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EFFECT OF EXOGENOUS ICE SLURRY ON PHYSIOLOGICAL STRAIN INDEX DURING EXERCISE IN THE HEAT

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EFFECT OF EXOGENOUS ICE SLURRY ON PHYSIOLOGICAL STRAIN INDEX DURING EXERCISE IN THE HEAT.

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Ice slurry solution (IS) ingested during exercise in the heat may alleviate physiological strain index (PSI) by lessening the rise of core temperature (Tc), and heart rate (HR.) PURPOSE: To investigate IS influence on PSI during submaximal running in the heat. METHODS: Six recreationally trained subjects (60±3 ml*kg^{-1}*min^{-1}) participated in two running trials on an outdoor track (30±1.5˚C, 25%RH). The two trials were run at the same absolute intensity (187.6 m*min^{-1}), and given either an ambient carbohydrate drink (25˚C) or IS (-1˚C) in random order. Subsequently, three recreationally aerobic trained subjects (59±3 ml*kg^{-1}* min^{-1}) participated in two running trials inside a climate chamber (34˚C, 40%RH). Subjects acclimatized in the chamber for 15 minutes then ran for 1hr with increasing speed every 20 minutes followed by an incremental time trial (TT) test to exhaustion. RESULTS: Using 2x3 ANOVA, outside runners had a significantly lower PSI (5.4±1.6 vs. 7.1±1.3; P=0.01), however HR (P=0.63), Tc (P=0.56), Tsk (P=0.55), and sweat rate (P=0.06) did not reach significance (P>0.05). Chamber runners had a significantly increased TT performance when given IS compared to ambient drink (8.2±2.1 min vs 6.4±1.8 min; P=0.01). Although chamber runners did not achieve significantly lower PSI (P=0.35), HR (P=0.51), Tc (P=0.51), Tsk (P=0.43), sweat rate (P=0.21) or RPE (P=0.58) when given IS. Nevertheless, CONCLUSIONS: These findings indicate that IS may have a significant impact on PSI. The IS also significantly increased TT performance. These data show the potential for increased running performance when IS is given during moderate exercise in the heat.

Table of Contents

Chapter One: Introduction

Introduction

Exposure to environmental heat is inevitable in professional and recreational behavior that requires being outdoors (Cheuvront & Haymes, 2001; Cuddy & Ruby, 2011; B. R. Ely et al., 2009; Galloway & Maughan, 1997; Peiffer & Abbiss, 2011; Pitsiladis & Maughan, 1999b; Sawka, Cheuvront, & Kenefick, 2012; Shirreffs et al., 2005) Shirreffs, S. M., Aragon-Vargas, L. F., Chamorro, M., Maughan, R. J., Serratosa, L., & Zachwieja, J. J.). Fire fighters, military personnel, high-energy expenditure workers and recreational athletes alike can be in danger of heat strain/stress while in everyday work or play in hot environments. Hot and humid environments create an increased perceived discomfort called heat strain (Bouchama & Knochel, 2002). Heat strain can cause volitional fatigue, hyperthermia, heat exhaustion/stroke, cardiovascular strain, central nervous system dysfunction, and death (Bouchama & Knochel, 2002; Cheuvront, Kenefick, Montain, & Sawka, 2010). Although it may be easy to blame the uncontrollable variable that is the environment, poor choices or mandatory clothing for personal protection can also contribute to the development of heat strain/stress (Cheuvront et al., 2010; Giesbrecht, Jamieson, & Cahill, 2007; Hostler et al., 2010; Montain, Sawka, Cadarette, Quigley, & McKay, 1994).

Research shows that as core temperature (T_c) increases so does rating of perceived exertion (RPE), while conversely work output and the time towards volitional fatigue decreases (Angus, Febbraio, Lasini, & Hargreaves, 2001; Barr, Reilly, & Gregson, 2011; Borg, 1970a; Cheung & McLellan, 1998; Cuddy, Ham, Harger, Slivka, & Ruby, 2008). However, if the rise in

T_c can be reduced, slowed or stopped, work output can be maintained while keeping heat stress fairly low, and reducing the possibility of a Heat Related Injury (HRI) (Buller, Latzka, Yokota, Tharion, & Moran, 2008a; Moran, Shitzer, & Pandolf, 1998).

Heat strain plagues those who are exposed to heat. Researchers have been actively trying to reduce heat strain/stress in order to maintain performance through several methods (Arngrïmsson, Petitt, Stueck, Jorgensen, & Cureton, 2004; Booth, Marino, & Ward, 1997; Cotter, Sleivert, Roberts, & Febbraio, 2001; Hessemer, Langusch, Brück, Bödeker, & Breidenbach, 1984; Lee & Haymes, 1995; Olschewski & Brück, 1988; Pitsiladis & Maughan, 1999a; Siegel et al., 2010). Drinking Ice Slurry (IS) in regular intervals has been shown to work well as a pre-cooling technique to reduce pre-exercise T_c (Siegel et al., 2010; Yeo, Fan, Nio, Byrne, & Lee, 2012). The extra energy required to melt ice into water while in the stomach could create a cooler internal environment, potentially suppressing or slowing the rise in T_c while being exposed to heat (Siegel et al., 2010).

Problem

During prolonged bouts of effort, elevated T_c can lead to fatigue regardless of the amount of water consumed (Cuddy & Ruby, 2011). However, pre-cooling with IS has been successful in reducing T_c and improving time trial (TT) performances (Dugas, 2011; Siegel, Mate, Watson, Nosaka, & Laursen, 2011; Yeo et al., 2012); it's possible that ice slurry ingestion exercise could slow, stop or even reduce T_c with the correct amount and timing during a high demand bout of effort.

Purpose

The purpose of this study is to determine the ability of a carbohydrate IS drink, compared to ambient temperature carbohydrate drink during a bout of exercise at a fixed workload for 60min, to reduce T_c, heart rate (HR), PSI, skin temperature (T_{sk}), and RPE.

Null Hypotheses

1. No change in RPE with administration of IS compared to ambient temperature carbohydrate drink.
2. No significant difference on HR with administration of IS compared to ambient temperature carbohydrate drink.
3. No significant difference on T_c with administration of IS compared to ambient temperature carbohydrate drink.
4. No significant difference on Physiological Strain Index (PSI) with administration of IS compared to ambient temperature carbohydrate drink.
5. No significant difference on T_{sk} with administration of IS compared to ambient temperature carbohydrate drink.

Significance and Rationale

This research could affect the way fire fighters, military personnel and professional or recreational athletes view HRI prevention. If a significant reduction in PSI is observed from the use of IS, those populations at risk can easily adopt the use of IS into their ‘feeding’ schedule to prevent or lessen the number of HRIs.

Limitations

1. Data were collected outside during the hotter times of the summer. To do this, we chose the historically hotter weeks of the year along with the hotter times of day to run the trials and collect data, typically those days have been late July, early August, around the mid afternoon hours. These data were collected and monitored with a portable weather station.

2. Lifestyle of subjects was not modified or controlled, instead subjects were asked to fill out a food and activity recall sheet before the first trial and repeat it prior to the second trial. Subjects were asked to avoid strenuous exercise for 24 hours prior to completing the exercise trials.

3. To reduce error, all involved in data collection were thoroughly trained on all pieces of equipment and monitored during data collection times to reduce the chance of error during data collection.

4. Subjects were recruited by convenience and separated in two groups by order of appearance (odd numbers ambient drink (CNT) first, IS second; even numbers IS first, ambient drink second).

5. Air quality in Missoula, MT can be very poor due to wildfires in the region; air quality was monitored on local websites.

Delimitations

1. All subjects were recreational athletes doing controlled workload running trials. The effects of the IS while using impermeable clothing such as body armor or fireproof clothing were not be explored in this study.

Definition of Terms

- Heat Strain/Stress: physiological consequences, such as increased T_c and/or HR, or perceptual consequences, such as raised RPE (Borg, 1970a; Buller et al., 2008a). Heat strain/stress can cause any of the following: volitional fatigue, hyperthermia, heat exhaustion/stroke, cardiovascular strain, central nervous system dysfunction, and death (Bouchama & Knochel, 2002).

- Ice slurry: blended mixture of ice and carbohydrate drink making it an icy drink.

- Physiological Strain Index (PSI): calculates heat stress on the body utilizing T_c and HR. PSI stratifies the risk for a HRI on a scale of 0 - 10 (Buller, Latzka, Yokota, Tharion, & Moran, 2008b; Moran et al., 1998). PSI is based on an equation from Moran et al. (Moran et al., 1998) using T_c and HR. $T_{c(0)}$ and HR_0 are the initial core temperature and heart rate measured at the start of exercise, and $T_{c(t)}$ and HR_t are from any one time during the bout of effort.

$$PSI = 5 (T_{c(t)} - T_{c(0)}) * (39.5 - T_{c(0)})^{-1} + 5 (HR_t - HR_0) * (180 - HR_0)^{-1}$$

- Recreational Athlete: someone who exercises on a regular basis and is fit enough to complete the trial demands as defined in the purpose and experimental design.

- VO_2 peak: maximal amount of oxygen an individual can use during an incremental maximal exercise test.

Chapter Two: Review of Literature

Hot Environment Fatigue

Hot environments have a negative effect on exercise and work performance (Cheuvront et al., 2010; Cuddy & Ruby, 2011; M. R. Ely, Cheuvront, Roberts, & Montain, 2007; Peiffer & Abbiss, 2011; Rowell, Brengelmann, Murray, Kraning, & Kusumi, 1969). Cheuvront et al. (2010) reviewed the effects of environmental heat and dehydration on exercise performance. They noted that, as skin temperature (T_{sk}) and core temperature (T_c) rose, either time to failure decreased or the pace was significantly slowed, and work rate slowed significantly to achieve a similar rate of perceived exertion (RPE). As for dehydration, researchers have found that dehydration alone did not significantly reduce self-selected effort, but in combination with high environmental temperature, dehydration acts as a catalyst, and performance decrements are greater (Cheuvront et al., 2010).

Ely et al. (2007) reviewed environmental data compared to finish times of marathon runners from 130 races spanning a 36-year period. The goal of this review was to investigate how different ambient temperatures affected running performance. The data were divided based on wet-bulb globe temperatures quartiles (WBGT) (Q1 $5.1^{'}$-10^{0}Celsius (C), Q2 10.1°-15°C, Q3 15.1°-20°C, Q4 20.1°-25°C), to separate performance decrements as ambient temperatures increase. Researchers found a significant and progressive slowing in pace of all runners (male, female, recreational and elite) as environmental heat increased from Q 1 to Q 4.

