THE EFFECT OF DIFFERING VOLUMES OF ICE SLURRY INGESTION DURING EXERCISE IN THE HEAT

Kyle R. Cochrane
University of Montana

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THE EFFECT OF DIFFERING VOLUMES OF ICE SLURRY INGESTION DURING EXERCISE IN THE HEAT

By

KYLE RYAN COCHRANE

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Approved by:

Sandy Ross, Dean of the Graduate School
Graduate School

Brent Ruby, Ph.D., FACSM, Chair
Health and Human Performance

Charles Dumke, Ph.D., FACSM
Health and Human Performance

Stephen Lodmell, Ph.D.
Division of Biological Sciences
The Effect of Differing Volumes of Ice Slurry Ingestion During Exercise in the Heat

Chairperson: Brent Ruby, Ph.D., FASCM

**Purpose:** To determine the effects of full volume (2 g/kg) and half volume (1 g/kg) ice slurry ingestion during exercise in the heat on thermoregulatory responses. **Methods:** Twelve males ingested two volumes of ice slurry (FULL, 2 g/kg, 0.7 ± 0.2°C; HALF, 1 g/kg, 0.7 ± 0.2°C) or room temperature water (RT, 2 g/kg, 36.4 ± 0.2°C), while walking at 40% VO$_{2}$peak for 180 minutes in a hot environment (35.5 °C and 50% humidity). Core temperature (T$_{C}$), skin temperature (T$_{sk}$), heart rate (HR), physiological strain index (PSI), rating of perceived exertion (RPE), sweat rate and feeling of hotness by visual analog scale (VAS) were measured. **Results:** No difference in T$_{C}$ at termination of exercise between FULL (38.4 ± 0.5 °C), HALF (38.8 ± 0.7 °C) or RT (38.8 ± 0.7 °C). T$_{sk}$ was lower in FULL (36.4 ± 0.7 °C) at minute 170 compared to HALF (36.8 ± 0.6 °C) and RT (36.8 ± 0.6 °C). HR was lower in FULL (142 ± 11 bpm) at minute 170 compared to HALF (157 ± 19 bpm) and RT (154 ± 18 bpm). PSI was lower in FULL (5.9 ± 1.7) at minute 170 compared to HALF (7.4 ± 2.5) and RT (7.5 ± 2.3). RPE was lower in FULL (14.0 ± 1.6) at minute 170 compared to HALF (15.3 ± 1.8) and RT (15.0 ± 1.8). VAS was lower in FULL (62.3 ± 19.4) compared to RT (74.5 ± 15.4) but did not differ from HALF (72.7 ± 12.5). **Conclusion:** At the termination of exercise, PSI was lower in FULL compared to RT, however there was no difference between HALF and RT. This suggests that the temperature and form of the fluid ingested play a larger role on physiological strain than does volume of fluid ingested.
Chapter 1: Introduction

Introduction

Militaries attempting to mitigate heat related injuries go as far back as 24 B.C. when Roman soldiers drank, and rubbed a mixture of olive oil and wine on their bodies to quell the effects of the extreme Egyptian environment ("A roman experience with heat stroke in 24 B.C," 1967). Today soldiers, wild-land firefighters, and recreationally active individuals all face the challenge of thermoregulation in hot environments. The term heat related illness (HRI) encompasses exertional heat-related injuries ranging in severity from heat cramps, to heat exhaustion to the most severe, heat stroke (Becker & Stewart, 2011). In 2014, there were 344 cases of heat stroke and 1,683 cases of “other heat injury” in the US military (HRI requiring hospitalization)("Update: heat injuries, active component, U.S. Armed Forces, 2014," 2015). In an attempt to mitigate the risk of HRI adequate hydration has been suggested. The American College of Sports Medicine (ACSM) recommends drinking to match sweat rates, with the aim of avoiding a greater than 2% loss of body weight during exercise in the heat (M. N. Sawka et al., 2007). Hydration recommendations established by the U.S. military call for drinking 0.5 L/hour when performing easy work in a “Green” WBGT index (78-81.9 °F) and nearly 1 L/hour when performing either hard work or when in a “Black” WBGT index (>90°F). These recommendations aim to decrease the incidences of HRIs by attenuating heat strain stemming from physical activity in a hot environment. However, along with drinking recommendations, work rest ratios have been established for WBGT indexes, 50/10 minutes of work/rest during moderate work under Green flag conditions and only 20/40 minutes of work/rest during moderate work under Black flag conditions (Table 1) (Kolka, Latzka, Montain, & Sawka, 2003)
As a result of metabolic heat produced from contracting skeletal muscle, peripheral vasodilation and skin blood flow increases. Blood flow to the skin dissipates metabolic heat by cooling through evaporative and non-evaporative mechanisms (Becker & Stewart, 2011). These mechanisms aim to maintain eutherma in the body. The gradient between core temperature and skin temperature is an important factor for thermoregulation (Cuddy & Ruby, 2011). This gradient narrows due in part to increases in work intensity, increases in skin temperature and higher ambient temperatures, causing an inability to dissipate metabolic heat as effectively (Michael N. Sawka & Young, 2006). When metabolic heat production exceeds the rate of dissipation, the body is in danger of cellular pathophysiology. Hyperthermic tissue risks cellular damage due to degradation of the cell membrane (Armstrong et al., 2007). For instance, gut cell membrane breakdown can lead to endotoxic shock caused by lipopolysaccharide fragments from intestinal bacteria entering systemic circulation (Hubbard, Matthew, Durkot, & Francesconi, 1987).

Body core temperatures greater than 39°C have been associated with fatigue in individuals exerting themselves in hot environments (Ely et al., 2009). Exceeding 39°C puts an individual at greater risk of succumbing to an HRI (Armstrong et al., 2007). Various techniques exist in hastening this precipice to hyperthermia, which may result in HRI. Pre-cooling with cold-water immersion, ice vests or ice slurry ingestion have all been shown to improve endurance in hot environments (Jones, Barton, Morrissey, Maffulli, & Hemmings, 2012). For military populations, the use of cooling techniques to hasten increases in core temperature and increase time to fatigue have the additional caveat that they must be practical in a field setting. Because of this challenge, the simplicity of ice slurry is an attractive choice.

Kay and Marino suggested that the mechanism by which fluid ingestion improves performance in the heat is due in part to the improved heat storage capacity (Kay & Marino, 2000). This suggests that the lower the drink temperature, the higher the heat capacity. Previous work in this laboratory
(unpublished thesis work) has shown that frequent ingestion of either an ice slurry or cold liquid reduced physiological strain during 90 minutes of exercise in a hot environment. Subjects drank 2.5 g•kg\(^{-1}\) every 10 minutes of a carbohydrate drink at either room temperature (21.5 ± 1.0 °C), cold (-0.7 ± 0.2 °C) or as an ice slurry (-1.4 ± 0.2 °C), while walking at 50% VO\(_2\) peak. At minutes 30, 60 and upon termination of exercise, cold and ice slurry trials were both significantly lower than the room temperature trials. Similarly, physiological strain index (PSI) followed the same trend with cold and ice slurry trials being significantly lower than the room temperature trial after 30 minutes of exercise. These data demonstrate the effectiveness of a heat sink. When given similar volumes, a cold drink or ice slurry is more effective at attenuating heat strain than room temperature water alone.

