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Effects of Various Partial Body Cooling Techniques on Core Temperature during Recovery from Prolonged Cycling-Induced Heat Stress

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EFFECTS OF VARIOUS PARTIAL BODY COOLING TECHNIQUES ON CORE
TEMPERATURE DURING RECOVERY FROM PROLONGED
CYCLING-INDUCED HEAT STRESS

by

Afton Danielle Seeley, M.S.

A thesis submitted to the Graduate College
in partial fulfillment of the requirements
for the degree of Master of Science
Human Performance and Health Education
Western Michigan University
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The purpose of this study was to investigate the effects of using an ice-vest and a palm cooling device on core and skin temperatures, heart rate, and perceived thermal comfort during a one hour recovery period following exercise in the heat. Ten recreationally active adults cycled for one hour at 50% VO_2 peak on a cycle ergometer while exposed to 36°C 45% relative humidity environmental conditions. Following exercise, each subject was exposed to an ice vest, a palm cooling device, or a non cooling control while seated in the environmental chamber for 60 more minutes. No significant difference was found between any of the three recovery conditions with regards to change in rectal temperature ($P = 0.61$), heart rate ($P = 0.13$), or Gagge thermal sensation ratings ($P = 0.56$). The rate of core temperature decline in the recovery period was also not found to be different between the three conditions when assessed at 15, 30, 45, or 60 minutes. There was a significant difference between the change in skin temperature during the recovery period between the vest and non-cooling control condition ($P = 0.004$). The significant condition-by-time interaction indicated that the differences in change in skin temperature between vest and control existed specifically at 10, 15, 20, 25, 30, 45, and 55 minutes of recovery.

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I would like to thank my family for continued support in all of my academic pursuits. I would like to give a special thank you to my mother who has always provided a profound faith and confidence in my abilities and my father who has always provided an uncompromising example of hard work. You have both deeply influenced my confidence, academic career, and life.

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Afton Seeley

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CHAPTER I

INTRODUCTION

Exercise in the heat demands unique physiological compensation to handle the increased difficulty of thermoregulation. High ambient temperatures reduce the body's ability to utilize cooling mechanisms that rely on radiation and convection due to a significantly lesser heat gradient (Casa, 1999). Along with a marked increase in evaporative cooling, the circulatory system attempts to assist cooling via cutaneous vasodilation. Because exercise demands a substantial increase in muscle blood flow, the ability to thermoregulate via cutaneous vasodilation is often competitive with the demand for enhanced muscle blood flow (Holtz, 1996). This competition can lead to an overall positive heat gain leading to an increased core temperature. A positive heat gain is to be expected with the muscular work of exercise; however, upon reaching a "critical core temperature", athletes can experience a marked decrement of aerobic performance. This is supported, in part, by research indicating that despite differences in initial core temperature, cyclists performing cycle ergometer exercise (60% maximal O_2 uptake) at 40°C fatigued at an identical core temperature (40.1-40.3°C) and muscle temperature-based (40.7-40.9°C) hyperthermia (Gonzalez-Alonso et al., 1999). This research speaks to the contribution of a critically high core temperature in the development of fatigue, although the exact mechanism by which hyperthermia induces fatigue is still being investigated. Nybo & Nielsen (2001) observed that hyperthermia induced by cycle ergometry at 60% VO_2 max until exhaustion in 40°C conditions demonstrated significantly greater central nervous system activation fatigue compared to a neutral environment control as measured via maximal voluntary contraction of the knee

extensors and hand-grip (46% decrease vs. 18% decrease with control). Although this may indicate that central nervous system (CNS) fatigue plays a role in volitional fatigue, research has not conclusively determined if a reduction in CNS activation causes volitional fatigue. Regardless, the effects of hyperthermia on exercise performance, via compensatory changes in blood flow and/or central nervous system fatigue, can negatively impact the athletic performance of endurance athletes ranging from recreational to elite.

Because of the negative impact of a significantly elevated core temperature on endurance performance, research has been able to demonstrate performance enhancement in athletes that begin exercise with a lower starting core temperature. González-Alonso et al. (1999) investigated time to exhaustion in cyclists that began exercise at three different core temperatures (36, 37, 38°C). Time to exhaustion was found to be significantly inversely related to initial body temperature (63 ± 3 , 46 ± 3 , and 28 ± 2 min, respectively). Uckert & Joch (2007) found similar results when they investigated use of a cooling vest twenty minutes prior to treadmill running. The pre-cooling condition allowed significantly longer time to exhaustion (32.5 ± 5.1 minutes) compared to a warm-up (26.9 ± 4.6 minutes) and a control (30.3 ± 4.3 minutes). This research indicates that beginning exercise at a lower core temperature allows a larger “window” of heat gain until a critical core temperature is reached and performance is impacted. With this idea in mind, using current and practical cooling techniques during recovery from a bout of endurance exercise may help to enhance performance in a subsequent bout as long as the devices are able to significantly and quickly decrease core temperature.

Along with the impact on endurance performance, an increased core temperature, especially during prolonged exercise, also poses a significant risk of heat illness. Heat stroke, the most serious heat related syndrome, is marked by a core temperature elevation greater than 40.5°C and failure of an individual's sweating mechanisms (Coris, Ramirez, & Van Durme, 2004). It is imperative that once heat stroke has developed, or as symptoms of lesser heat related syndromes develop, prompt cooling is initiated. Without prompt cooling, the thermoregulatory failure caused by heat stroke will fail to reverse naturally and organ failure may ensue (Armstrong, De Luca, & Hubbard, 1990). A variety of practical and easily administered cooling techniques including ice vests and palm cooling devices have been devised to help decrease core temperature during exercise recovery. Such devices can be used to prolong and enhance subsequent exercise performance as well as offset the abovementioned development of heat related illness.

A phase-changing cooling ("ice") vest utilizes a frozen substance to absorb body heat as a function of its specific heat capacity as a solid, its latent heat of fusion upon melting, and its specific heat capacity as a liquid (House, Lunt, Taylor, Milligan, Lyons, & House, 2013). An ice vest provides a heightened heat gradient that favors the drawing of heat out of the blood that perfuses the skin. The cooled blood then circulates back to the core, effectively contributing to the maintenance or development of a negative heat balance. Sudden vasoconstriction upon vest application is a common concern regarding the usage of such a cooling device as it may stunt heat loss. House et al. (2013) investigated the use of cooling vests of four different temperatures (0, 10, 20, and 30°C) both during and following stepping exercise while wearing firefighting gear in 40° C conditions. Results indicate that all cooling vest temperatures significantly decreased heat

storage during recovery with the 0°C vest demonstrating the largest effect. Although there seemed to be no vasoconstriction elicited by any of the vests, participants favored the 10°C cooling vest as the 0° vest was reported as too cold and caused erythema on the site of application. Other research investigating the use of an ice vest in military/occupational situations underneath clothing have proven ice vests to be beneficial in reducing heat strain (House 1996; Cadarette et al., 2002; House et al., 2003). Investigation into the use of ice vests by hyperthermic athletes post-exercise, though, has proven significantly less successful at decreasing core temperature, with many studies citing a loss in the ability to cool via evaporation an issue with the torso encompassing ice vests (House et al., 2013). Lopez et al. (2008) demonstrated that after treadmill running in a 33°C and 55% relative humidity condition that elicited a core temperature of 38.7°C and a body mass loss of 3.27%, a comparison of an ice vest to a no ice vest condition showed no difference in time to return to baseline core temperature. The effectiveness of cooling may have been nullified due to the removal of subjects from environmental heat during recovery and placement into a thermoneutral environment. This may have allowed an increased skin blood flow heat dissipation that surpassed the overall effects of the cooling vest. Thus, further research is needed to determine the effectiveness of ice vests for hyperthermic athletes when recovery is conducted in the heat in which exercise was performed.

One of the newest cooling technologies is a hand cooling device produced by AVAcore Technologies consisting of a rigid chamber with a flexible airtight vacuum-seal about the wrist. This device is proposed to transfer body heat through the arteriovenous anastomoses (AVAs) present in the palm which effectively dissipate heat at elevated core

temperatures (Bergersen, 1993). The battery powered cooling device creates a thermal gradient with the palm while the negative pressure in the vacuum chamber draws a larger volume of blood into the AVAs to speed heat exchange rate and prevent vasoconstriction (Zhang, Bishop, Casaru, & Davis, 2009). Research has focused largely on the use of this hand cooling device during exercise, with only a small and inconclusive body of support for its use in recovery. Zhang et al. (2009) investigated the use of an AVAcore hand cooling device as opposed to a control during firefighter recovery from walking and arm curl exercise in the heat (33.7°C). Although no significant impact was noted in the first 30 minutes of recovery, the hand cooling device produced significantly lower rectal temperatures during the last 10 minutes of recovery. This may indicate a stronger role for the hand cooling device in the later stages of recovery after blood flow heat dissipating mechanisms have decreased. Kuennen, Gillum, Amorim, Kwon, & Schneider (2010) also investigated the use of a palm cooling device during 50 minutes of a simulated armoured vehicle transport versus a no cooling control. Hand cooling application was administered following three exercise bouts in the heat (42.2°C; 36.5% relative humidity) that elicited a core temperature increase to 38.8°C. The palm cooling device elicited core, skin, and mean body temperatures significantly lower than the no cooling control from 15-50 minutes of recovery. Thermal sensation was also lower from 30-50 min with the palm cooling device. Not all research is as conclusive as the aforementioned with a variety of studies indicating a lack of advantageous cooling in recovery (Walker, Zupan, McGregor, Cantwell, & Norris, 2009; Amorim, Yamada, Robergs, & Schneider, 2010).

