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IMPLICATIONS OF DISCONTINUOUS EXERCISE (WALK/RUN) ON THE MAINTENANCE OF THERMOREGULATION IN THE HEAT

By

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IMPLICATIONS OF DISCONTINUOUS EXERCISE ON THE MAINTENANCE OF THERMOREGULATION IN THE HEAT

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Increases in physiological strain index (PSI) can be a barrier to endurance performance. The efficacy of discontinuous work on the attenuation of rises in PSI during exercise in the heat remains unclear. PURPOSE: To evaluate discontinuous exercise on the maintenance of thermoregulation in the heat. METHODS: Eight recreationally active men (age 28.5±5.5 yr, body mass 75.3±11.5 kg, VO_{2peak} 56.3 ±6.3 $ml*kg^{-1}*min^{-1}$) performed 2 trials of 60 minutes each (discontinuous (DCON) run/walk and continuous (CONT) running) matched for overall work. Five of these subjects performed the trials outdoors (OUT) on a 400m gravel track at 30.9 ±3.1 °C and humidity of 25.5±5.5% RH. The speeds for the trials were 187.8 and 203.8 m/min for CONT and DCON, respectively. During the DCON trial, participants ran for 8.5 minutes then walked at 1 minute (80.5 m/min). Subsequently, three men acclimated to a climate chamber (IN) for 15 minutes and then performed DCON and CONT incremental trials on a treadmill at 34°C and 40% humidity. The trials were similar to the OUT conditions, where work was matched over the course of 1 hr, but with 3 different intensities increasing every 20 minutes. This was followed by a time trial (TT) which included an incremental increase in treadmill grade at 187.8 m/min until failure. RESULTS: The OUT group exhibited a significant effect of trial in DCON and CON for Tsk (36.75±1.3 vs 34.2±0.6 ˚C; P=0.002) and a trend towards significance in HR (152±14 vs 132±30 bpm; P=0.095) and PSI (6.1±2.1 vs 5.2±3.1, P=0.062). The IN group showed an effect of time for HR (141±21 vs 150±30 bpm for DCON and CON, respectively; P=0.016).

There was no significant difference in TT performance (P=0.15) between trials. CONCLUSION: These findings imply that when total work is held constant DCON has a significant impact on HR and Tsk but not on Tc or PSI during exercise in the heat and that the Dcon trial did not result in elevated PSI despite working at a higher workload than the control trial.

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Chapter 1: Introduction

Introduction

Increases in physiological strain index (PSI) are a constant barrier to endurance performance in athletes, warfighters, firefighters and any additional work situations in hot/humid environments (1-4, 6, 7, 10, 15, 20, 24, 28, 29). Workers regularly exposed to high heat/humid work environments are susceptible to heat related injuries (HRI) as a result of uncompensable metabolic and environmental heat and increases in core temperature (Tc) (8, 21, 39, 42, 48). The proceeding physiological strain causes an increase in perception of thermal stress, cardiovascular strain, heat stroke, heat exhaustion, central nervous system dysfunction, fatigue and potentially death (1, 3, 6, 7, 8, 10, 15, 19, 20, 21, 23, 42, 48, 55). In addition to the metabolic heat generated during exercise the radiant environmental heat, humidity and clothing of the subject can all impact PSI and increase the risk for HRI (8, 19, 39, 55).

Previous research has shown that as components of PSI, Tc and heart rate (HR), increase the time to exhaustion decreases and the perception of stress causes deleterious effects on performance (8, 19, 21, 42). Traditionally the rises in Tc and HR have been thought to be reversed by either increasing the hydration status or cessation of the work load (43). Current research demonstrates that increasing fluid ingestion may not have an impact on Tc and may lead to hyponatremia which further impairs the workers ability to recover (10, 24, 28, 43). The time tested method of relaxing PSI is to halt work and rest in a cool environment in order to allow recovery and limit the likelihood of a HRI (8, 19, 21, 48, 49).

Work/rest cycles have been demonstrated to have an effect on the increase in Tc and HR. During workloads with compensable heat stress the evaporative cooling effect of the sweating mechanism can offload metabolic heat to the environment and effectively cool the body by environmental heat transfer. In addition to evaporative heat loss the cessation of exercise has been shown to attenuate the increases in HR and thusly a decrease in PSI and avert HRI (2, 8, 10, 15, 21, 23, 40, 42, 48, 49, 55).

Problem

While discontinuous exercise protocols have been used in combination with other methods of pre-cooling, intermittent cooling and post-cooling the link between compensable heat stress, outdoor intermittent exercise bouts of running have not been evaluated or validated as an effective method of PSI compensation.

Purpose

The purpose of this study is to determine the effects of discontinuous work/rest exercise cycles on the attenuation of rises in PSI, core temperature (T_c), heart rate (HR) and RPE in comparison to a continuous exercise protocol at a fixed workload 65% running VO_2 peak for 60min.

Null Hypotheses

1. No significant change in RPE with work/rest cycle compared to continuous exercise.
2. No significant difference in HR with work/rest cycle compared to continuous exercise.
3. No significant difference in T_c with work/rest cycle compared to continuous exercise.

4. No significant difference in Physiological Strain Index (PSI) with work/rest cycle compared to continuous exercise.
5. No significant difference in T_{sk} with work/rest cycle compared to continuous exercise.

Significance and Rationale

The findings of this research would have implications on individuals for whom physiological strain is a realistic and constant detriment to performance. If a discontinuous protocol can be shown to attenuate the elevation of Tc then a reevaluation of programing in high heat stress environments can be assessed and the potential for applying conditional work/rest cycle bouts can potentially mitigate the increases in PSI brought on by exercise in a hot environment.

Limitations

1. Data collection will occur in the historically hottest time of day in the historically hottest month of the summer. These trials will take place in August during the mid-afternoon hours in Missoula, MT where average high temperatures during the first three weeks of August vary between 28.8°C and 31.1°C and will be assessed by wet bulb globe temperature on the day of the trial. Participants' extracurricular lifestyles cannot be controlled and in order to minimize bias and introduction of extraneous variable a dietary and physical activity recall for the previous day will be recorded and will be repeated for the succeeding trials. Subjects will be asked to avoid strenuous exercise for 48 hours prior to the exercise trials.

2. Human error in usage of instrumentation is a confounding variable and should be minimized by having all members involved in data collection thoroughly trained and monitored during data collection times to reduce potential human error.

3. Subjects will be recruited by convenience and cannot be randomly sampled. They will be separated into two groups by order of appearance (odd numbers continuous trial first, discontinuous trial second; even numbers discontinuous trial first, continuous trial second).

Delimitations

1. All participants in this study will be males who are recreational athletes. Due to the effects of the menstrual cycle on core temperature, females will be excluded from this study.

Definition of Terms

- Moderately Trained/Recreational Athletes: one who exercises on a regular basis and meet a minimum VO_2 peak of 50 $ml*kg^{-1}*min^{-1}$.

- Heat Strain/Stress: physiological consequences, such as increased T_c and HR, or perceptual consequences, such as raised RPE (5). Heat strain/stress can cause the following: volitional fatigue, hyperthermia, heat exhaustion/stroke, cardiovascular strain, central nervous system dysfunction, and death (8).

- 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 (18). PSI is based on an equation from Moran et al.(40) using T_c and HR. $T_{c(0)}$ and HR_0 were 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.

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

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

- Sweat rate: sweat produced by the body over time in weight lost in before and after trial mass.

$$(L/min) = ((BW_{pre}\ (kg) + Liquid\ Ingested\ (kg)) - (BW_{post}\ (kg))/Time\ of\ trial\ in\ minutes)$$

- Sweat Loss: $(L) = (BW_{pre}\ (kg) + Liquid\ Ingested\ (kg)) - (BW_{post}\ (kg))$

Chapter 2: Review of Literature

Hyperthermia, Fatigue and Heat Related Injury

High heat environments have long been a hindrance to both short and long term exercise/work activities. One metabolic by product of ATP hydrolysis is energy given off in the form of heat which in turn elevates body core temperature and can hasten fatigue (23, 54). Thus, a quickening of the rate of glycogen depletion in working muscle decreases the ability to maintain a high level of work output for long periods of time. An additional effect of heat dissipation from working muscle is an increase in body core temperature (Tc) commonly measured as rectal/esophageal temperature by probe thermometers or inter-gastrointestinal capsules carrying a thermistor. Hyperthermia is defined as an increase in core temperature above the set range specified for the normal active state of humans, which is 37°C at rest and 38°C during moderate-intensity exercise (47). Rises in Tc are attributed to heat related illness and injury (HRI) (21) and can result in permanent damage as well as death (5). HRI is a unique ailment, as all humans are susceptible to thermal stress and while uncommon, even those who adequately prepare for activities in extreme temperatures can fall victim to a HRI (4). Thermal stress is defined as environmental conditions that cause an individual to gain or lose heat whereas thermal strain is the physiological response to said stress (44). In a recent report by the Armed Forces Health Surveillance Center there were 362 incidences of heat stroke and 2652 incidences of other heat related injury (1). Hot weather exercise effects many populations across the globe. There are many documented instances of HRI and high Tc during exercise in the military (1), endurance athletes (2, 15, 28, 29), wild land firefighters (10) and during pre-season football practices (3, 20). These instances are often treated by increasing hydration which in these circumstances is known to not be the determining factor in Tc regulation (10). A wild land firefighter reached a Tc of 40.1°C and regardless of

fluid ingestion collapsed with an HRI and was removed from work (10). As a result of the susceptibility of the population to HRI, research into maintenance of thermoregulatory methods is a growing field and has much to offer. Finding an economical and viable method of temperature regulation is a critical endeavor for the scientific community.

Thermal Perception, Physiological Strain Index and Exercise

It has been previously suggested that endurance activities are limited by a critical Tc of ~40°C (56). This has recently been challenged suggesting that it is not the limiting critical value for exercise performance as performance was not degraded in an 8km time trial and was not indicative of fatigue in subjects recording Tc >40°C (16). Thermal stress is typically conveyed as an indexed measure of physiological strain or PSI. PSI is a matrix of Tc and heart rate combined with environmental measures to assess the stress endured by an individual during work (39). It is also suggested that thermal discomfort as a result of sensations of increased temperature are related to core and skin temperatures as the production of heat is not the problem but the dissipation of metabolic heat becomes the limiting factor in performance (49). It is well known that performance is also closely tied to the shunting of blood from active muscle to dilated peripheral vessels in order to dissipate heat. This in turn increases the perception of thermal stress by way of increased skin temperature at the cost of decreasing Tc and VO_2 (14).

Moderating Thermal Stress

Methods of decreasing PSI and thermal stress vary from pre-cooling, mid-event cooling, intermittent cooling and acclimatization. Heat loss is based on a temperature gradient between skin and muscle and improvements in performance have been noted in submaximal running efforts when the subject was kept in a cool environment prior to the test versus a hot

environment (33). Cold showers (12), fans with and without skin wetting (37), water perfused suits (51), water immersion (11, 30), ice packs (46) ice vests (11, 36) and walk/run cycles (13, 45) have all been used to show changes in core/skin temperature during exercise.

Blood Flow Redistribution

During exercise blood flow is shunted to the working muscles to provide oxygen and substrates for ATP production. As Tc increases peripheral dilation allows the transfer of metabolic heat away from the working muscle to the skin for evaporative transport which causes skin temperature to rise.(57) Cheuvront et al, in 2010, published a review of different aspects related to impairment of aerobic performance in relation to heat stress and dehydration. The researchers assessed that the competition for blood between working muscle and skin, increased Tc and a low core/skin temperature gradient all have negative impacts on VO2 and thus performance. They demonstrated that rises in skin temperature have an inverse relationship with Tc tolerance and consequently a positive relationship with skin blood flow. In addition to these physiological factors, increased thermal perception, decreased plasma volume and inducement of hyperthermia all give cause for reduction in performance, possibility of HRI and possibly death in extreme cases (9).

Sweat Response/Evaporative Cooling

Wendt et al. discussed the temperature gradient between ambient air and skin temperature. They noted that at 36°C the gradient reverses and heat is gained by radiation instead of lost by convection. At this point heat loss by evaporation is the preferred method of cooling. They further go on to point out that the effectiveness of perspiration evaporation is based on whether the relative humidity in which a more arid climate will evaporate sweat faster and that in more

humid environments the need for evaporative heat loss can exceed the environments ability to accommodate more water and thus inducing the risk of heat related injury (57).

Intermittent Work-Rest Cycles

Schlader et al. in 2009, suggested that self-selected intermittent pacing is effective at self-governing the alleged 40°C Tc threshold for exercise performance and that in combination with thermal perception of skin temperature that athletes "give up" at these levels of thermal strain (48). Price et al. in 2009, found that varying methods of pre and mid-cooling had an effect on Tc in comparison to no exogenous cooling. The results demonstrated that the exogenous cooling strategies resulted in a ~1.0°C cooler Tc at the end of the trial than the control (no cooling). They also noted that there was still a decrease in Tc during the rest phase of the control group by 0.3°C which would suggest that the rest cycle did impact the attenuation of Tc increases (45). Conversely, Kraning and Gonzalez in 1991 reported that a 120 minute intermittent work cycle consisting of 10-min exercise-rest periods induced a higher level of physiological strain than a continuous work protocol. The experimental intermittent trial subjects walked for 4 minutes then jogged for 2 minutes and sat resting for 4 minutes while wearing either t-shirts and shorts or semi-permeable chemical protective suits. A continuous exercise trial with identical clothing options was also performed to differentiate the effects of intermittent cycle in comparison. There was a noticeable dip in Tc during the intermittent trials while the continuous trial showed no attenuation of Tc increases. Their results also demonstrated that in uncompensable heat stress situations discontinuous and continuous work both resulted in failure to complete the exercise protocol at times of 65 minutes and 79 minutes respectively. The authors suggested that these discrepancies might be attributed to non-thermal factors such as the interruption of transport by

evaporation and or postural differences and work load transition as no variations in airflow were provided (27).

In 2006 Maxwell et al. used an intermittent cycling sprint protocol of 20 sets of 10 seconds passive rest, 5 seconds sprint at 7.5% body mass on the flywheel and 105 seconds of recovery in a hot/humid and cool/arid to determine if recovery intensity was an effective method of delaying the increase of PSI. They found that active recovery at 35% VO_2 peak in a hot environment prolonged the number of sprints completed (15 sprints) and allowed for a higher maintenance of peak power output in comparison to the 50% VO_2 peak (10 sprints) as well as slowing the increase in PSI, 0.56 units per minute versus 0.79 respectively (32).

Practical Applications

The current research demonstrates that discontinuous exercise in a controlled environment with exogenous cooling can yield attenuation in Tc. The purpose of this study is to determine if a structured work/rest protocol in an outdoor environment with evaporative cooling can demonstrate a significant attenuation in the rise of Tc and HR without the aid of exogenous cooling. This study will bridge the gap between controlled laboratory environment research and real world applications to not only warfighters and wild land firefighters but also to the weekend hiker, monthly marathon participant, geocaching explorer and any other population which does work in the uncontrollable environment.

Chapter 3: Methodology

Participants and Settings

Outdoor Trials:

Subjects for this study were 5 recreationally active male volunteer participants 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 filled out the Physical Activity Readiness – Questionnaire to assess cardiovascular disease risk factors. Subjects signed an informed consent form approved by the Institutional Review Board of the University of Montana in Missoula, MT. Preliminary data was collected in the Human Performance Laboratory at the University of Montana in Missoula, MT. Trial data was collected on the 400m dirt track at Toole Park in Missoula, MT.