Findings by McConell et al. show that a greater volume of ingested drink during exercise in the heat improves performance (McConell, Burge, Skinner, & Hargreaves, 1997). This aligns with the mechanism associated with improving heat storage capacity via fluid ingestion as suggested by Kay and Marino (Kay & Marino, 2000). Ice slurry has been shown to be comparable to cold-water immersion as a method of pre-cooling for exercise in the heat (Kaufman, 2012; Siegel, Maté, Watson, Nosaka, & Laursen, 2012). When considering the effectiveness of ice slurry in attenuating heat strain, the volume of ingested fluid needed comes into question. Decreasing the temperature of an ingested fluid may generate enough of an improved heat storage capacity to justify a decrease in total volume of fluid ingested.

**Problem**

Past research in this laboratory demonstrated the use of ice slurry as an effective means of attenuating heat strain during exercise in the heat. However, a more thorough investigation as to the necessary volumes required to elicit this attenuation in heat strain is necessary.
Purpose

The purpose of this study is to examine the differing effects of full volume (2 g•kg⁻¹) and half volume (1 g•kg⁻¹) ice slurry ingestion compared to equal volume room temperature water (2 g•kg⁻¹) during exercise in the heat on thermoregulatory responses.

Null Hypotheses

Volume of ice slurry will have no effect on core temperature during exercise in a hot environment.

Volume of ice slurry will have no effect on skin temperature during exercise in a hot environment.

Volume of ice slurry will have no effect on heart rate during exercise in a hot environment.

Volume of ice slurry will have no effect on physiological strain index during exercise in a hot environment.

Volume of ice slurry will have no effect on RPE during exercise in a hot environment.

Significance of Study

This study will provide more insight into the practical applications of ice slurry as a means to mitigate heat stress during long-duration exercise in the heat. Most importantly though, the comparison of differing volumes of ice slurry will examine whether fluid volume or fluid temperature play a greater role in thermoregulation. This knowledge will better prepare individuals who perform strenuous work in hot environments in the ability to decrease the occurrence of heat injuries.
Limitations

1. Participants’ lifestyles cannot be controlled between trials. A dietary and activity log will be maintained and replicated prior to each trial as a means to establish a level of control over confounding variables.

2. Subjects will be recruited from a recreational active population. Subjects will be randomly ordered for trial exposure.

3. To limit the human error associated with data collection, all research personal will be similarly trained and the equipment being properly calibrated.

4. During the six-week data collection period the outside environmental conditions can vary drastically. This changing environment may influence heat acclimatization and alter core temperature.

Delimitations

1. Participants are required to be recreationally active males. Due to the menstrual cycle’s effects on thermoregulation, females will be excluded from this study.

Definition of Terms

-Physiological Strain Index (PSI): a measure of heat stress on the body. Will be calculated using recorded $T_c$ and HR using the equation developed by Buller et al. (Buller, Latzka, Yokota, Tharion, & Moran, 2008)

$$\text{PSI} = 5 \left( T_{c(0)} - T_{c(t)} \right) \left( 39.5 - T_{c(0)} \right)^{-1} + 5 \left( HRT - HR_{0} \right) \left( 180 - HR_{0} \right)^{-1}$$

-Sweat rate: sweat loss over time taking into account changes in pre and post nude body weights, urine output, fluid intake and respiratory water loss as calculated from Mitchell and colleagues (Mitchell, Nadel, & Stolwijk, 1972).
Sweat Loss (L) = (BW_{pre}(kg) + \text{ liquid Ingested (kg)}) – (BW_{post}(kg) + \text{ Urine Weight (kg)} + \text{ Respiratory Water Loss (kg)})

-Ice slurry: liquid mixture of ice and water.
Chapter 2: Review of Literature

Thermoregulation

Thermoregulation in the body consists of a give and take between metabolic heat production and the body’s ability to effectively dissipate excess heat into the environment. Two processes, behavioral changes and physiological responses dictate this give and take. Behavioral changes such as decreasing activity levels, type of clothing worn, motivation and choosing what type of environment activity takes place in are all under conscious control and are thus determined by the individual. Physiological responses are an unconscious response, and reflective of both the environment and individual’s level of training, these responses include sweating, metabolic heat production and heat dissipation via changes in blood flow (Kenefick, Cheuvront, & Sawka, 2007; Michael N. Sawka & Young, 2006). Working to maintain body temperature homeostasis is deemed heat exchange. During exercise, this exchange occurs between the surrounding environment and the combined non-evaporative and evaporative processes on the skin. Conduction, convection and radiation consist of non-evaporative processes, while the evaporative properties of the liquid to vapor phase change on the skin surface become critical in thermoregulation in hot environments. When exercising in temperatures that exceed skin temperature, the body becomes stressed to effectively maintain body temperature and rely solely on evaporative processes, and reductions in exercise performance may occur (Nielsen et al., 1993). An increase in core temperature due to metabolic heat production is reflective of exercise intensity. The surrounding environment (ambient temperature, humidity, fluid motion) alters skin temperature. In an attempt to rid the body of excess metabolic heat, blood is shunted to the skin to be cooled by evaporative processes. For effective cooling to occur, a gradient between skin and ambient environment (water vapor) must be present. The closer skin temperature is to the local environment, the lower the rate of evaporation is which translates to a decreased cooling
ability (González-Alonso et al., 1999; Kenefick et al., 2007; Romanovsky, 2014; Michael N. Sawka & Young, 2006)

**Heat-Related Illness**

Any form of physical activity in a hot environment challenges the body’s thermoregulatory system. When an individual’s thermoregulatory system becomes compromised and is unable to maintain a core temperature below 40°C, there becomes a salient risk of a heat-related illness (Becker & Stewart, 2011). Exertional heat illness becomes a dangerous threat for populations that are highly physically active in hot environments, such as military personal and wild-land fire fighters. Initially, exertional heat cramps and/or exertional heat exhaustion may occur if high intensity exercise is performed in a hot environment and adequate rest, hydration or acclimatization needs are not met. If not properly addressed, an individual may quickly degrade further and succumb to exertional heatstroke (EHS). EHS is categorized by a core body temperature greater than 40°C with central nervous impairments and possible organ failure (Armstrong et al., 2007).

**Cooling Methods**

Various modalities exist to mitigate heat stress and increase performance. Cooling garments, cold-water immersion and cold drink ingestion are three commonly used methods, each with varying effectiveness and practicality (Arngrímsson, Petitt, Stueck, Jorgensen, & Cureton, 2004; Cotter, Sleivert, Roberts, & Febbraio, 2001; Lee, Maughan, & Shirreffs, 2008; Marino & Booth, 1998; Siegel & Laursen, 2012; Tyler, Sunderland, & Cheung, 2015). Marino and Booth conducted a study in which competitive runners underwent a 60-minute cold-water (23-24°C) immersion immediately followed by a 30-minute time trial on a treadmill. The researchers observed that in the 30-minute time trial, running distance was improved by 304 ± 166m in the pre-cooled group. The authors suggest the cold-water immersion was modest enough to avoid eliciting negative physiological
responses which may be deleterious to time trial performance. This, combined with reduced body heat content resulted in greater heat storage, which the authors suggest aided in avoiding a critical core temperature and mitigating performance (Marino & Booth, 1998). In a similar study, Yeargin et al. looked at the effects of cold or ice water immersion between two bouts of exercise. Participants first completed a distance run at a “challenging, yet comfortable pace” which averaged 11.6 ± 0.3 miles of hilly terrain in a hot environment (27°C). The subject then completed 12-minutes of shoulder to upper leg immersion in cold-water (13.98 ± 0.31°C), ice water (5.23 ± 0.21°C) or mock treatment (29.50 ± 0.72°C, air temperature). Once completed, the subjects towed off, were allowed to briefly stretch then completed a two-mile time trial. Both ice water (37.14 ± 0.15°C) and cold-water (37.39 ± 0.2°C) immersion resulted in significantly lower rectal temperatures than the mock trial (37.82 ± 0.14°C). Interestingly, cold-water immersion was the only treatment that had significantly faster times in the time trial compared with the mock trial. The ice water treatment did have improved time trial performance, although not significant. The subjects reported being “cold and stiff” following the ice water treatment, the authors suggest this hindered performance (Yeargin et al., 2006).