As previously stated, a variety of research has demonstrated core temperature blunting affects of the above cooling mechanisms *during* exercise. However, application

of these cooling devices during endurance or other types of exercise is highly impractical. It may be more practical to envision that cooling could take place during recovery between exercise bouts or following exercise as opposed to during. Research regarding heat illness has nominated whole-body cold water immersion as the quickest and most effective means of cooling to spare organ damage (Binkley et al., 2002). The practicality and availability of this treatment is arguable as well. Smaller devices such as an ice vest or palm cooling device are more portable, with ice or ice packs easily transported in a cooler to athletic events.

Overall, the purpose of this study was to investigate the effects of using an ice-vest and a palm cooling device on core and skin temperatures, heart rate, and perceived thermal comfort during a one hour recovery period following exercise in the heat. The effects on these variables may speak to the ability of the cooling devices to influence performance in a subsequent endurance bout and offset the development of heat illness. This study is unique in that it aims to directly compare devices, including the relatively inconclusive RTX palm cooling device, in standardized hot recovery conditions that simulate continued environmental exposure often unavoidable after an exercise event in the heat. It is hypothesized that both cooling strategies would decrease core temperature, skin temperature, heart rate, and perceived thermal comfort post-exercise compared to a control, with the palm cooling device demonstrating the largest cooling effect, rate of cooling, and dampening of perceived thermal strain throughout the entirety of recovery.

CHAPTER II

RESEARCH METHODS

Subjects and Research Design

Ten subjects (six males, four females) (age: 25 ± 3 years; body mass: 75.5 ± 12.5 kg; height: 172.5 ± 8.9 cm; BMI: 25.19 ± 2.53 kg·m⁻²; VO₂ peak: 3.29 ± 0.83 L·min⁻¹ (43.6 ± 7.5 mL·kg⁻¹·min⁻¹)) participated in this study. All subjects were at least recreationally active (exercise at least three times per week) and met the following inclusionary criteria: 1) non-smoker; 2) healthy, free of disease and free of medication use which may affect the cardiovascular or metabolic responses during exercise; 3) free of any orthopedic injuries or conditions that would make exercise difficult; 4) classified as “Low Risk” (asymptomatic for cardiovascular, respiratory, or metabolic diseases and possessing \leq one risk factor for atherosclerotic cardiovascular disease) based on American College of Sport Medicine risk stratification guidelines; and 5) not obese (body mass index < 30 kg·m⁻²). Subjects completed two health history questionnaires prior to participation to assess the abovementioned criteria. The study was approved by the Human Subjects Institutional Review Board at Western Michigan University.

The study was conducted utilizing a randomized cross-over design with three recovery conditions: 1) hand cooling device (RTX), 2) phase-changing ice vest (Vest), and 3) a no cooling control (CON). Subjects visited the Human Performance Research Laboratory at Western Michigan University on four separate occasions. The first visit consisted of a graded exercise test and the following three visits consisted of exercise bouts in the heat followed by one of the three recovery cooling conditions. The research

was conducted over a 12 week time frame with each subject having at least two days between tests.

Procedures

The investigator requested that subjects refrain from drinking any alcohol or intaking any caffeine the day of the visits to the laboratory due to the fact that caffeine can increase heart rate, increase nervous system activity, and contribute to dehydration which may affect the responses to exercise. In addition, the investigator requested that the subject abstain from exercise the day of the visits to the laboratory. Each subject was asked to wear a t-shirt, shorts, socks, and athletic shoes for each of the visits to the laboratory.

Graded Exercise Test

Upon arrival to the laboratory, each subject had his/her anthropometric measurements assessed. Height and weight were measured using standardized techniques and a stadiometer and digital scale, respectively. Each subject then completed a graded exercise test on a cycle ergometer (Corival, Lode B.V., Groningen, Netherlands) to determine peak oxygen consumption (VO_{2peak}) as a measure of aerobic fitness. The VO_{2peak} value obtained served as a means to determine appropriate exercise bout intensity for the experimental trials. Each subject was fitted for seat height on the cycle ergometer, with the participant's knee within 10-15° of flexion at the pedal's lowest point. Each subject was fitted with a nose clip and a mouthpiece for the collection of expired respiratory gases using the metabolic measurement cart (TrueOne 2400, ParvoMedics, Sandy, UT) and a heart rate monitor (Polar USA, Lake Success, Long

Island, NY). The assessment consisted of a graded protocol that began with 2 minutes of cycling at 40W for female and 60W for male subjects. The cycling intensity was increased every minute thereafter by 20W until volitional fatigue. Volitional fatigue was determined as the point during exercise when each subject felt like they could exercise no longer or could no longer maintain a pedaling frequency of at least 50 RPM.

Heart rate was measured via telemetry that required that each subject strap a heart rate monitor around the chest. Heart rate was then continuously monitored using a heart rate watch. Lastly, each subject was instructed on the use of the Borg Ratings of Perceived Exertion (RPE) chart. This procedure required that each subject point to a number on a chart representing the level of fatigue he/she felt. Heart rate was recorded every 30 seconds of the exercise bout while RPE was recorded the last thirty seconds of each stage. Once the exercise test protocol was terminated, each subject continued to cycle at a low intensity for five to ten minutes as an active cool-down while monitored for normal post-exercise physiologic recovery. Each subject was given water *ad libitum* and heart rate was monitored to ensure a physiologically normal decline to baseline.

Experimental Trials

Each subject completed three experimental trials in a randomized order following an exercise bout in the heat (36°C 45%RH; heat index sensation- 41°C; WGBT- 35°C). Upon arrival to the laboratory, each subject's body weight was measured and he/she was instrumented with the various measurement devices. Thirty minutes prior to entering the climate chamber a bolus of plain water was administered that was equivalent to five mL per kilogram of body mass as a means to standardize hydration status. A rectal

temperature probe (Physitemp Instruments Inc., Clifton, NJ) was inserted 13cm past the anal sphincter by each subject (in private) for the measurement of internal (core) body temperature. Skin thermocouples (Physitemp Instruments Inc., Clifton, NJ) were also attached to the surface of the skin at four sites on the right side of the body (chest, tricep, quadriceps, calf) using waterproof tape (Hy-tape, Hytape International Inc., Patterson, NY) for the measurement of mean skin temperature. The four sites contributed to the calculation of mean skin temperature ($MST = 0.3t_{\text{chest}} + 0.3t_{\text{arm}} + 0.2t_{\text{thigh}} + 0.2t_{\text{leg}}$) (Ramanathan, 1964). Rectal and skin thermocouples were interfaced to a data acquisition system (Thermes USB, Physitemp Instruments Inc., Clifton, NJ) that was interfaced to a PC computer. Lastly, a telemetry heart rate monitor was strapped around each subject's chest for the measurement of heart rate.

Each trial was separated by at least 48 hours and consisted of the following sequence:

- 30 minutes of seated rest in the climate chamber at 36°C (45%RH; heat index sensation-41°C; WGBT- 35°C)
- 60 minutes of cycling at 50% VO_2 peak at 36°C(45%RH; heat index sensation-41°C; WGBT- 35°C) OR until core temperature reaches 39°C
- 60 minutes of seated rest at 36°C (45%RH; heat index sensation-41°C; WGBT- 35°C) with one of the cooling conditions

During the first of the three recovery cooling conditions each subject breathed into the metabolic cart for approximately the first ten minutes of exercise. The metabolic cart recorded VO_2 values every 15 seconds. VO_2 values from 5:15 to 7:00 after the start

of exercise were manually recorded and averaged. If the average VO_2 value in $\text{L}\cdot\text{min}^{-1}$ was not within $50 \pm 5\%$ peak VO_2 the intensity was adjusted accordingly.

Overall, the intensity for each bout followed the same wattage scheme: 1) two minute warm-up at half of the predicted 50% VO_2 eliciting wattage, 2) at two minutes, the intensity was increased to the predicted 50% VO_2 eliciting wattage, and 3) wattage was adjusted at about eight minutes of exercise.

Body mass was measured immediately before each trial and immediately after the one hour of recovery. Skin temperature and core temperature were continuously monitored throughout the passive heating, the heated exercise bout and recovery. Skin temperature was measured using superficial skin thermocouples at four sites (chest, triceps, quadriceps, calf). Core temperature was measured using a rectal thermocouple and heart rate was continuously monitored using a polar heart rate strap and watch. Heart rate and thermal sensation, as assessed using the Gagge Thermal Sensation Scale, were recorded during the last five minutes of passive seated heating, every five minutes of heated exercise, and every five minutes during the recovery portion.

Cooling Devices

The ice vest used was (Kool Max Poncho Vest, Polar Products, Stow, Ohio) adjustable to fit all subject torso sizes. The poncho vest was used with ice packs (Kool Max Ice Packs, Polar Products, Stow, Ohio) that were fixed in ten individual pockets disbursed on the front and the back of the torso. Subjects were seated in a backed chair with feet planted on the floor. The RTX palm cooling device (CoreControl, AVAcore Technologies, Ann Arbor, MI) was also administered in a seated position and fixed to the

right hand/forearm. Subjects were instructed to place their hand over the small soft disc at the bottom of the device to ensure standardized exposure. The control condition purely consisted of subjects quietly sitting with feet planted on the floor with as limited movement as possible.

Statistical Analysis

A repeated-measures, 2-way ANOVA (cooling condition x time) was used to assess core temperature (T_C), mean skin temperature (T_{sk}), heart rate, and Gagge thermal sensation ratings. Values are presented in both absolute and relative (change in variable from baseline) terms. When appropriate, post-hoc comparisons were conducted using the Bonferonni adjustment. Mean rectal temperature recovery data for each condition was split into 0-15, 15-30, 30-45, and 45-60 minute intervals. The slope of the each interval was determined using Microsoft Excel. A paired samples t-test was then performed to determine if statistical significance existed between conditions with regards to each time interval. Statistical significance was set at $P \leq 0.05$ for all analyses, and data was analyzed using SPSS (version 19 for Windows; IBM, Armonk, NY). All results are presented as mean \pm S.E.