Indoor Trials:

Three recreationally active male volunteer participants from the Missoula, MT area within the ages of 18 and 40 years old with a running VO_2 peak $\geq$ 50 ml*kg^{-1}*min^{-1} were recruited for the indoor trials. Subjects filled out the Physical Activity Readiness – Questionnaire to assess cardiovascular disease risk factors. Subjects signed an informed consent form approved by the Institutional Review Board of the University of Montana in Missoula, MT. Data was collected and trials were conducted in an environmental chamber (Tescor, Warminster, PA) in the Montana Center for Work Physiology and Exercise Metabolism (WPEM).

Experimental Design

Preliminary Testing

Physical Activity Readiness Questionnaire (PAR-Q):

Preliminary testing included a pre-screening of participants involving a PAR-Q assessment for any known coronary artery disease risk factors to prevent potential complications from symptoms the participant might not be aware.

Hydrodensitometry:

Body composition was measured using a hydrostatic weighing tank with 3 force transducers using data collecting software (Exertech, Dresbach, MN) while estimating residual volume from subject's height and weight. Subjects fasted for $\geq$ 3 hours prior to body density assessment. Dry body weight was assessed on a weight scale (Befour Inc., Cedarburg, WI) and height was measured. Subjects were submerged and weighed repeatedly, until a within 100g consistency between measurements was recorded. Underwater weight was used to calculate body density to predict percent body fat using estimated residual volume and the Siri equation.

Maximal Aerobic Capacity (VO_2 peak):

Subjects fasted for $\geq$ 3 hours prior to performing a running VO_2 peak test. Running VO_2 peak tests were done on a treadmill ergometer (Fullvision, Inc., Newton, KS), a 5-minute warm-up (2.5 mph and 1 % grade) was done prior to conducting the Bruce Protocol to measure running VO_2 peak. The Bruce Protocol's first stage: 1.7 mph and a 10% grade for 3 minutes, after the first stage the workload was raised 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. To measure running VO_2 peak, expired gases were collected and analyzed every 15 seconds via a 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)); and 4) rate of perceived exertion (RPE) > 17 and volitional fatigue.

Experimental Trials

***Outdoor Trials**:*

Exercise Protocol

On testing days subjects arrived at the underwater weighing room in McGill Hall to have a body mass for beverage dose and sweat loss calculation and urine specific assessment to insure adequate hydration. Each subject was given a Ziploc bag containing a urine sample container, plastic razor blade for chest shaving, skin temperature patch, core temperature pill, heart rate chest strap and monitor, vital sense monitoring device, nitrile glove and neoprene waist pack for vital sense device carrying. Participants were then escorted to Toole Park walking slowly to the designated testing area at the outdoor track. All exercise trials were separated by at least one week and all trials met a total workload of 7 mph. Both trials were calculated to be the same total workload with one trial being continuous (CON) exercise at 7.0 mph and the other trial was a work rest cycle (discontinuous, DCON) of 1 minute walking at 3.0 mph and 8:34 minutes at 7.6 mph making up the deficit pace with the remaining laps. Calculation of pace strategy is as follows:

Pace = [(min/mile in decimal)(speed in mph) – (rest interval duration in minutes)(rest interval speed in mph)]/(min/mile in decimal)-(rest interval duration in minutes)

Weather:

Experimental trials were restricted to similar times of the day and temperatures $\geq 27^0$ C and $\leq 31^0$ C with sunny skies, and low cloud coverage, humidity $\geq$ 25% and $\leq$ 45%. These are climate averages as found in the weather.com database. The use of a portable wet bulb globe temperature monitoring apparatus from the Montana Center for Work Physiology an Exercise Metabolism was used to determine the temperature and humidity. The DCON trial occurred on day 3 with a starting temperature of 32°C and finishing temperature of 30.8°C and average humidity was 23%. The CON trials were held on two days where the first day temperature was 30°C at the start of the trials and 34°C at the finish of the trials and average humidity of 28%. The second day of CON trial had a starting temperature of 27.8°C and ended at 32°C with relative humidity at 22%.

Clothing:

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

Drink Administration:

During the 60-minute exercise trials subjects drank 2.0ml*Kilogram (Kg) of body weight (BW) of ambient temperature carbohydrate drink (Powerade, at about 26°C), and was be dispensed every 8 minutes 34seconds which was at the start of the DCON walk period and on the mile for the CON trial.

Heart Rate, Core Temperature, and Skin Temperature:

Heart rate (HR), core temperature (T_c) and skin temperature (T_{sk}) was continuously monitored and recorded throughout the exercise trials. HR data was monitored continuously by a chest-strap

and receiver watch (Polar Electro, Kempele, FL), T_c was measured once per second with an oral pill (AgriTemp Physiological Monitoring System HQ Inc. Palmetto, FL), T_c data was monitored and collected by CorTemp data recorder (HQ Inc. Palmetto, FL). T_{sk} was monitored second by second by an adhesive wireless skin patch on the left pectoralis major approximately 1 to 2 inches laterally from the sternum (AgriTemp Physiological Monitoring System HQ Inc. Palmetto, FL). The data was downloaded after the completion of the days' trial.

Indoor Trials:

Exercise Protocol:

Participants met at WPEM where they were weighed and beverage dose was calculated then a skin temperature sensor and rectal thermocouple was fitted. All exercise trials were separated by at least one week and all trials met a total workload (65% VO_2 peak for 60 minutes) measured from running VO_2 peak with the CON trial being run at 1% grade and 20 minutes at 5.5 mph, 20 minutes at 6.0 mph and 20 minutes at 6.5 mph and the DCON trial being 1% grade for 20 minutes at 5.2 mph with a 60 second interval at 3.0 mph at 9 and 19 minutes, 20 minutes at 6.3 mph with a 60 second interval at 3.0 mph at minutes 29 and 39 and 20 minutes at 7.6 mph with a 60 second interval at 3.0 mph at minutes 49 and 59. Both trials were calculated to be the same total workload with one trial being continuous exercise and the other trial being discontinuous. At the end of both protocols the treadmill was set to 7.0 mph and grade was increased every 60 seconds until voluntary subject failure. Discontinuous pacing strategy calculated as follows:

Pace = [(min/mile in decimal)(speed in mph) – (rest interval duration in minutes)(rest interval speed in mph)]/(min/mile in decimal)-(rest interval duration in minutes)

Environment:

Experimental trials were held on similar times of the day and the temperature of the environmental chamber was set to 34^0 C with relative humidity at 40%. The use of a portable wet bulb globe temperature monitoring apparatus from the Montana Center for Work Physiology and Exercise Metabolism was used to determine the temperature and humidity. A fan was propped in front of the treadmill to simulate air flow over the skin. The back of the fan was gated with a thera-band webbing to restrict airflow from the fan to reproduce wind speed at which the subjects were running.

Clothing:

Clothing was provided by the subjects: running shoes, low cut socks, running shorts (above the knee) and were instructed to run shirtless. The same clothing was worn in all experimental trials.

Drink Administration:

During the 60-minute exercise trials subjects drank 2.0ml*Kilogram (Kg) of body weight (BW) of ambient temperature carbohydrate drink (Powerade, at about 26°C), dispensed every 10 minutes beginning at the 9^{th} minute of the first stage and were to be finished by the end of the walk interval for DCON and 60 seconds later for CON. No other fluids were administered until the end of the protocol post-time trial.

Heart Rate, Core Temperature, and Skin Temperature:

Heart rate (HR), skin (T_{sk}) and core temperature (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 hard wired rectal thermometer (Mallinckrodt Medical, St. Louis, MO) and T_{sk} was collected with a hard wired skin temperature sensor (Mallinckrodt

Medical, St. Louis, MO) placed on the skin over the pectoralis major approximately 1 to 2 inches laterally from the sternum. T_{sk} and T_c data was monitored and collected by DASYLab Software (Measurement Computing Co., Norton, MA).

Indoor and Outdoor Trials:

Physiological Strain Index (PSI):

PSI was calculated using the formula from Moran et al.(40) using T_c and HR data where $T_{c(0)}$ and HR_0 where 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 and adjusted for fluid intake.

Statistical Analysis

SPSS 22.0 was used to perform repeated measures general linear model ANOVA using trial and time in 2x2, 2x3, 2x4, 2x5, 2x6, and 2x7 analyses for T_c, T_{sk}, HR and PSI with post-hoc analysis for main effects of trial, time and time*trial interaction. T-tests were performed for time trial and sweat rate. All data are presented as means $\pm$ SD.

Chapter 4: Results

Outdoor:

Five moderately trained men ages 28± 4.6 yr, body mass 73.3± 9.1 kg, percent body fat 9.2± 3.1%, VO_{2peak} 59.3± 2.9 $ml*kg^{-1}*min^{-1}$ completed both trials. Using 2x3 ANOVA, outdoor runners did not demonstrate an effect of the discontinuous intervention and all effects are indicative of failing to reject the null hypothesis. The temperature for the outdoor trials averaged 32± 2.8°C for control trial day one and 29.9 ± 3.0°C for control trial day two and 31.4 ± 0.8°C for the single day Dcon trial (Table 3). The average humidity for the control trials was 28± 4.2% for day one and 22.4± 3.4% day two and 22.6± 0.1% for the single day Dcon trial (Table 3). The average wind speed for the control trials did not register on the testing equipment and during the Dcon trial was 1.5mph± 0.71 SD (Table 3). Sweat Loss did not differ significantly between trials (Figure 12). A statistically significant difference of the main effect of time was demonstrated for the control vs. Dcon for Tc (Fig. 1), Tsk (Fig. 2), HR (Fig. 3) and PSI (Fig. 4). A statistically significant difference for the main effect of trial was demonstrated in Tsk (Fig 2) and HR (Fig 3). A statistically significant main effect of time and trial interaction was demonstrated in HR (Fig. 3). 2x4 ANOVA was used to examine the effect on PSI of removing time 0 from the data set to eliminate the physiological changes that occur during the rest to exercise transition resulting in a main effect of time approaching significance (Fig. 5).

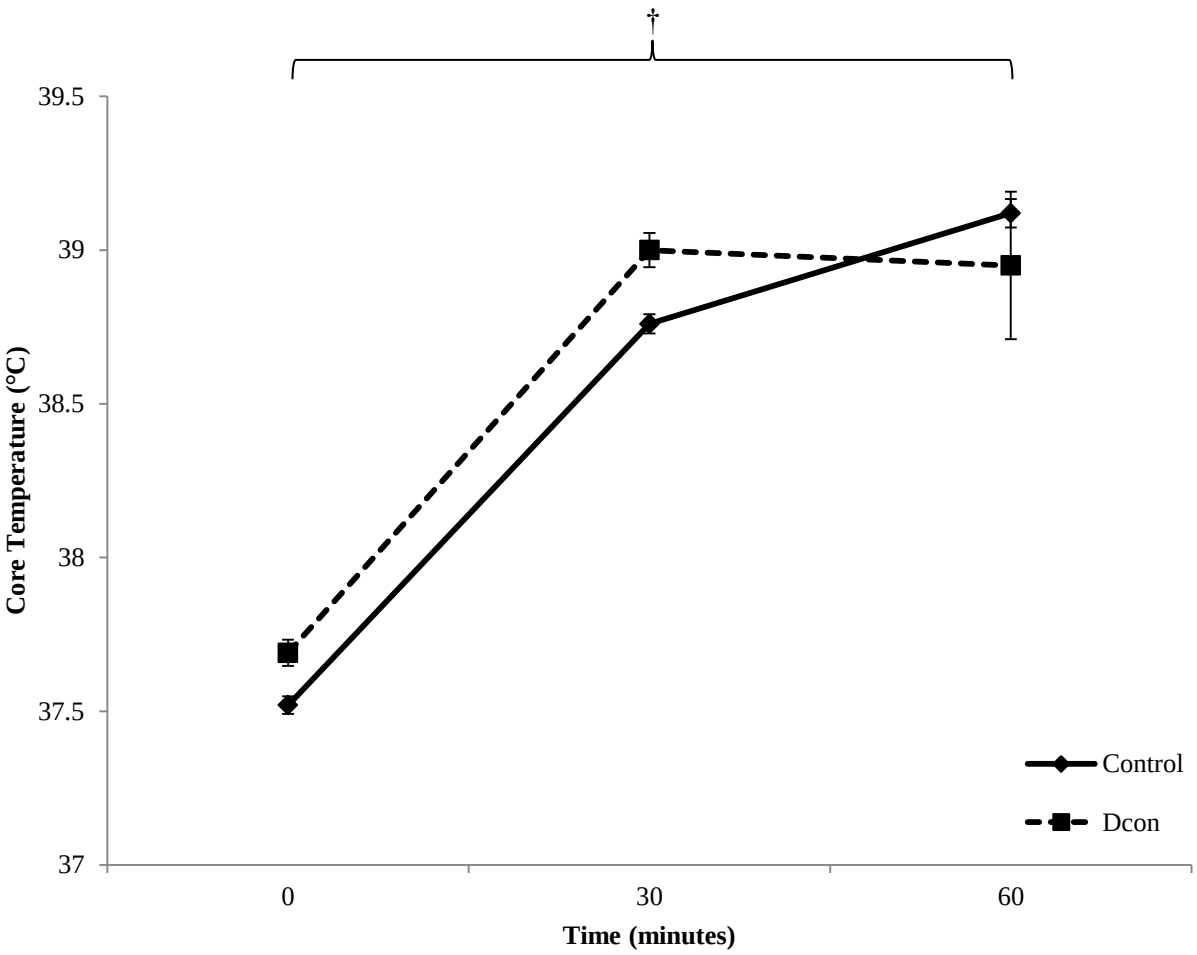

Figure 1. Outdoor Core Temperature (Tc) during continuous and Dcon trials. Main effect of time: †) $p<0.001$. Main effect of trial approached significance at $p=0.092$.