As a means to facilitate precooling, a cooling vest worn during active warm-ups was examined by Arngrímsson et al.. Participants wore a cooling vest or a regular t-shirt during active warm-ups prior to completing a 5-km run in a hot environment (32°C, 50% relative humidity). The authors observed a 0.21 ± 0.20°C lower core temperature in the cooling vest group compared to the t-shirt group at the start of the 5-km run. Core temperature remained significantly different between the two groups until the final time point of the 5-km run, although a difference was observed it was not deemed significant (p=0.073). Additionally, the rise in core temperature during the run was not different between trials. Most important to competitive runners, there was a significant difference in run performance between the vest and t-shirt trials. Overall, the cooling vest group decreased run time by
13 seconds. The authors noted that the observed improvements in performance occurred in the latter portion of the run (Arngrímsson et al., 2004).

**Ice Slurry**

In an attempt to mimic the beneficial effects of pre-cooling, but hoping to produce a more practical modality for field use, Siegel et al. compared an ice slurry drink to cold-water immersion. Three experimental trials had participants complete a 30-minute pre-exercise protocol of ingesting 7.5 g•kg⁻¹ of body weight ice slurry mixture (-1°C), cold-water immersion in a 24°C water tank (and 7.5 g•kg⁻¹ of body weight warm fluid, 37°C, for comparable hydration statuses) or ingesting 7.5 g•kg⁻¹ of body weight of warm fluid (37°C). Once the pre-exercise protocol was complete, participants ran to exhaustion at their first ventilatory threshold in a hot environment (34.0 ± 0.1°C, 52 ± 3% relative humidity). Running times were significantly longer for both cold-water immersion and ice slurry ingestion compared to control, 56.8 ± 5.6 min, 52.7 ± 8.4 min and 46.7 ± 7.2 min, respectively. At exhaustion, rectal temperatures of control and cold-water immersion were comparable (39.48 ± 0.36°C and 39.48 ± 0.34°C). The ice slurry trial resulted in a significantly higher rectal temperature (39.76 ± 0.36°C) versus control (p=0.042), and a higher, although not significant difference compared to ice water immersion (p=0.065). Ice slurry and cold-water immersion both had significantly lower mean ratings of perceived exertion (RPE) compared to control during exercise. The authors suggest that due to ice slurry ingestion possibly lowering brain temperatures or altering thermoreceptors, the participants may have perceived the exercise as easier, even though higher rectal temperatures were recorded (Siegel et al., 2012). Expanding on the practicality and effectiveness of ice slurry ingestion during exercise, others have shown improved performance in the heat in both cycling and Olympic distance triathlon (Lee, Shirreffs, & Maughan, 2008; Stevens, Dascombe, Boyko, Sculley, & Callister, 2013).
Fluid Volume

The American College of Sports Medicine’s (ACSM) position stand on hydration states that persons participating in physical activity should avoid dehydration as classified as greater than 2% body weight loss from water deficits (M. N. Sawka et al., 2007). Due to individual differences, type of physical activity and environment daily sweat losses can vary between 0.5 to 2.0 L•hour⁻¹; American football players for example have daily sweat rates of approximately 8.8 L•day⁻¹ (Godek, Bartolozzi, & Godek, 2005; M. N. Sawka et al., 2007). These differences make a blanket hydration recommendation difficult; instead, it is more practical for an individual to determine his or her own hydration recommendations. In an analysis by Noakes, a reasonable drinking suggestion for marathon running was to drink ad libitum, but no more than 400-800 mL•hour⁻¹ (with body size considered) (Noakes & IMMDA, 2003). To examine improper water ingestion during exercise, McConell and colleagues tested the effects of consuming a volume of water estimated to prevent body weight loss (2.32 ± 0.10 L), 50% of that volume (1.16 ± 0.05 L) or receiving no fluid replacement. The researchers had subjects complete the three trials in a 21 °C, 43% relative humidity environment while cycling at 69 ± 1% VO₂peak for two hours, followed by a ride to exhaustion at 90% VO₂peak. After the two hours of cycling, heart rate and rectal temperature were significantly lower in both the full replacement and half replacement than no fluid replacement. Additionally, full replacement was significantly lower than half replacement. The full replacement trial also resulted in a significantly longer ride to exhaustion compared to no fluid replacement trial; there were no differences between full and half replacement. The authors suggest that matching fluid intake to fluid loss during exercise will result in greater performance while reducing heat strain. Interestingly, the authors noted that some subjects had difficulty ingesting such a large volume of water. Additionally, the full replacement trial resulted in significantly decreased plasma sodium levels (136.6 ± 0.8 mmol/L) (McConell et al., 1997). While these levels of plasma sodium are above clinical levels (<
130 mmol/L), they add merit to the position that drinking to replace body weight loss increases the risk of exercise-associated hyponatremia (Montain, 2008; M. N. Sawka et al., 2007). This further supports the position that while exercising in the heat, it is best to drink to thirst and not exceed approximately 800 mL•hour\(^{-1}\).
Chapter 3: Methodology

Participants

Twelve males, between the ages of 18 and 40 were recruited from the University of Montana and local community to take part in the study. Subjects were required to pass a pre-screening Physical Activity Readiness-Questionnaire (PAR-Q) and possess a VO\textsubscript{2} peak of $\geq 40 \text{ ml•kg}^{-1}•\text{min}^{-1}$. Subjects were explained, in depth, the experimental protocol to include any risks associated with the study. Subjects signed an informed consent form, approved by the University of Montana Institutional Review Board. Preliminary testing was conducted at the Montana Center for Work Physiology and Exercise Metabolism (WPEM) located at the University of Montana.

Experimental Testing

Preliminary Testing

Physical Activity Readiness-Questionnaire (PAR-Q)

A PAR-Q was used to identify any subjects who may be at risk for complications stemming from coronary artery disease. Subjects not meeting the PAR-Q requirements were dropped from the study.

Hydrodensitometry

Body composition was assessed via an underwater weighing tank (Exertech, Dresbach, MN) utilizing estimated residual volume based on height and weight. Subjects were required to fast for > 3 hours prior to testing. Dry weight was determined with a scale (Befour Inc., Cedarburg, WI) and height was measured. While repeatedly submerged, subjects were weighed until a measure consistently within 100g was recorded. Body density and percent body fat were determined from the Siri equation (Siri, 1993).