CHAPTER III

RESULTS

Exercise Intensity

The average VO_2 of all exercise bouts was $1.68 \pm 0.14 \text{ L}\cdot\text{min}^{-1}$ that was elicited by an average workload of 92 ± 11 Watts. The average VO_2 was $51.00 \pm 0.57 \%$ of the mean peak VO_2 ($3.29 \pm 0.26 \text{ L}\cdot\text{min}^{-1}$) established via an initial graded exercise protocol.

Exercise Period

The response in rectal temperature during the exercise period is displayed in Figure 1. Overall, there was no difference in rectal temperature during exercise between the three conditions (CON: 37.73 ± 0.06 , Vest: 37.80 ± 0.07 , RTX: 37.71 ± 0.10 °C; $P = 0.66$). As expected, there was a significant main effect for time with rectal temperature increasing throughout the exercise period ($P < 0.001$). The condition-by-time interaction was not significant indicating that the change in rectal temperature during exercise between the three conditions was similar ($P = 0.71$).

The response in skin temperature during the exercise period is displayed in Figure 2. Overall, there was no difference in skin temperature during exercise between the three conditions (CON: 36.93 ± 0.06 , Vest: 36.89 ± 0.10 , RTX: 36.85 ± 0.12 °C; $P = 0.69$). As expected, there was a significant main effect for time with skin temperature increasing throughout the exercise period ($P < 0.001$). The condition-by-time interaction was not significant indicating that the change in skin temperature during exercise between the three conditions was similar ($P = 0.12$).

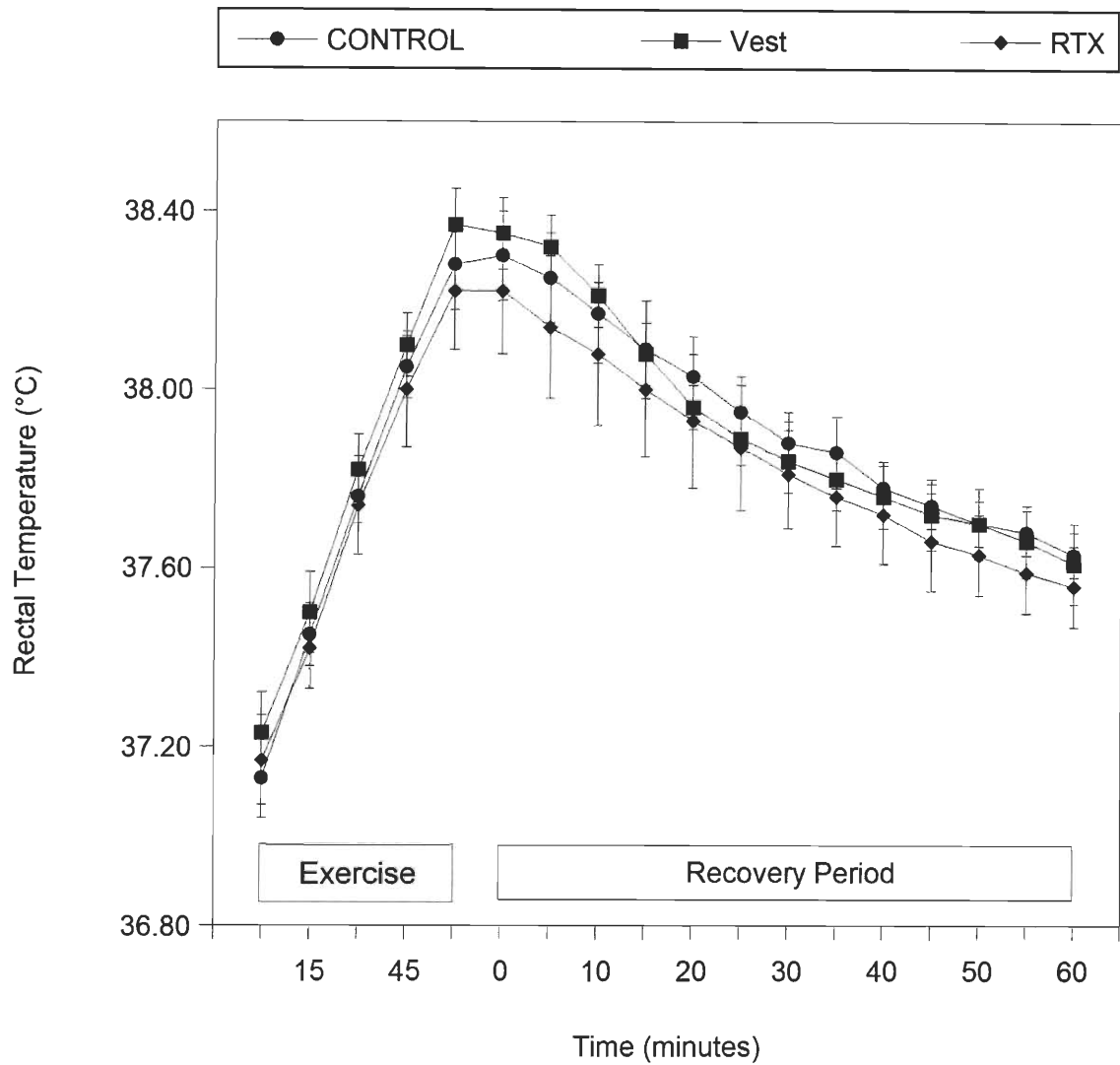


Figure 1. Rectal temperature during exercise and cooling or non-cooling recovery in the heat ($M \pm SE$)

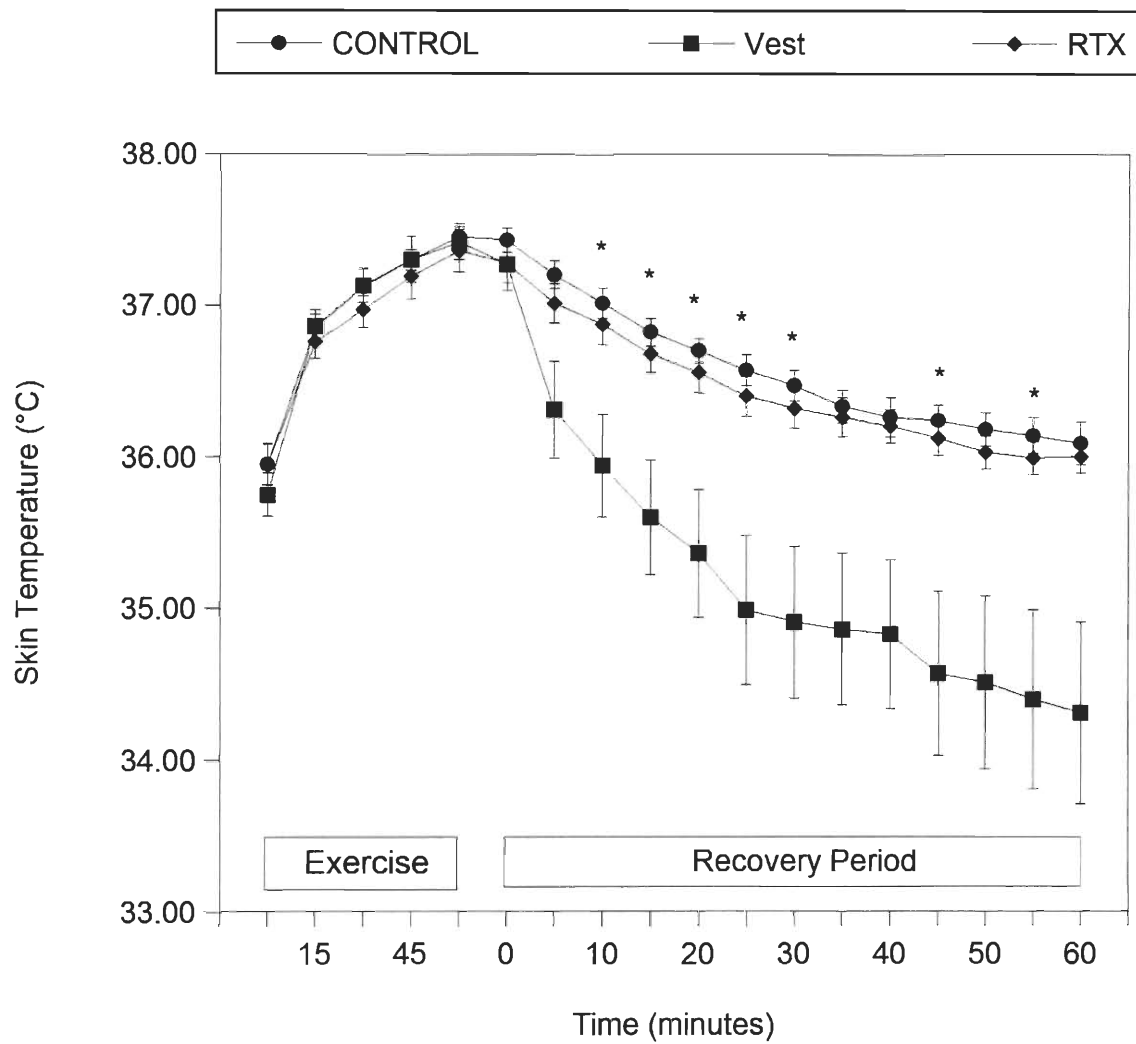


Figure 2. Skin temperature during exercise and cooling or non-cooling recovery in the heat ($M \pm SE$)

*** denotes significant difference between vest and control condition ($P \leq 0.05$)**

The response in heart rate during the exercise period is displayed in Figure 3. Overall, there was no difference in heart rate during exercise between the three conditions (CON: 135 ± 4 , Vest: 135 ± 3 , RTX: 136 ± 4 beats per minute; $P = 0.93$). As expected, there was a significant main effect for time with heart rate increasing throughout the exercise period ($P < 0.001$). The condition-by-time interaction was not significant indicating that the change in heart rate during exercise between the three conditions was similar ($P = 0.66$).