Environmental Heats' Effect on Skin and Core Temperature

T_c rises during physical activity regardless of the environmental temperature (B. R. Ely et al., 2009), however the rate of rise and its effect on performance is much more notable in higher

ambient temperature environments (Cuddy & Ruby, 2011; Gallagher et al., 2012; Garrett, Creasy, Rehrer, Patterson, & Cotter, 2012; Kenefick, Cheuvront, & Sawka, 2007). Ely et al. (2009) were able to show that the 40°C T_c ceiling is not an absolute; they noted that two different subjects were able to maintain running performance with a mean T_{sk} of 30.3°C and a T_c >41°C when the ambient temperature was approximately 13°C.

Sawka et al. (2012) reviewed the role of T_{sk} in the reduction of aerobic performance and found that while subjects could push themselves over 40°C T_c and maintain performance, the effects of a hot environment elevating T_{sk} past 27°C seemed to cause impairments in performance. These studies provide an alternative view to the more accepted notion of decreased performance with T_c passing 39°C alone (Cheung & McLellan, 1998; Latzka et al., 1998; Montain et al., 1994; Nielsen et al., 1993; Sawka et al., 1992).

Physiological Strain Index, Heat Stress and Strain

Physiological Strain Index (PSI) is a combination of biological feedback (T_c and HR) that allows us to interpret and predict the potential for heat injury. Moran et al. (1998) developed PSI by using T_c and HR as independent variables giving a scale from 0-10 to identify risk. Buller et al. (Buller et al., 2008a), used Moran's data and five other PSI models in order to create a PSI model that would enable the use of T_{sk} and HR, making it more user friendly. On this scale, scores > 7.5 are identified to be "at risk" for heat injury.

Rodriguez et al. (2011) used PSI as a measure while determining how different wildland firefighting techniques stress the body in both physiological demands and thermal strain. He found that direct attacks (directly fighting fire), had a significantly higher level of demand and strain compared to indirect attacks (doing fire related work away from fire) or mixed attacks

(doing both direct and indirect fire attacks) alike, driving up T_c and HR, therefore driving PSI up as well.

Heat stress is defined as when a hot and humid environment causes perceived discomfort (Bouchama & Knochel, 2002). Also, heat stress can be caused by restrictive clothing and physical activity, independent of environmental heat (Cheuvront et al., 2010; Sawka et al., 1992).

Heat strain is the next classification up from heat stress and can lead to: hyperthermia, heat exhaustion/stroke, cardiovascular/cognitive strain or death (Bouchama & Knochel, 2002; Cheung & McLellan, 1998; Cuddy & Ruby, 2011; Galloway & Maughan, 1997).

Thermoregulation

Human energy metabolism is inefficient since more than 75% of its energy production is lost as heat (Wendt, van Loon, & Lichtenbelt, 2007). Due to this inefficiency, there are many mechanisms in place to dissipate metabolic heat and maintain T_c in homeostasis. Even though all these mechanisms work well under mild conditions, the exposure to environmental heat, intense physical activity, or both, causes these mechanisms to become overwhelmed, resulting in steady rise in T_c (Wendt et al., 2007).

A specific heat controlling mechanism is peripheral vasodilation, which drives blood away from the inner tissues and working muscle and towards the skin surface in an attempt to allow the environment to dissipate metabolic heat. (Kenney & Johnson, 1992; Sawka et al., 2012; Wendt et al., 2007) This attempt to reduce body heat through vasodilation can be so great that it can draw up to 8 $L*min^{-1}$ of blood towards the body surface (Kenney & Johnson, 1992). This mechanism does have a threshold, as T_c nears and passes 38^0C or dehydration sets in, blood is shunted away from the skin and back towards the working muscle to maintain the level of effort. This poses a problem as it reduces the body's ability to dissipate heat and can put the body

into further risk for heat stress or heat strain (Kellogg, Johnson, Kenney, Pergola, & Kosiba, 1993; Kenney & Johnson, 1992; Wendt et al., 2007).

Sweating is another piece in the mosaic of heat dissipation. Vasodilation relies on convection but when environmental heat exceeds 36°C, convection is no longer an effective method of cooling (Wendt et al., 2007). In turn, sweating benefits from evaporation to remove heat from the body. This occurs most effectively in dry environments (Cheuvront & Haymes, 2001).

Populations Normally Exposed to Heat Stress

Those whom may be exposed to heat stress are countless, and there are several reasons why any particular member of society may be put in to a situation where heat can become a problem. Leisurely hobbies, geographical location, or professions alike may expose participants to heat stress. Military combatants, fire fighters (structure and wildland), triathletes, football players, and even "soccer moms" on their afternoon jogs can fall victim to heat stress or strain. If it is hot outside, the heat related complications can vary from some discomfort to catastrophic outcomes depending on the events leading up to the heat injury (Bouchama & Knochel, 2002; Caldwell, Patterson, & Taylor, 2012; Cuddy & Ruby, 2011; M. R. Ely et al., 2007; Nolte, Noakes, & van Vuuren, 2011).

Even the acclimatized population is at risk for heat injuries. Marom et al. (Marom, Itskoviz, Lavon, & Ostfeld, 2011) documented a case where five healthy Israeli soldiers were unable to continue with a training event due to exertional heat stroke (EHS). All of the soldiers were immediately removed from the training site, treated in the field and taken to a hospital where they received further care. While in the hospital, all of the measured values for T_c, urine markers or blood work came back unremarkable and had near normal values, which is expected

since the soldiers were being actively treated from the field to the hospital. Weeks following their discharge from the hospital, these soldiers were tested for heat tolerance and the results came back as normal. This highlights that even acclimatized, highly trained and well-equipped personnel can fall victim to environmental heat when poor cooling strategies are employed.

Cooling Strategies

The most commonly used cooling strategy is drinking more liquid, usually in the form of water or sports drink (Cheung & McLellan, 1998; Cuddy et al., 2008; Sawka et al., 1992; Selkirk, McLellan, & Wong, 2006; Shirreffs et al., 2005). However, there is evidence that points towards hydration levels not being indicative of hyperthermia protection (Angus et al., 2001; Cuddy et al., 2008; Cuddy & Ruby, 2011; Fujii, Honda, Hayashi, Kondo, & Nishiyasu, 2008; Hostler et al., 2010; Latzka et al., 1998; Selkirk et al., 2006; Yokota et al., 2012). The academic and research communities are actively searching for a strategy that will solve the heat stress problem: pre-cooling, cooling vests, hand cooling devices, hand and forearm submersion, neck cooling, total body immersion, cold intravenous (IV) fluids, work/rest cycles, different fluid types and fluid intake schemes are all currently being investigated (Amorim, Yamada, Robergs, & Schneider, 2010; Barr, Gregson, Sutton, & Reilly, 2009; Barr et al., 2011; Casa, Kenny, & Taylor, 2010; Castle, Maxwell, Allchorn, Mauger, & White, 2012; Chinevere et al., 2008; Clements et al., 2002; Gao, Kuklane, & Holmer, 2010; Giesbrecht et al., 2007; Kim, Coca, Williams, & Roberge, 2011; Leicht et al., 2009; Selkirk, McLellan, & Wong, 2004; Tyler, Wild, & Sunderland, 2010; Zhang, Bishop, Casaru, & Davis, 2009).

Zhang et al. (2009) found that during discontinuous cycles of exercise while subjects wore structural fire type clothing, active cooling by using a hand-cooling device did elicit a

decrease in T_c but that was only after 30 minutes of active cooling in comparison to passive cooling (just sitting inactively in the heat).

Some of the data have shown very favorable effects in maintaining T_c lower than the control trial that did not receive the treatment, however most of these schemes are not practical. Pre-cooling works well at first, but then the T_c rate of rise becomes steeper (Yeo et al., 2012) . Cooling vests are very effective while they are actively cooling but their working times are limited and once they stop cooling, the vests increase the heat problem by adding another non-breathable layer to the user (Chinevere et al., 2008; Gao et al., 2010; Kim et al., 2011).

Neck cooling has been looked into by Tyler et al. (Tyler et al., 2010), with significant results towards improving performance while the subjects were exposed to hot environments for prolonged bouts of cycling, however neck cooling failed to elicit a response during a 15 minute cycling time trial (TT), and there were no significant changes in HR, RPE or T_c.

Giesbrecht et al. (Giesbrecht et al., 2007) found that during 20 minute work/rest cycles totaling 60 minutes of work and 60 minutes of rest, using a hand and forearm submersion into cool (20°C) or cold (10°C) water during the rest cycles, had significant effect in decreasing T_c, HR, and T_{sk}, while increasing tolerance to environmental heat and work output during the work cycles.

Ice Slurry

Siegel et al. (Siegel et al., 2011) found that providing 1.25 $g*kg^{-1}$ (body weight) of IS (-1°C) versus warm fluid (40°C) had a significant effect on maximal voluntary isometric contraction of the elbow flexors after exhaustion in submaximal running on a treadmill in the heat (34.1°C).

Yeo et al. (Yeo et al., 2012) found that pre-cooling with an IS (-1.4°C) had a non-significant effect in a 10 kilometer running time trial (TT) in a 28°C environment compared to ambient temperature drink (30.9°C). Although running times were slightly faster with IS pre-cooling, gastrointestinal temperatures (T_{GI}) were not different and the rate of rise of T_{GI} were higher for the IS group, and by the end of the exercise and recovery times T_{GI} was higher in the IS group than those treated with ambient drink.

Stanley et al. (Stanley, Leveritt, & Peake, 2010) compared an IS (-0.8°C) to a cool drink (18.4°C) during cycling performance. Subjects were warmed up in a 34°C environment for 75 minutes then given a 50 minute rest period. The subjects were then given either the IS or a cool drink, before performing a TT to a predetermined amount of work (75% of VO_2 peak x 30 min). There was no significant difference between treatments in TT performance, but T_c was significantly lower at the end of the TT for those treated with the IS.

Dugas et al. (Dugas, 2011) used a progressive treadmill protocol to volitional fatigue on their subjects while administering either a flavored IS (-1°C) or a flavored cold drink (4°C) 30 minutes before the test. The IS group was able to run significantly longer (50.2 min) compared to the cold water drink (40.7 min). T_c started lower and remained lower through the duration of the exercise, however during recovery the IS groups T_c surpassed the cold water group.