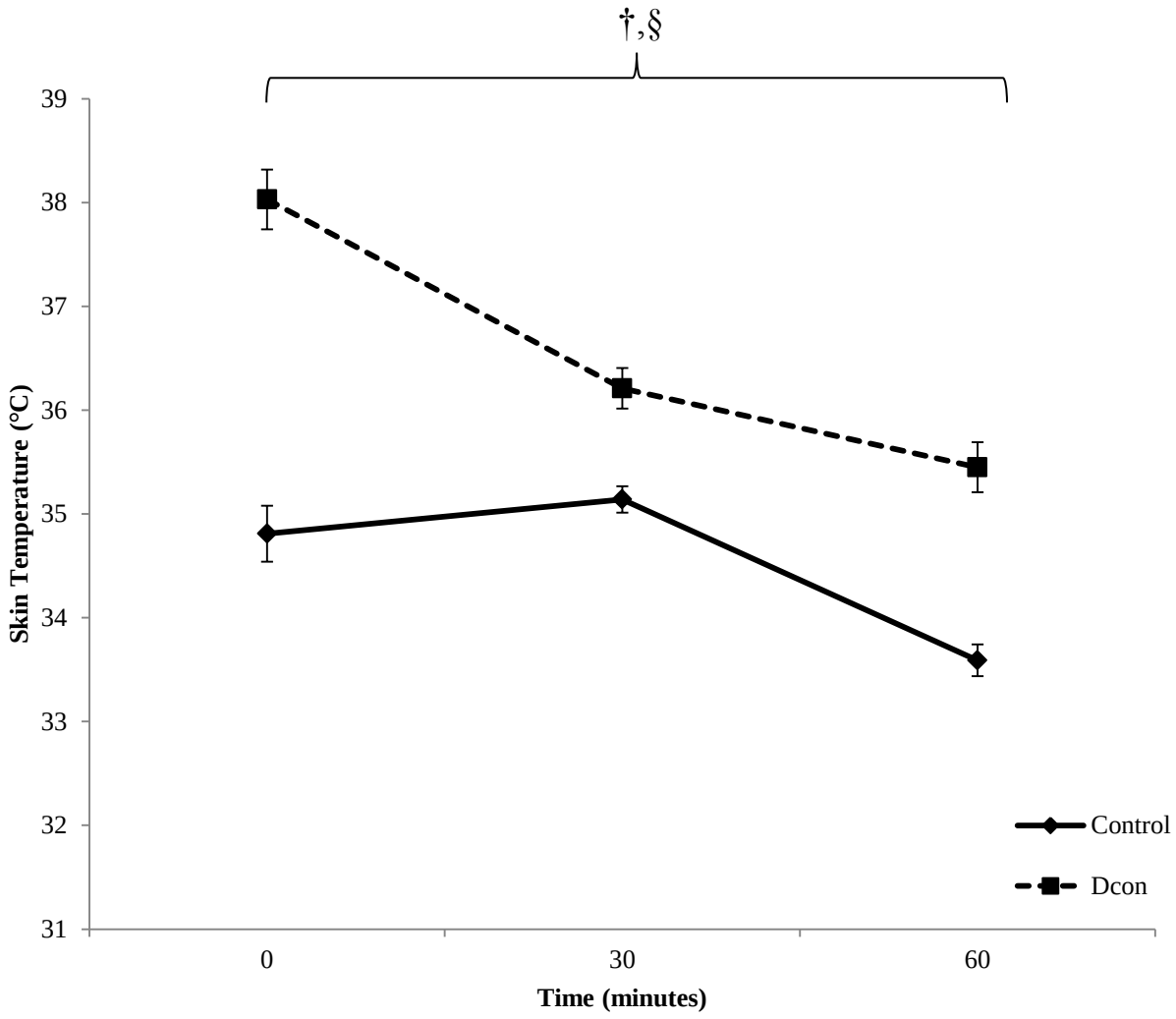

Figure 2. Outdoor Skin Temperature (Tsk) during continuous and Dcon trials. Main effect of trial: §) p=0.002, main effect of time: †) p=0.023.

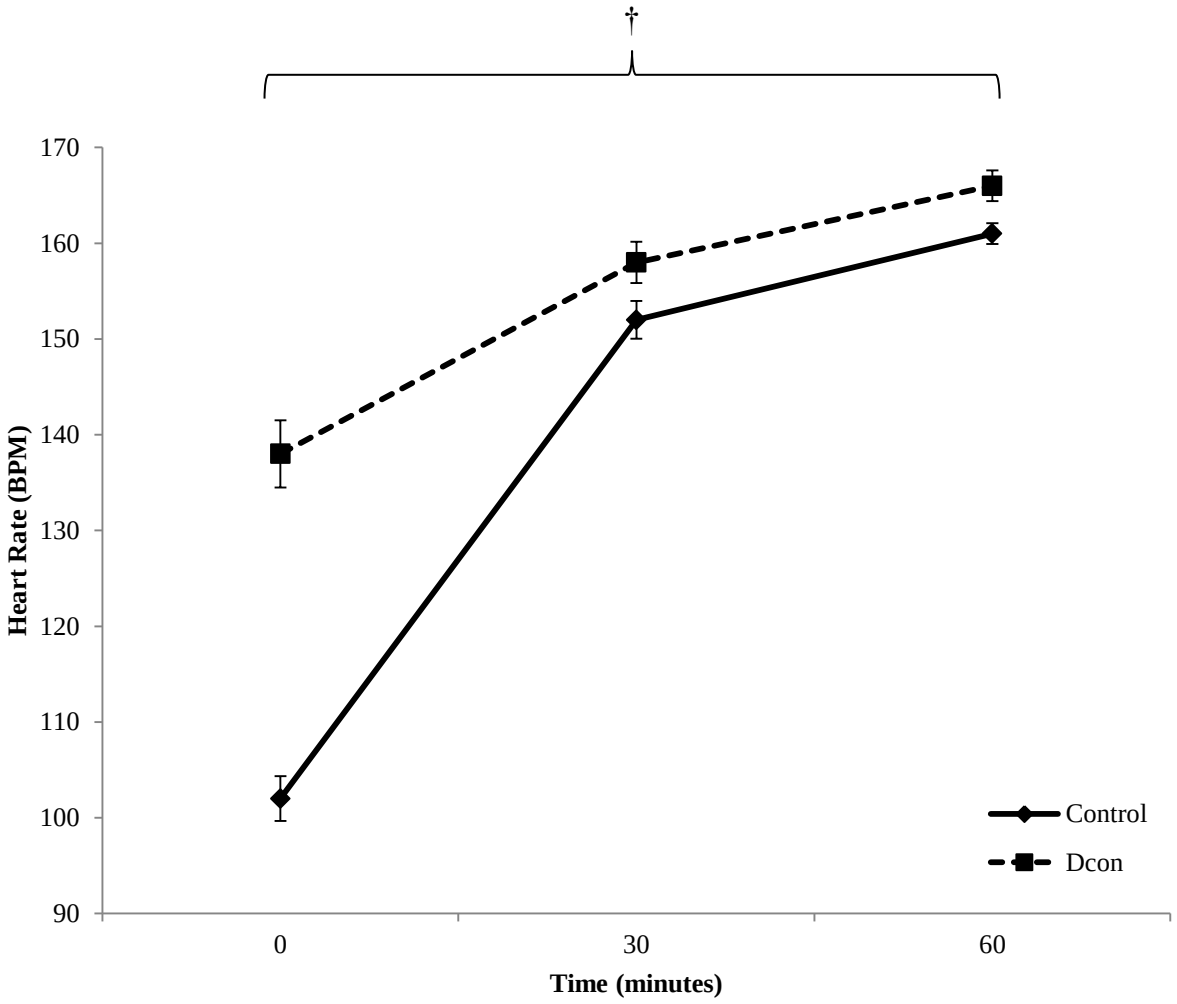

Figure 3. Outdoor Heart Rate (HR) during continuous and Dcon trials. Main effect of time †) p=0.013. Main effect of trial approached significance at p=0.095.

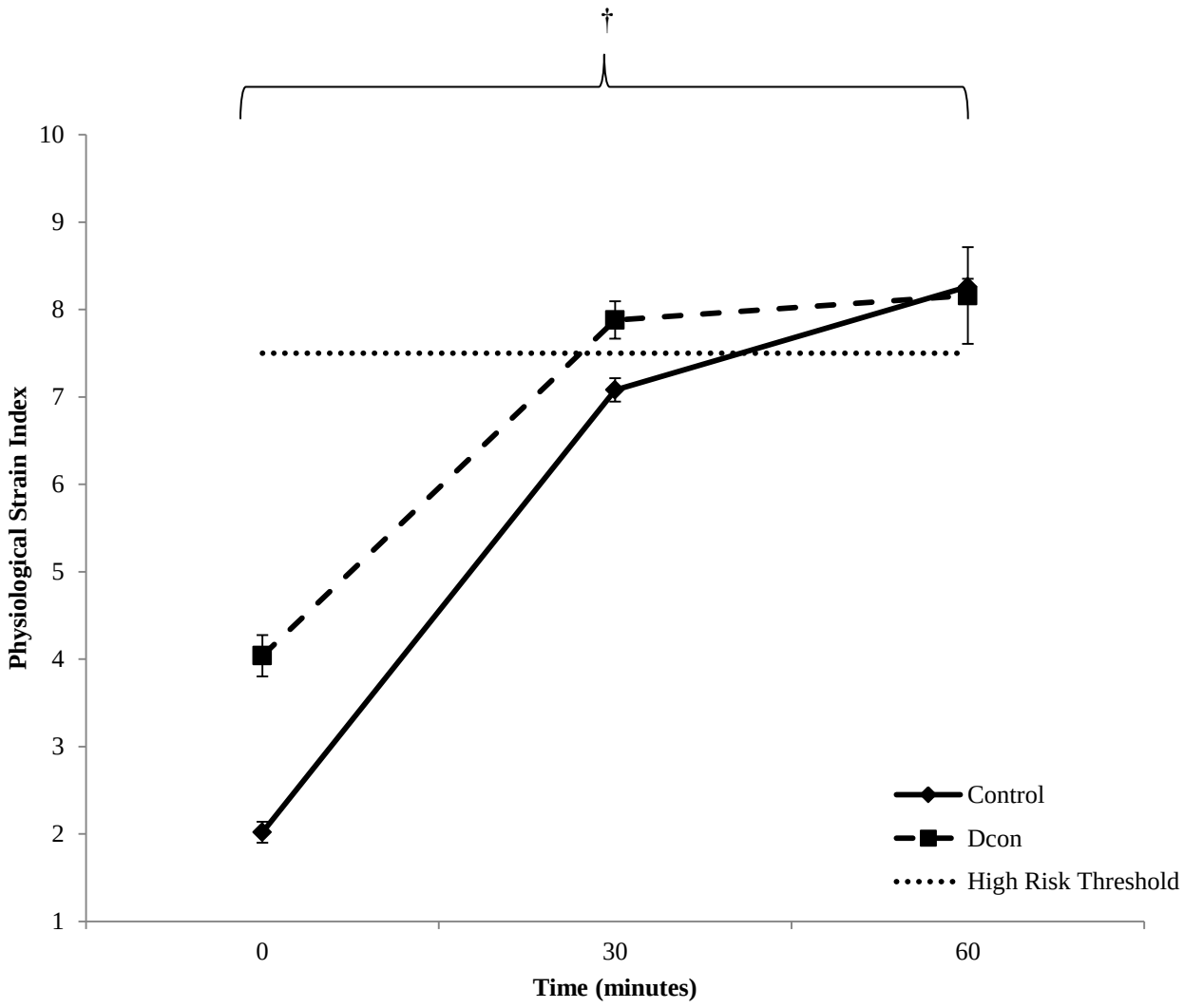

Figure 4. Outdoor Physiological Strain Index (PSI) during continuous and discontinuous (Dcon) trials with high risk PSI threshold. Main effect of time: †) $p<0.001$. Main effect of trial approached significance at $p=0.062$.

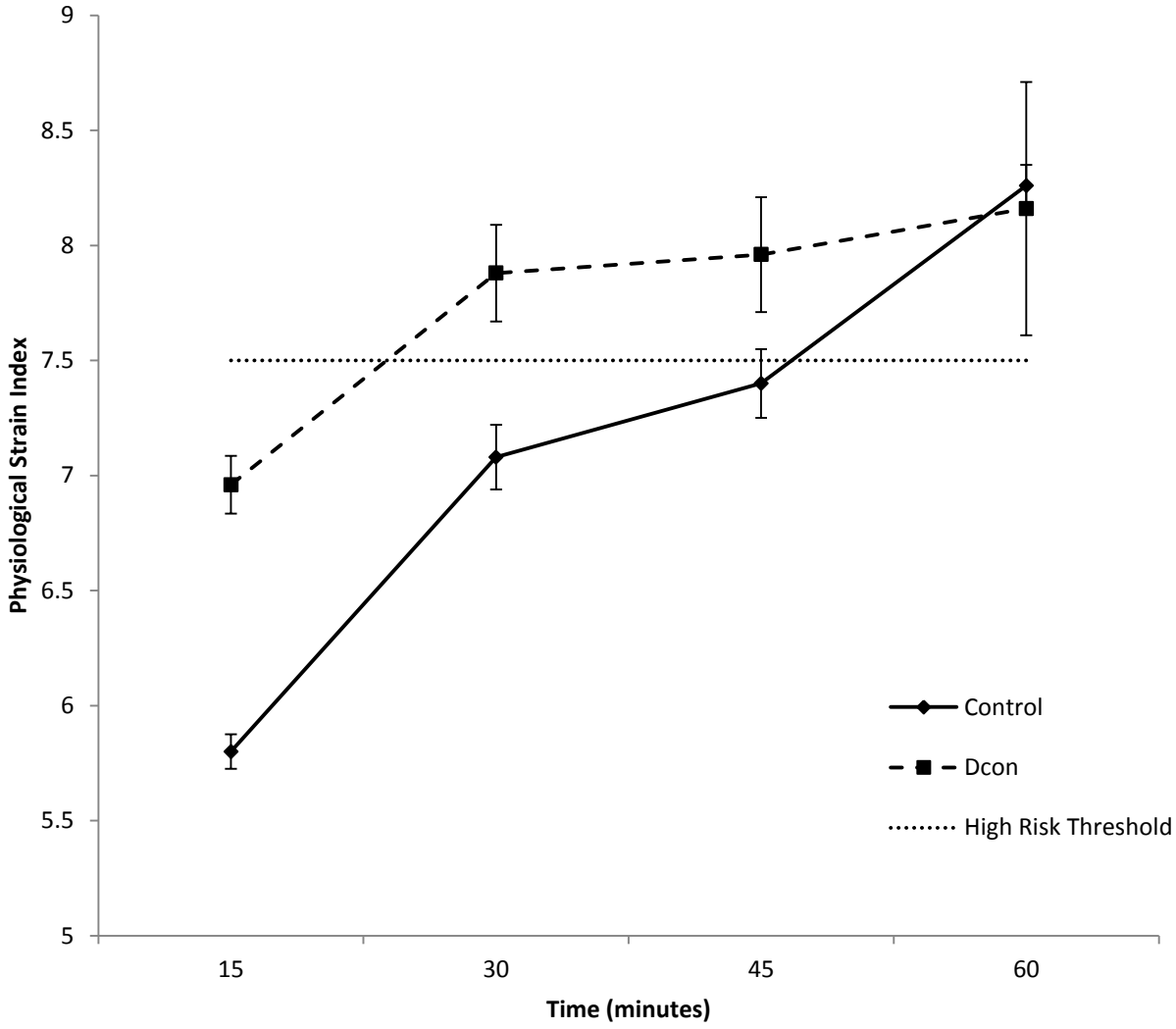

Figure 5. Outdoor PSI using 2x4 ANOVA without time 0 during continuous and Dcon trials with high risk PSI threshold. A main effect of time approaching significance at p=0.067.

Indoor:

Three moderately trained men ages 29.7± 2.1 yr, body mass 81.6± 7.7 kg, percent body fat 14.7± 1.5%, VO_{2peak} 55.3± 5.0 $ml*kg^{-1}*min^{-1}$ completed the trials. Using 2x3 ANOVA, indoor runners demonstrated a non-significant effect of the discontinuous intervention. The average humidity for the control trials was 40% for each of the trial days (Table 4) with wind speeds evaluated at 6.35± 0.35mph for the control trial and 7.15± 1.2mph (Table 4). The temperature for the indoor trials was 34°C for each of the two trial days (Table 4). No main effects were observed for Tc (Fig.6) or Tsk (Fig.7), a main effect of time for HR (Fig.8) and no main effects for PSI (Fig.9) was observed. 2x4 ANOVA was used to examine the effect on PSI of removing time 0 from the data set to eliminate the physiological changes that occur during the rest to exercise transition with no main effects observed (Fig. 10). TT time to failure (Fig.11) and sweat rate results did not differ significantly between trials (Fig.12).