The response in Gagge thermal sensation during the exercise period is displayed in Figure 4. Overall, there was no difference in thermal sensation during exercise between the three conditions (CON: 6 ± 0.5 , Vest: 6 ± 0.5 , RTX: 6 ± 0.5 ; $P = 0.88$). As expected, there was a significant main effect for time with thermal sensation increasing throughout the exercise period ($P < 0.001$). The condition-by-time interaction was not significant indicating that the change in thermal sensation during exercise between the three conditions was similar ($P = 0.91$).

Recovery Period

The change in rectal temperature during the recovery period is displayed in Figure 1. Overall, there was no difference in the change in rectal temperature during the 60 minute recovery period between the conditions (CON: 0.66 ± 0.10 , Vest: 0.73 ± 0.12 , RTX: $0.66 \pm 0.11^\circ\text{C}$; $P = 0.61$). As expected, there was a significant main effect for time for the change in rectal temperature with rectal temperature progressively decreasing during the recovery period ($P < 0.001$). The condition-by-time interaction was not significant indicating that the pattern of the decrease in rectal temperature during the recovery period was similar between the three conditions ($P = 0.48$).

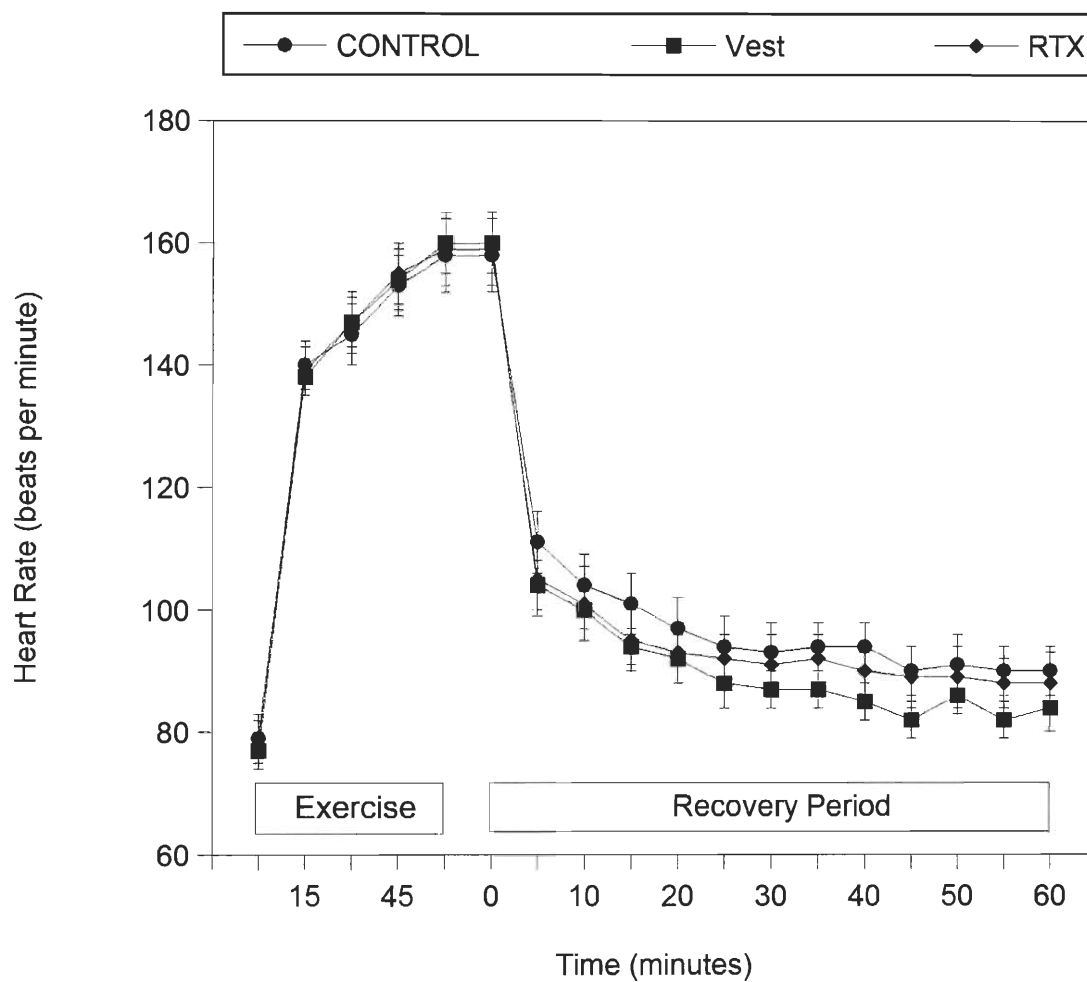


Figure 3. Heart rate during exercise and cooling or non-cooling recovery in the heat ($M \pm SE$)

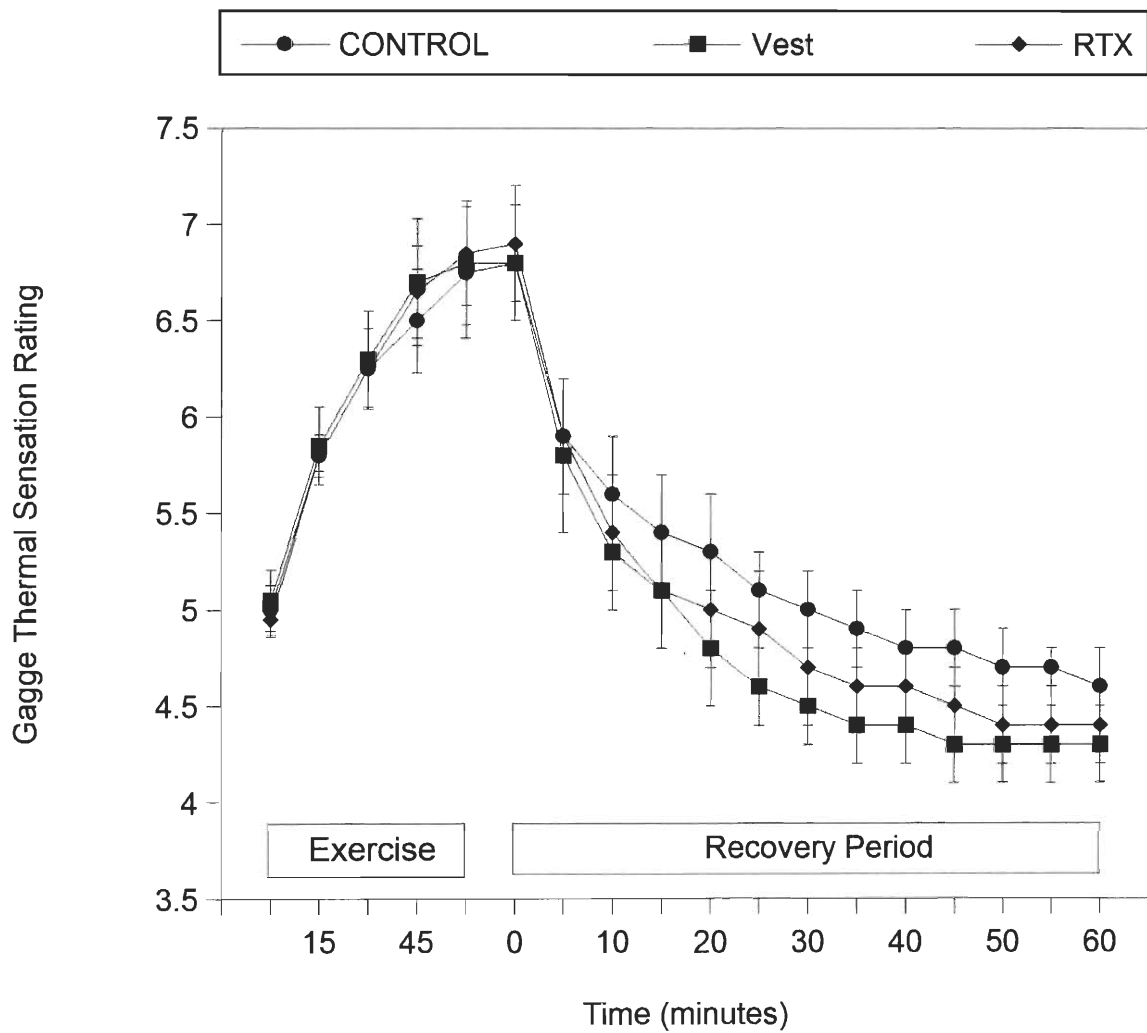


Figure 4. Gagge thermal sensation ratings during exercise and cooling or non-cooling recovery in the heat ($M \pm SE$)

The change in skin temperature during the recovery period is displayed in Figure 2. Overall, there was a significant main effect for the change in skin temperature during the 60 minute recovery period between the conditions (CON: 1.34 ± 0.18 , Vest: 2.96 ± 0.55 , RTX: $1.28 \pm 0.18^\circ\text{C}$; $P = 0.004$). Further post hoc analysis revealed that the change in skin temperature during recovery was significantly greater with the vest condition compared to the control condition ($P = 0.05$). As expected, there was a significant main effect for time for the change in skin temperature with skin temperature progressively decreasing during the recovery period ($P < 0.001$). The condition-by-time interaction for the change in skin temperature during the recovery period was also significant ($P < 0.001$). Further post hoc analysis revealed that the vest condition demonstrated a significantly larger change in skin temperature than the control condition at 10 ($P = 0.03$), 15 ($P = 0.03$), 20 ($P = 0.03$), 25 ($P = 0.03$), 30 ($P = 0.04$), 45 ($P = 0.05$), and 55 ($P = 0.05$) minutes of exercise recovery.