Kaufman et al. (2012) used a steady state treadmill protocol where subjects walked at 50% running VO_2 peak for 90 minutes while ingesting either an IS (-1.4°C), cold drink (-0.7°C) or a ambient drink (21.5°C) at the rate of 2.5 g*kg^{-1} body weight every 10 minutes. The researchers were able to identify significant T_c differences between the IS, cold drink and ambient drink trials. Furthermore the IS significantly reduced sweat rate when compared to ambient drink.

These IS studies are suggestive of the potential effects that the IS can have in T_c maintenance, by cooling from within. The current uses in the literature can be categorized as pre-cooling for moderate to high metabolic demand or an intervention during exercise with a low metabolic demand. This leads to the hypothesis that a reduced rate of rise of T_c may be possible with an IS carbohydrate drink administration during prolonged moderate to high metabolic demand exercise.

Chapter Three: Methodology

Participants and Settings

For this study, 6 recreationally active male volunteer participants from the Missoula, MT area within the ages of 18 and 40 years, with a running VO_2 peak $\geq$ 50 $ml*kg^{-1}*min^{-1}$ were utilized. Subjects agreed with and signed an informed consent form approved by the Institutional Review Board (IRB) of the University of Montana in Missoula (Appendix A), this form outlined the study and provided consent. Subjects filled out the Physical Activity Readiness Questionnaire health/exercise questionnaire (PAR-Q, Appendix B) screening for known cardiovascular disease risk. Preliminary data were collected in the Human Performance Laboratory (HPL) and in the Montana Center for Work Physiology and Exercise Metabolism (WPEM) at the University of Montana in Missoula, MT for preliminary trials. Trial data were collected on an outside quarter mile dirt track at Toole Park in Missoula, MT (River Bowl track).

Subsequent indoor trials were completed with 3 recreationally active male volunteers from the Missoula, MT area, within the ages of 18 and 40 years, and have a running VO_2 peak $\geq$ 50 $ml*kg^{-1}*min^{-1}$. Subjects agreed with and signed an informed consent form approved by the Institutional Review Board (IRB) of the University of Montana in Missoula. This form outlined the study and provided consent. Subjects filled out the Physical Activity Readiness Questionnaire (PAR-Q) screening for known cardiovascular disease risk. Data were collected and trials were conducted in an Environmental Chamber (Tescor, Warminster, PA) in WPEM.

Experimental Design

Preliminary Testing

Physical Activity Readiness Questionnaire (PAR-Q):

PAR-Q screening for known risk factors of cardiovascular disease, this questionnaire was administered prior to any testing or evaluation, to ensure subjects' cardiovascular safety. These results determined if a subject was eligible to participate in the study.

Hydrostatic Weighing:

Body composition was measured using a hydrostatic weighing tank with digital scales using data collecting software (Exertech, Dresbach, MN) while estimating residual volume from subject's height and weight. Subjects were asked to fast for $\geq$ 3 hours prior to hydrostatic weighing. Dry body weight was recorded on a weight scale (Befour Inc., Cedarburg, WI) and height was measured. Subjects were submerged and weighed repeatedly, until 0.1 kg consistency was achieved. Underwater weight was used to calculate body density to predict percent body fat using estimated residual volume and the Siri equation (Siri, 1993).

Maximal Aerobic Capacity (running VO_2 peak):

Subjects fasted for $\geq$ 3 hours prior to a running VO_2 peak test. Running VO_2 peak tests were done on a treadmill ergometer (Fullvision, Inc., Newton, KS), a 3-minute warm-up (2.5 mph and 1% grade) was done prior to conducting the Bruce Protocol. The Bruce Protocol begins at the first stage: 1.7 mph and a 10% grade for 3 minutes, after the first stage the workload was increased to 2.5 mph and 12% grade, 3.4 mph and 14% grade, 4.2 mph and 16% grade, and 5 mph and 18% grade after 2 minutes on each stage has elapsed, respectively (Will & Walter, 1999). To measure running VO_2 peak, expired gases were collected and analyzed every 15 seconds via metabolic cart (Parvomedics, Inc., Sandy, UT). VO_2 peak is met when one of the

following criteria is reached: 1) plateau in VO_2 despite an increased workload; 2) Respiratory Exchange Ratio (RER) is greater than 1.10; 3) heart rate within 10 beats of the subjects' predicted heart rate maximum (206bpm – (AGE * 0.6667)); 4) rate of perceived exertion (RPE) > 17; or 5) volitional fatigue.

Experimental Trials

Outdoor Trials:

Conditions:

Experimental trials were restricted to similar times of the day and temperatures $\geq 27^{\circ}$ C and $\leq 31^{\circ}$ C, with little cloud coverage, humidity $\geq$ 25% and $\leq$ 45%. These are normal averages for August for Missoula, MT as found in the weather.com database and were monitored with a portable weather station (table 4).

Clothing:

Clothing was restricted to: running shoes, low cut socks, running shorts (above the knee) and a technical fabric t-shirt (provided by WPEM). The same or equivalent clothing was worn in all subsequent trials.

Exercise Protocol:

Participants met in HPL for preliminary testing, and experimental trials. Trials were separated by at least one week and experimental trials were held at a constant absolute workload (7 mph for 60 minutes) controlled by quarter mile split times. Both control and experimental trials were at the same absolute workload with the trials differing only by the type of drink given, ambient temperature drink (kept in the shade) or IS drink. Pre and post nude weights were taken to assess total weight loss.

Drink Administration:

During the 60-minute exercise trials subjects drank 2.0 ml*kilogram^{-1} (kg) of body weight (BW), the drink was dispensed via bicycle water bottle at the completion of every mile. Type of beverage given varied per trial and the order was randomized: ambient temperature drink (CNT) or IS.

Heart Rate, Skin and Core Temperature:

HR, T_{sk} and T_c were monitored and recorded throughout the exercise trials. HR data was monitored by a chest-strap and receiver watch (Polar Electro, Kempele, FL), T_c was measured with a rectal pill and T_{sk} with an adhesive skin patch (AgriTemp Physiological Monitoring System HQ Inc. Palmetto, FL) collected by CorTemp data recorder (HQ Inc. Palmetto, FL). All data were downloaded after each trial; the frequency of sampling was that of one data point per second and for reporting purposes data points five seconds before and after the minute mark were averaged for each minute of interest.

Indoor Trials:

Conditions:

Trials were conducted in an environmental chamber (Tescor, Warminster, PA) set to 34° C and 40% relative humidity in WPEM.

Clothing:

Clothing was provided by the subject but restricted to: running shoes, low cut socks, and running shorts. Subjects were asked to run shirtless and similar clothing was worn for all trials.

Exercise Protocol:

Participants met in WPEM for the exercise trials. Trials were separated by at least one week, following a different protocol from the outdoor trials including 15 minutes of acclimatization

sitting inside the chamber, 20 minutes of treadmill running at 5.5 mph at 1% grade, 20 minutes at 6 mph at 1% grade, and 20 minutes at 6.5 mph at 1% grade, for a total of 60 minutes averaging 6 mph at 1% grade. After the 60 minutes of running, subjects were asked to complete a performance trial consisting of treadmill running at 7 mph starting at 1% grade and increasing 1% grade every minute until failure was reached.

Drink Administration:

During the 60-minute exercise trials subjects drank 2.0 $ml*kg^{-1}$ of body weight (BW), dispensed with a bicycle water bottle every 10 minutes. Type of beverage varied per trial and order was randomized: CNT or IS.

Heart Rate, Skin, Core Temperature, RPE:

HR, T_{sk} and T_c were monitored and recorded throughout the exercise trials. HR data was monitored by a chest-strap and receiver watch (Polar Electro, Kempele, FL), T_c was measured with a rectal thermometer (Mallinckrodt Medical, St. Louis, MO) and T_{sk} was collected with a wired skin temperature sensor (Mallinckrodt Medical, St. Louis, MO) placed on the skin over the left pectoralis major approximately 1 to 2 inches laterally from the sternum. T_{sk} and T_c data were monitored and collected by DASYLab Software (Measurement Computing Co., Norton, MA). RPE was collected just before administering the beverage drink every 10 minutes to capture the end of each running stage during the 60-minute protocol.

Both Indoor and Outdoor Trials:

Physiological Strain Index (PSI):

PSI was calculated using the calculation from Moran et al. (Moran et al., 1998) using T_c and HR data where $T_{c(0)}$ and HR_0 are the initial core temperature and heart rate values measured at the start of exercise and $T_{c(t)}$ and HR_t is any value measured within the exercise period:

$$PSI = 5\,(T_{c(t)} - T_{c(0)}) * (39.5 - T_{c(0)})^{-1} + 5\,(HR_t - HR_0) * (180 - HR_0)^{-1}$$

Body Mass and Sweat Loss:

Body mass was measured in the nude before and after each trial on a scale (Ohaus, Pine Brook, NJ) located in a private room behind a closed door. Subjects used the restroom prior to the before trial weight and were asked to weigh themselves prior to using the restroom after the trial. Sweat rate was determined by changes in pre and post-exercise trial nude body mass accommodating for fluid intake, using the following equation:

Sweat Loss (L) = (BW_{pre} (kg)) – (BW_{post} (kg) – (Liquid Ingested (L))

Early Termination:

Trials were terminated if subjects reached any one of the following conditions

$T_c \geq 39.9^{\circ}$ C

HR $\geq$ 95% HR max

RPE $\geq$ 17 – Volitional Fatigue

If any one of these criteria had been met, subjects would be stopped, walked to the shade and given whatever liquid they desired to recover while being observed by a CPR certified researcher.

Statistical Analysis:

Statistical analyses were run through IBM SPSS – Statistics program. Subject descriptive, means, standard deviations and T_c, T_{sk}, HR, PSI, RPE were calculated using a repeated measures general linear model equation (ANOVA) using two factors (time and treatment). 2x7, 2x6, 2x5, 2x4, 2x3, 2x2 ANOVAs were run to investigate main effects of time. A 2x3 ANOVA is reported in the results section to equally represent both outdoor and indoor trials.

Chapter Four: Results

Participants:

Six subjects completed the outside trials and three subjects completed the inside trials. Subjects' age, VO_2 peak and body fat percentages are reported bellow a mean $\pm$ SD.