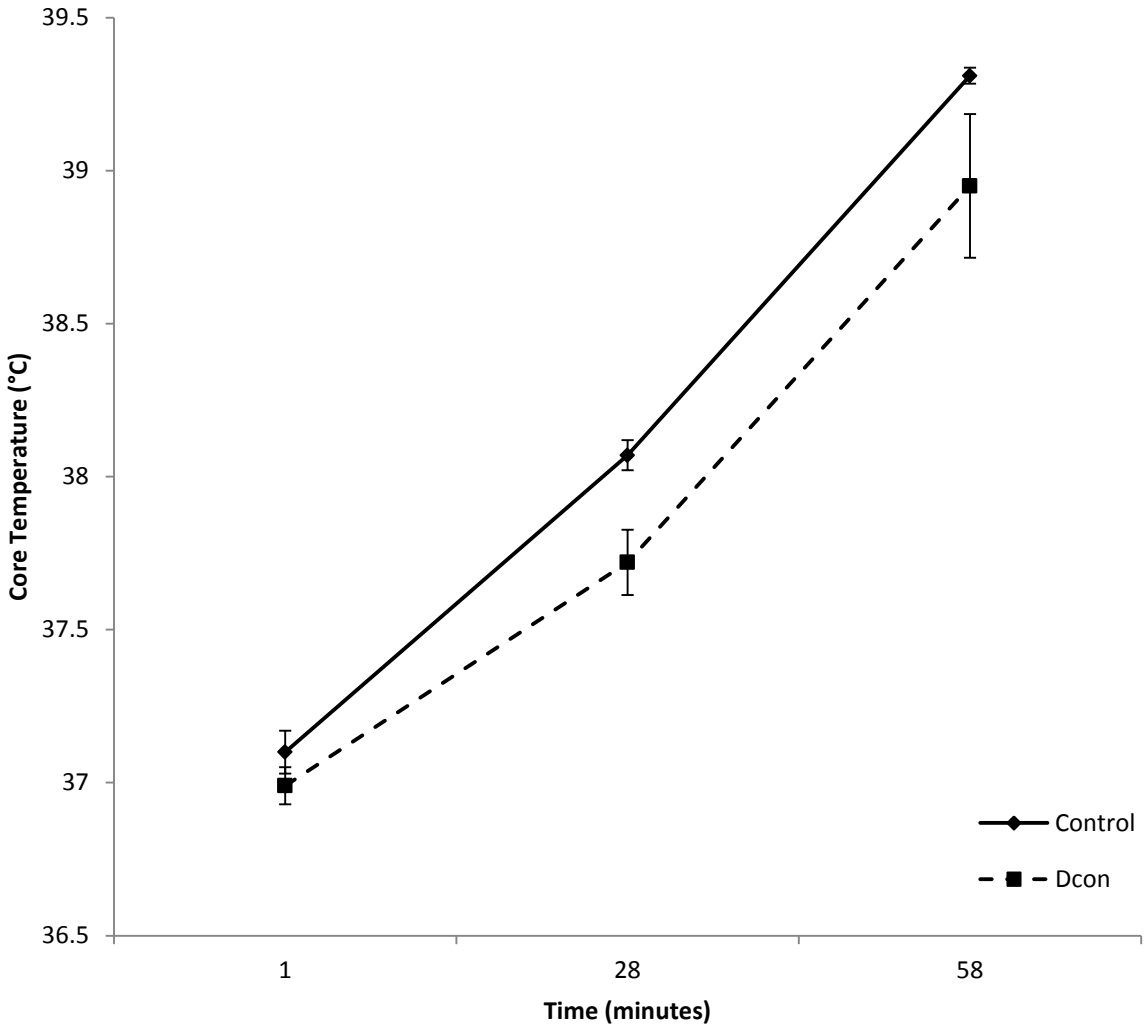

Figure 6. Indoor Tc during continuous and Dcon trials with no main effects.

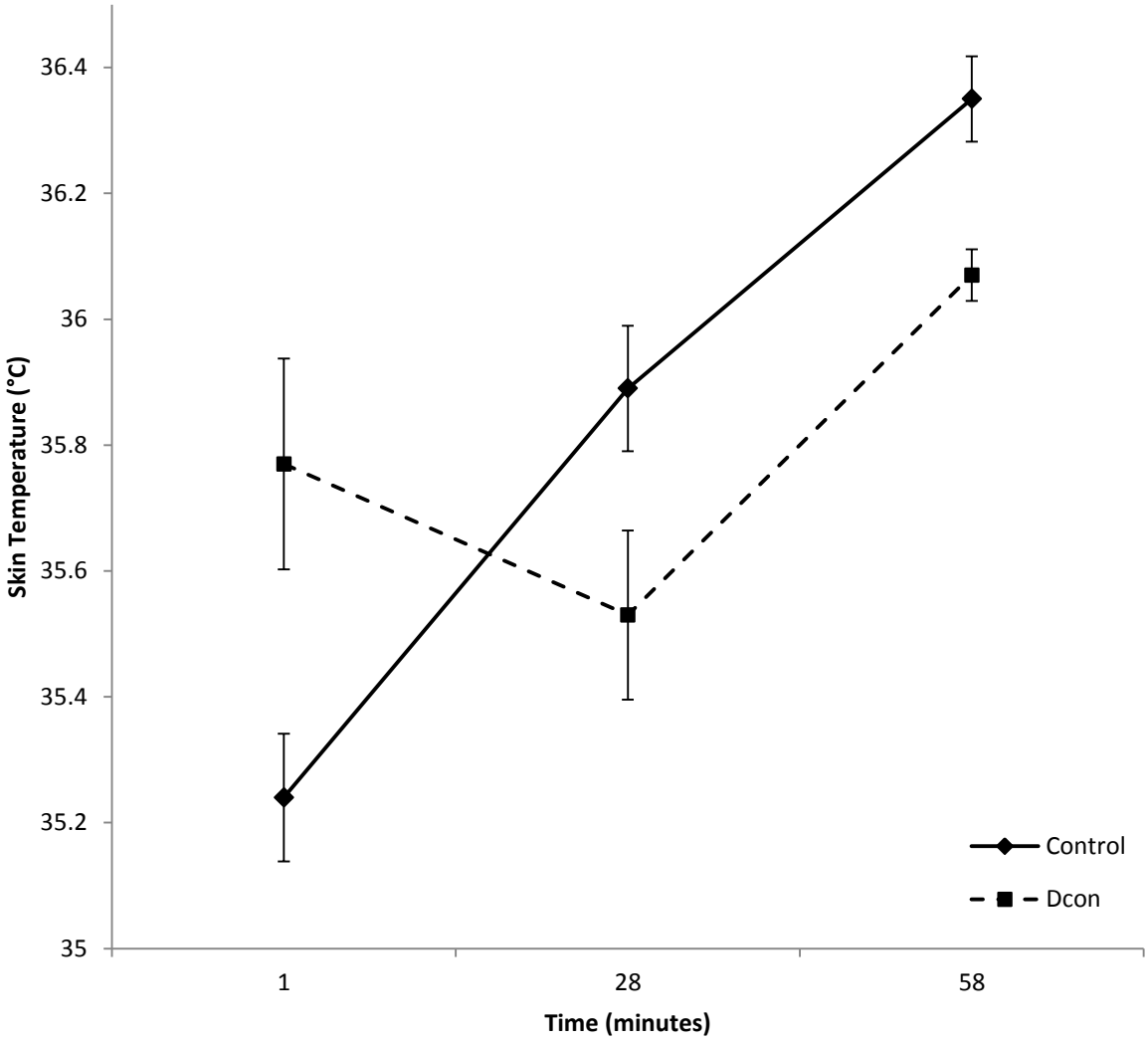

Figure 7. Indoor Tsk during continuous and Dcon trials with no main effects.

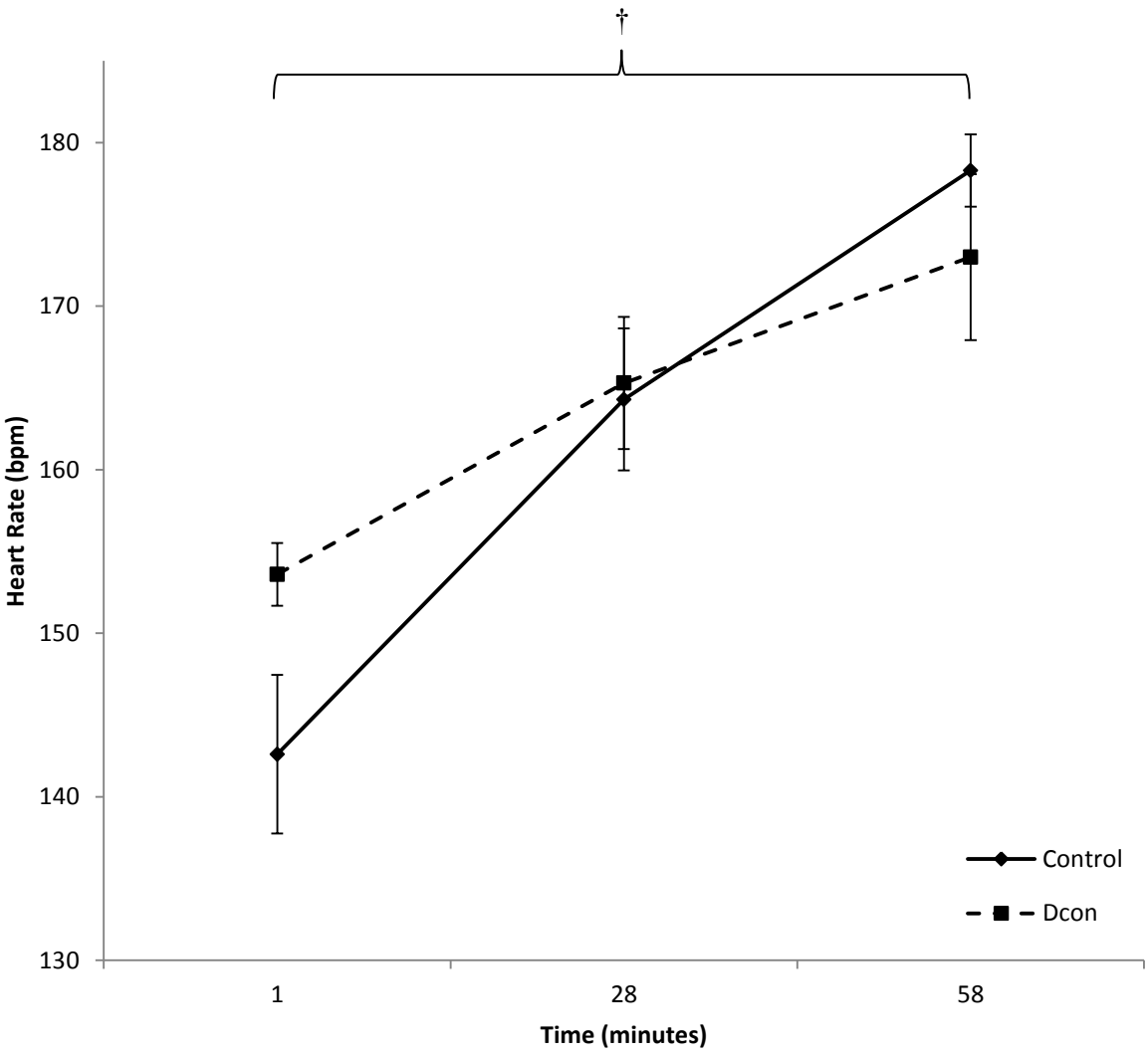

Figure 8. Indoor HR during continuous and Dcon trials. Main effect of time: †) p=0.016.

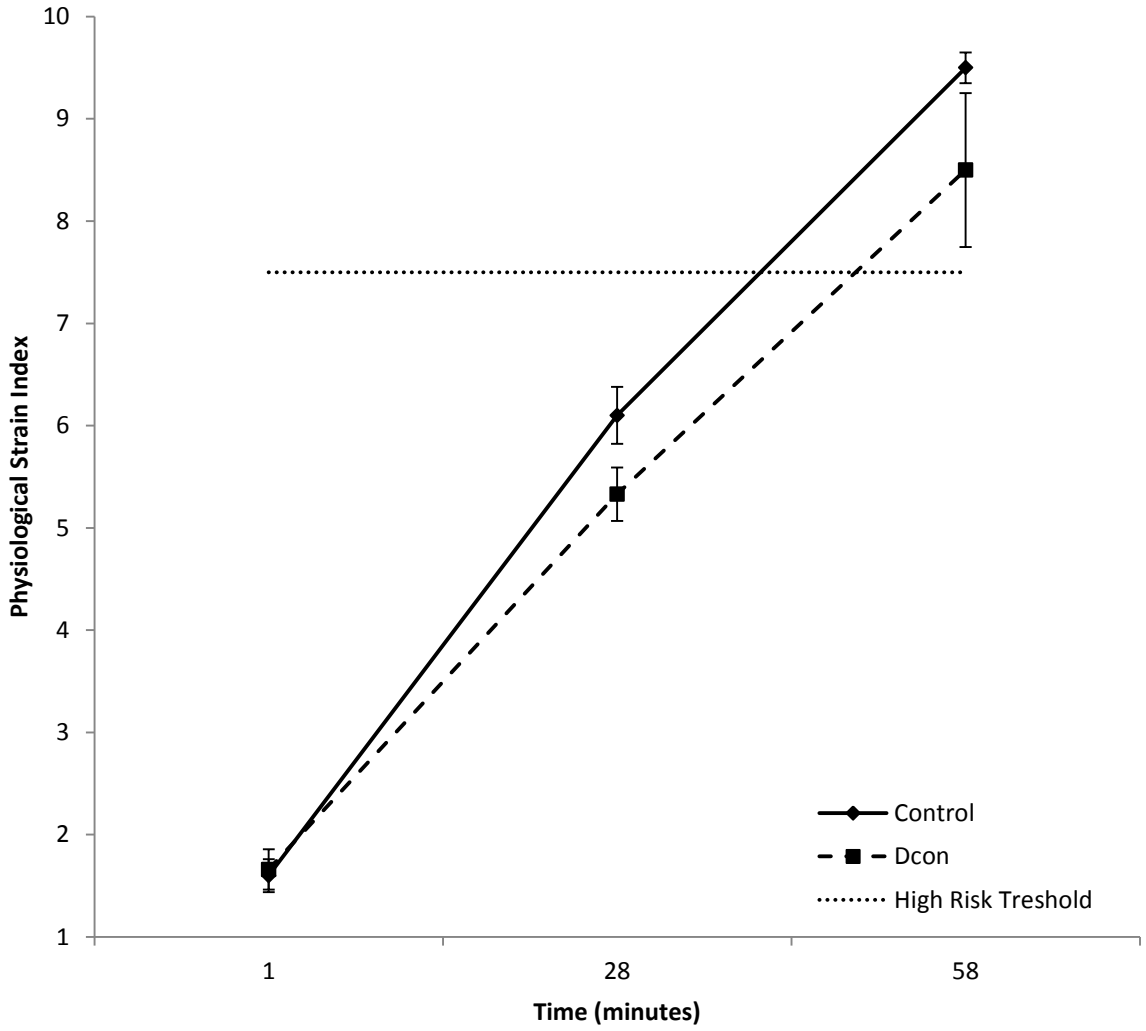

Figure 9. Indoor PSI during continuous and Dcon trials with high risk PSI threshold with no main effects.