The change in heart rate during the recovery period is displayed in Figure 3. Overall, there was no difference in the change in heart rate during the 60 minute recovery period between the conditions (CON: 68 ± 5 , Vest: 76 ± 4 , RTX: 71 ± 5 beats per minute; $P = 0.08$). As expected, there was a significant main effect for time for the change in heart rate with heart rate progressively decreasing during the recovery period ($P < 0.001$). The condition-by-time interaction was not significant indicating that the pattern of the decrease in heart rate during the recovery period was similar between the three conditions ($P = 0.13$).

The change in Gagge thermal sensation during the recovery period is displayed in Figure 4. Overall, there was no difference in the change in thermal sensation during the

60 minute recovery period between the conditions (CON: 2 ± 0.3 , Vest: 2.5 ± 0.3 , RTX: 2.5 ± 0.3 ; $P = 0.56$). As expected, there was a significant main effect for time for the change in thermal sensation with thermal sensation progressively decreasing during the recovery period ($P < 0.001$). The condition-by-time interaction was not significant indicating that the pattern of the decrease in thermal sensation during the recovery period was similar between the three conditions ($P = 0.48$).

Recovery Rectal Temperature Linear Regression

The linear regression for rectal temperature during the recovery period is displayed in Figure 5. From 0-15 minutes of condition exposure in the recovery period, no significant difference was found between the rate of rectal temperature decline (slope) between the three conditions ($P = 0.75$). From 15-30 minutes of condition exposure in the recovery period, no significant difference was found between the rate of rectal temperature decline (slope) between the three conditions ($P = 0.41$). From 30-45 minutes of condition exposure in the recovery period, no significant difference was found between the rate of rectal temperature decline (slope) between the three conditions ($P = 0.80$). From 45-60 minutes of condition exposure in the recovery period, no significant difference was found between the rate of rectal temperature decline (slope) between the three conditions ($P = 0.99$).

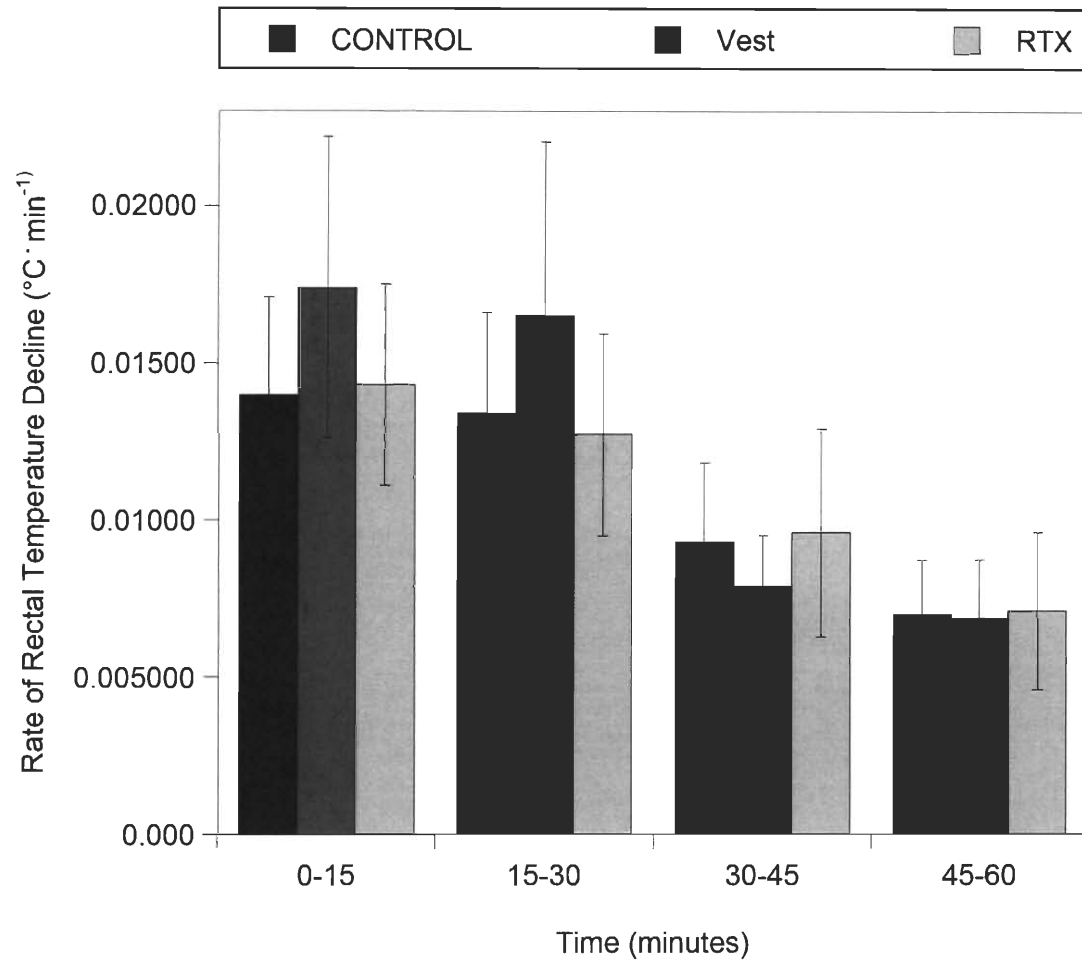


Figure 5. Rate of rectal temperature decline during exercise recovery for cooling and non-cooling conditions ($M \pm SE$)

(Slope values are presented as absolute values).

CHAPTER IV

DISCUSSION

The purpose of this study was to investigate the effects of using an ice-vest and a palm cooling device on core and skin temperatures, heart rate, and perceived thermal comfort during a one hour recovery period following exercise in the heat. Overall, the lack of significant difference between the rectal temperature values attained through exercise indicates a similar level of heat stress between the three conditions (maximum core temperature: CON: 38.28 ± 0.10 , Vest: 38.37 ± 0.08 , RTX: $38.22 \pm 0.13^{\circ}\text{C}$). Contrary to the hypothesis, no significant difference was found between any of the three cooling conditions (CON, Vest, and RTX) with regards to the decrease in rectal temperature during the recovery period. The rate of change in rectal temperature during the 60 minute recovery was similar between all three conditions. The Vest condition demonstrated a significantly larger change in skin temperature from 0 to 60 minutes of the recovery period compared to the RTX and CON conditions. Skin temperature was significantly lower for the Vest condition compared to the CON recovery condition at seven of the thirteen exercise recovery time points. Change in heart rate and change in Gagge thermal sensation over the 60 minute recovery period were not significantly different between CON, Vest, and RTX cooling conditions. These results are a reflection of continued environmental heat stress into exercise recovery, as opposed to exercise recovery conducted in a thermoneutral environment, indicating that cooling device effectiveness may be altered by recovery temperature.

Previous research supports this study's similar change in rectal temperature findings between cooling conditions. Amorim, Yamada, Robergs, & Schneider (2010)

compared the effectiveness of a hand cooling device to that of a water bath hand immersion, water-perfused vest, and a no cooling control at reducing rectal temperature during recovery from exercise (treadmill walking with speed and grade combination that elicited 50% VO_2 peak until 38.5°C rectal temperature was reached) in the heat (42°C 30% RH). The cooling exposure recovery, similar to this study, was conducted in the heat rather than ambient conditions but was approximately 40 minutes rather than 60 minutes. Even with a standardized rectal temperature end-point to the exercise bout (38.5°C), no significant enhancement of rectal temperature decline during exercise recovery resulted from the RTX condition compared to the other conditions studied. The researchers cite severe environmental recovery conditions as a possible explanation why the RTX hand cooling device may have been less successful at augmenting rectal temperature decrease during recovery. While our study had a slightly lower environmental temperature (36°C), it did have a larger relative humidity (45%) continued into the exercise recovery period, making it relatively comparable to Amorim et al. (2010). The continued exposure to heat stress while recovering with the cooling device may impact the overall ability of the RTX to enhance cooling. This suggests that perhaps it is not the cooling device doing the majority of the cooling in those studies in which it demonstrates greater core temperature decline in recovery (Zhang et al., 2009), rather enhanced conduction and convection allowed by the less stressful environmental conditions.

Ballardin et al. (2007) investigated a larger 75 minute recovery period following 20 minutes of treadmill walking at 4 km/hr in 35°C heat with 85% relative humidity. Environmental conditions were linearly lowered to 21°C and 40% relative humidity during recovery and subjects were exposed to an RTX palm cooling device, liquid-cooled

vest, or control non cooling condition. Overall, the RTX palm cooling device was not found to be more effective at decreasing rectal temperature following exercise in the heat than control or vest conditions. This research would seem to dispute the abovementioned continued recovery heat stress argument; however, Balldin et al. (2007) only managed to increase rectal temperature from 37.17°C to 37.72°C. This relatively insignificant rectal temperature increase resulting from a very slight heat stress could speak to an attenuated need to cool due to the smaller stress placed on the body to recruit cooling mechanisms. The minor heat gain by the body would not recruit as much blood perfusion to the skin, which would negatively impact the ability of the hand cooling device to cool the blood and send it back to the core. The current study successfully increased rectal temperature from 37.17°C to 38.22°C. While this increase is greater than that of Balldin et al. (2007), it still may have impacted the ability of the RTX to enhance rectal temperature drop during recovery. This idea, paired with the overall small surface area available for cooling with the RTX device compared to other cooling techniques (e.g. cold water immersion), may help to explain the lack of significant enhancement in rectal temperature cooling with the RTX device.