TRIAL	N	AGE (years)	VO_2 PEAK ($ml*kg^{-1}*min^{-1}$)	BODY FAT (percentage)
OUTSIDE	6	26.8 $\pm$ 2.5	62.1 $\pm$ 1.2	9.6 $\pm$ 1.8
INSIDE	3	27 $\pm$ 1.5	59.4 $\pm$ 1.7	10.8 $\pm$ 2.2

Outside:

Sweat rate (figure 1), T_{sk} (figure 2), T_c (figure 3), and HR (figure 4) did not reach statistical significance for the interaction of time and treatment. PSI was significantly lower in both the effect of the treatment and the interaction of treatment and time (figure 5). HR, T_c, and PSI had significant differences as a main effect of time ($P<0.01$). T_{sk} did not reach significance ($P>0.05$) for any of the main effects.

There was a trend for sweat rate to be lower during the IS trial.

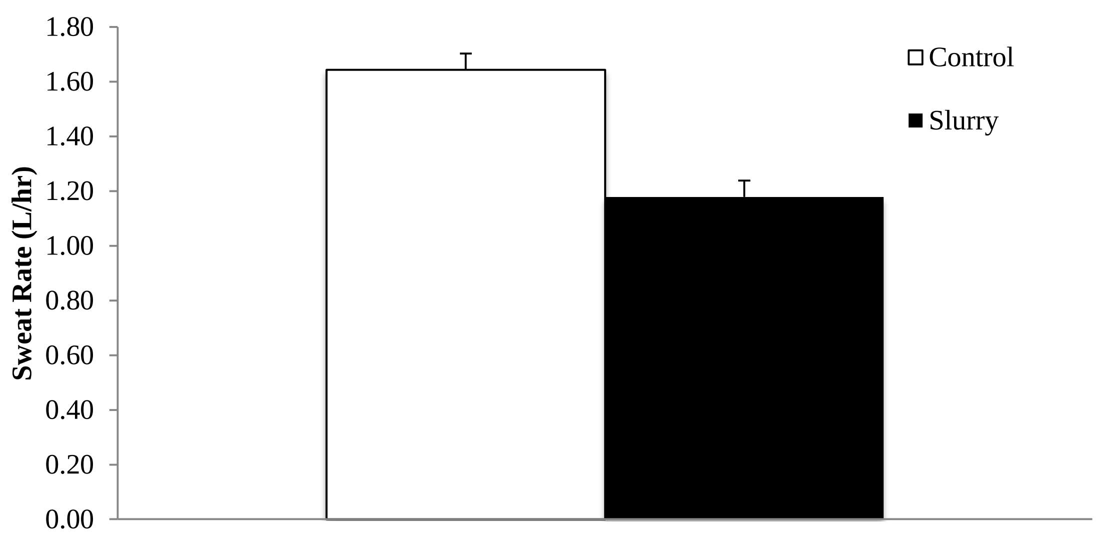

Figure 1. Sweat rate from 60 minutes of running outdoors in the heat for IS and CNT drink, expressed as mean $\pm$ SEM. P = 0.06, 2 Tailed T-Test

Skin temperature is highly responsive to the environment and this phenomenon was well documented during the outdoor running trials. Both trials began with similar temperatures and winds speeds but as the trials got underway the environment changed slightly and differently for each day; these differences in cloud coverage, sun exposure, wind speeds, and temperature caused the skin to react according to the environment and not prediction models from laboratory experiments.

On the IS day, the weather was steady from beginning to end with a light breeze, which helped T_{sk} stay fairly consistent. The CNT trial conditions were 1.2° C hotter before the trial started, but within 15 minutes of the trial beginning the wind and some cloud cover moved overhead which explains the quick drop in T_{sk} in the first 30 minutes; approximately 15 minutes before the end of the trial the wind slowed down and the clouds dissipated, which elicited the rise in T_{sk}. The means and standard deviations of the trials as a whole were not significantly different.

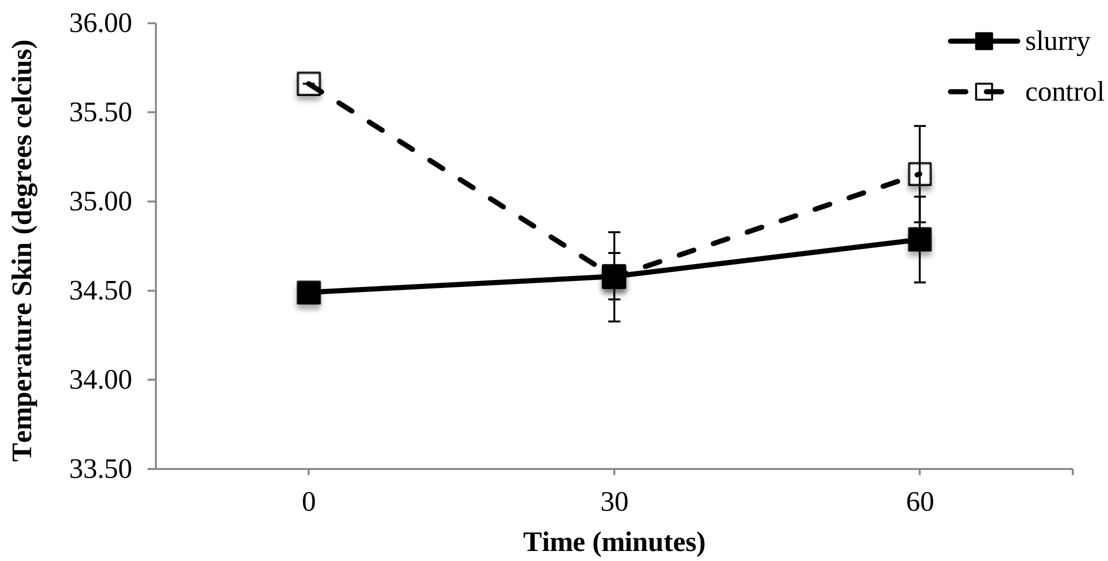

Figure 2. Skin Temperature during 60 minutes of running outdoors in the heat for IS and CNT drink, expressed as mean ± SEM. P = 0.55 interaction of time and treatment

Core temperature is not as easily manipulated by the weather and more so dictated by the accumulation of metabolic heat and the inability to off load this heat through the skin or cooling from within by consuming a cold drink.

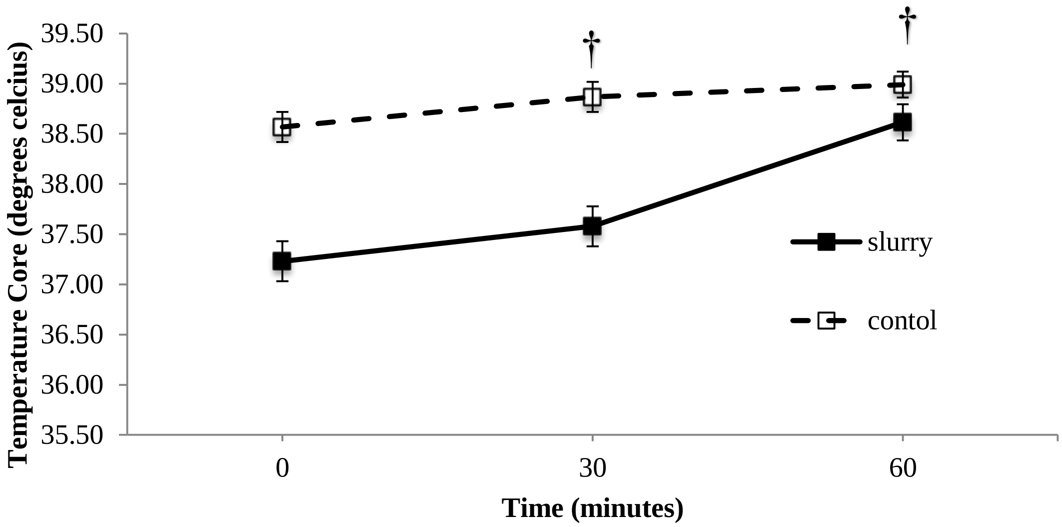

Figure 3. Core Temperature during 60 minutes of running outdoors in the heat for IS and CNT drink, expressed as mean ± SEM. † P < 0.01 for the main effect of time.

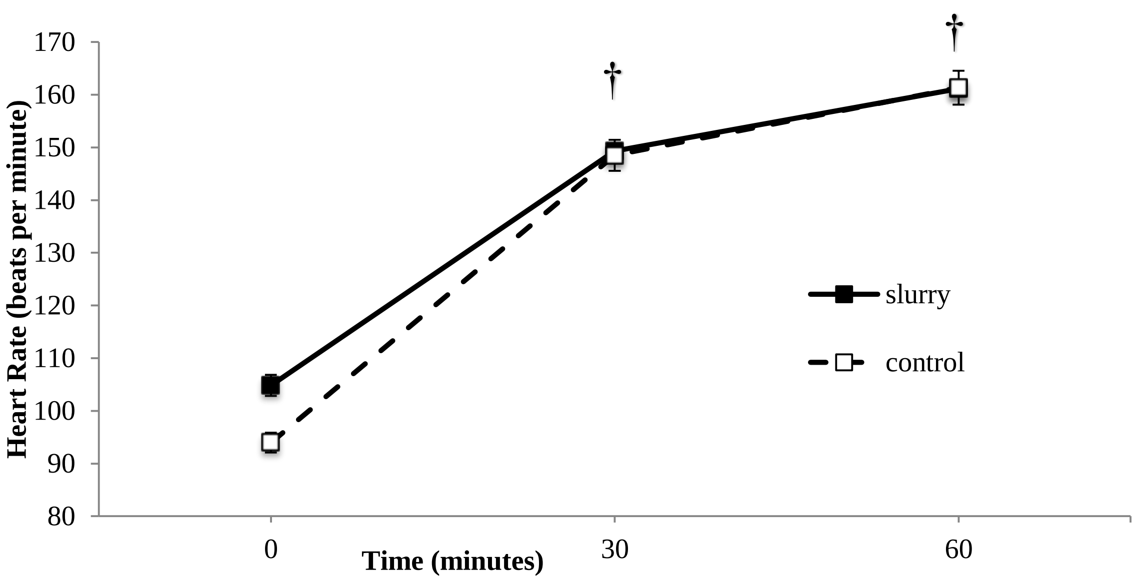

Figure 4. Heart Rate during 60 minutes of running outdoors in the heat for IS and CNT drink, expressed as mean ± SEM. † P < 0.01 for the main effect of time.