Peak Aerobic Capacity (VO\textsubscript{2} peak)
Participants arrived at the lab fasted for \( \geq 3 \) hours prior to VO\(_2\) peak testing. A running VO\(_2\) peak test was performed on a treadmill ergometer (Fullvision, Inc., Newton, KS). Following a 5-minute warm-up, the Bruce Protocol was performed. This test was initiated at the first stage: 1.7 mph and a 10% grade for 3 minutes. After completion of the first stage the workload was raised to 1.11 m•sec\(^{-1}\) and 12% grade, 1.51 m•sec\(^{-1}\) and 14% grade, 1.87 m•sec\(^{-1}\) and 16% grade, and 2.23 m/sec and 18% grade, respectively. In order to measure VO\(_2\) peak, the participants’ expired gas was collected and analyzed every 15 seconds by a metabolic cart (Parvomedics, Inc., Sandy, UT). Heart rate was monitored and recorded using a heart rate watch and chest strap (Polar Electro, Kempele, FL). VO\(_2\) peak was considered to be met when one of following criteria was met: 1) there was a plateau in VO\(_2\) despite an increased workload; 2) Respiratory Exchange Ratio (RER) was greater than 1.10; 3) a heart rate within 10 beats of the participants’ predicted maximal heart rate was reached; and 4) volitional fatigue occurs in combination of a RPE > 17.

**Experimental Trials**

*Exercise Protocol*

The experimental trials consisted of three visits to the laboratory, with each visit separated by approximately 14 days. Participants arrived at the laboratory after completing at least an eight hour fast. Besides water, no additional food or beverages were allowed during the fast. Participants were asked to maintain a 24-hour dietary log prior to their first trial, and replicate this for the subsequent trials. Additionally, subjects maintained a physical activity log for 48 hours prior to their first trial and replicated this for the additional trials, with no exercise the 24 hours prior to a trial.

Upon arrival to the laboratory for experimental trials, subjects were asked to void, provide a urine sample and have nude body weight measured in private (Ohaus, Pine Brook, NJ). A 5 ml blood sample was collected using a venipuncture technique prior to and immediately following exercise.
The site was cleaned with alcohol prior to the blood draw, and wiped clean afterwards. These samples were collected to evaluate changes in blood glucose, electrolytes and hematocrit (Abbott Point of Care Inc., Princeton, NJ). Subjects were then outfitted with two skin temperature sensors (Mallinckrodt Medical, St. Louis, MO) to monitor changes in skin temperature ($T_{Sk}$). Sensors were placed on the chest, approximately 5 cm above the nipple on the left pectoralis muscle, and on the back at a similar level. Core temperature ($T_c$) was continuously monitored with a rectal thermometer (Mallinckrodt Medical, St. Louis, MO) which the subject inserted, in private, approximately 12 cm past the anal sphincter. $T_c$ and $T_{Sk}$ were collected using DASYLab Software (Measurement Computing CO., Norton, MA). Heart rate (HR) was monitored with a heart rate watch and chest strap (Polar Electro, Kempele, FL).

Subjects wore personal shoes and uniform (pants and long sleeve shirt) common to Air Force personal (5.11 Tactical, Modesto, CA). Participants exercised on a treadmill ergometer (Fullvision Inc., Newton, Kansas) for 3 hours at 40% of the maximal exercise intensity that was achieved during the peak VO$_2$ test. In a work to rest cycle of 25 minutes work and 5 minutes rest, subjects completed each experimental trial in an environmental chamber (Tescor, Warminster, PA) maintained at 35.5°C and 50% relative humidity. At the half way point of each trial, 90 minutes, subjects consumed a commercially available sports bar consisting of approximately 45 g of carbohydrate. Upon completion of each trial, subjects exited the environmental chamber, towed off and again had nude weight measured in private. Subjects then dressed, and again had 5 ml of blood collected and provided a urine sample.

**Drink Administration**

Subjects completed the three experimental trials in a randomized order consisting of full ice slurry (FULL) (2 g•kg$^{-1}$ of body weight per dose at 0.7 ± 0.2°C), half volume ice slurry (HALF) (1 g•kg$^{-1}$ of
body weight per dose at 0.7 ± 0.2°C) or room temperature water (RT) (2 g•kg\(^{-1}\) of body weight per dose at 36.4 ± 0.2°C). Ice slurry was made using a commercial snow cone machine (Carnival King, Lancaster, PA) and water, in a mixture of 1/3 crushed ice and 2/3 water (by weight) of the subjects calculated dose. Drink administration occurred every 10 minutes throughout the trial, with the exception of minutes 0, 60 and 120. Additionally, upon arrival at the lab for each experimental trial subjects drank 200 ml of cold-water (7.2 ± 0.2°C) prior to entering the environmental chamber.

**Physiological Strain Index**

Using the equation developed by Moran et al. (Moran, Shitzer, & Pandolf, 1998), Physiological Strain Index (PSI) was calculated using recorded T\(_c\) and HR.

\[
PSI = 5 \left( T_{c(t)} - T_{c(0)} \right) \left( 39.5 - T_{c(0)} \right)^{-1} + 5 \left( HR_t - HR_0 \right) \left( 180 - HR_0 \right)^{-1}
\]

**Subjective Metrics**

The 6-20 rating of perceived exertion (RPE) scale as developed by Borg (Borg, 1982) was used as a subjective measure of a subject’s work intensity in the heat. RPE was measured every 10 minutes during the experimental trials. Additionally, to rate a subject’s feelings of “hotness” a unidirectional visual analog scale (VAS) was used (Aitken, 1969). A 10 cm horizontal line with “not hot” on the left end and “very hot” on the right end was presented to the subject at the end of each experimental trial. Subjects placed an “X” on the line at the location that best represented their current feeling. The location of the “X” was measured from the left end of the spectrum and reported.

**Sweat Loss and Percent Dehydration**

Sweat loss was calculated by using changes in pre and post nude body weights, urine output, fluid intake and estimated respiratory water loss.
Sweat Loss (L) = (BW_{pre}(kg) + liquid Ingested (kg)) – (BW_{post}(kg) + Urine Weight (kg) + Respiratory Water Loss (kg))

Using the equation developed by Mitchell et al. (Mitchell et al., 1972), respiratory water loss was estimated from VO$_2$. VO$_2$ was estimated using the ACSM prediction equations (Medicine, 2013).

$$M_e = 0.019 \cdot VO_2 \ (L\cdot min^{-1}) \cdot (44-P_a)$$

$M_e$ = rate of evaporative water loss (g•min$^{-1}$)

$P_a$ = water vapor pressure (mmHg)

Water vapor pressure determined as per Fox et al. (Fox, Bowers, & Foss, 1993).

$$P_a = 13.955 - 0.6584T + 0.0419T^2$$

$T$ = temperature ($^\circ$C)

Sweat loss is presented as sweat rate, with body surface area (BSA) (g•m$^{-2}$•min$^{-1}$) taken into account (Mosteller, 1987).

$$BSA = Kg^{0.5} \cdot cm^{0.5} \cdot 60^{-1}$$

BSA = body surface area (m$^2$)

Kg = body mass in kilograms (kg)

cm = height in centimeters (cm)

Percent dehydration calculated using the method described by Gonzalez-Alonso et al. (González-Alonso, Mora-Rodríguez, Below, & Coyle, 1997).

$$\% \ dehydration = ((BW_{post} - BW_{pre})/BW_{pre}) \cdot 100$$
**Statistical Analysis**

Core temperature, skin temperature and heart rate were analyzed as a 3 X 4 repeated measures ANOVA (trial x time).

The 6-20 RPE scale developed by Borg (Borg, 1982) and PSI expressed with the 0-10 scale developed by Moran et al. (Armstrong et al., 2007) and were analyzed as a 3 X 3 repeated measures ANOVA (trial x time).