A few studies, in contrast to the current study, were successful at demonstrating a significantly larger decrease in core temperature during recovery. For example, Kuennen et al. (2010) had subjects perform three exercise bouts (6.1 km·hr⁻¹, 2-4% grade) in 42.2°C 36.5% relative humidity environmental conditions until esophageal temperature reached a 38.8°C threshold. Recovery was performed in the heated environment in which exercise was conducted. Subjects demonstrated that compared to a non-cooling control an RTX device was able to elicit a significantly lower esophageal and skin temperature at

15-50 minutes of exercise recovery as well as significantly lower thermal sensation ratings from 30-50 minutes of exercise recovery. This research demonstrates that the RTX may still be capable of greater cooling compared to a non-cooling control in a heated exercise recovery but a large increase in core temperature that enables a larger “cooling window” is necessary.

Although the main device of interest for this study was the RTX hand cooling device, the vest condition was also unable to significantly impact rectal temperature decline during recovery from exercise in the heat, thus warranting discussion. Lopez, Clearly, Jones, & Zuri (2008) investigated the influence of a HeatShield ice vest compared to a no vest control on rectal temperature decline during recovery from treadmill running at 60% of the age-predicted heart rate range in 33.1°C 55% relative humidity environmental conditions. Recovery was variable in length and continued until the subject reached baseline rectal temperature. Overall, no difference in rectal temperature decrease during exercise recovery was found between the two conditions and time to return to baseline temperature was also not significantly different. The researchers concluded that the ice vest application was no more effective for rapid reduction of rectal temperature than resting in a thermoneutral environment. This similarity in rectal temperature reduction between vest and control conditions was attributed to the use of the vest condition purely during exercise recovery when rectal temperature was already significantly elevated by a non-compensable heat stress as opposed to use during both exercise and recovery. Similar to the RTX, perhaps the recovery cooling is also confounded by the large increase in convective and conductive heat loss inherent to the removal of subjects from the heat stress. Our study, unlike Lopez et al. (2008), did not

remove subjects from the environmental heat stress and yet found similar insignificant results. A possible explanation lies in the large surface area covered by the vest which may impede evaporative cooling that may otherwise serve to cool core temperature (Barwood et al., 2009).

Another proposed idea is that perhaps the sudden cold application of the vest to the torso, with enhanced blood flow due to activation of cooling mechanisms, caused sudden vasoconstriction lessening the ability of the ice vest to cool blood at the periphery (skin) to send to the deep core. House et al. (2013) investigated this idea by testing the use of four different ice vests that melted at 0, 10, 20 or 30°C during 45 minutes or recovery following 45 minutes of stepping exercise in 40°C 46% relative humidity environmental conditions. No significant change in skin blood flow to the torso was detected immediately upon donning any of the four ice vests suggesting that perhaps blood flow is not as impacted as proposed. These researchers also discovered that as the melting point decreased with the vests, a lower rectal temperature was demonstrated. The overall decrease in rectal temperature in recovery, which might be comparable to the current study, is confounded by the fact that the subjects wore the ice vests both during exercise as well as the recovery period. Perhaps the relatively higher rectal temperature and greater vasodilation at the skin immediately following exercise when the ice vest was donned in our study, compared to the lower rectal temperature upon donning prior to exercise, lent to a greater likelihood of skin vasoconstriction and therefore a large impact on the ability of the ice vest to cool subjects more significantly compared to RTX and control conditions.

Also worth noting is the phase-changing nature of the ice vest investigated. Generally the rate of cooling from a substance that is phase-changing, like the ice vests used in this study, is determined by the temperature gradient between the skin and the frozen or melting substance (House et al., 2013). Therefore as subjects were cooled by the ice vest, so too the ice vest was warmed by the subject and environmental air, decreasing cooling capability over time. This could help to explain the lack of change in rectal temperature when looking at the change in rectal temperature for the vest compared to RTX and control over the entire 60 minute recovery period. A linear regression was performed to determine slope at 15 minute intervals through the 60 minutes of recovery. Although the rate of change in rectal temperature was not significantly different between the three conditions, it is worth noting that the rate of change increased from 0-15 to 0-30 minutes (-0.0178 to -0.0189 $^{\circ}\text{C} \cdot \text{min}^{-1}$) and then progressively declined through 45 and 60 minutes (-0.0151 and -0.0124 $^{\circ}\text{C} \cdot \text{min}^{-1}$) of recovery. Perhaps then if the vest temperature could be maintained, although there would still be a small decline in cooling ability as rectal temperature declined throughout recovery, cooling rate could stay elevated more significantly. Research investigating the use of liquid perfused vests seems to point to their use as a viable means to decrease core temperature. Balldin et al. (2007) investigated a 75 minute recovery period following 20 minutes of treadmill walking at 4 km/hr in 35°C heat with 85% relative humidity. Environmental conditions were linearly lowered to 21°C and 40% relative humidity during recovery. Exposure to a liquid cooled cooling vest during this recovery, when compared to an RTX hand cooling device and no cooling control, demonstrated a significantly lower rectal temperature, heart rate, and subjective heat scores. Perhaps more research directly investigating the thermal gradients

during exposure to a phase-changing ice vest compared to a liquid-cooled vest is necessary to determine application to recovery from exercise in the heat.

The vest condition was able to demonstrate a significantly larger change in skin temperature during exercise recovery compared to the RTX and control. Logically this may be explained by the placement of one of the ice vest ice packs directly over the chest thermocouple. Due to the 30% contribution of the chest thermocouple to the mean skin temperature calculation (Ramanathan, 1964), the decrease in skin temperature may be a more accurate representation of the change in chest skin temperature than a change in whole body skin temperature. Despite this misrepresentation, a lowered skin temperature at the chest may still have an impact on thermoregulatory function via peripheral afferent feedback mechanisms (Huizenga, Zhang, Arens, & Wang, 2004). Perhaps localized vasoconstriction or the magnitude of uncompensable heat stress impacted the ability of the lowered skin temperature to translate into a lower rectal temperature. Despite the perceptual link between thermal sensation and skin temperature (Chatonnet & Cabanac, 1965), thermal sensation was also not significantly altered with vest application. This may be attributable to personal bias present in perceptual reporting that can result from differences in heat tolerance and psychological bias that may lead to overestimation of thermal relief upon cessation of exercise.

This study has potential limitations that may confound the results. First, the study is limited by its inclusion of females whose rectal temperature data could not be exactly scheduled around the core temperature variations of the menstrual cycle. Two of the four female subjects reported irregular menstrual cycles linked to oral contraceptives making follicular phase identification impossible. The other two female subjects did have regular

menstrual cycles; however, because the current study used a cross-over design, in which each subject performed all cooling strategies, the variability in core temperature with hormone fluctuations of the menstrual cycle should be minimal. Second, use of a standardized rectal temperature end-point rather than a time end-point to exercise may have not only provided a larger gradient for cooling but also made the study's results more comparable to studies that found significant cooling enhancement for the vest or RTX hand cooling device. Third, the use of rectal temperature as a measurement of core temperature may impact the interpretation of the current study. While hyperthermia research usually relies on the use of rectal temperature as a measure of core temperature, literature has determined that rectal temperature is not able to respond as quickly to rapid change in core temperature as esophageal temperature (Easton, Fudge, & Pitsiladis, 2007). Lee, Williams, & Schneider (2000) demonstrated that core temperature increase following 20 minutes of 65% VO_2 peak ergometry was 25% larger using esophageal temperature compared to rectal temperature and core temperature decline over a 20 minute recovery was 68% greater with esophageal measurement compared to rectal. Esophageal temperature, though, does pose significant practicality concerns as many subjects struggle to place and tolerate the temperature probe. Therefore rectal temperature was selected for use in this study.

In conclusion, neither the RTX palm cooling device or the phase-changing ice vest were any more effective at reducing rectal temperature, heart rate, or thermal sensation during exercise recovery in the heat compared to a non-cooling control. This may speak to a large impact of the environmental temperature during recovery on the effectiveness of portable cooling devices and suggests that the viability of a phase-

changing ice vest and palm cooling device on core temperature decline during a heated exercise recovery is minimal. The ice vest however, was able to elicit a lower skin temperature compared to the non-cooling control during recovery due to thermocouple placement. Although this lower skin temperature was not able to elicit a lower core temperature or a reduced thermal strain, this peripheral activity may still impact overall thermoregulatory function. Further research is necessary to pinpoint the exact environmental conditions and elevated core temperatures for which RTX or vest application may be beneficial.