PSI did have significant differences in the main effect of time, treatment and the interaction of time and treatment. HR and T_c at time 0 were not significantly different between trials.

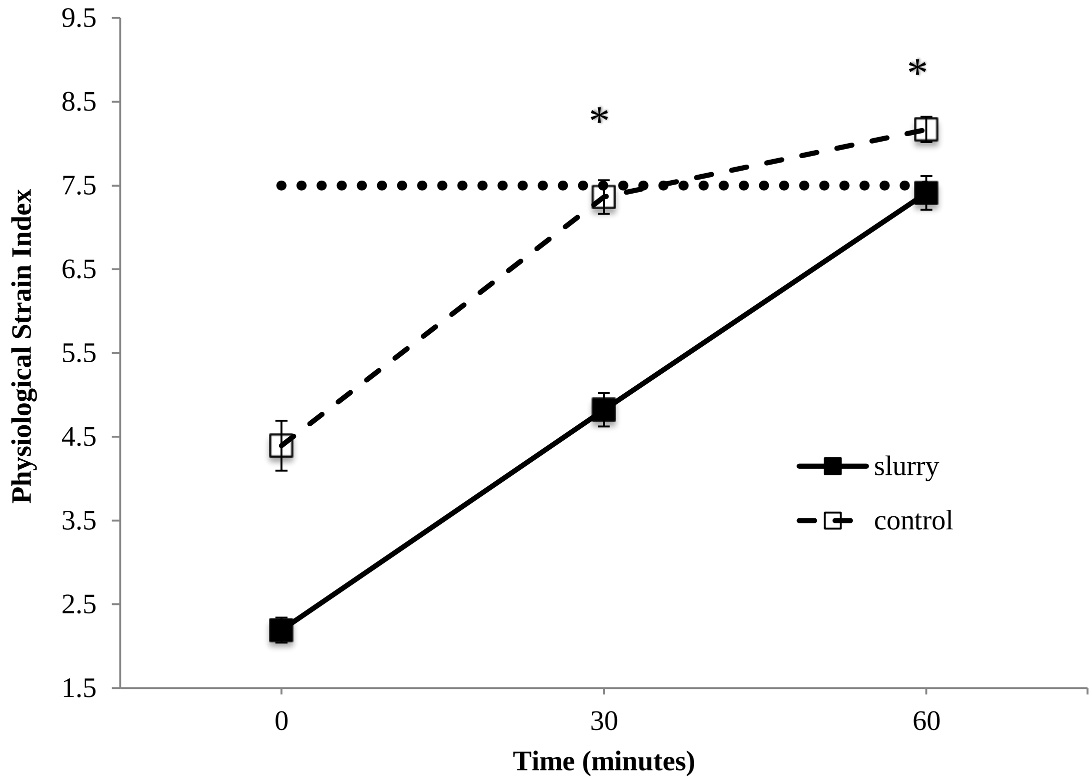

Figure 5. Physiological Strain Index during 60 minutes of running outdoors in the heat, expressed as mean $\pm$ SEM. * P = 0.01 between IS and CNT for the interaction of time and treatment.

Inside:

Sweat rate (figure 6), T_{sk} (figure 8), T_c (figure 9), HR (figure 10), and PSI (figure 11) did not reach a statistical significance for main effect of time or treatment, not the interaction of time and treatment. Nevertheless, chamber runners had statistically significant lower RPE (figure 7) and longer time trial performance (figure 12) when given IS compared to CNT drink.

Indoor sweat rate was not significantly different between treatments.

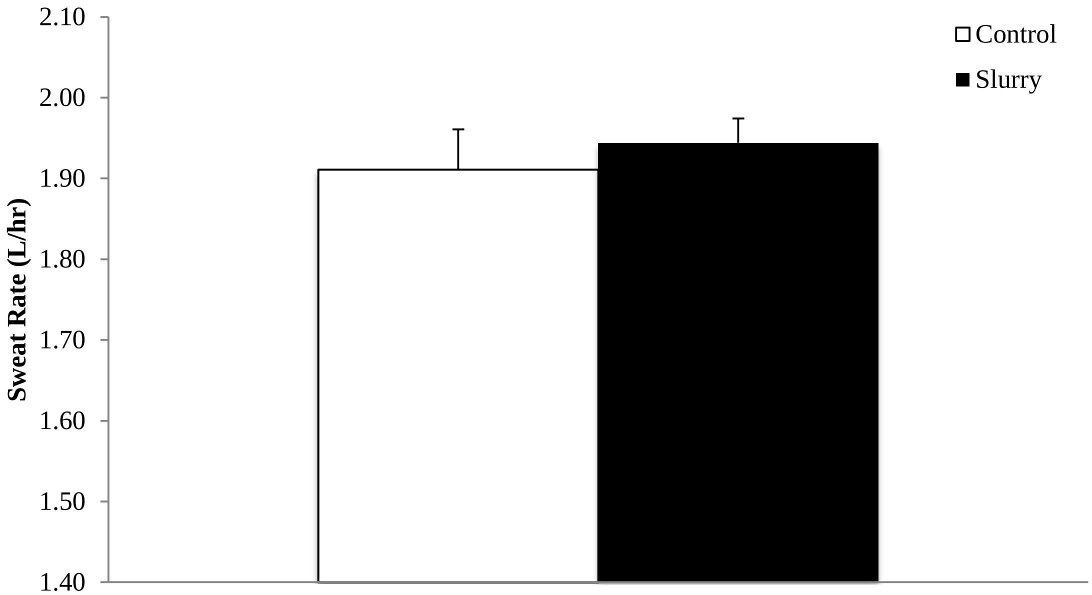

Figure 6. Sweat rate from 60 minutes of running indoors in the heat for IS and CNT drink, expressed as mean ± SEM. P = 0.06, 2 Tailed T-Test

Indoor RPE was not significantly lower throughout the trial, prior to the TT, during the IS trial.

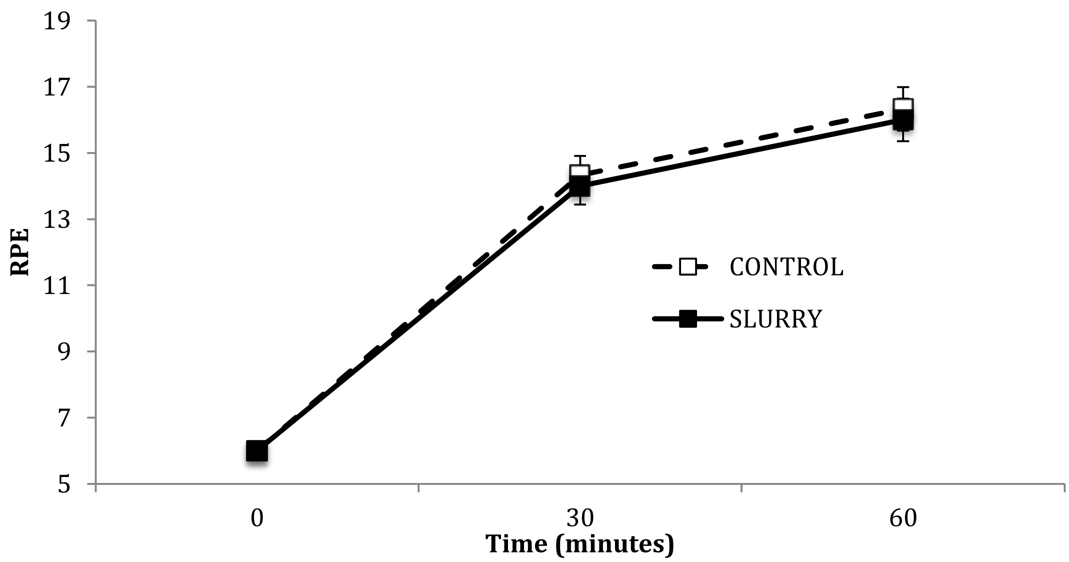

Figure 7. RPE throughout the running indoors in the heat for IS and CNT drink, expressed as mean ± SEM.   P = 0.58 for the interaction of time and treatment.

Indoor T_{sk} had no significant differences for main effect of time, treatment, and the interaction of time and treatment.

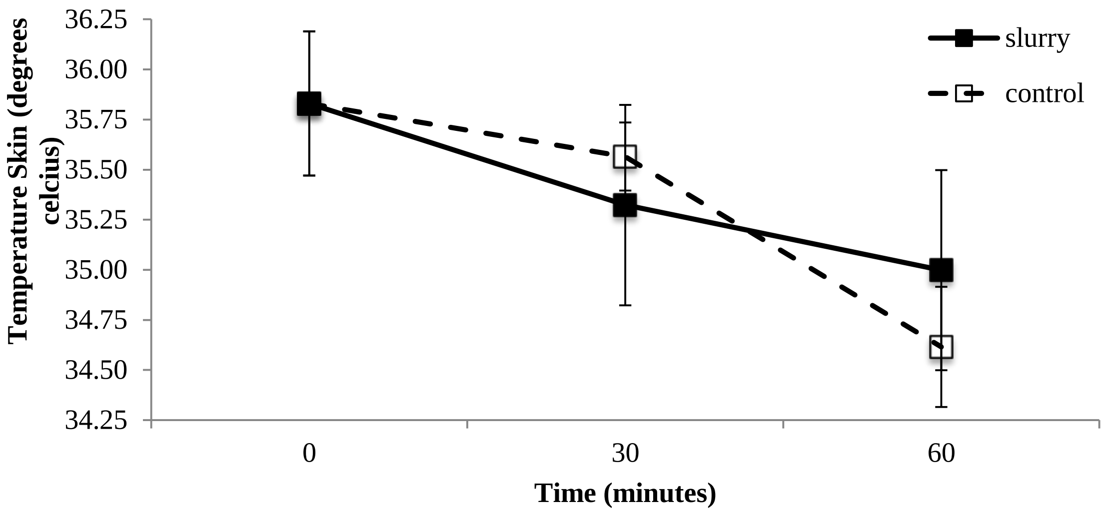

Figure 8. Skin Temperature during 60 minutes of running indoors in the heat for IS and CNT drink, expressed as mean $\pm$ SEM. P = 0.43 for the interaction of time and treatment

T_c for the indoor trials did not reach significant differences for main effect of time, treatment, and the interaction of time and treatment (P>0.05).

