period? ____
How many periods have you had in the last year? ____ What was the longest time between periods in the last year? ____________________________ My periods are now (circle one):

Regular- every 24-35 days
Irregular- every 36 days or more
Absent - no periods for the past three months

Y/N Are you currently taking a form of birth control?
If yes, what kind? ____

Y/N Is there a history of osteoporosis in your family?

Y/N Is there a history of repeated fracture in anyone in your family?

Y/N Have you had repeated fractures or repeated stress fractures before?

Other Medical Conditions:

Y / N Have you ever been told, for any reason, that you should not participate in exercise?
If yes, explain:____
____
____

Y/N Do you know of, or believe, there is any reason that should prevent you from participating in exercise?
If yes, explain:
____
____
____

I certify that the answers to the preceding questions are correct and true to the best of my knowledge. Permission is hereby granted to the attending physician, Dr. Coris for further examination.

Name ___________________________________ Signature________________________
(Please print)

Date_________________________

Appendix B: Exercise Protocol

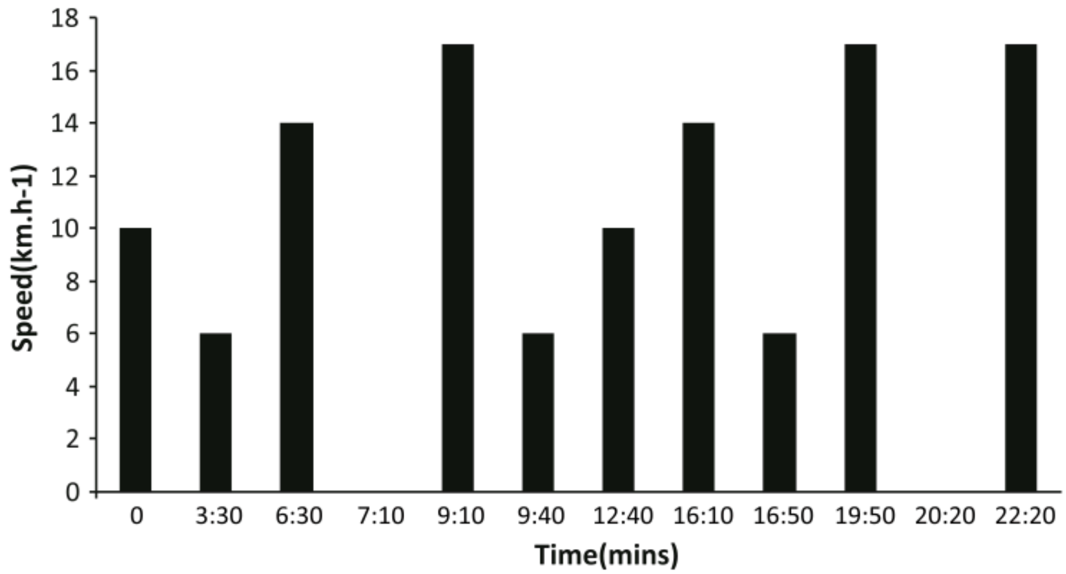

Figure 1: Exercise protocol Davis et al. (2011)

Appendix C: Ratings of Perceived Exertion Scale

6-20 Point Borg RPE Scale

6 No exertion at all

7 Extremely light

8

9 Very light

10

11 Light

12

13 Somewhat hard

14

15 Hard (heavy)

16

17 Very hard

18

19 Extremely hard

20 Maximal exertion

Borg & Noble (1974)