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Appendix A
ACSM Risk Factors for Cardiovascular Disease

TABLE 2.3. ATHEROSCLEROTIC CARDIOVASCULAR DISEASE (CVD) RISK FACTOR THRESHOLDS FOR USE WITH ACSM RISK STRATIFICATION

| POSITIVE RISK FACTORS | DEFINING CRITERIA |
|---|---|
| Age | Men ≥ 45 yr; Women ≥ 55 yr |
| Family history | Myocardial infarction, coronary revascularization, or sudden death before 55 yr of age in father or other male first-degree relative, or before 65 yr of age in mother or other female first-degree relative |
| Cigarette smoking | Current cigarette smoker or those who quit within the previous 6 months or exposure to environmental tobacco smoke |
| Sedentary lifestyle | Not participating in at least 30 min of moderate intensity (40%–60% $\dot{V}O_2R$) physical activity on at least three days of the week for at least three months (20,23) |
| Obesity ^a | Body mass index ≥ 30 kg \cdot m ² or waist girth > 102 cm (40 inches) for men and > 88 cm (35 inches) for women (2) |
| Hypertension | Systolic blood pressure ≥ 140 mm Hg and/or diastolic ≥ 90 mm Hg, confirmed by measurements on at least two separate occasions, or on antihypertensive medication (10) |
| Dyslipidemia | Low-density lipoprotein (LDL-C) cholesterol ≥ 130 mg \cdot dL ⁻¹ (3.37 mmol \cdot L ⁻¹) or high-density lipoprotein (HDL-C) cholesterol < 40 mg \cdot dL ⁻¹ (1.04 mmol \cdot L ⁻¹) or on lipid-lowering medication. If total serum cholesterol is all that is available use ≥ 200 mg \cdot dL ⁻¹ (5.18 mmol \cdot L ⁻¹) (3) |
| Prediabetes | Impaired fasting glucose (IFG) = fasting plasma glucose ≥ 100 mg \cdot dL ⁻¹ (5.50 mmol \cdot L ⁻¹) but < 126 mg \cdot dL ⁻¹ (6.93 mmol \cdot L ⁻¹) or impaired glucose tolerance (IGT) = 2-hour values in oral glucose tolerance test (OGTT) ≥ 140 mg \cdot dL ⁻¹ (7.70 mmol \cdot L ⁻¹) but < 200 mg \cdot dL ⁻¹ (11.00 mmol \cdot L ⁻¹) confirmed by measurements on at least two separate occasions (8) |
| NEGATIVE RISK FACTOR | DEFINING CRITERIA |
| High-serum HDL cholesterol [†] | ≥ 60 mg \cdot dL ⁻¹ (1.55 mmol \cdot L ⁻¹) |

Note: It is common to sum risk factors in making clinical judgments. If HDL is high, subtract one risk factor from the sum of positive risk factors, because high HDL decreases CVD risk

^aProfessional opinions vary regarding the most appropriate markers and thresholds for obesity; therefore, allied health professionals should use clinical judgment when evaluating this risk factor.

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Appendix B
Subject Recruitment Flyer

RESEARCH VOLUNTEERS NEEDED FOR:

Effects of Various Partial Body Cooling Techniques on Core Temperature during Recovery from Prolonged Cycling-induced Heat Stress

PURPOSE: Investigate the use of ice vests and a palm cooling device during one hour of recovery from exercise in the heat as a means to determine their effects on core temperature, skin temperature, heart rate, perceived exertion and thermal comfort.

WHO: Males and females between the ages of 18 and 40 years who are non-smoking, healthy, recreationally active, and not obese.

VISITS:

- One orientation/maximal exercise test (60 minutes)
 - Measurements of height, weight, and health questionnaire
 - Maximal exercise test on a cycle ergometer
 - About 8 to 15 minutes of actual exercise
- Three recovery cooling sessions on separate visits (2.5 hours per visit)
 - 30 minutes of passive seated heating in hot temperature (96.8°F)
 - 1 hour of moderate cycling in hot temperature (96.8°F)
 - 1 hour of passive seated recovery in hot temperature (96.8°F)
- Total time commitment = 8.5 hours

WHERE:

Human Performance Research Laboratory
(Exercise Science Laboratory)
Student Recreation Center
Western Michigan University

If interested in learning more about the study, please contact Afton Seeley at afton.d.seeley@wmich.edu or Dr. Cheatham at 269-387-2542 for more information.

Cooling Research
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Appendix C
Informed Consent Document

Western Michigan University
Human Performance and Health Education

Principal Investigator: Christopher C. Cheatham, Ph.D.

Student Investigator: Afton Seeley, B.S.

Title of Study: Effects of Various Partial Body Cooling Techniques on Core Temperature during Recovery from Prolonged Cycling-induced Heat Stress

You have been invited to participate in a research project titled “Effects of Various Partial Body Cooling Techniques on Core Temperature during Recovery from Prolonged Cycling-induced Heat Stress.” This project will serve as Afton Seeley’s thesis project for the requirements of the Master of Science in Exercise Physiology degree. This consent document will explain the purpose of this research project and will go over all of the time commitments, the procedures used in the study, and the risks and benefits of participating in this research project. Please read this consent form carefully and completely and please ask any questions if you need more clarification.

What are we trying to find out in this study?

When we exercise, our working muscles produce heat, causing an increase in body temperature. Our bodies have natural mechanisms to deal with an increase in core temperature, including an increase in skin blood flow and an increase in sweat rate. Our natural body mechanisms can only deal with so much heat and after a prolonged bout of exercise in the heat, core temperature will steadily increase. At a high enough body temperature, fatigue will take place and performance will be impacted negatively. A variety of mechanisms/cooling techniques including ice vests and palm cooling devices have been devised to help decrease core temperature during recovery and may therefore logically prolong subsequent optimal exercise performance. The purpose of this study is to assess the use of ice vests and a palm cooling device to affect core temperature, skin temperature, heart rate, and thermal comfort during recovery from a cycling bout in the heat.

Who can participate in this study?

In order to be eligible to participate, you must be a male or female between the ages of 18 and 40 years and meet the following criteria:

- Non-Smoker;
- You must be healthy, free of disease and free of medication use which may affect the cardiovascular or metabolic responses during exercise;
- You must be free of any orthopedic injuries or conditions that may make exercise difficult;

- You must be classified as “Low Risk” for cardiovascular disease based on the American College of Sports Medicine’s Risk Stratification guidelines;
- You must be recreationally active;
- You must not be classified as obese.

If you agree to participate and sign this consent form, these criteria will be determined by having you complete several health history questionnaire forms. The student investigator will be present during completion of all health history questionnaires to clarify any language or inclusionary confusion. The first questionnaire will assess your past health history including past surgeries, diagnosed conditions, and medications you are currently taking. The second will ask you to report heart health markers such as blood pressure, cholesterol, and activity level. The results of these forms will determine if you are a suitable participant for the study.

The determination of whether or not you are classified as obese will be determined from measurements of your height and weight.

Where will this study take place?

This study will take place in the Human Performance Research Laboratory which is located on the first floor of the Student Recreation Center at Western Michigan University.

What is the time commitment for participating in this study?

If you choose to be part of this study, you will be asked to come to the laboratory on four separate occasions. The first day will take approximately one hour. The following three sessions will take approximately 2.5 hours each.

Thus, the total time commitment is approximately 8.5 hours.

Overall, we would like to have you finish the study within approximately eight weeks of starting it.

What will you be asked to do if you choose to participate in this study?

We will ask you to come to our laboratory four times. The first visit is the Orientation/Graded Exercise Test” visit and the second through fourth sessions will each consist of 30 minutes of passive sitting, 1 hour of moderate (50% maximal oxygen consumption) cycling, and 1 hour of passive seated recovery with one of the three cooling conditions (ice vest, palm cooling device, and no cooling control). The second through fourth sessions will be conducted in the environmental chamber at 36°C (96.8°F) with 45% relative humidity.

Graded Exercise Test Visit

If you choose to participate in the study and sign the informed consent form, we will have you complete two health history questionnaires and measure your height and weight. We will use this information to determine if you are eligible to continue participating in the study.

We will then have you perform a maximal exercise test on a stationary bike to determine your fitness level (the maximum amount of oxygen your body can utilize). We will strap a heart rate monitor around your chest. We will also explain how to use the Borg Ratings of Perceived Exertion (RPE) Scale. This is a scale with numbers and words describing how hard the exercise is. To use the scale, you simply point to the number that corresponds with how you are feeling. We will then hook you up to the “Metabolic Measurement Cart” to measure how much oxygen your body uses during exercise and how much carbon dioxide you produce. To do this, you will breathe through a clean, sanitized mouthpiece (similar to a snorkel mouthpiece) and you will wear a pair of noseclips so that you can only breathe through your mouth. The “Metabolic Measurement Cart” will use the air you blow out to determine the amount of oxygen used and carbon dioxide produced.

You will then begin the exercise test. You will pedal on a stationary bike for two minutes at an easy pace. We will then make the exercise more difficult every one minute by increasing the resistance you have to pedal against. When the resistance increases to a level that you can't pedal against, the exercise test will be over. The exercise may become too hard due to leg fatigue, overall fatigue, rapid breathing, or other factors relating to maximal exercise. The exercise test will take between 8 and 15 minutes. After the test is over we will have you pedal at a very low intensity so that you can cool-down. During this test we will record your heart rate every 30 seconds and ask that you indicate how hard the exercise feels every 1-2 minutes.

Cooling Condition Sessions

When you get to the laboratory for the cooling condition sessions, we will again measure your body weight. You will be given a fixed amount of water to drink before you enter the environmental chamber to make sure you are properly hydrated. You will then be given instructions on how to insert the rectal temperature probe and you will insert the probe yourself in a private restroom. We will then attach some small wires and tubes to your skin to measure the temperature of your skin and skin blood flow. Once you are hooked up to all the instruments, you will enter the environmental chamber which will be 74°F. You will be asked to sit in a comfortable chair as the temperature is increased to 96.8°F for 30 minutes. After the 30 minutes of seated rest, you will exercise in the 96.8°F air on a stationary bike at a moderate intensity for an hour or until your core temperature increases to 39°C. During the entire test the relative humidity of the air will be 45%. Following the cycling, you will be asked to be seated in the 96.8°F air and you will be cooled by one of five conditions: ice vest, palm cooling device, or a no intervention control. You will be asked to use two more number-based scales to describe how you

perceive your body temperature and how comfortable you feel. You will stay seated for an hour with the device applied. We will then again measure your body weight.

Ice Vest: The vest will be placed around your torso and will progressively warm as you cool down. There may be slight discomfort from the cold application but the cold will not be applied directly to the skin.