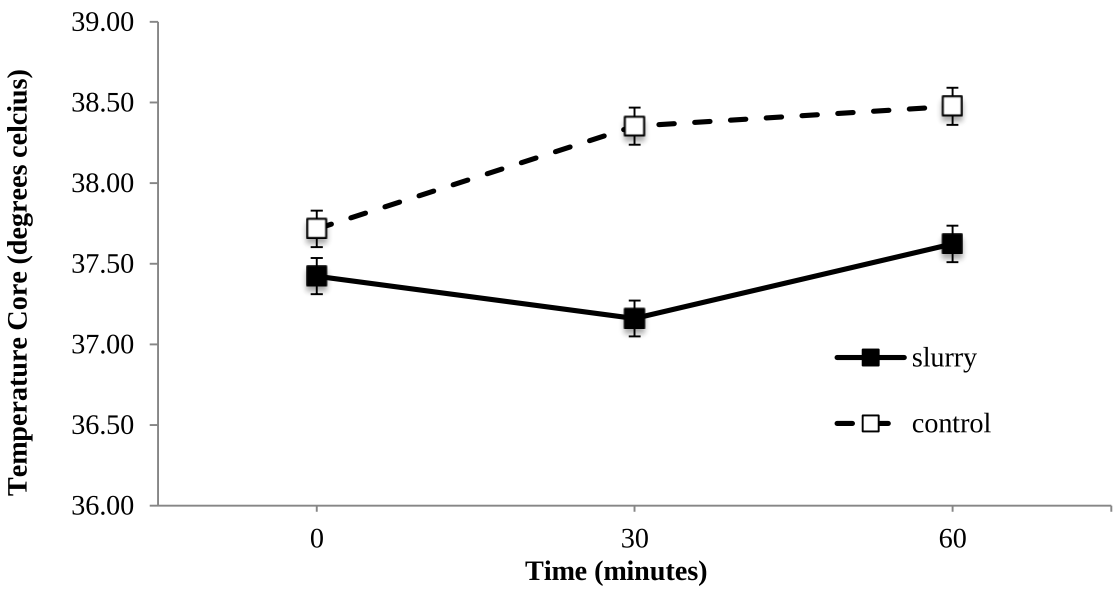

Figure 9. Core Temperature during 60 minutes of running indoors in the heat for IS and CNT drink, expressed as mean $\pm$ SEM. P = 0.51 for the interaction of time and treatment

Indoor HR had a significant difference in the main effect of time as expected from the onset of exercise combined with cardiac drift. Although it did not reach significance it is interesting to note the marked 20 beats per minute separation of HR at the end of the trial, as the IS appears to reduce the amount of cardiac drift in the later stages of the running trial.

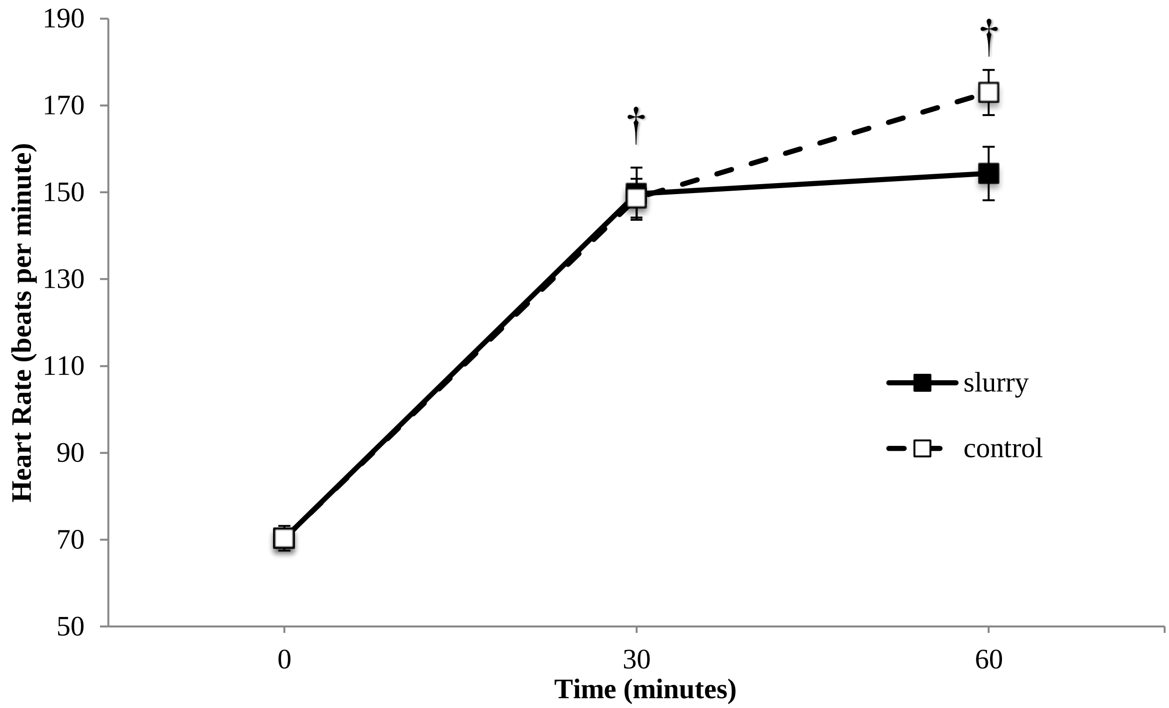

Figure 10. Heart Rate during 60 minutes of running indoors in the heat for IS and CNT drink, expressed as mean ± SEM. † P = 0.03 as a main effect of time.

PSI had a significant main effect of treatment, but no significant differences in the main effect of time and the interaction of time and treatment.

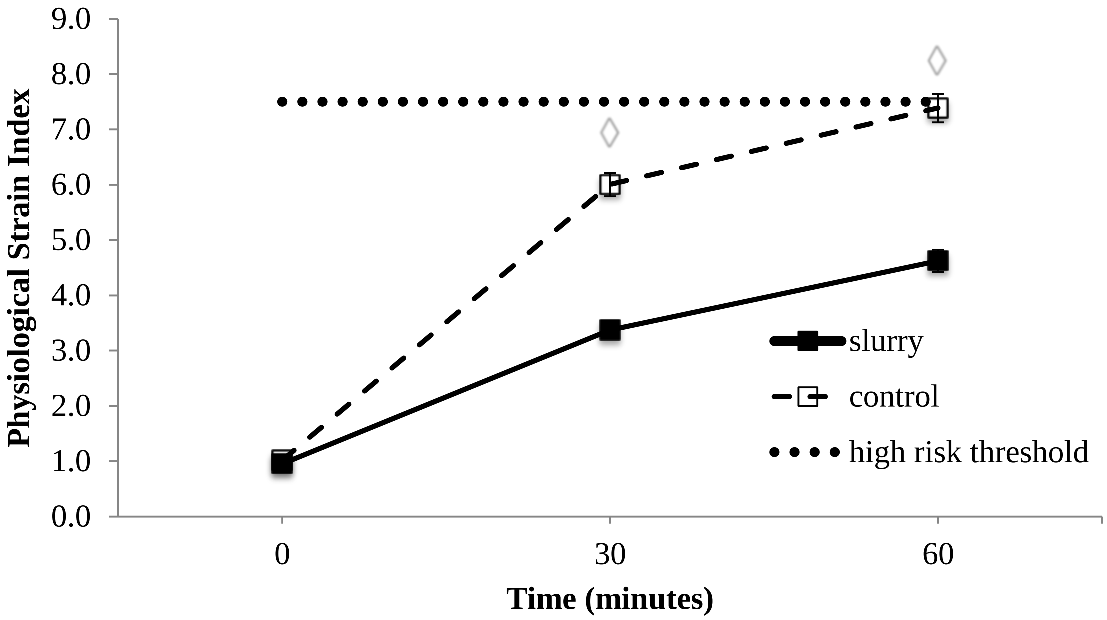

Figure 11. Physiological Strain during 60 minutes of running indoors in the heat for IS and CNT drink, expressed as mean ± SEM. ◊ P = 0.01 for the main effect of treatment

Subjects were able to go significantly longer when IS was given as the treatment during the time trial following the 60 minutes at steady state.

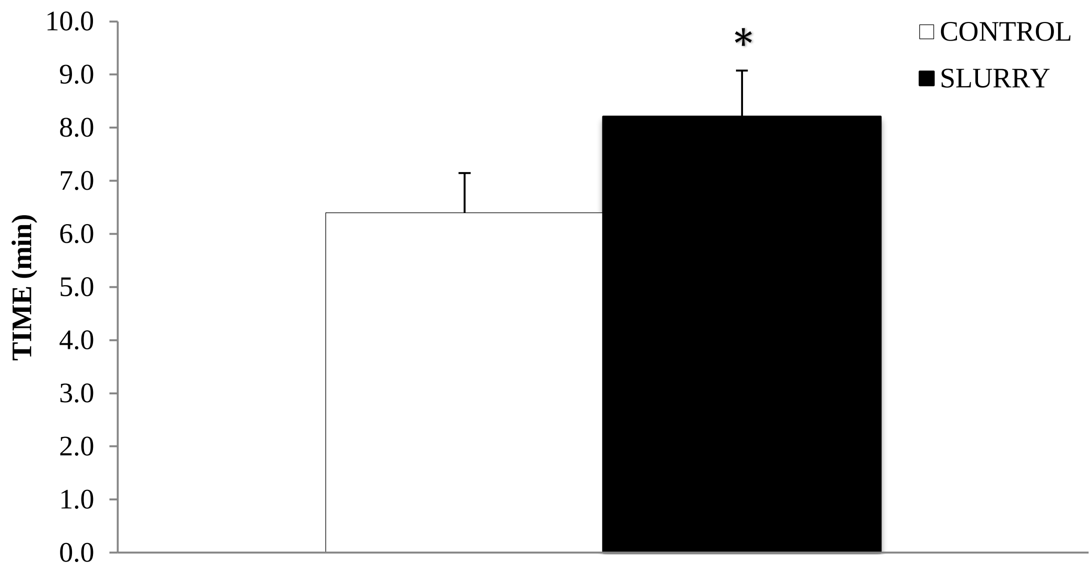

Figure 12. Performance trial finish time for running indoors in the heat for IS and CNT drink, expressed as mean ± SEM. * P = 0.01, 2 Tailed T-Test

Chapter Five: Discussion

This paper addresses the void in the literature by delivering IS during submaximal running in the heat. As far as we know providing IS during running in the field has not been used thus far. Typically, IS has been given either as a pre-coolant prior to a maximal effort (time trial) event or during a far less demanding aerobic bout (walking). Adding the elements of running and during exercise drink delivery in the field posed new challenges that had not yet been addressed by previous studies.