USG and blood measures were analyzed as a 3 X 2 repeated measures ANOVA (trial x time).

VAS, plasma volume shift and sweat rate expressed relative to BSA as “g•m⁻²•min⁻¹” were analyzed with a one-way repeated measures ANOVA.

Analyses was done using SPSS 22.0 with the level of significance set at p<0.05 with Bonferroni correction. Descriptive data are represented as mean ± SD and graphical representations of physiological data will be reported as mean ± SEM.
Chapter 4: Results

Subject Descriptive Data

Twelve recreationally active males were recruited to participate in the study, age 24.3 ± 4.1 years, height 69.3 ± 2.5 (in.), weight 73.7 ± 9.5 (kg), percent body fat 9.7 ± 5.1%, VO\textsubscript{2} peak 61.5 ± 7.9 ml•kg\textsuperscript{-1}•min\textsuperscript{-1}. Total drinking volumes were 2.4 ± 0.3 L FULL, 1.3 ± 0.2 L HALF and 2.4 ± 0.3 L RT. Drinking volumes per hour were 730 ± 90 g•kg\textsuperscript{-1}•min\textsuperscript{-1} FULL, 354 ± 62 g•kg\textsuperscript{-1}•min\textsuperscript{-1} HALF and 731 ± 92 g•kg\textsuperscript{-1}•min\textsuperscript{-1} RT.

Core Temperature

T\textsubscript{C} data (n=10) were analyzed at minutes 0, 50, 110 and 170 (Figure 1). Rectal probe complications resulted in elimination of data for two subjects.

Although the trial by time interaction was not significant, the main effect for trial demonstrated significantly lower values for FULL compared to RT (37.8 ± 0.1, 38.1 ± 0.1, and 38.2 ± 0.2 °C for FULL, HALF and RT, respectively). Main effects for time were also observed demonstrating that temperature was increased at 50, 110, and 170 minutes compared to time 0.

Skin Temperature

T\textsubscript{Sk} data (n=10) were analyzed at minutes 0, 50, 110 and 170 (Figure 2). Data of two subjects were not used due to unreliable data. There was a significant time by trial interaction demonstrating a significantly lower skin temperature at minute 170 for FULL compared to HALF and RT. However, there were no differences between RT and HALF.
Heart Rate

HR data (n=12) were analyzed at minutes 0, 50, 110 and 170 (Figure 3). There was a significant time by trial interaction demonstrating a significantly lower HR at minute 170 for FULL compared to HALF and RT.

Rating of Perceived Exertion

RPE data (n=12) were analyzed at minutes 50, 110 and 170 (Figure 4). There was a significant time by trial interaction demonstrating a significantly lower RPE at minute 170 for FULL compared to HALF and RT.

Physiological Strain Index

PSI data (n=10) were analyzed at minutes 50, 110 and 170 (Figure 5). There was a significant time by trial interaction demonstrating a lower PSI at minute 170 for FULL compared to HALF and RT. Additionally, there was a trend towards a significantly lower PSI at minute 110 for FULL compared to RT and HALF (p=0.058). Complications with rectal probes eliminated data for two subjects.

Urine Specific Gravity and Blood Measures

All measurements are stated in Table 2 (n=12). Main effects for time for creatinine (Crea) and total CO₂ (TCO₂) demonstrated decreases in the post exercise measurement, while ionized calcium (iCa), potassium (K) and hematocrit (Hct) showed increases. Urea nitrogen (BUN) demonstrated a time by trial interaction of higher post measurements for HALF and RT. Glucose (GLU) demonstrated a time by trial interaction indicating an increased post glucose concentration in HALF compared to FULL. There was significant time by trial interaction demonstrating a lower HALF post measurement of Chloride (Cl) compared to FULL and RT. There was a significant time by trial interaction demonstrating a higher HALF post measurement of sodium (Na) compared to FULL and RT.
Visual Analog Scale

The visual analog scale (VAS) used to quantify how hot a subject felt demonstrated a significant main effect for trial. FULL (62.3 ± 19.4) was significantly lower than RT (74.5 ± 15.4) but did not differ from HALF (72.7 ± 12.5) (p=.201).

Plasma Volume

There were no significant differences in calculated change in plasma volume between the trials (-4.5 ± 5.9%, -8.4 ± 5.9% and -7.4 ± 6.3% for FULL, HALF and RT, respectively (p=0.15).

Sweat Rate

Absolute sweat rate in ml•hr⁻¹ was not significantly different between the trials (850 ± 137, 839 ± 156 and 902 ± 145 ml•hour⁻¹ for FULL, HALF and RT, respectively, p=.161). Similarly, when sweat rate was adjusted to body surface area, the results demonstrated no significant difference across trials (7.6 ± 1.4, 7.5 ± 1.5 and 8.1 ± 1.6 g•m⁻²•min⁻¹ for FULL, HALF and RT, respectively, p=.133).

Percent Dehydration

Percent dehydration demonstrated a significant main effect for trial. HALF (-1.81 ± .78 %) was significantly greater than FULL (-0.50 ± .86 %) and RT (-0.60 ± .74 %).
Figure 1. Core temperature at minutes 0, 50, 110 and 170. Main effect for trial, FULL less than RT: a) \( p = 0.01 \). Main effects for time, increased core temperature compared to minute 0: b) \( p < 0.01 \).
Figure 2. Skin temperature at minutes 0, 50, 110 and 170. Time by trial interaction at minute 170 demonstrating a lower skin temperature for FULL compared to HALF: a) \( p = .037 \); FULL compared to RT: b) \( p = .019 \). No significant differences were observed between HALF and RT.
Figure 3.

Figure 3. HR at minutes 0, 50, 110 and 170. Time by trial interaction at minute 170 demonstrating a lower heart rate for FULL compared to HALF: a) $p = .001$; FULL compared to RT: b) $p = .011$. No significant difference observed between HALF and RT.
Figure 4. RPE at minutes 50, 110 and 170. Time by trial interaction at minute 170 demonstrating a lower RPE for FULL compared to HALF: a) $p = .007$; FULL compared to RT: b) $p = .042$. No significant difference observed between HALF and RT.
Figure 5. PSI at minutes 50, 110 and 170. Time by trial interaction at minute 170 demonstrating a lower PSI for FULL compared to HALF: a) $p = .006$; FULL; compared to RT: b) $p = .007$. No significant difference observed between HALF and RT.