Appendix D: Thirst Scale

Thirst Scale

1 Not Thirsty At ALL

2

3 A Little Thirsty

4

5 Moderately Thirsty

6

7 Very Thirsty

8

9 Very, Very Thirsty

Engell, 1987; Riebe, 1997

Appendix E: Thermal Scale

Thermal Sensation

0- unbearably cold

1- very cold

2- cold

3- cool

4- comfortable

5- warm

6- hot

7- very hot

Davis et al., 2012

Appendix F: VO_{2max} Treadmill Protocol

MAX TREADMILL DATA FORM

Participant Name: ______________________________ Date: __________

Technician Name: ______________________________

	Time (min)	Speed (mph)	Grade (%)	HR (bpm)	RPE	BP (mmHg)
Pre-Exercise: Seated		X	X		X	
Graded Exercise Test	1:00	3.0	0.0			X
	2:00	4.0	0.0			X
	3:00	5.0	0.0			
	4:00	6.0	0.0			X
	5:00	7.0	0.0			X
	6:00	8.0	0.0			
	7:00	8.0	2.0			X
	8:00	8.0	4.0			X
	9:00	8.0	6.0			
	10:00	8.0	8.0			X
	11:00	8.0	10.0			X
	12:00	8.0	12.0			
	13:00	8.0	14.0			X
	14:00	8.0	16.0			X
	15:00	8.0	18.0		X	X
Cool-Down	1:00				X	X
	3:00				X	X
	5:00				X	X
Recovery	15:00	X	X		X	

Primary Results

HR Max	
VO2 Max	
RPE Max	
Ventilatory Threshold	

Appendix G: IRB Approval Letter

UNIVERSITY OF SOUTH FLORIDA

RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-7091

4/22/2014

Taylor Welch School of Physical Education & Exercise Science Heat Stress Lab 4202 E. Fowler Avenue Tampa, FL 33620

RE: Full Board Approval for Initial Review

IRB#: Pro00015888

Title: The Physiological Effects of Precooling Beverage Temperatures on Heat Strain in Collegiate Women's Soccer Players

Study Approval Period: 4/7/2014 to 4/7/2015

Dear Ms. Welch:

On 4/7/2014, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents outlined below.

Approved Item(s):

Protocol Document(s):

IRB protocol.docx MEDICAL HISTORY.docx

Consent/Assent Document(s)*: Informed consent .docx.pdf

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

Please Note: The IRB has determined that future reviews of this study may be conducted under Expedited category 9.

As the principal investigator of this study, it is your responsibility to conduct this study in

accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

E. Verena Jorgensen, M.D., Chairperson USF Institutional Review Board

Appendix H: Tables Means By Time Point

Precooling: Table 1A Mean T_{GI} by time point

Time	Room T_{GI} (°C)	Cold T_{GI} (°C)	Slush T_{GI} (°C)
0:00	37.38 ± 0.41	37.42 ± 0.16	37.34 ± 0.41
0:05	37.24 ± .054	37.39 ± 0.36	37.33 ± 0.42
0:10	37.12 ± 0.72	37.21 ± .077	37.29 ± 0.43
0:15	36.98 ± 0.95	37.2 ± 0.6	37.22 ±0.46
0:20	37.05 ±0.86	37.23 ± 0.47	37.14 ± 0.46
0:25	37.06 ±0.84	37.17 ± 0.5	37.05 ± 0.5
0:30	36.99 ±0.93	37.12 ± 0.55	36.96 ± 0.51
0:35	37.18 ±0.69	37.14 ± 0.51	36.97 ± 0.5
Range	36.98 ± 0.95 - 37.38 ± 0.41	37.12 ± 0.55 - 37.42 ± 0.16	36.96 ± 0.51 - 37.34 ± 0.41

Gastrointestinal Temperature = core body temperature °C. (N)= number of participants.

Exercise: Table 2A Mean T_{GI} by time point

Time	Room T_{GI} (°C)	Cold T_{GI} (°C)	Slush T_{GI} (°C)
0:00	37.18 ±0.69	37.14 ± 0.51	36.97 ± 0.5
0:15	37.88 ± 0.58	37.75 ± 0.45	37.86 ± 0.46
0:30	38.69 ± 0.53 (9)	38.59 ± 0.37	38.63 ± 0.39
0:45	38.89 ± 0.39 (6)	38.93 ± 0.36 (8)	39.02 ± 0.47 (7)
Range	37.88 ± 0.58- 38.89 ± 0.39	37.75 ± 0.45 - 38.93 ± 0.36	37.86 ± 0.46 - 39.02 ± 0.47

Gastrointestinal Temperature = core body temperature °C. (N)= number of participants.

Re-cooling: Table 3A Mean T_{GI} by time point

Time	Room T_{GI} (°C)	Cold T_{GI} (°C)	Slush T_{GI} (°C)
0:00	38.89 ± 0.39 (6)	38.93 ± 0.36 (8)	39.02 ± 0.47 (8)
0:05	38.68 ± 0.51 (7)	38.74 ± 0.39 (8)	38.87 ± 0.46 (8)
0:10	38.42 ± 0.54 (7)	38.43 ± 0.49 (8)	38.54 ± 0.55 (8)
0:15	38.14 ± 0.66 (7)	37.99 ± 0.79 (8)	38.32 ± 0.55 (8)
Range	38.14 ± 0.66 - 38.68 ± 0.51	37.99 ± 0.79 - 38.74 ± 0.39	38.32 ± 0.55 - 38.87 ± 0.46

Gastrointestinal Temperature = core body temperature °C. (N)= number of participants.