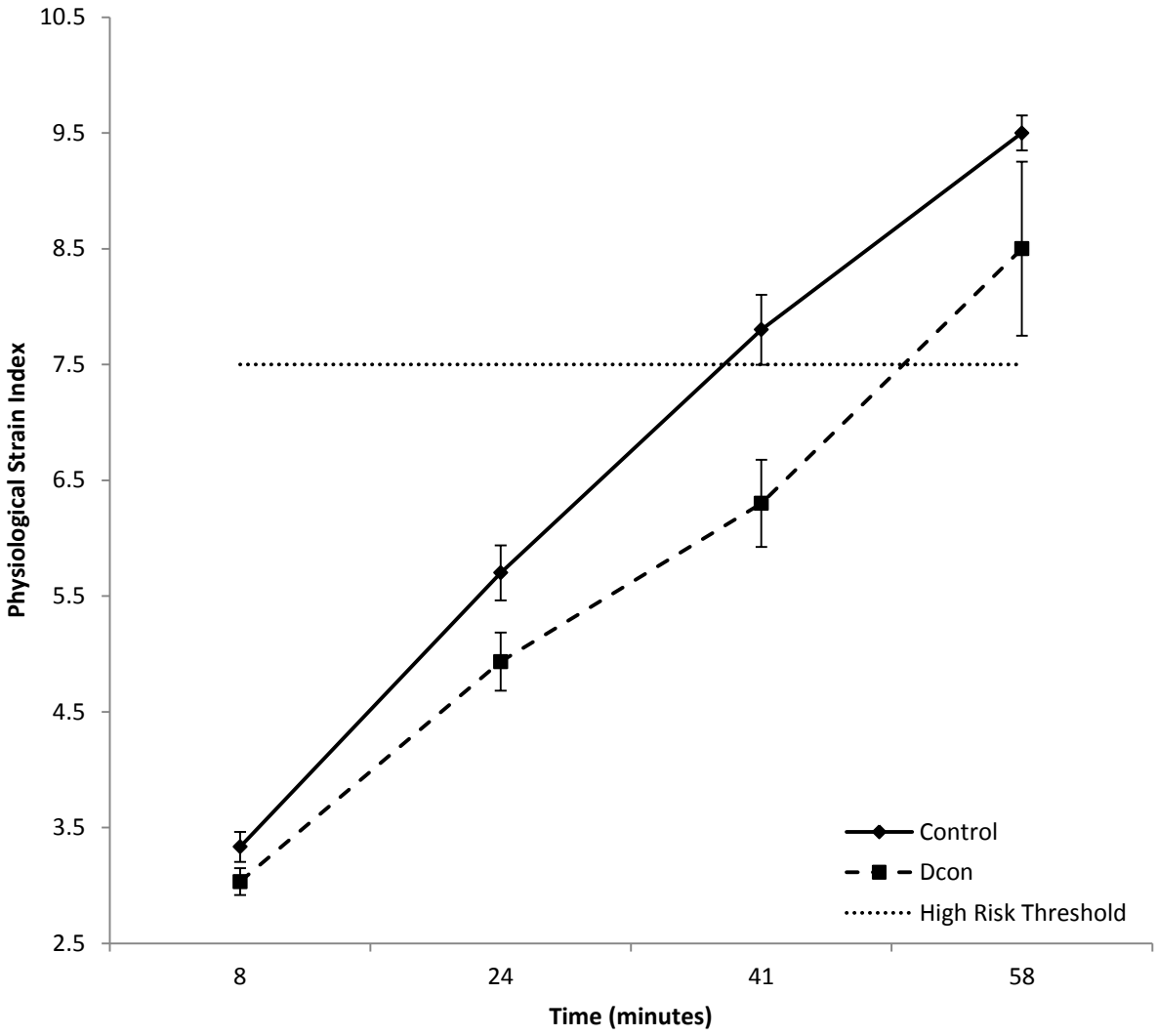

Figure 10. Indoor PSI using 2x4 ANOVA with no time 0 during continuous and Dcon trials with high risk PSI threshold with no main effects.

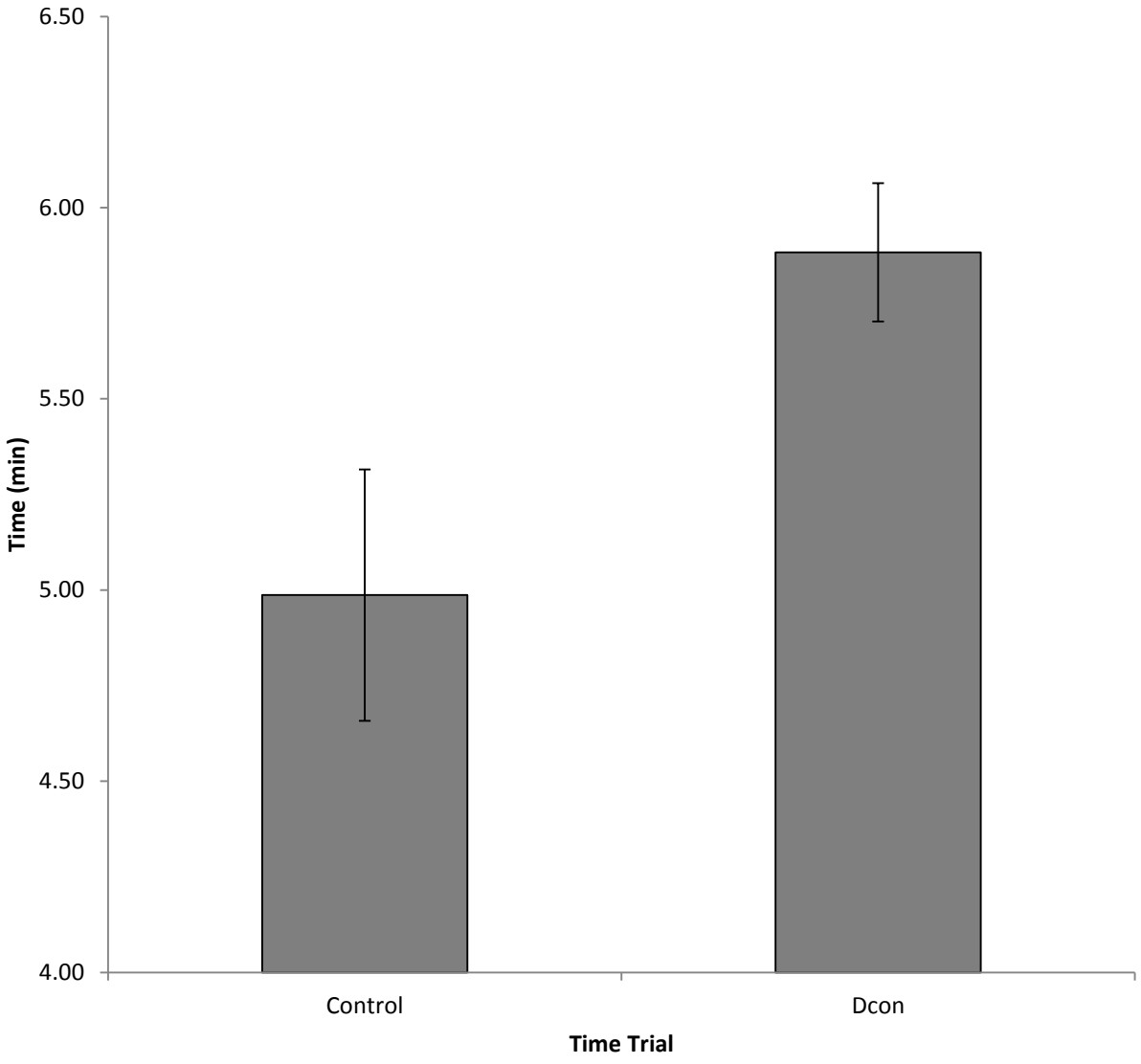

Figure 11. Indoor time trial in minutes until failure in continuous and Dcon trials p=0.15.

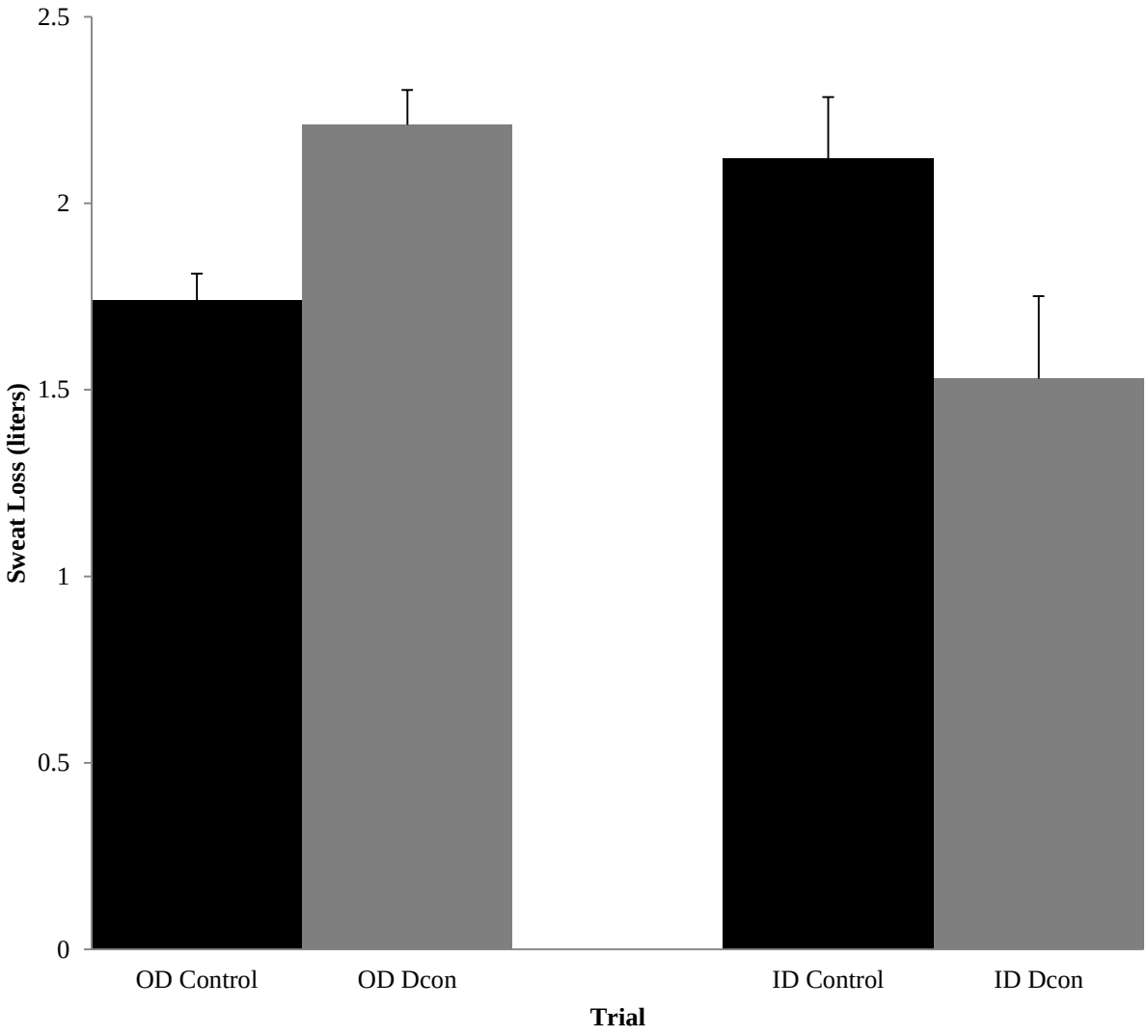

Figure 12. Sweat loss in liters between continuous and Dcon in outdoor and indoor trials.

Chapter 5: Discussion

The purpose of this study was to evaluate the effect of discontinuous exercise on the attenuation of increases in PSI during exercise in the heat. In previous studies, intermittent exercise bouts were subject to either uncompensable heat via clothing (27,35,47) and wet bulb globe temperature (27) or exogenous cooling sources either pre, during or post exercise trial in moderate temperature environments (11,12,13,36,37,45,46,51). The current study relied primarily on the effects of evaporative cooling from increased sweating during the walk interval. We found that when the two protocols, Dcon and continuous, were matched for work that the Dcon protocol did not cause elevations in or attenuations to the increases in Tc, Tsk, HR or PSI.

Previous studies have used combinations of randomized sprinting (2,12,15), hard running, jogging, walking and resting (27) as well as cycle ergometry (32,36) to evaluate interactions between Tc, Tsk and rest cycles. This effect of cooling was anticipated to be accentuated during the post-exercise bout of walking where blood flow is shunted away from the working muscles to dissipate metabolic heat through sweat response. Kraning et al., in 1991 compared continuous and discontinuous exercise in both compensable and uncompensable trials. The discontinuous trial consisted of sitting at 1 MET, walking at 3 METs, and jogging at 8 METs in either t-shirt and shorts or chemical protective equipment. Their results demonstrated that in the uncompensable protective equipment both Tc and Tsk continued to rise sharply over the duration of the trial and six of eight subjects failed to complete the trials. No subject failed before completing less than 60 minutes or with a Tc below 39°C. The compensable trial demonstrated a drastically different curve of gradual increase in Tc yet Tsk tapered and decreased over time (27). These findings suggest that in a compensable environment the sweat

response to exercise over time can elicit a lower Tc and Tsk. In comparison, the current study did not use uncompensable heat and increased the running workload to 10.2 METs and the walking partition to 3.3 METs. The compensable component of the current study used technical fabric shirts and performed the exercise trials in the outdoor environment in order to simulate a real world application where athletes are subjected to compensable physiological stressors.

Grossl et al., in 2012, compared intermittent and continuous cycling bouts at maximal lactate steady state to evaluate total time to exhaustion. Not only did the intermittent (Dcon) group last 24% longer than the continuous group but the absolute power output of the Dcon group was 268 ± 29W compared to 251± 29W in the continuous group (22). This corroborates similarly with the results in the current study where Dcon participants worked at a higher intensity than the continuous group and performed longer, albeit not statistically significant $p=0.15$, in the indoor post-exercise trial TT.

Schlader et al., in 2009 and 2010, commented on the role of thermal balance between the increased metabolic heat produced by exercise and the need to either gain or dissipate heat relative to that thermal balance. The inclusion that at a certain ambient temperature, metabolic heat production can exceed the capacity for heat loss which causes an uncompensable situation when the rate of evaporative heat loss cannot accommodate the amount of heat generation (48,49). The focus of the Dcon protocol in the current study was to elicit the sweat response by performing moderate intensity exercise in a hot environment in compensable circumstances in order to evaluate the interaction of sweat rate and metabolic heat dissipation.

There was no use of exogenous cooling in these trials and it was decided to pursue data relating to the Tsk and ambient air temperature gradient with the intention of evaluating its effect on evaporative cooling. The intent of giving ambient temperature carbohydrate drink was to

negate any effect of cold beverage ingestion as the focus of this research was to prioritize evaporative heat loss through increased sweat rate.