![Figure 5. PSI at minutes 50, 110 and 170. Time by trial interaction at minute 170 demonstrating a lower PSI for FULL compared to HALF: a) $p = .006$; FULL; compared to RT: b) $p = .007$. No significant difference observed between HALF and RT.](image)
Table 2

<table>
<thead>
<tr>
<th>Measure</th>
<th>FULL Pre</th>
<th>FULL Post</th>
<th>HALF Pre</th>
<th>HALF Post</th>
<th>RT Pre</th>
<th>RT Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>USG</td>
<td>1.013 ± 0.09</td>
<td>1.013 ± 0.06</td>
<td>1.014 ± 0.07</td>
<td>1.017 ± 0.05</td>
<td>1.012 ± 0.07</td>
<td>1.016 ± 0.05</td>
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<tr>
<td>Na (mmol/L)</td>
<td>141.4 ± 1.0</td>
<td>138.1 ± 1.4</td>
<td>141.8 ± 1.6</td>
<td>140.9 ± 1.8†</td>
<td>141.5 ± 1.0</td>
<td>138.3 ± 1.9</td>
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<tr>
<td>K (mmol/L)*</td>
<td>4.1 ± 0.3</td>
<td>4.3 ± 0.2</td>
<td>4.0 ± 0.3</td>
<td>4.5 ± 0.3</td>
<td>4.0 ± 0.2</td>
<td>4.4 ± 0.2</td>
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<tr>
<td>CL (mmol/L)</td>
<td>101.0 ± 1.9</td>
<td>99.4 ± 1.3</td>
<td>101.4 ± 2.0</td>
<td>103.0 ± 2.3†</td>
<td>101.2 ± 2.2</td>
<td>100.2 ± 1.3</td>
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<tr>
<td>iCa (mmol/L)*</td>
<td>1.2 ± 0.0</td>
<td>1.2 ± 0.0</td>
<td>1.2 ± 0.0</td>
<td>1.2 ± 0.1</td>
<td>1.3 ± 0.0</td>
<td>1.2 ± 0.0</td>
</tr>
<tr>
<td>TCO2 (mmol/L)*</td>
<td>25.8 ± 2.1</td>
<td>23.5 ± 2.1</td>
<td>25.8 ± 1.5</td>
<td>23.1 ± 1.4</td>
<td>25.3 ± 1.8</td>
<td>23.3 ± 2.2</td>
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<tr>
<td>GLU (mg/dL)</td>
<td>90.7 ± 6.7</td>
<td>96.8 ± 7.6</td>
<td>89.3 ± 7.3</td>
<td>105.3 ± 12.5#</td>
<td>89.3 ± 7.2</td>
<td>101.9 ± 9.0</td>
</tr>
<tr>
<td>BUN (mg/dL)</td>
<td>14.9 ± 3.7</td>
<td>15.5 ± 3.5</td>
<td>14.3 ± 3.8</td>
<td>16.6 ± 3.4^</td>
<td>13.6 ± 3.4</td>
<td>15.7 ± 3.2^</td>
</tr>
<tr>
<td>Crea (mg/dL)*</td>
<td>1.0 ± 0.1</td>
<td>1.2 ± 0.1</td>
<td>1.0 ± 0.1</td>
<td>1.3 ± 0.3</td>
<td>1.0 ± 0.1</td>
<td>1.3 ± 0.2</td>
</tr>
<tr>
<td>Hct (PCV)*</td>
<td>46.9 ± 1.7</td>
<td>48.1 ± 1.9</td>
<td>46.1 ± 1.9</td>
<td>48.3 ± 1.7</td>
<td>47.1 ± 2.2</td>
<td>49.1 ± 2.5</td>
</tr>
<tr>
<td>Hgb (g/dL)</td>
<td>15.9 ± 0.6</td>
<td>16.4 ± 0.7</td>
<td>15.7 ± 0.7</td>
<td>16.4 ± 0.6</td>
<td>16.0 ± 0.8</td>
<td>15.9 ± 2.6</td>
</tr>
<tr>
<td>AnGap (mmol/L)</td>
<td>16.6 ± 1.2</td>
<td>20.6 ± 1.7</td>
<td>19.4 ± 1.2</td>
<td>20.2 ± 1.3</td>
<td>20.3 ± 1.7</td>
<td>19.9 ± 1.5</td>
</tr>
</tbody>
</table>

Table 2. Blood data: main effect for time * p<0.05; time by trial interaction between HALF and both FULL and RT ‡ p<0.05; time by trial interaction between HALF and FULL # p<0.05; different from Pre ^ p<0.05.
Chapter 5: Discussion

Numerous studies have shown the efficiency of various cooling interventions in extending time to fatigue while exercising in the heat. These methods have included the use of cooling garments during warm-ups, cooling pads, water immersion prior to and between bouts of exercise and ice slurry ingestion prior to exercise in the heat (Arngrímsson et al., 2004; Cotter et al., 2001; Marino & Booth, 1998; Siegel et al., 2012; Yeargin et al., 2006). The purpose of the present study was to investigate the effects of ingesting differing volumes of ice slurry on heat strain during exercise in a hot environment, and to explore the relationship that fluid volume and fluid temperature have on thermoregulation. Significant decreases were observed in full volume slurry for $T_{Sk}$, HR, RPE and PSI compared to half volume ice slurry and room temperature water. However, half volume ice slurry was no different at mitigating heat strain as room temperature water.

As a response to exercise, $T_C$ will increase in proportion to relative exercise intensity, propensity of metabolic heat dissipation and predisposing factors (acclimation, illness, etc.) (Byrne, Lee, Chew, Lim, & Tan, 2006; Davies, Brotherhood, & Zeidifard, 1976). At termination of exercise, $T_C$ reached $38.39 \pm .51 ^\circ C$, $38.82 \pm .72 ^\circ C$ and $38.89 \pm .76 ^\circ C$ for FULL, HALF and RT, respectively, with no significant differences between them ($p=0.24$), although there appeared to be an emerging trend towards a difference (Figure 1). One explanation for the lack of a clear difference is the selected work intensity may have been too low (40% VO$_2$ peak) compared to other studies in this lab (unpublished data) and other thermoregulatory studies in which the selected intensity was between 50-70% VO$_2$ peak (González-Alonso et al., 1999; Kaufman, 2012; Lee, Shirreffs, et al., 2008). These more intense, shorter intensities may see more effects from ice slurry than the present study. However, at the termination of exercise $T_{Sk}$, HR, PSI and RPE were all significantly lower in the FULL trial compared to HALF and RT. This clearly indicates FULL is more effective at mitigating the physiological strain associated with exercise in the heat than RT or a HALF ice slurry.
Interestingly though, at the termination of exercise there were no differences in $T_C$, $T_{sk}$, HR, PSI and RPE between HALF and RT.

A decreased $T_C$ would allow greater blood flow to the skin, aiding evaporative heat loss and in turn decreasing $T_{sk}$ and reducing HR, allowing for increased time to volitional fatigue (Michael N. Sawka & Young, 2006; Siegel et al., 2010). In the present study, the combination of lower $T_C$ (trending toward significance) and $T_{sk}$ resulted in a significantly decreased RPE and PSI for the FULL trial at the termination of exercise. PSI and RPE were significantly lower for FULL, compared to HALF and RT. This suggests that FULL both reduced perceived exertion and the actual physiological strain caused by exercising in the heat.

Although the physiological responses differed between the two doses of ice slurry, the physiological responses of HALF and RT did not differ (Figures 1-5). These similarities speak to the capacity of a heat sink to mitigate physiological strain. The theoretical effectiveness of an ice slurry in attenuating $T_C$ rise is due to the specific heat capacity of solid ice versus ambient temperature liquid water. The energy required for the phase change from ice to water is $334 \text{kJ} \cdot \text{kg}^{-1}$, allowing for the dissipation of metabolic heat (Kaufman, 2012; Yeo, Fan, Nio, Byrne, & Lee, 2012). Additionally, by ingesting an ice slurry the hypothalamus may be affected, resulting in a decreased perception of exertion and an altered sweating threshold (Cheuvront et al., 2009; Mündel, King, Collacott, & Jones, 2006; Stevens et al., 2013). The influence of ice slurry on a sweating threshold may have had an effect in the current study as sweat rates between trials were not significant, there appeared to be a trend between FULL and RT ($p=0.13$) and HALF and RT ($p=0.165$).