The intent of this study was to explore the effects of IS on the reduction of PSI during submaximal exercise in the heat. We found that the provision of IS attenuated the rise in PSI during the outdoor running trials. Indoor runners did not have an attenuation of PSI when given IS but indoor runners did have a significantly prolonged time trial to exhaustion when given IS.

PSI is a combination of biological feedback (T_c and HR) that allows us to interpret and predict the potential for heat injury. A PSI score greater than 7 puts you at high risk for a heat related event.

Kaufman et al. reported significantly lower PSI scores (11.5 vs. 10.0 $P<0.05$ @ 90 minutes) when giving 2.5 $g*kg^{-1}$ of IS every 10 minutes, however there was discomfort expressed by the subjects at this dose (brain freeze) (Kaufman et al. 2012). Discomfort was successfully avoided during both indoor and outdoor trials in the current study by only giving the participants 2 $g*kg^{-1}$. Participants mentioned that the first couple feedings were large and uncomfortable, however, in the later stages of all trials, participants mentioned that the feedings were either appropriate or insufficient.

The reduction in volume consumed by the participants as compared to Kaufman's trials, may explain the muted effects that IS had on T_c, T_{sk}, HR, and sweat rate. As Kaufman was able

to show significant differences in the interaction of time and treatment between similar parameters compared to room temperature drink and we were not able to achieve those results. This inability to show significance could be attributed to shorter trial times, lower environmental temperatures for both outside and inside trials, and limited number of participants due to issues that will be discussed later. Nonetheless, together with the Kaufman study, our data support the ability of IS to lower PSI when exercising in the heat. This may be important for the attenuation of heat stress in both athletes and workers with occupational hazards.

Stevens et al. used IS during a simulated Olympic length triathlon where the swim and cycle portions of the triathlon were kept to a low-moderate intensity, leaving only the run portion as the measured performance (Stevens, Dascombe, Boyko, Sculley, & Callister, 2013). Participants were given 10 $g*kg^{-1}$ of IS ($-1^{\circ}C$) or room temperature fluid (32°-$34^{\circ}C$) to drink freely between the 17th and 45th minute of the cycle portion of the trial. Researchers observed statistical significance in lower T_c, increased VO_2 in the last half kilometer of running, and decrease in 10k completion time when IS was given. These findings are supported by the improved indoor time trial prior to volitional fatigue in the current study.

Yeo et al. used IS as a pre-cooling drink (Yeo et al., 2012) and found that maximal voluntary aerobic performance improved ($0.6 \pm 1.6\%$). Participants ingested $8g*kg^{-1}$ 30 minutes prior to running a 10k foot race in the heat ($28.2 \pm 0.8^{\circ}C$). This bolus dose lowered T_c by $0.5^{\circ}C$ compared to $0.1^{\circ}C$ when given an ambient drink before the trial but T_c was significantly higher at the end of the race in the IS trial. Together with the data from the current study, IS appears to elevate exercise performance in the heat whether provided during or as a precooling treatment.

Siegel et al. also used IS as a pre-coolant (Siegel et al., 2011). After participants reached volitional aerobic fatigue in a hot environment ($34^{\circ}C$), the researchers allowed the participants to

rest in a thermo-neutral environment (24°C), and gave them a small IS bolus of 1.25g*kg^{-1} prior to measuring maximal voluntary isometric contraction of the arm (MVC). IS group had a significantly higher MVC when compared to the CNT group, however, T_c, T_{sk}, HR and running to fatigue times at 1st ventilatory threshold in the heat (34.1 ± 0.1°C, 37.2 ± 4.5% RH) did not differ.

Outdoor trials in our study proved to be difficult due to the variability in day-to-day weather patterns. With better preparation and insight of the cumbersome nature of field research, we would have faired better by doing the trials during the month of July, which is hotter and generally has a more homogeneous weather pattern. Because of this, not all of the 12 participants that volunteered were able to complete both CNT and IS trials; the weather cooled off significantly on the 3rd week of trials and warmer temperatures did not return. This change in weather reduced the outside participant numbers from 12 to only 6 that completed both control and intervention trials.

The loss of subjects compounded problems as it limited the degrees of freedom in which we were able to use, thus limiting the repeated measures ANOVAs, thus limited to 2x3s instead of the originally desired 2x7s. Although we were able to run a 2x6 ANOVA for the outside group, the largest ANOVA we were able to compute for the inside was 2x3 due to the degrees of freedom restricted from an N = 3. Because of this, we chose to report the outside ANOVAs as 2x3s, to maintain continuity. Appendixes A, B, and C report the ANOVAs and T-Tests in P-Values that were calculated for both outdoor and indoor trials.

The asymmetric airflow that the environmental chamber has is not congruent with the treadmill speeds, therefore, to best mimic a natural running environment (air flow across the chest aiding evaporative cooling) a large fan with terrabands taped to the back grate limiting the

amount of air being allowed through was fashioned and altered throughout the indoor running trials in an attempt to match treadmill speeds and mimic outdoor evaporative cooling. We achieved some success while using this fan gating technique, however, the sporadic nature of the wind speeds produced by the environmental chamber either added to or detracted from the gated fan speed. We were able to keep wind speeds ranging from 5.8 to 8.0 mph with an average of 0.9 mph over the average running speed of 6 mph.

Researching the caloric demand to turn the semi solid IS into a liquid and raising 0°C liquid to body temp liquid; Weast (1981) states that it takes 334Kj of energy per Kg of ice for it to melt in water and there's a 1 calorie per gram per degree cost to raise water temperature ($1kcal*kg^{-1}*°C$). The average IS consumption was 1008 grams per trial, this leads us to a total energy demand of approximately 117 Kcals over the 60 minute running trial.

Schlader et al. (2010), described that thermal comfort/sensation interaction on self-regulation of exercise pace and reductions in work-rate. This research did not directly investigate thermal sensation, however, all participants clearly expressed feeling more comfortable and enjoying IS consumption over CNT. This suggests that by administering IS, thermal discomfort could have been depressed which allowed the longer TT times and greater performance.

Practical Applications:

Together with previously published studies on the effects of IS, it appears that IS can reduce PSI and improve aerobic performance. It may be beneficial to carry IS in place of an ambient temperature drink while exercising in hot environments whenever possible.

Carrying IS can be done easily as there are several commercially available insulated liquid carriers that will keep the IS in its semi-frozen state for prolonged periods of time.

Furthermore, the use of IS during athletic events in the heat could be easily implemented in place of the cold drinks that are typically served and potentially elicit an ergogenic effect for participants.

For recreational athletes who want to exercise in the heat and achieve whatever goal they may have, the use of IS can decrease the likelihood of a heat related injury. This protection allows the athletes to stay out in the heat longer at the desired intensity, making those hot training days more effective.

Conclusion:

This study has shown that IS consumption in steady intervals during submaximal running in the heat can have a significant effect on PSI, and aerobic performance. In conclusion, drinking IS periodically while exercising in the heat can reduce the potential for a heat injury by reducing PSI, and improving aerobic performance during the later stages of events in the heat.

Appendixes:

Appendix A

Informed Consent Form

Montana Center for Work Physiology and Exercise Metabolism

SUBJECT INFORMATION AND CONSENT FORM

PROJECT IN BRIEF: The effects of ice slurry ingestion and discontinuous work intervals during exercise in the heat

RESEARCHERS: Dr. Charles Dumke, PhD 406-243-6176
Dr. Brent Ruby, PhD
Timothy Hampton
Felipe von Sydow

The University of Montana
32 Campus Drive
McGill Hall – HHP
Missoula, MT 59812
(406) 243 – 6176 (Dr. Charles Dumke, PhD)

Please read the following information carefully and feel free to ask questions. Only sign the final page when you are satisfied procedures and risks have been sufficiently explained to you.

REQUIREMENTS

This research study requires that you meet the following criteria:

- Participants must be males between the ages of 18 and 40 with a VO_2 max $\geq$50 ml*kg^{-1}*min^{-1} and $\leq$ 60ml*kg^{-1}*min^{-1}.

PURPOSE OF THE STUDY

The purpose of this study is to determine the effects of ice slurry ingestion and discontinuous work/rest cycles during exercise on core temperature and performance in the heat.

TEST PROCEDURES

4 VISITS TO THE LABORATORY WILL BE REQUIRED (6 HOURS), AS SUMMARIZED BELOW

PRE TESTING (Visit 1)

1. A pre-screening assessment which involves a health/exercise questionnaire (Par-Q)

a. Prior to any testing, you will complete a physical activity readiness questionnaire (PAR-Q) to screen for known risk factors of coronary heart disease.
b. If you successfully complete the PAR-Q, you will then provide written informed consent following the reading of this document.

2. A measure of percent body fat obtained using underwater weighing
    a. This test session will require that you do not eat for a minimum of 3 hours prior to the testing. Prior to the test, body weight will be recorded in your bathing suit. You will then be asked to complete between 3 – 6 underwater weighing procedures. The underwater weight requires that you are submersed in our weighing tank (similar to a hot tub) and that you maximally exhale as much air as possible while underwater. The underwater weight will be recorded within 2-4 seconds and then you will be signaled to surface. This procedure will be repeated until three measurements have been obtained that are within 100 grams of each other. A nose clip will be provided upon request. This test will take approximately 20 minutes.
3. A maximal treadmill ergometer test to measure aerobic fitness
    a. This test will consist of walking or running on a laboratory treadmill to volitional fatigue. The workload of the treadmill will increase every three minutes and will progress to fatigue. You will be encouraged to continue until volitional fatigue, the point at which you can no longer continue running. During this test you will wear a nose clip and headgear that will support a mouthpiece. This will allow us to measure the amount of oxygen that the body uses during this exercise so we can determine the appropriate exercise intensities for your experimental trial runs. Heart rate will be measured using an elastic chest strap that is worn on the skin under your shirt around your chest. This test will take approximately 30 minutes. You will be asked to fast for approximately 3 hours prior to this test.