The key finding of the indoor trials was that despite working at a greater intensity, the Dcon group maintained similar PSI across the duration of the trial. This finding suggests that, while not statistically significant, that a Dcon intervention may attenuate the rise in PSI during exercise in the heat. One limitation of the outdoor research was the lack of ideal weather conditions for appropriate Tsk to ambient temperature gradient. At 36°C ambient temperature one's body gains heat through radiant heat and evaporative cooling becomes the body's preferred method of heat dissipation (57). During the three trial days mean relative humidity was 24.3% ± 3.2 SD (Table 3) which is not an uncompensable heat stress environment. As noted, (Table 3) the ambient temperature did not reach 36°C during any of the trials and thusly the ideal circumstances for evaporative cooling might not have been achieved even though relative humidity remained low. Even more importantly, there were discrepancies between testing days in the control and Dcon trials by several degrees (Table 3), this led to an inconsistency in the starting and finishing temperatures for the different trials. One subject completed their control trial on a day that began and ended 2.0°C hotter with 5% greater relative humidity than the four other subjects control trials. The four other subjects control trial began >4°C cooler than the Dcon trial and ended >1°C hotter with no significant difference in relative humidity. These circumstances led to inconsistencies in physiological measurements which when normalized for starting Tc, Tsk and HR demonstrated an observable difference between the two trials in favor of the Dcon protocol. The inability to control the environment and changes in weather from day to day in the late summer hindered the progress of the study and forced a different approach as the complete investigation was to include 12 subjects yet only five completed the trials before the

weather became too moderate to continue. As a result of this loss of subjects, the statistical power of the experiment was reduced as our residual degrees of freedom became four instead of the intended 11. This loss of statistical power led to the use of 2x3 ANOVA which illustrates a broader picture of a very precise interaction between changes in Tsk, HR and the exercise/rest transitions. With that loss of statistical power in mind, the selected time points of 30 and 60 minutes for the indoor trials each capture the end of a run component of the stage and thus the steady state exercising portion of those stages. This illustrates that during the outdoor trials, subjects were able to maintain Tc, HR and PSI despite exercising at a higher intensity. The complication of field research variability in climate may be remedied by re-starting the trials in the mid-summer months of July and August where the climate in Missoula is more predictable and ideal for evaluating this research hypothesis.

In response to the diminished availability of ideal outdoor conditions the experiment was brought into a controlled environmental chamber indoors. The re-designed protocol had incremental increases in treadmill speed yet control and Dcon trials were both matched for an absolute workload of 6mph. While not statistically significant, the results show that the Dcon trial did not result in elevated PSI despite working at a higher workload than the control trial. These results suggest that even though a more physiologically demanding protocol was enacted upon the Dcon group, they were able control heat stress accumulation with intermittent walking periods in the same environment. The addition of a performance time trial (TT) at the end of the exercise protocol was included to determine if a performance advantage could be gained between the control and Dcon protocols. While the results were not statistically significant there were improvements in performance in two of the three subjects whom ran longer post-Dcon trial. To simulate the evaporative effect of wind over the skin a gated fan was constructed to moderate

airflow at prescribed speeds based on treadmill running velocity and increased in coercion with each successive stage to simulate outdoor running. This measure had some success but the turbulent environment in the environmental chamber hindered any consistent measures or control of circulating air from the fan. The chamber has a series of exhaust and circulation fans that were positioned above the heat lamps which the treadmill was positioned under and competed with the treadmill fan for circulation of airflow which in turn would create dead-zones of no air flow or extremely turbulent and un-controllable flow thus leading to inconsistencies in measured air speed. Future investigations should consider alternative placements of the treadmill in relation to the heat lamps and chamber fans as their contribution might increase or decrease the efficacy of the treatment if it relies on measures of Tsk and sweat evaporation.

The indoor trials demonstrated non-significant differences in Tc, Tsk, HR and PSI with the Dcon trial being consistently lower across the three subjects. A re-designed outdoor experiment in a more climate stable time of year would be an ideal circumstance to further the research into this topic.

Practical Applications:

With the burgeoning popularity of endurance running and a growing community of outdoor exercise enthusiasts the implications of exercise in the heat are affecting more people each year. In addition to the non-professional exercise enthusiast, the occupational athlete must also find ways to accommodate for the changes in the outdoor environment in order to avoid heat related injury. The efficacy of a run/walk, walk/rest, run/jog or other discontinuous exercise protocol, may be of relevant interest in avoiding overtaxing one's ability to dissipate metabolic heat by taking advantage of the evaporative cooling capabilities of one's body. This may bring importance to the rest intervals afforded both athletes in training in the heat, as well as

occupational athletes, as evaporative cooling may be most effective when metabolic heat production is reduced.

Conclusion:

The indoor trials demonstrated that in a consistent environment, a discontinuous exercise protocol can result in similar PSI and Tsk over the duration of an exercise bout despite exercising at a higher intensity. The outdoor trials did elicit a similar effect but the complications in both consistency of weather conditions and residual degrees of freedom from failing to successfully complete the trials might lend power to future endeavors into Dcon experimental analysis. The implicit findings that it is possible to work harder and potentially attenuate the rise in PSI during an exercise bout in compensable heat would seem to give credence to the possibility of failing to reject the null hypothesis that there will be no significant difference between PSI in Dcon and continuous exercise trials.

Appendix I: IRB Approval

Form RA-108
(Rev. 8/10)

VP RESEARCH & DEV. THE UNIVERSITY OF MONTANA
AUG - 6 2013
Revised

THE UNIVERSITY OF MONTANA-MISSOULA
Institutional Review Board (IRB)
for the Use of Human Subjects in Research
CHECKLIST / APPLICATION

IRB Protocol No.:
149-13

At The University of Montana (UM), the Institutional Review Board (IRB) is the institutional review body responsible for oversight of all research activities involving human subjects outlined in the U.S. Department of Health and Human Services Office of Human Research Protection (www.hhs.gov/ohrp) and the National Institutes of Health, Inclusion of Children Policy Implementation (http://grants.nih.gov/grants/funding/children/children.htm).

Instructions: A separate registration form must be submitted for each project. IRB proposals are approved for three years and must be continued annually. **Faculty members** may email the completed form as a Word document to *IRB@umontana.edu*. **Students** must submit a hardcopy of the completed form to the Office of the Vice President for Research & Development, University Hall 116.

1. **Administrative Information**

Project Title: The effects of ice slurry ingestion and discontinuous work intervals during exercise in the heat	
Principal Investigator: Charles Dumke	Title: Professor
Email address: Charles.dumke@mso.umt.edu	
Work Phone: (406) 243-6176	Cell Phone:
Department: HHP	Office location: McGill 103

2. **Human Subjects Protection Training** *(All researchers, including faculty supervisors for student projects, must have completed a self-study course on protection of human research subjects* ***within the last three years*** *(http://www.umt.edu/research/complianceinfo/IRB/) and be able to supply the "Certificate(s) of Completion" upon request. Add rows to table if needed.*

NAME and DEPT.	PI	CO-PI	Faculty Supervisor	Research Assistant	DATE COMPLETED Human Subjects Protection Course
Charles Dumke	X	☐	☐	☐	11/2011
Brent Ruby	☐	X	☐	☐	4/2013
Felipe von Sydow	☐	☐	☐	X	8/2012
Timothy Hampton	☐	☐	☐	X	8/2012

3. **Project Funding**

Is grant application currently under review at grant funding agency? ☐Yes *(If yes, cite sponsor on ICF if applicable)* ☒ No			Has grant proposal received approval and funding? ☐Yes *(If yes, cite sponsor on ICF if applicable)* ☒ No	
Agency	Grant No.	Start Date	End Date	PI
				Charles Dumke
Is this part of participant's thesis or dissertation? ☒Yes ☐No von Sydow and Hampton ✓		If **yes**, date the participant successfully presented participant's proposal to participant's committee:30 July 13		

For UM-IRB Use Only

IRB Determination:

X Approved Exempt from Review, Exemption # ____ *(see memo)*
X Approved by Expedited Review, Category # 3, 4 *(see* ***Note to PI****)*
____ Full IRB Determination
____ Approved *(see* ***Note to PI****)*
____ Conditional Approval *(see memo)* - IRB Chair Signature/Date: _____
____ Conditions Met *(see* ***Note to PI****)*
____ Resubmit Proposal *(see memo)*
____ Disapproved *(see memo)*

Risk Level: Minimal

Final Approval by IRB ~~Chair~~ Coordinator: Paula A Baker Date: 8-7-13 Expires: 8-6-2014

*** Note to PI:** Study is approved for one year. Use any attached IRB-approved forms (signed/dated) as "masters" when preparing copies. If continuing beyond the expiration date, a continuation report must be submitted. Notify the IRB if any significant changes or unanticipated events occur. Notify the IRB in writing when the study is terminated.

1

The University of Montana

INSTITUTIONAL REVIEW BOARD
for the Protection of Human Subjects in Research
FWA 00000078

Research & Creative Scholarship
University Hall 116
The University of Montana
Missoula, MT 59812
Phone 406-243-6672 | Fax 406-243-6330

Date: August 7, 2013

To: Charles Dumke, HHP
Brent Ruby, HHP

From: ☒ Paula Baker, IRB Coordinator
☐ Dan Corti, IRB Chair

RE: IRB #149-13: "The effects of ice slurry ingestion and discontinuous work intervals during exercise in the heat"

Your IRB proposal cited above has been **APPROVED** under **expedited review** by the Institutional Review Board in accordance with the Code of Federal Regulations, Part 46, section 110. Expedited approval refers to research activities that (1) present no more than minimal risk to human subjects, and (2) fit within the following category for expedited review as authorized by 45 CFR 46.110 and 21 CFR 56.110:

3. Prospective collection of biological specimens for research purposes by noninvasive means.
Examples: (a) hair and nail clippings in a nondisfiguring manner; (b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction; (c) permanent teeth if routine patient care indicates a need for extraction; (d) excreta and external secretions (including sweat); (e) uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue; (f) placenta removed at delivery; (g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor; (h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques; (i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings; (j) sputum collected after saline mist nebulization.

4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)
Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject=s privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

All consent forms used for this project must be date-stamped and signed by the IRB. Use the PDF sent with this approval notice as a "master" from which to make copies.

Amendments: Any changes to the originally-approved protocol must be reviewed and approved by the IRB ***before*** being made (unless extremely minor). Requests must be submitted using Form RA-110.

Unanticipated or Adverse Events: You are required to timely notify the IRB if any unanticipated or adverse events occur during the study, if you experience an increased risk to the participants, or if you have participants withdraw from the study or register complaints about the study. Use Form RA-111.

Continuation: Federal and University of Montana IRB policy requires you to file an annual Continuation Report (Form RA-109) for expedited studies. You must file the report within 30 days prior to the expiration date, which is **August 6, 2014**. *Tip: Put a reminder on your calendar now.* A study that has expired is no longer in compliance with federal or University IRB policy, and all project work must cease immediately.

Study Completion or Closure: Finally, you are also required to file a Closure Report (Form RA-109) when the study is completed or if the study is abandoned. See the directions on the form.

Please contact the IRB office with any questions at (406) 243-6672 or email irb@umontana.edu.

The University of Montana

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/min and $\leq$ 60ml/kg/min.

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)

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Date Approved 8-7-13
Chair/Admin

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.

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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

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Chair/Admin

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.

The University of Montana IRB
Expiration Date 8-6-2014
Date Approved 8-7-13
Chair/Admin

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) 243-6672.

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 _____

The University of Montana IRB
Expiration Date 8-6-2014
Date Approved 8-7-13
Chair/Admin

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 _____

The University of Montana IRB
Expiration Date 8-6-2014
Date Approved 8-7-13
Chair/Admin Paula A. Kohler

Appendix II: 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.

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

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 or GUARDIAN (for participants under the age of majority) _____ 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.

CSEP | SCPE

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Appendix III

Table 1. Outdoor Subject Descriptive Characteristics (N=5)

Variable	Mean ±	SD
Age (yr)	28.0±	4.6
Body Weight (kg)	73.3±	9.1
Percent Body Fat (%)	9.2±	3.1
Fat Free Mass (FFM) (kg)	66.6±	7.9
Fat Mass (kg)	6.7±	2.3
VO_{2peak} Treadmill ($ml*kg^{-1}*min^{-1}$)	59.3±	2.9

Table 2. Indoor Subject Descriptive Characteristics (N=3)

Variable	Mean ±	SD
Age (yr)	29.7±	2.1
Body Weight (kg)	81.6±	7.7
Percent Body Fat (%)	14.7±	1.5
Fat Free Mass (FFM) (kg)	69.6±	6.3
Fat Mass (kg)	11.9±	1.2
VO_{2peak} Treadmill ($ml*kg^{-1}*min^{-1}$)	55.3±	5.0

Table 3. Outdoor Weather Characteristics

Day	Trial	N	Start Temp (°C)	End Temp (°C)	Mean ±	SD
1	Control	1	30.0	34.0	32.0	2.8
2	Dcon	5	32.0	30.8	31.4	0.8
3	Control	4	27.8	32.0	29.9	3.0

Day	Trial	N	Start Humidity (%)	End Humidity (%)	Mean ±	SD
1	Control	1	31.0	25.0	28.0	4.2
2	Dcon	5	22.6	22.5	22.6	0.1
3	Control	4	24.8	20.0	22.4	3.4

Day	Trial	N	Start Wind (mph)	End Wind (mph)	Mean ±	SD
1	Control	1	0	0	0	0
2	Dcon	5	1	2	1.5	0.71
3	Control	4	0	0	0	0

Table 4. Indoor Climate Chamber Weather Characteristics

Trial	N	Start Temp (°C)	End Temp (°C)	Mean ±	SD
Control	3	34.0	34.0	34.0	0.0
Dcon	3	34.0	34.0	34.0	0.0

Trial	N	Start Humidity (%)	End Humidity (%)	Mean ±	SD
Control	3	40.0	40.0	40.0	0.0
Dcon	3	40.0	40.0	40.0	0.0

Trial	N	Start Wind (mph)	End Wind (mph)	Mean ±	SD
Control	3	6.6	6.1	6.35	0.35
Dcon	3	6.3	8	7.15	1.20

Table 5. Outdoor trial ANOVA table, alpha set at 0.05.

	2X2			2X3		
	TIME	TRIAL	TIME*TRIAL	TIME	TRIAL	TIME*TRIAL
TC	1.000	0.002	0.521	0.000	0.092	0.932
TSK	0.004	0.025	0.161	0.023	0.002	0.286
HR	0.044	0.000	0.011	0.013	0.095	0.624
PSI	0.000	0.144	0.191	0.000	0.062	0.453

	2X4			2X5		
	TIME	TRIAL	TIME*TRIAL	TIME	TRIAL	TIME*TRIAL
TC	0.001	0.010	0.041	0.048	0.257	0.513
TSK	0.051	0.013	0.287	0.374	0.000	0.769
HR	0.007	0.000	0.078	0.092	0.011	0.234
PSI	0.140	0.140	0.011	0.093	0.034	0.120

	2X6			2X7		
	TIME	TRIAL	TIME*TRIAL	TIME	TRIAL	TIME*TRIAL
TC	-	0.159	-	-	0.639	-
TSK	-	0.000	-	-	0.858	-
HR	-	0.013	-	-	0.116	-
PSI	-	0.026	-	-	0.068	-

Table 6. Indoor trial ANOVA table, alpha set at 0.05.