The differing volumes of fluid administered in each trial impacted blood measures. Post exercise measures of both sodium (Na) and chloride (Cl) saw a trial by time interaction between HALF and both FULL and RT. HALF was better able to maintain Na near normal, resting levels, $140.9 \pm 1.6$
mmol/L. It is worth noting that post exercise levels of Na in both FULL and RT, 138.1 ± 1.4 and 138.3 ± 1.9 mmol/L, respectively, were nearing criteria (<135 mmol/L of Na) of exercise-associated hyponatremia as outlined by Rosner and Kirven (Rosner & Kirven, 2007) despite an intake less than 1 L•hour⁻¹. Hct and USG saw no significant differences between pre and post measures, or between trials. This is interesting considering the amount of water subjects received during the duration of a given trial, 2.39 ± 0.27 L (10 g•kg⁻¹•hr⁻¹) and 1.26 ± 0.18 L (5 g•kg⁻¹•hr⁻¹) for FULL/RT and HALF, respectively. This spans the volume of liquid that is commonly administered in other studies, 7.5-12 g•kg⁻¹•hr⁻¹ (Siegel et al., 2010; Stevens et al., 2013).

Although HALF resulted in significantly more dehydration compared to RT, thermoregulatory responses were not significantly different. Regardless of significantly greater dehydration, the ability of the HALF trial to adequately attenuate the elevation of heat stress adds to emerging research that hyperhydration and euhydration are not the sole strategies by which to avoid a HRI (Cotter, Thornton, Lee, & Laursen, 2014; Cuddy & Ruby, 2011). Despite FULL and RT resulting in similar percent dehydration, thermoregulatory responses were significantly different. This indicates that temperature of ingested fluid plays a large role in aiding thermoregulation. There appears to be an overemphasis in hydration as a means of mitigating heat strain. This can result in underestimating the heat stress imposed on the body possibly leading to an HRI, or over-hydrating and risking hyponatremia. Cuddy and Ruby presented a case in which a wild-land firefighter suffered heat exhaustion (core temperature of 40.1 °C) even though fluid consumption averaged 840 mL•hr⁻¹ (Cuddy & Ruby, 2011). Drinking to excess can also dangerously decrease electrolyte levels risking decreased performance or possibly death (Montain, 2008). In a study monitoring runners of the Boston Marathon Almond et al. found that of the 488 runners monitored throughout the run, 13% were classified as hyponatremic (Almond et al., 2005). The ACSM’s recommends avoiding greater than 2% body weight loss during exercise in the heat (M. N. Sawka et al., 2007). A half volume of
ice slurry verged on violating this recommendation despite demonstrating no significant difference in thermoregulatory markers seen when ingesting room temperature water at twice the volume. Together these data indicate that exogenous fluid temperature may be a more important attenuator of heat stress than fluid volume.

The current study provides insight into current gaps in research regarding the use of ice slurry as a means to mitigate heat strain. This study shows that heat strain can be attenuated during prolonged, moderate-intensity exercise in a hot environment with frequent doses of ice slurry. The protocol and methods differed from other studies in that we provided the ice slurry only during exercise, rather than as a pre-cooling mechanism. Additionally, our protocol more closely resembles real world working situations for military and WLFF personal in regards to intensity, duration and outer garments. To our knowledge, this was the first study to examine differing volumes of ice slurry. Although the effects of the half-volume ice slurry were not as effective as full-volume in reducing PSI, we show that a half-volume slurry is no different than room temperature water. This suggests that fluid temperature may have a greater impact on thermoregulation than does fluid volume. This speaks to the effectiveness of a heat sink to mitigate heat strain.
Appendix I: IRB-Approval

SUBJECT INFORMATION AND INFORMED CONSENT

Study Title: The effect of differering volumes of ice slurry ingestion during exercise in the heat.

Sponsor: Air Force Special Operations Command

Investigator(s):
- Dr. Brent Ruby Brent.Ruby@mso.umt.edu
- Dr. Chuck Dumke Charles.Dumke@mso.umt.edu
- John Cuddy John.Cuddy@mso.umt.edu
- Walter Hailes Walter.Hailes@mso.umt.edu
- Kyle Cochrane Kyle.Cochrane@umontana.edu

Inclusion Criteria:
- Participants must be males between ages 18-40
- Participants must have a VO2 max of at least 40 ml/kg/min
- Participants must pass the health/exercise PAR-Q questionnaire with no “yes” answers

Exclusion Criteria:
- Females
- Males younger than 18 or older than 40
- Males with a VO2 max less than 40 ml/kg/min
- Participants that have a known risk factor for coronary artery disease as determined by a “yes” answer on the health/exercise PAR-Q questionnaire

Purpose:
It has been well established that ingesting ice slurry prior to exercise in the heat decreases core temperature and increases time to exhaustion versus ingestion of cold (4°C/39°F) water. While we hypothesize that ice slurry will decrease core temperature and increase time to exhaustion of exercise in the heat, the amplitude of these effects is not well understood. Furthermore, it is not known what volume of ice slurry will provide a similar physiological effect of cold water. The purpose of this study is to determine the effects of different volumes of ice slurry ingestion during exercise in the heat on thermoregulatory and exercise responses.

Procedures:
Four total visits to the laboratory will be required, consisting of approximately 13 hours of testing. The first visit for pre-testing will require approximately one hour. The three additional visits for experimental trials will each require approximately four hours each, as summarized below. Experimental trials will be separated by two-weeks.

PRE TESTING (Visit 1)
You will be asked to fast for approximately 3 hours prior to this test.
1. Physical activity readiness 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.
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 submerged 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. This test will be completed in the air-conditioned laboratory area.

3. A maximal treadmill ergometer test to measure aerobic fitness
   a. This test will consist of walking and running on a laboratory treadmill to volitional fatigue. The speed and/or grade of the treadmill will increase every three minutes and will progress to fatigue. You will be encouraged to continue to walk/run until volitional fatigue. 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. Heart rate will be measured using an elastic chest strap that is worn on the skin under your shirt around the chest. This test will take approximately 30 minutes.

EXERCISE TRIALS IN THE HEAT (Visits 2, 3 and 4)
All three exercise trials are the same except each trial will have a different drink to be ingested during exercise. There is approximately two weeks spacing between heat trials.

1. The day(s) prior to all exercise sessions, you are required to do the following:
   a. No cardiovascular exercise (running, swimming, cycling, etc.) is permitted the day before an exercise trial. If you regularly lift weights you are permitted to do so but you cannot lift for legs; all lifting must be for upper body only.
   b. You will be required to log physical activity 2 days prior to your first exercise trial. Your activity logged will be repeated two days in advance of your second and third exercise trials.
   c. You will be required to keep a dietary log for the day prior to the exercise session. For the second and third trial, you will be asked to consume the same foods and quantity of those foods that you did for the first trial.
   d. You will be asked to begin the trials having completed at least an 8 hour fast. During the 8 hours preceding the trials you are permitted ONLY water. No other food or beverage is allowed during the 8 hours leading up to your exercise trial.
   e. NO ALCOHOL CONSUMPTION 24 hours before the testing period. Alcohol is a diuretic and compromises hydration status so its use must not occur before the exercise trials

2. Exercise trials
   a. You will exercise (walk on a treadmill at a specified speed and incline) for 3 hours with 50 minutes work and 10 minutes rest in a hot room (approximately WBGT of 31°C / 88°F) at 40-50% of the maximal exercise intensity that you achieved during the maximal exercise test. You will wear standard issue Air Force pants and shirt. During the 3 hour walk exercise session you will consume about 1 to 4 liters of fluid (depending on body weight) that consists of cool water (about 27°C / 80°F), frozen ice slurry (about 0°C / 30°F) or decreased volume frozen ice slurry (about 0°C / 30°F). Order of trials will be randomized.
   b. Prior to each trial, you will insert a rectal thermometer in privacy behind a locked room so that your core body temperature can be monitored throughout the exercise period.