Precooling: Table 4A Mean T_{SK} by time point

Time	Room T_{SK} (°C)	Cold T_{SK} (°C)	Slush T_{SK} (°C)
0:00	33.43 ± 0.79 (8)	33.55 ± 1.01	33.7 ± 0.88
0:05	33.7 ± 1.04 (9)	33.93 ± 1.05	34.15 ± 0.84
0:10	33.94 ± 1.10	34.16 ± 1.0	34.43 ± 0.71
0:15	34.29 ± 0.87	34.45 ± 1.01	34.53 ± 0.61
0:20	34.44 ± 0.8	33.69 ± 3.39	34.65 ± 0.53
0:25	34.53 ± 0.77	34.68 ± 0.79	34.77 ± 0.54
0:30	34.63 ± 0.74	34.6 ± 0.79	34.7 ± 0.42
0:35	34.44 ± 0.77	34.87 ± 0.77	34.86 ± 0.59
Range	33.43 ± 0.79 - 34.63 ± 0.74	33.55 ± 1.01 - 34.87 ± 0.77	33.7 ± 0.88 - 34.86 ± 0.59

Skin Temperature = Average temperature °C. (N)= number of participants.

Exercise: Table 5A Mean T_{SK} by time point

Time	Room T_{SK} (°C)	Cold T_{SK} (°C)	Slush T_{SK} (°C)
0:00	34.44 ± 0.77	34.87 ± 0.77	34.86 ± 0.59
0:15	35.04 ± 0.5	35.32 ± 0.66	35.18 ± 0.62
0:30	35.38 ± 0.63 (9)	35.63 ± 0.53	35.75 ± 0.68 (9)
0:45	35.53 ± 0.6 (7)	35.73 ± 0.39 (8)	35.77 ± 0.84 (7)
Range	35.04 ± 0.5 - 35.53 ± 0.6	35.32 ± 0.66 - 35.73 ± 0.39	35.18 ± 0.62 - 35.77 ± 0.84

Skin Temperature = Average temperature °C. (N)= number of participants.

Re-cooling: Table 6A Mean T_{SK} by time point

Time	Room T_{SK} (°C)	Cold T_{SK} (°C)	Slush T_{SK} (°C)
0:00	35.53 ± 0.6 (7)	35.73 ± 0.39 (8)	35.77 ± 0.84 (8)
0:05	35.83 ± 0.42 (6)	35.82 ± 0.62 (8)	35.88 ± .031 (8)
0:10	35.53 ± 0.7 (7)	35.73 ± 0.62 (8)	35.45 ± 0.42 (8)
0:15	35.39 ±0.6 (7)	35.46 ± 0.6 (8)	35.38 ± 0.12 (8)
Range	35.39 ±0.6 - 35.83 ± 0.42	35.46 ± 0.6 - 35.82 ± 0.62	35.38 ± 0.12 - 35.88 ± .031

Skin Temperature = Average temperature °C. (N)= number of participants.

Precooling: Table 7A Mean HR by time point

Time	Room HR (BPM)	Cold HR (BPM)	Slush HR (BPM)
0:00	74.7 ± 13.57	78.3 ± 7.63	74.1 ± 10.65
0:05	74.4 ± 9.43	74.9 ± 5.97	72.0 ± 10.8
0:10	78.8 ± 9.61	76.3 ± 9.74	72.2 ± 12.24
0:15	79.2 ± 12.2	73.5 ± 10.14	72.1 ± 11.55
0:20	75.0 ± 12.36	73.5 ± 8.96	72.2 ± 12.22
0:25	77.4 ± 15.28	75.6 ± 9.66	74.6 ± 10.24
0:30	76.6 ± 11.82	79.2 ± 12.34	74.6 ± 13.15
0:35	104.8 ± 22.92	98.1 ± 21.86	93 ± 29.57
Range	74.4 ± 9.43 - 104.8 ± 22.92	73.5 ± 10.14 - 98.1 ± 21.86	72.0 ± 10.8 - 93 ± 29.57

(N)= number of participants.