	2X2			2X3		
	TIME	TRIAL	TIME*TRIAL	TIME	TRIAL	TIME*TRIAL
TC	0.022	0.340	0.623	0.114	0.269	0.693
TSK	0.074	0.406	0.132	0.537	0.762	0.127
HR	0.039	0.257	0.477	0.016	0.639	0.459
PSI	0.017	0.163	0.558	0.124	0.232	0.733

	2X4			2X5		
	TIME	TRIAL	TIME*TRIAL	TIME	TRIAL	TIME*TRIAL
TC	-	0.263	-	-	0.246	-
TSK	-	0.544	-	-	0.591	-
HR	-	0.104	-	-	0.065	-
PSI	-	0.045	-	-	0.118	-

	2X6			2X7		
	TIME	TRIAL	TIME*TRIAL	TIME	TRIAL	TIME*TRIAL
TC	-	0.247	-	-	0.262	-
TSK	-	0.327	-	-	0.767	-
HR	-	0.134	-	-	0.056	-
PSI	-	0.178	-	-	0.060	-

Figure 13. Outdoor Individual Skin Temperature Subject 1.

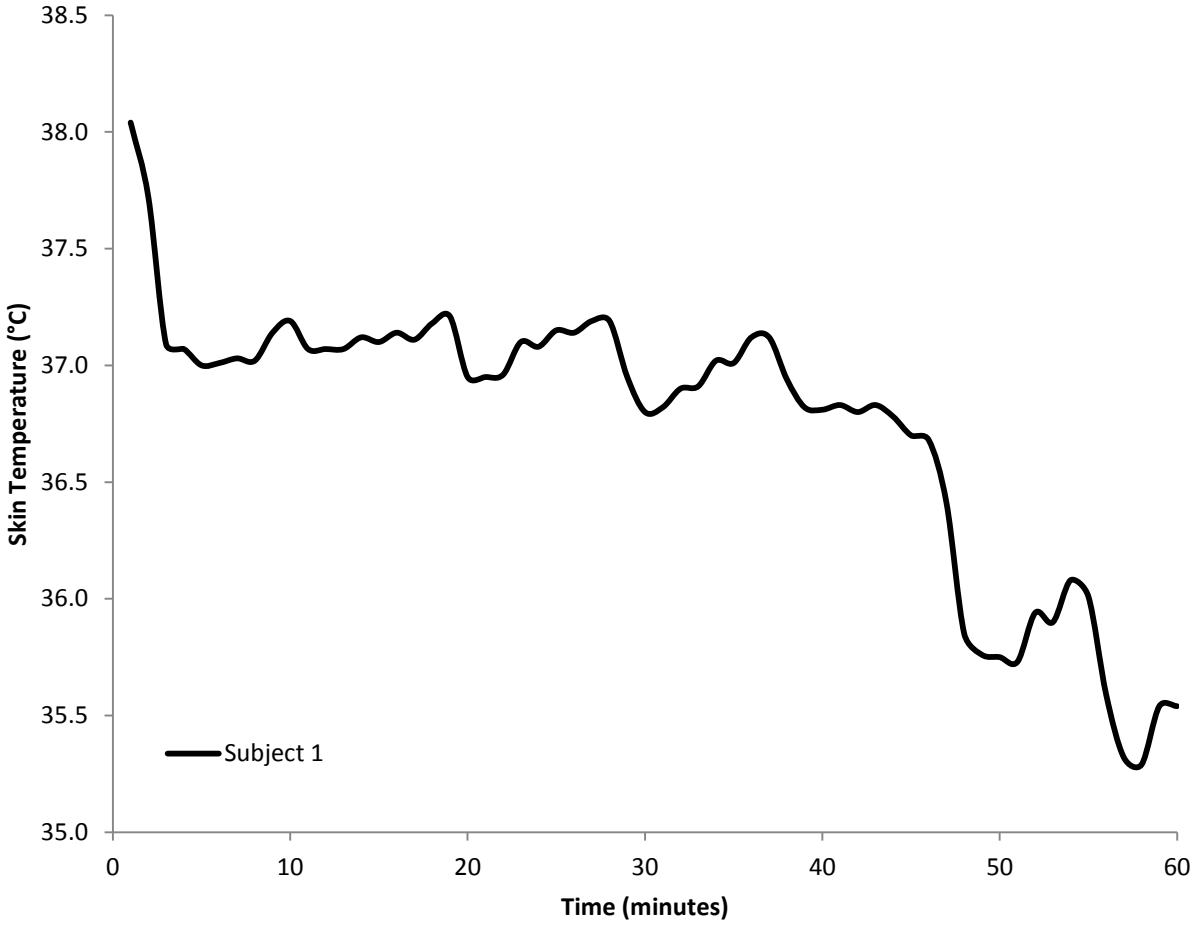


Figure 14. Outdoor Individual Skin Temperature Subject 2.

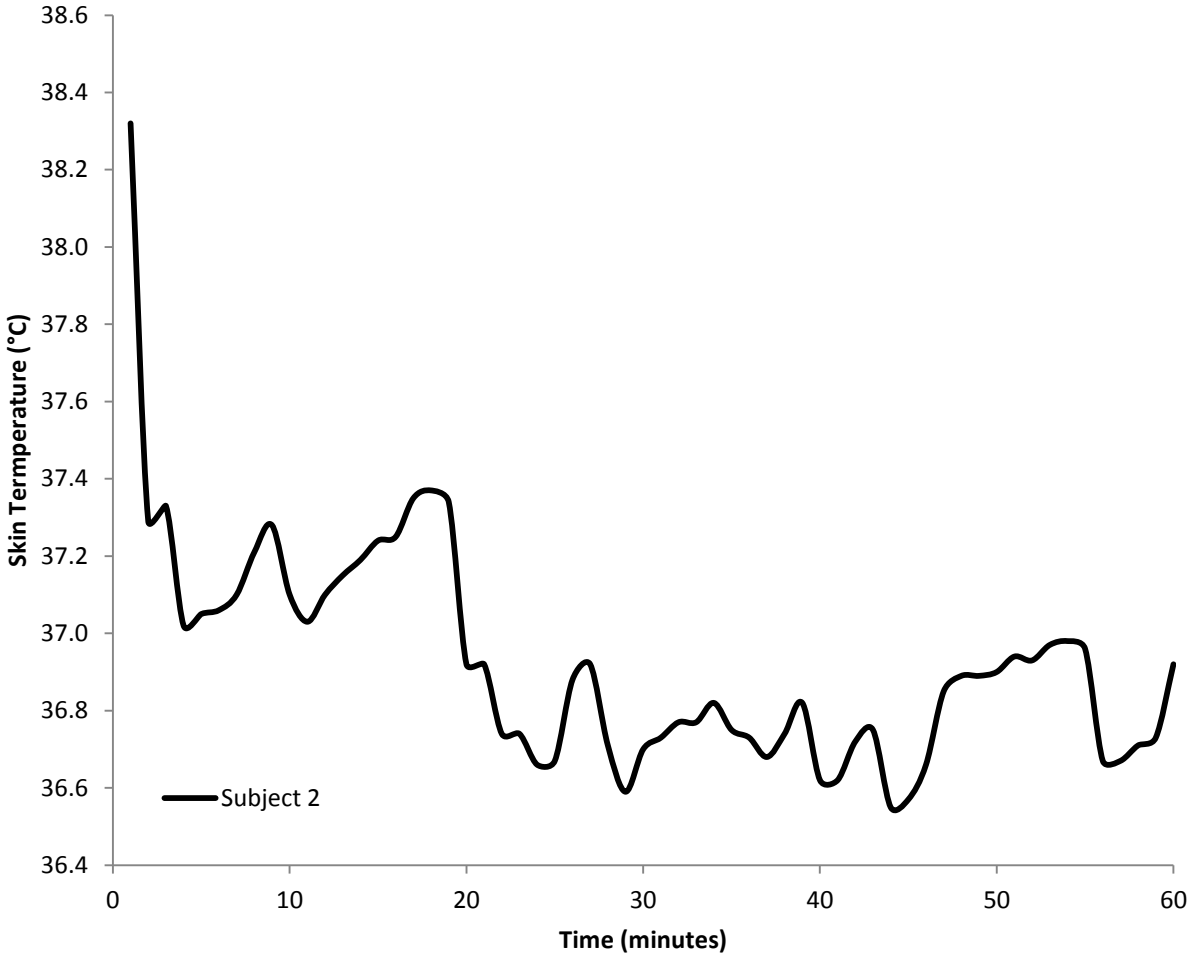


Figure 15. Outdoor Individual Skin Temperature Subject 3.

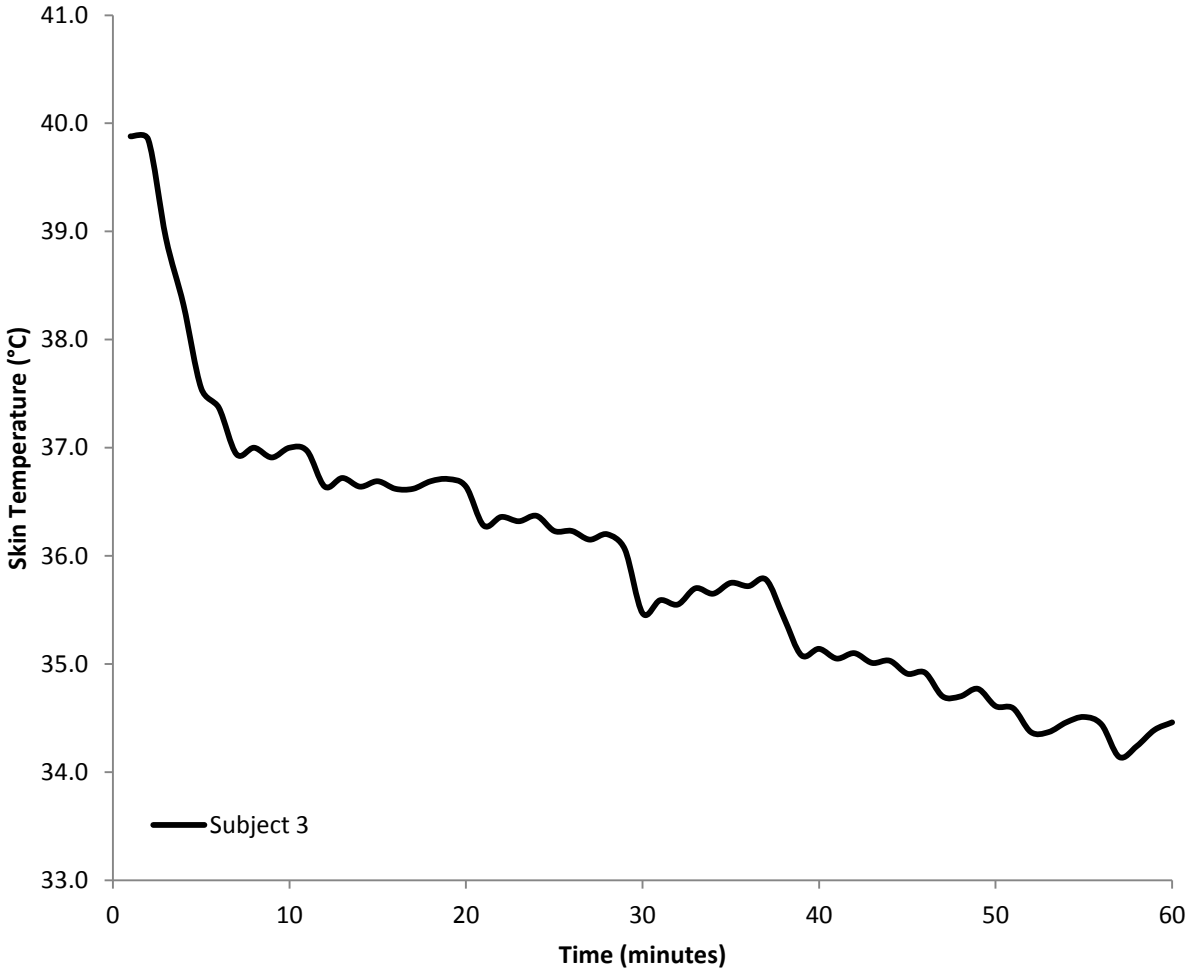


Figure 16. Outdoor Individual Skin Temperature Subject 4.

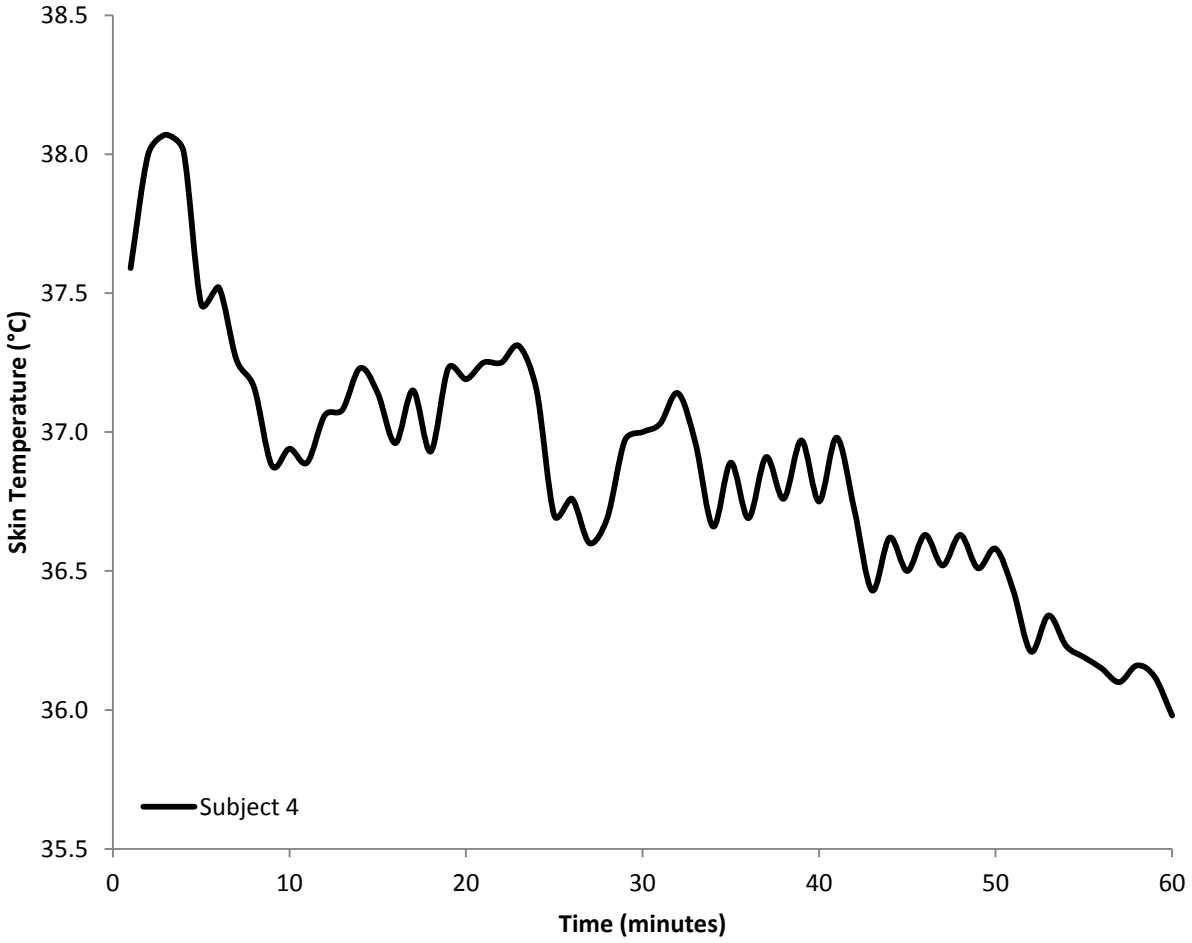


Figure 17 Outdoor Individual Skin Temperature Subject 5.