EXPERIMENTAL TRIALS (Visits 2-4)

Experimental Protocol

You will run for 60 minutes at between 65% and 75% VO_2 max at the Riverbowl Track John Toole Park (Missoula, MT) in either a discontinuous protocol with ambient carbohydrate drink, carbohydrate drink ice slurry or ambient carbohydrate drink (order will be randomized):

1. Discontinuous Exercise with Ambient Carbohydrate Drink
2. Continuous Exercise with Ice Slurry Carbohydrate Drink
3. Continuous Exercise with Ambient Carbohydrate Drink

Exercise trials

a. The participant will exercise (run on the outside track) for 60 minutes between 65-75% of VO_2 peak exercise intensity that the participant achieved during the maximal exercise test in WPEM or HPL. During the 60 minute run exercise sessions the participant will consume about 0.8 – 1.5 liters of fluid (depending on body weight) that consists of ambient carbohydrate drink (about 20 degrees Celsius), or frozen carbohydrate ice slurry (about -1 degrees Celsius). During the work rest cycle trial participants will be given ambient carbohydrate drink. The order of trials will be randomized.

b. Prior to each trial, the participant will insert a rectal thermometer pill in privacy behind a locked room so that participant's core body temperature can be monitored throughout the exercise period.
c. Heart rate will be monitored through an elastic chest strap that's worn on the skin around the chest. Participant's heart rate will be monitored throughout the exercise period.
d. A skin temperature monitor will be attached to the heart rate monitor strap and placed on the participant's chest just below the pectoral muscle. Participant's skin temperature will be monitored throughout the exercise period.
e. Body weight will be taken before and after each exercise session. Body weight will be measured in privacy on a calibrated scale.
f. Urine samples will be collected before and after each trial to ensure participants are euhydrated before the trial and how that has changed after completing the trial.

2. The day(s) prior to all exercise sessions, the participant are required to do the following:
   a. No cardiovascular exercise (running, swimming, cycling, etc.) is permitted the day before an exercise trial. If the participant regularly lift weights the participant are permitted to do so but the participant cannot lift for legs; all lifting must be for upper body only in the 24 hours beforehand.
   b. The participant will be required to log physical activity 2 days prior to participant's first exercise trial. The participant activity logged will be repeated two days in advance of participant's second and third exercise trial
   c. The participant will be required to keep a dietary log for the day prior to the exercise session. For the second and third trial, the participant will be asked to consume the same foods and quantity of those foods that the participant did for the first trial.
   d. The participant will be asked to begin the trials having completed at least a 3 hour fast. During the 3 hours preceding the trials the participant are permitted ONLY water. No other food or beverage is allowed during the 3 hours leading up to participant's exercise trial.
   e. NO ALCOHOL CONSUMPTION the day before the testing period. Alcohol is a diuretic and compromises hydration status, its use must not occur before the exercise trials.

RISKS AND DISCOMFORTS

1. In some participants the ingestion of frozen ice slurry may cause the common "brain freeze" and some discomfort, which should go away after a few moments of ingestion.
2. Mild discomfort may result during and after the exercise. These discomforts include shortness of breath, tired or sore legs, nausea and possibility of vomiting.
3. Exercising outdoors in the heat and exposed to the sun will result in profuse sweating and the perception of feeling very hot. Adverse reactions to heat stress can include heat exhaustion, heat stroke, and heat syncope. However, core body temperature will be monitored during every testing session; if body temperature goes above 41°C, the exercise test will be terminated. Fluids and shade will be provided to the participant as well to mitigate these

risks. If the participant feels too hot to continue exercise, the test will be terminated and the participant will be removed from the heat and relocated to the shade.

4. Muscle soreness after the tests may occur as a result of the exercise, but should not persist.
5. Certain changes in body function take place when any person exercises. Some of these changes are normal and others are abnormal. Abnormal changes may occur in blood pressures, heart rate, heart rhythm or extreme shortness of breath. Very rare instances of heart attack have occurred. Every effort will be made to minimize possible problems by the preliminary evaluation and constant surveillance during testing. The laboratory has standard emergency procedures should any potential problems arise.
6. Mild symptoms of dehydration such as headache and general fatigue may result during and after the exercise. To minimize the risk of excessive dehydration, participant's body temperature will be monitored continuously during exercise. If core temperature goes above 41°C, the exercise test will be terminated.
7. The participant will be informed of any new findings that may affect participant's decision to remain in the study.
8. During any of the exercise tests should symptoms, such as chest discomfort, unusual shortness of breath or other abnormal findings develop, the exercise physiologist conducting the research will terminate the test. Guidelines by the American College of Sports Medicine will be followed to determine when a test should be stopped. These symptoms include moderate to severe angina (chest pain), increased dizziness, shortness of breath, fatigue and participant's desire to stop.

PAYMENT FOR PARTICIPATION

There will be no compensation for participation in this study.

BENEFITS OF PARTICIPATION

1. The information from these tests will provide you with an accurate assessment of your aerobic fitness and body composition that can be compared with norms for your age and sport but may be of little benefit to your understanding of your personal fitness. There are no other direct benefits to the participants in the study.
2. There is no promise that you will receive any benefit as a result of taking part in this study.

CONFIDENTIALITY

1. Your records will be kept private and not be released without consent except as required by law.
2. Your identity will be kept confidential.
3. If the results of this study are written in a scientific journal or presented at a scientific meeting, names will not be used.
4. All data, identified only by an ID #, will be stored in our laboratory.
5. The signed consent form and information sheet will be stored in a locked cabinet separate from the data.

COMPENSATION FOR INJURY

Although we believe that the risk of taking part in this study is minimal, the following liability statement is required in all University of Montana consent forms: In the event that you are injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of the University of Montana or any of its employees, you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title 2, Chapter 9. In the event of a claim for such injury, further information may be obtained from the University's Risk Manager or Office of Legal Counsel. (Reviewed by University Legal Counsel, March 23, 2012)

VOLUNTARY PARTICIPATION AND WITHDRAWAL

It is important that you realize that you are free to withdraw from the study at any time. A copy of this consent form will be provided for you at your request. In addition, the data collected during this study will be done at no cost to you.

QUESTIONS

You may wish to discuss this with others before you agree to take part in this study. If you have any questions about the research now or during the study contact Dr. Charles Dumke, PhD at (406) 243-6176 (office), or Charles.dumke@umontana.edu. If you have any questions regarding your rights as a subject, you may contact the chair of the IRB through the University of Montana Research Office at (406) 243-6670.

STATEMENT OF CONSENT

I have read the above statements and understand the risks involved with this study. I authorize Dr. Charles Dumke, PhD and such assistants that he may designate, to administer and conduct the testing as safely as possible with a minimal amount of discomfort. If I have additional questions, I may contact Dr. Charles Dumke, PhD at (406) 243-6176 or by email at Charles.Dumke@mso.umt.edu

Participant (print) ____________________________________

Signature ____________________________________

Date ____________________________________

Disclosure of Personal Health Information
My individual health information that may be used to conduct this research includes:

Age, height, weight, %body fat, VO_2 *max.*

I authorize *Dr. Charles Dumke, PhD* and the researcher's staff to use my individual health information for the purpose of conducting the research project entitled "The effects of ice slurry ingestion and discontinuous work intervals during exercise in the heat".

Signature ________________________________
Date _____________

Statement of consent to be photographed during data collection

During the study, I understand that pictures may be taken. I provide my consent to having my picture taken during the course of the research study. I provide my consent that my picture may be used in some presentations related to this study. If pictures are used at any time for presentation, names and physiological data will not be associated with them.

Signature ____

Date ____________________________

Appendix B
PAR-Q

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

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

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ____________________

SIGNATURE OF PARENT ____ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...

TABLES

Table 1 – Outside ANOVA
Values reported as P-Values.

OUTSIDE	2X2			2X3		
	TIME	TRMT	TIME*TRMT	TIME	TRMT	TIME*TRMT
T_c	0.000	0.625	0.664	0.000	0.890	0.561
HR	0.000	0.404	0.309	0.000	0.373	0.630
PSI	0.000	0.001	0.062	0.000	0.000	0.008
T_{sk}	0.036	0.621	0.621	0.103	0.932	0.552
	2X4			2X5		
	TIME	TRMT	TIME*TRMT	TIME	TRMT	TIME*TRMT
T_c	0.002	0.732	0.490	0.016	0.012	0.079
HR	0.005	0.028	0.123	0.007	0.296	0.087
PSI	0.003	0.000	0.254	0.001	0.032	0.046
T_{sk}	0.235	0.840	0.813	0.008	0.939	0.728
	2X6			2X7		
	TIME	TRMT	TIME*TRMT	TIME	TRMT	TIME*TRMT
T_c	0.082	0.640	0.598	.	0.968	.
HR	0.111	0.003	0.248	.	0.000	.
PSI	0.000	0.055	0.077	.	0.955	.
T_{sk}	0.813	0.018	0.313	.	0.012	.

Table 2 – Inside ANOVA
Numbers reported as P-Values.

INSIDE	2X2			2X3		
	TIME	TRMT	TIME*TRMT	TIME	TRMT	TIME*TRMT
T_c	0.017	0.519	0.916	0.154	0.743	0.513
HR	0.002	0.404	0.157	0.032	0.474	0.509
PSI	0.010	0.087	0.073	0.133	0.012	0.35
T_{sk}	0.879	0.035	0.112	0.341	0.155	0.434
RPE	0.006	0.184	0.184	0.106	0.423	0.577
	2X4			2X5		
	TIME	TRMT	TIME*TRMT	TIME	TRMT	TIME*TRMT
T_c	.	0.74	.	.	0.004	.
HR	.	0.341	.	.	0.429	.
PSI	.	0.061	.	.	0.003	.
T_{sk}	.	0.372	.	.	0.514	.
RPE	.	1.000	.	.	0.508	.
	2X6			2X7		
	TIME	TRMT	TIME*TRMT	TIME	TRMT	TIME*TRMT
T_c	.	0.005	.	.	0.776	.
HR	.	0.225	.	.	0.338	.
PSI	.	0.002	.	.	0.005	.
T_{sk}	.	0.000	.	.	0.103	.
RPE	.	0.423	.	.	0.423	.

Table 3 – Inside T - Test
Numbers reported as P-Values.

MEASURE	TTEST
Time Trial	0.01

Table 4 – Outside Weather Data
Numbers reported as trial and total averages

OUTDOOR TRIAL	TEMP (C)	HUMIDITY (%)	WIND (mph)
1	32	28	0
2	30.6	26.1	3
3	29.9	22.4	0
AVERAGES	30.8	25.5	1.0

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