Exercise: Table 8A Mean HR by time point

Time	Room HR (BPM)	Cold HR (BPM)	Slush HR (BPM)
0:00	104.8 ± 22.92	98.1 ± 21.86	93 ± 29.57
0:15	166.3 ± 15.37	165.7 ±13.0	165.7 ± 13.65
0:30	164.89 ± 21.91 (9)	166.1 ± 19.9	165.8 ± 14.92
0:45	164.5 ± 8.19 (6)	164.75 ± 15.71 (8)	168.71 ± 6.32 (7)
Range	164.5 ± 8.19 - 166.3 ± 15.37	164.75 ± 15.71- 166.1 ± 19.9	165.7 ± 13.65 - 168.71 ± 6.32

(N)= number of participants.

Re-cooling: Table 9A Mean HR by time point

Time	Room HR (BPM)	Cold HR (BPM)	Slush HR (BPM)
0:00	164.5 ± 8.19 (6)	164.75 ± 15.71 (8)	168.71 ± 6.32 (7)
0:05	120.14 ± 7.54 (7)	119.88 ± 14.12 (8)	119.25 ± 7.94 (8)
0:10	116.0 ± 12.38 (7)	117.38 ± 15.61 (8)	113.63 ± 8.53 (8)
0:15	115.86 ± 13.08 (7)	108.0 ± 12.2 (8)	109.13 ± 12.62 (8)
Range	115.86 ± 13.08 - 120.14 ± 7.54	108.0 ± 12.2 - 119.88 ± 14.12	109.13 ± 12.62 - 119.25 ± 7.94

(N)= number of participants.

Precooling: Table 10A Mean Thirst Sensation by time point

Time	Room Thirst	Cold Thirst	Slush Thirst
0:00	2.8 ± 1.62	2.7 ± 1.06	2.8 ± 1.69
0:05	2.5 ± 0.85	2.5 ± 1.43	1.7 ± 1.06
0:10	2.5 ± 1.18	2.2 ± 1.23	1.6 ± 0.84
0:15	2.3 ± 0.95	1.8 ± 0.92	1.5 ± 0.85
0:20	2.2 ± 0.92	1.8 ± 0.92	1.3 ± 0.67
0:25	2.0 ± 0.82	1.8 ± 0.92	1.3 ± 0.67
0:30	1.9 ± 0.74	1.8 ± 0.92	1.3 ± 0.67
0:35	2.2 ± 1.03	2.2 ± 1.14	1.3 ± 0.67
Range	1.9 ± 0.74 - 2.8 ± 1.62	1.8 ± 0.92 - 2.7 ± 1.06	1.3 ± 0.67 - 2.8 ± 1.69

Thirst Scale= 1 not thirsty at all – 9 very, very thirsty. (N)= number of participants. (Engell, 1987; Riebe, 1997)

Exercise: Table 11A Mean Thirst Sensation by time point

Time	Room Thirst	Cold Thirst	Slush Thirst
0:00	2.2 ± 1.03	2.2 ± 1.14	1.3 ± 0.67
0:15	3.5 ± 1.78	4.2 ± 1.75	2.7 ± 1.95
0:30	4.89 ± 2.62 (9)	5.2 ± 2.39	4.1 ± 2.32 (9)
0:45	4.33 ± .82 (7)	5.25 ± 1.83(8)	4.0 ± 1.29 (7)
Range	3.5 ± 1.78 - 4.89 ± 2.62	4.2 ± 1.75 - 5.25 ± 1.83	2.7 ± 1.95 - 4.1 ± 2.32

Thirst Scale= 1 not thirsty at all – 9 very, very thirsty. (N)= number of participants. (Engell, 1987; Riebe, 1997)

Re-cooling: Table 12A Mean Thirst Sensation by time point

Time	Room Thirst	Cold Thirst	Slush Thirst
0:00	4.33 ± .82 (7)	5.25 ± 1.83(8)	4.0 ± 1.29 (7)
0:05	4.14 ± 1.77 (7)	3.88 ± 1.55 (8)	2.63 ± 2.33 (8)
0:10	3.29 ± 1.98 (7)	2.63 ± 1.51 (8)	2.13 ± 2.47 (8)
0:15	2.86 ± 2.04 (7)	2.38 ± 1.51 (8)	1.63 ± 1.41 (8)
Range	2.86 ± 2.04 - 4.14 ± 1.77	2.38 ± 1.51 - 3.88 ± 1.55	1.63 ± 1.41 - 2.63 ± 2.33