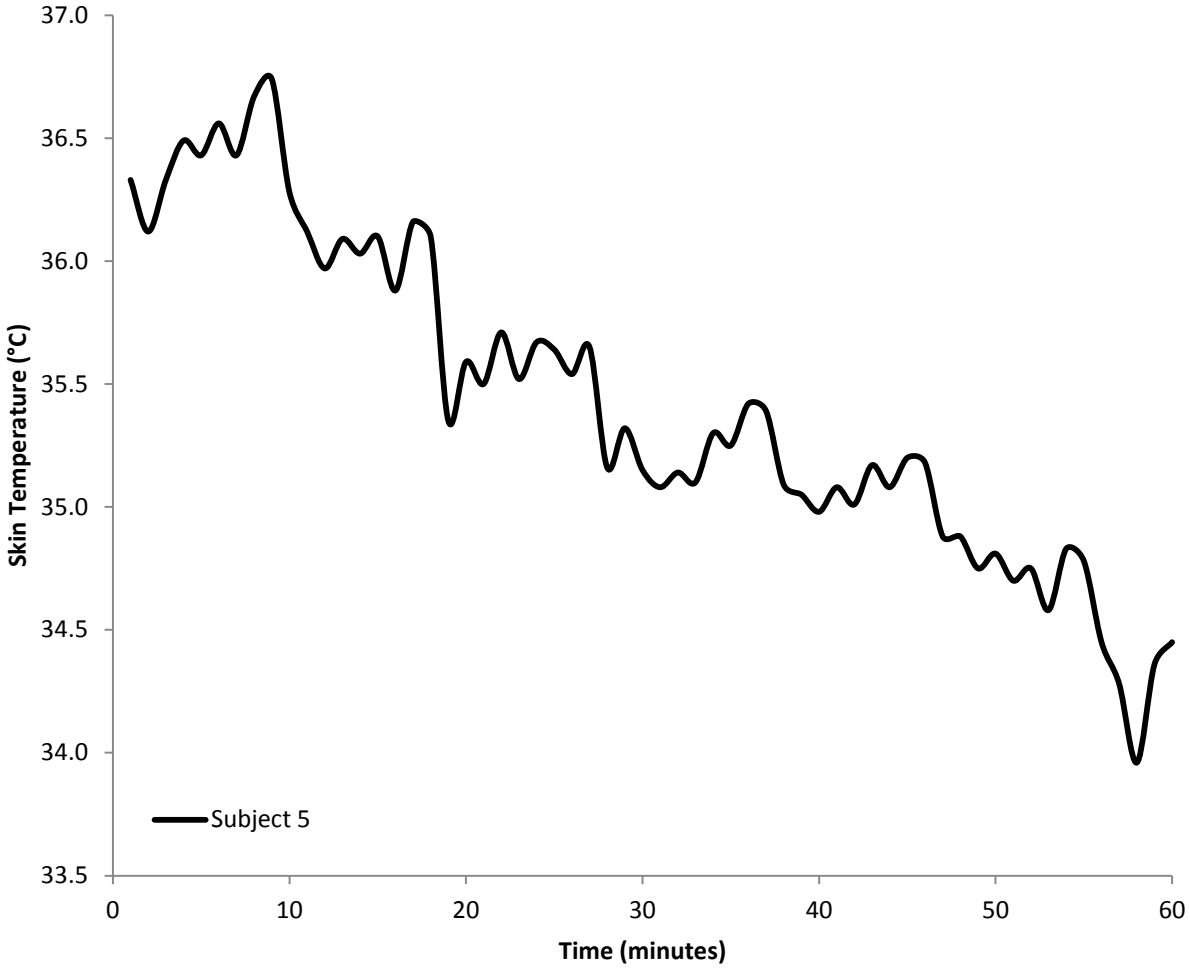


Figure 18 Indoor Individual Skin Temperature Subject 1.

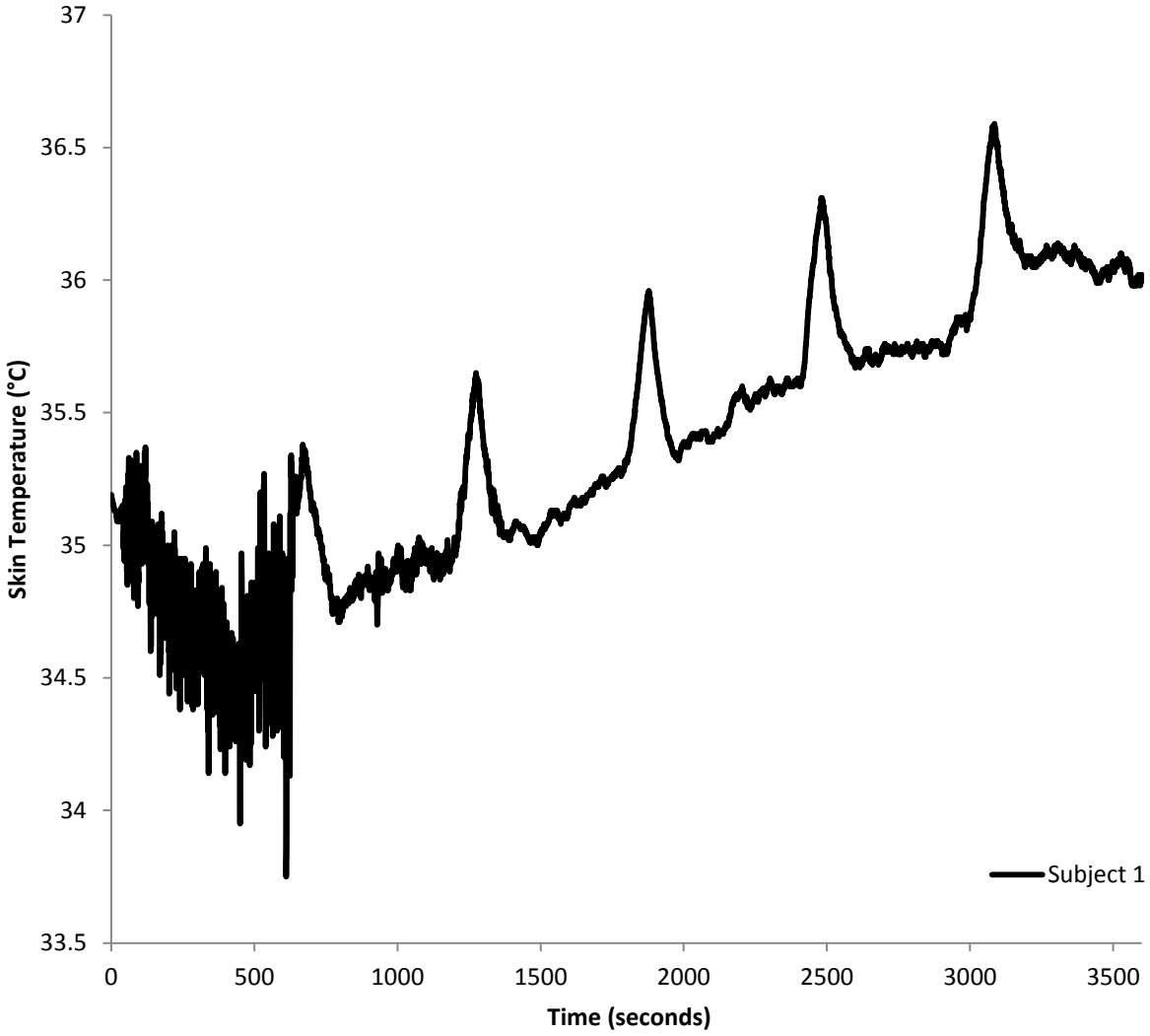


Figure 19 Indoor Individual Skin Temperature Subject 2.

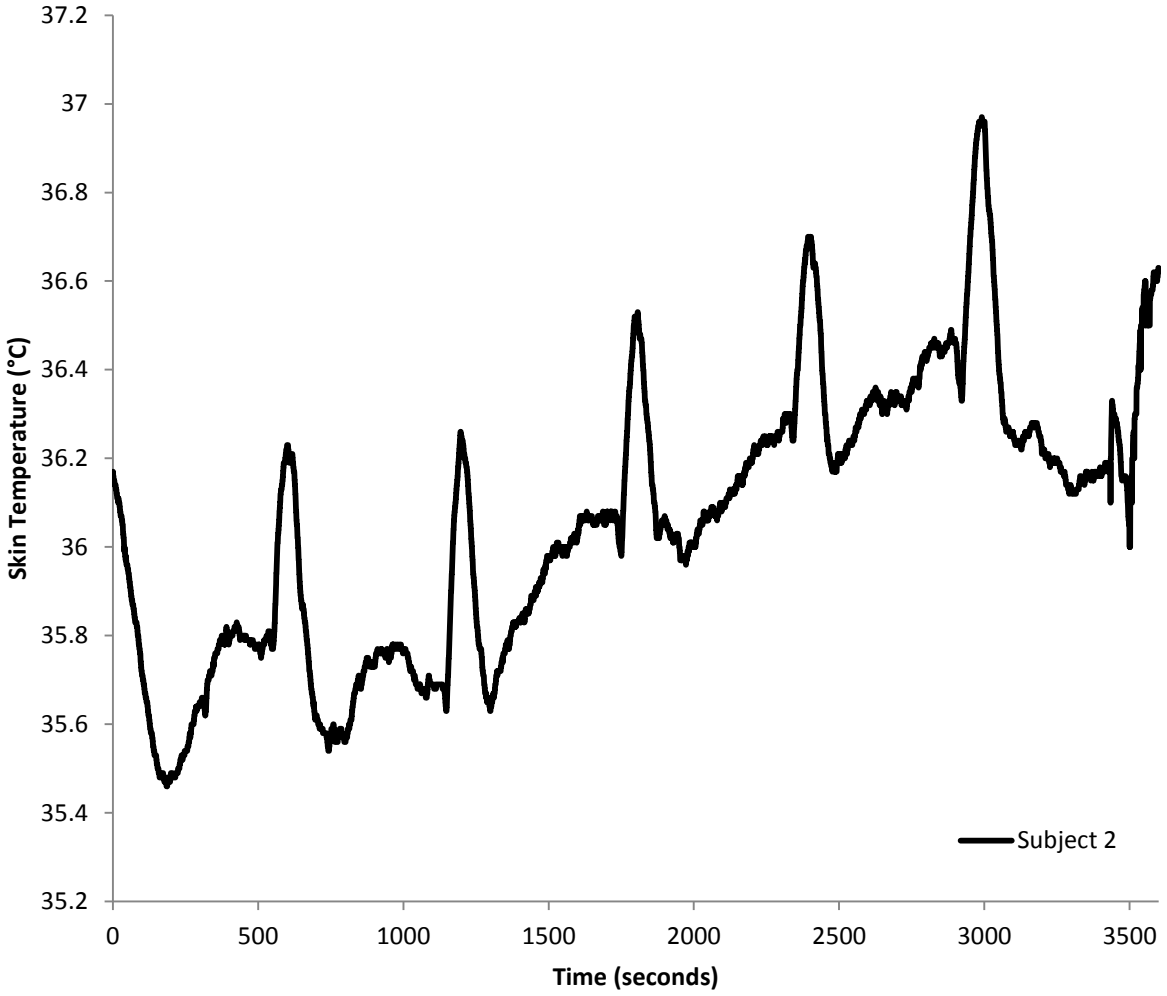
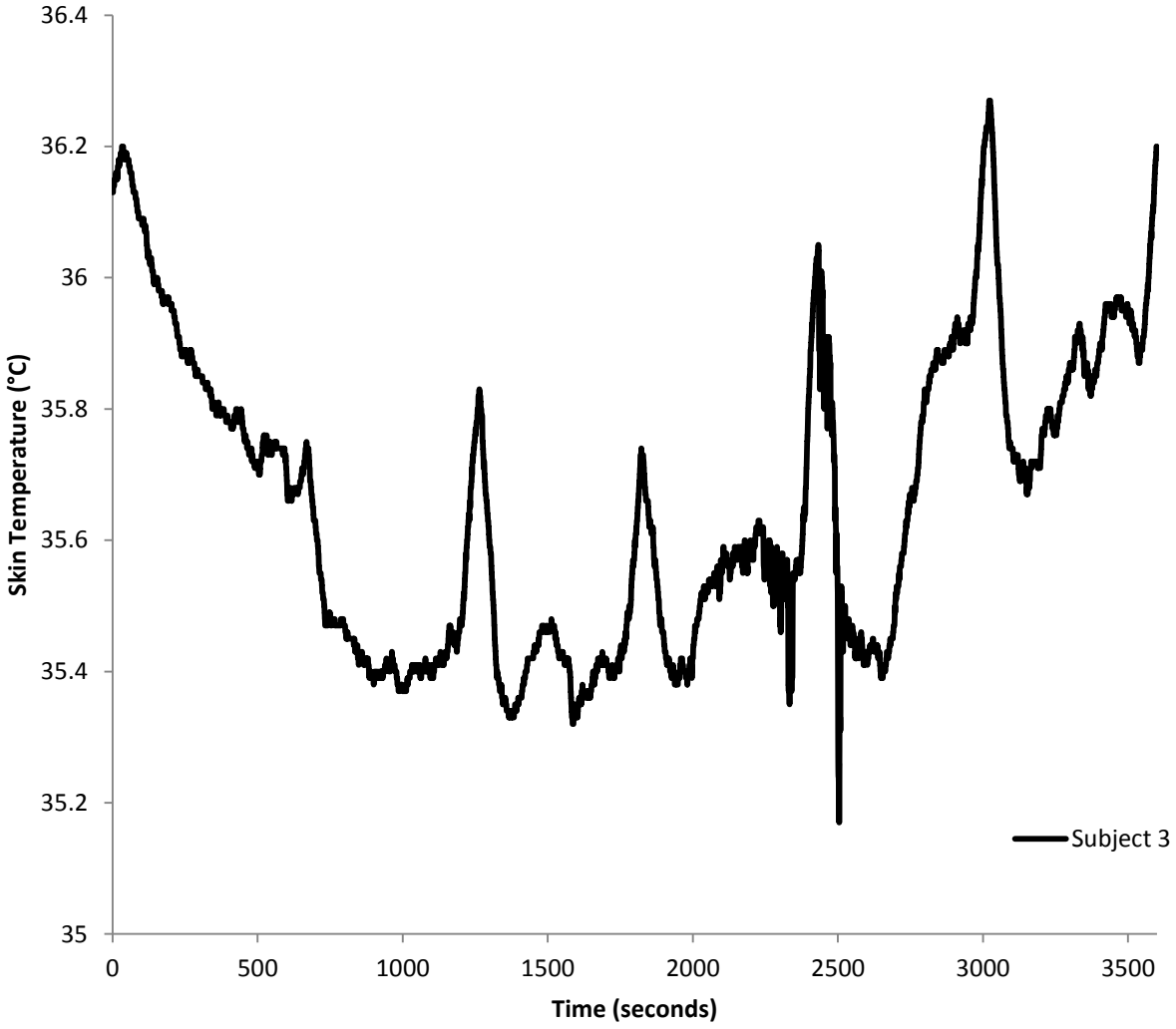


Figure 20 Indoor Individual Skin Temperature Subject 3.



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