The University of Montana IRB
Expiration Date 12-17-2015
Date Approved 1-22-2015
Chair/Adm
c. Prior to each trial, skin temperature measurement patches will be applied to the left side of the chest and upper back. Skin temperature will be monitored throughout the exercise period.

d. Nude body weight will be taken before and after each exercise session. Nude body weight will be measured in private on a calibrated scale.

e. Urine volume will be measured during each exercise session. You will be asked to void your bladder before each session. After the initial void, urine will be collected in a disposable plastic container and urine volume will be measured for the duration of each trial in order to accurately measure sweat rates.

f. Approximately 5ml blood samples will be collected using a venipuncture technique prior to and immediately following each 3 hour exercise session. The site will be cleaned with alcohol prior to the blood draw, and wiped clean afterwards. These samples will be collected to evaluate changes in blood glucose, electrolytes, and hematocrit.

Payment for Participation:

Upon completion of your third trial, you will be paid $200. If you only complete 1 trial you will receive $67, and if you only complete 2 trials you will receive $133.

Risks/Discomforts:

1. In some participants the ingestion of frozen ice slurry or cold water 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 in the heat chamber at 31 °C (88°F) WBGT 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 (105.8 °F), the exercise test will be terminated. Fluids will be provided to you as well to mitigate these risks. If you feel too hot to continue exercise, the test will be terminated and you will be removed from the heat chamber.

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, your body temperature will be monitored continuously during exercise. If body temperature goes above 41°C (105.8 °F), the exercise test will be terminated.

7. You will be informed of any new findings that may affect your 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.
9. There is some risk of infection with the blood sample, but precautions (cleaning the site with alcohol, sterile supplies, and wearing a band-aid) will be taken to minimize these.

Benefits:
1. The information from these tests will provide the participant with an accurate assessment of participant’s aerobic fitness and body composition that can be compared with norms for participant’s age and sport but may be of little benefit to participant’s understanding of participant’s personal fitness. There are no other direct benefits to the participants in the study.
2. There is no promise that the participant will receive any benefit as a result of taking part in this study.
3. The scientific benefit includes elucidating the effects of different volumes of ice slurry ingestion during exercise in the heat.

Confidentiality:
1. Your records will be kept private and not be released without consent except as required by law.
2. The following people from the University of Montana will have access to research files: Dr. Brent Ruby, Dr. Charles Dumke, John Cuddy, Walter Hailes, and Kyle Cochrane. Further, Department of Defense personnel will have access to research records to ensure protection of human subjects.
3. Your identity will be kept confidential unless the participant’s photo is taken and used in scientific presentations. You may only be photographed with the signed consent included in the consent form. Your name will not be used with photos.
4. If the results of this study are written in a scientific journal or presented at a scientific meeting, your name will not be used.
5. An anonymous identification number will be assigned to you. Your name will not be used on data sheets and any key linking your name to the study identification number will be kept separate and secured in a locked file.
6. The signed consent form and information sheet will be stored in a locked cabinet separate from the data.

Voluntary Participation/Withdrawal:
Your decision to take part in this research study is entirely voluntary. You may refuse to take part in or you may withdraw from the study at any time without penalty or loss of benefits to which you are normally entitled. If you decide to withdraw, you may leave the study for any reason.
You may be asked to leave the study for any of the following reasons:
1. Failure to follow the Project Director’s instructions;
2. A serious adverse reaction which may require evaluation;
3. The Project Director thinks it is in the best interest of your health and welfare; or
4. The study is terminated.
Compensation for Injury:
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 (406-243-2700; kathy.krebsbach@umontana.edu) or the Office of Legal Counsel (406-243-4742; legalcounsel@umontana.edu). (Reviewed by University Legal Counsel, May 9, 2013)

Questions:
If you have any questions about the research now or during the study contact: Dr. Brent Ruby, PhD, at home (406) 542-2513, cell (406) 546-4691 or at the Human Performance Laboratory (406) 243-2117, or via email at Brent.Ruby@mso.umt.edu or the faculty advisor, Dr. Chuck Dumke, PhD, via email at Charles.Dumke@mso.umt.edu. If you have any questions regarding your rights as a research subject, you may contact the UM Institutional Review Board (IRB) at (406) 243-6672.

Statement of Your Consent:
I have read the above description of this research study. I have been informed of the risks and benefits involved, and all my questions have been answered to my satisfaction. Furthermore, I have been assured that any future questions I may have will also be answered by a member of the research team. I voluntarily agree to take part in this study. I understand I will receive a copy of this consent form.

Printed Name of Subject

Subject's Signature

Date

Statement of Consent to be Photographed:
I understand that photographs may be taken during the study.
I consent to having my photograph taken.
I consent to use of my photograph in presentations related to this study.
I understand that if photographs are used for presentations of any kind, names or other identifying information will not be associated with them.

Subject's Signature

Date

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Expiration Date 12-19-2015
Date Approved 1-22-2015
Chair/Admin
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.

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 any of the above questions, talk with 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.

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 much 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.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

Name: ____________________________ Date: ____________________________

Signature: ________________________ Witness: ________________________

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.

Appendix II: PAR-Q
## Figures and Tables

### Table 1.

<table>
<thead>
<tr>
<th>Heat Category</th>
<th>WBGT Index, °F</th>
<th>Easy Work</th>
<th>Moderate Work</th>
<th>Hard Work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Work /Rest</td>
<td>Water Intake (Qt/hr)</td>
<td>Work /Rest</td>
</tr>
<tr>
<td>1</td>
<td>78-81.9</td>
<td>NL</td>
<td>½</td>
<td>NL</td>
</tr>
<tr>
<td>2 (Green)</td>
<td>82-84.9</td>
<td>NL</td>
<td>½</td>
<td>50/10 min</td>
</tr>
<tr>
<td>3 (Yellow)</td>
<td>85-87.9</td>
<td>NL</td>
<td>⅔</td>
<td>40/20 min</td>
</tr>
<tr>
<td>4 (Red)</td>
<td>88-89.9</td>
<td>NL</td>
<td>⅔</td>
<td>30/30 min</td>
</tr>
<tr>
<td>5 (Black)</td>
<td>&gt;90</td>
<td>50/10 min</td>
<td>1</td>
<td>20/40 min</td>
</tr>
</tbody>
</table>

- The work-rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hours of work in the specified heat category. Individual water needs will vary ± ¼ qt/hr.
- NL = no limit to work time per hour.
- Rest means minimal physical activity (sitting or standing), in shade if possible.
- Hourly fluid intake should not exceed 1⅓ qt. Daily fluid intake should not exceed 12 qt.
- Wearing body armor adds 5°F to WBGT Index
- Wearing MOPP over-garment adds 10°F (Easy Work) or 20°F (Moderate or Hard Work) to WBGT Index.

Taken from Kolka et al.
References