Thirst Scale= 1 not thirsty at all – 9 very, very thirsty. (N)= number of participants. (Engell, 1987; Riebe, 1997)

Precooling: Table 13A Mean Thermal Sensation by time point

Time	Room Thermal	Cold Thermal	Slush Thermal
0:00	4.5 ± 0.53	4.6 ± 0.7	4.4 ± 0.52
0:05	5.0 ± 0.82	4.7 ± 0.67	4.2 ± 0.42
0:10	4.7 ± 0.67	4.6 ± 0.7	4.1 ± 0.88
0:15	4.8 ± 0.79	4.4 ± 0.7	3.9 ± 0.74
0:20	4.6 ± 0.7	4.4 ± 0.7	3.8 ± 0.79
0:25	4.7 ± 0.67	4.5 ± 0.71	3.8 ± 0.79
0:30	4.8 ± 0.79	4.4 ± 0.84	3.8 ± 0.79
0:35	4.8 ± 0.79*	4.5 ± 0.71*	3.9 ± 0.74*
Range	4.5 ± 0.53 - 5.0 ± 0.82	4.4 ± 0.7 - 4.7 ± 0.67	3.8 ± 0.79 - 4.4 ± 0.52

Thermal scale= 0 unbearably cold – 7 very hot. (N)= Number of participants. (Davis et al., 2012) $P < 0.05$*

Exercise: Table 14A Mean Thermal Sensation by time point

Time	Room Thermal	Cold Thermal	Slush Thermal
0:00	4.8 ± 0.79*	4.5 ± 0.71*	3.9 ± 0.74*
0:15	6.0 ± 0.82	6.0 ± 0.92	5.6 ± 0.7
0:30	6.33 ± 1.0 (9)	6.3 ± 0.95	6.22 ± 0.97 (9)
0:45	6.17 ± 1.17 (7)	6.13 ± 1.13 (8)	6.14 ± 1.21 (7)
Range	6.0 ± 0.82 - 6.33 ± 1.0	6.0 ± 0.92 - 6.3 ± 0.95	5.6 ± 0.7 - 6.22 ± 0.97

Thermal scale= 0 unbearably cold – 7 very hot. (N)= Number of participants. (Davis et al., 2012)

Re-cooling: Table 15A Mean Thermal Sensation by time point

Time	Room Thermal	Cold Thermal	Slush Thermal
0:00	6.17 ± 1.17 (7)	6.13 ± 1.13 (8)	6.14 ± 1.21 (7)
0:05	5.57 ± 1.27 (7)	5.75 ± 1.39 (8)	5.75 ± 1.39 (8)
0:10	5.14 ± 1.21 (7)	5.5 ± 1.07 (8)	5.13 ± 1.46 (8)
0:15	4.86 ± 1.35 (7)	4.88 ± 0.99 (8)	4.88 ± 1.25 (8)
Range	4.86 ± 1.35 - 5.57 ± 1.27	4.88 ± 0.99 - 5.75 ± 1.39	4.88 ± 1.25 - 5.75 ± 1.39

Thermal scale= 0 unbearably cold – 7 very hot. (N)= Number of participants. (Davis et al., 2012)

Exercise: Table 16A Mean RPE by time point

Time	Room RPE	Cold RPE	Slush RPE
0:15	11.7 ± 3.6*	11.9 ± 3.75*	10.7 ± 3.27*
0:30	14.6 ± 3.53 (9)	13.8 ± 3.26	13.22 ± 3.77 (9)
0:45	13.38 ± 3.66 (6)	14.67 ± 3.64 (9)	12.75 ± 3.54 (7)
Range	11.7 ± 3.6 - 14.6 ± 3.53	11.9 ± 3.75 - 14.67 ± 3.64	10.7 ± 3.27 - 13.22 ± 3.77

Ratings of perceived exertion= 6 no exertion at all - 20 maximal exertion. (N)= number of participants. (Borg & Noble 1974). $P < 0.05$*