Palm Cooling Device: Your right hand will be placed in an airtight device that will circulate cool water across your skin.

No Intervention Control: You will sit quietly without a cooling device applied.

What information is being measured during this study?

This section will describe the measurements that we are going to take during your participation in the study.

Health Status/Medical History: We will be collecting information about your health status from the health history questionnaires.

Height and Weight: We will be measuring your height and your weight.

Core Temperature: Core temperature is the temperature inside your body. Core temperature will be measured using a rectal temperature probe. We will measure core temperature throughout the heat stress tests (second and third visits to the laboratory). To measure core temperature using a rectal temperature probe, you will be given a temperature probe with a small piece of tape on it. In a private restroom, you will be asked to insert the probe into your rectum approximately 5-6 inches (up to the piece of tape). The other end of the probe will come out the top of your shorts in the back. Before you insert the probe, we will ask you to place some lubricating jelly on the tip of the probe so that it goes in more comfortably.

Metabolic Rate / Oxygen Consumption: During your first visit to the laboratory, we will measure how much oxygen your body uses and how much carbon dioxide your body produces using a metabolic measurement system. To do this, you will breathe through a clean, sanitized mouthpiece (similar to a snorkel mouthpiece) and you will wear a pair of noseclips so that you can only breathe through your mouth. The air you blow out during exercise goes into the “Metabolic Measurement Cart” and the amount of oxygen and carbon dioxide in the air you breathe out is measured.”

Heart Rate: Your heart rate, or how many times your heart beats every minute will be measured throughout each visit to the laboratory. We will measure heart rate by strapping a heart rate monitor around your chest.

Skin Temperature: During the cooling condition sessions, we will measure the temperature of your skin at seven places on your body. To do this, we will attach small

wires to the top of your skin using tape and/or a small amount of a glue that is designed to be used on the skin.

Thermal Sensation and Comfort: Throughout the second through sixth visits to the laboratory, we will ask you how you feel temperature-wise and how comfortable you feel by asking you to point to a number on a chart.

Skin Blood Flow: We will measure how much blood is going to your skin at several places on your body. To do this, we will attach small lasers to the top of your skin using tape and/or a small amount of glue that is designed to be used on the skin.

What are the risks of participating in this study and how will these risks be minimized?

Measuring Height and Weight: There are no known risks associated with the measurement of height and body weight.

Measurement of Heart Rate and Thermal Sensation: There are no known risks associated with the measurement of heart rate using a telemetry heart rate monitor or measuring your thermal sensation by having you point to a chart.

Exposure to Heat: Rest and/or exercise in the heat can cause light-headedness, a feeling of tiredness, an increase in your body temperature, and an overall feeling of discomfort. During the experiment, we will be constantly monitoring your body temperature. If your body temperature increases past a certain level, we will stop the experiment and move you to a cooler temperature. The temperature that we stop the experiment at is below any dangerous level to your body.

Maximal Exercise: Intense, maximal exercise can cause feelings of tiredness, weakness, dizziness, and nausea. When exercising, there is always a risk for musculoskeletal injuries (muscle strains, pulls, cramping). Lastly, there is always a risk for a cardiac event (i.e. chest pain, heart attack). However, this risk is extremely low. The American College of Sports Medicine states that the risk of such an event in a younger healthy population is only 0.1 incidents out of every 10,000 maximal exercise tests. In order to minimize these risks, we will confirm that you are classified as “low-risk” using the health history questionnaires. Also, we will have you stretch before the exercise to reduce the risk for musculoskeletal injuries. Lastly, an investigator will always be next to the cycle ergometer and will be monitoring your heart rate and how you feel. The investigators all have experience in performing this test and are also first-aid and CPR certified.

Moderate-Intensity Exercise: Exercise may cause the feeling of fatigue, light-headedness, and an overall feeling of discomfort. There is also a risk for muscle soreness and musculoskeletal injuries (muscle pulls, strains). The exercise may be stressful but is generally easily tolerated by individuals and is not dangerous for healthy individuals.

The investigators are trained in performing exercise tests and are familiar with emergency procedures. Also, we will be monitoring your heart rate and body temperature to make sure that your body is tolerating the exercise.

Core Temperature: The measurement of core temperature using a rectal probe may cause some slight discomfort. The insertion of the probe may cause some slight discomfort but this will be minimized by using a lubricating jelly on the tip of the probe. The slight discomfort may continue while the temperature probe is in place.

Skin Temperature and Skin Blood Flow: There are no known risks associated with measuring skin temperature or blood flow by taping small wires to the surface of your skin.

Other Risk Considerations: Participation in this study requires approximately thirteen and a half hours of your time and therefore may be an inconvenience to you.

Other Protection Considerations: The principal investigator has extensive experience performing the measurements outlined in this application. The principal investigator was trained during his doctoral work at Kent State University and during his post-doctoral work at the John B. Pierce Laboratory at the Yale University School of Medicine. The student investigator has been trained in all of the laboratory exercises and has extensive experience in exercise testing. Also, after the exercise sessions, you will remain in the laboratory for at least one hour for recovery, during which you will be monitored to be sure you are recovering from exercise appropriately.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to you except as otherwise stated in this consent form.

What are the benefits of participating in this study?

You will learn about your fitness level and how your fitness level compares to individuals of your same age. Other than that, there may be no other direct benefits to your participation in this study.

Are there any costs associated with participating in this study?

There are no monetary costs to you for participating in this study.

Is there any compensation for participating in this study?

There will be a no compensation for participating in this study.

Who will have access to the information collected during this study?

The investigators will provide the data collected to outside investigators at AVAcore Technologies without financial compensation to Western Michigan University. To maintain confidentiality, a personalized identification number will be assigned to you and be used to record data collected throughout the study. Your name will never be associated with your data. If the results of the study are published in a journal or presented at a conference, no names or other identifying information will ever be used.

The original data will be retained in a locked cabinet for a minimum of three years after the completion of the study in the department of Human Performance and Health Education at Western Michigan University.

Preliminary health questionnaires completed by those deemed to be ineligible for the study will also be retained with the original data and retained in a locked cabinet for a minimum of three years after the completion of the study in the department of Human Performance and Health Education at Western Michigan University.

What if you want to stop participating in this study?

You can choose to stop participating in the study at any time for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study.

The investigator can also decide to stop your participation in the study without your consent.

Should you have any questions prior to or during the study, you can contact the primary investigator Christopher C. Cheatham at 269-387-2542 or chris.cheatham@wmich.edu. You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

I have read this informed consent document. The risks and benefits have been explained to me. I agree to take part in this study.

Please Print Your Name

Participant's signature

Date

Appendix D
Health History Questionnaires

Health/Medical History Questionnaire

Thank you for volunteering to participate in research at the Human Performance Research Laboratory of Western Michigan University. It is important that we have an accurate assessment of your present health status to assure that you have no medical conditions or previous injuries that may make participation in this study especially dangerous for you. *Please complete the health history questionnaire as accurately as you can.*

THIS MEDICAL HISTORY IS CONFIDENTIAL AND WILL BE SEEN ONLY BY THE INVESTIGATORS.

Name: _____

Date: _____

Date of Birth: _____ Present Age: _____ yrs

Ethnic Group (Please check all that apply):

- White
- Black
- Hispanic
- Asian
- Pacific Islands
- American Indian
- Other _____

HOSPITALIZATIONS AND SURGERIES

If you have ever been hospitalized for an illness or operation, please complete the chart below. Do not include normal pregnancies, childhood tonsillectomy, or broken bones.

| YEAR | OPERATIONS OR ILLNESS |
|------|-----------------------|
| | |
| | |
| | |

Are you under long-term treatment for any disease or medical condition, even if presently not taking medication? Yes No

If yes, please explain: _____

Name: _____

Medical History, page 2

MEDICATIONS

Please list all medications that you have taken within the past 8 weeks (include prescriptions, vitamins, over-the-counter drugs, nasal sprays, aspirins, supplements, etc.):

- Check this box if you have not taken any medications.

| MEDICATION | REASON YOU ARE PRESENTLY TAKING THIS |
|------------|--------------------------------------|
| | |
| | |
| | |

PROBLEMS AND SYMPTOMS

Please place an "X" in the box next to any of the following problems or symptoms that you have had:

General

- Mononucleosis If yes, when _____
 Recent weight loss while not on a diet
 Recent weight gain
 Thyroid disease
 Fever, chills, night sweats
 Diabetes
 Arthritis
 Heat exhaustion or heat stroke
 Abnormal chest x-ray

Problems and Symptoms (cont'd)

- Pain in chest (persistent and/or exercise related)
 Heart attack
 Coronary artery disease
 High blood pressure
 Rheumatic fever
 Peripheral vascular disease
 Blood clots, inflammation of the veins (phlebitis)
 Asthma, emphysema, bronchitis
 Shortness of breath At rest On mild exertion
 Discomfort in chest on exertions
 Palpitation of the heart; skipped or extra beats

Name: _____

Medical History, page 3

- Heart murmur, click
- Other heart trouble Please explain _____
- Lightheadedness or fainting
- Pain in legs when walking
- Swelling of the ankles
- Need to sleep in elevated position with several pillows
- High cholesterol If yes, what was the last measured value? _____

Nervous System

- Frequent or severe headaches
- Stroke
- Attacks of staggering, loss of balance, dizziness
- Persistent or recurrent numbness or tingling hands or feet
- Episode of difficulty in talking

Musculoskeletal

- Recent soft tissue injury (deep bruises, charley horse, muscle strain)
- Recent or chronic joint sprain If yes, which joint(s)? _____
- Unstable joint If yes, which joint(s)? _____
- Limited range of motion If yes, which joint(s)? _____
- Rheumatoid arthritis
- Back or neck pain, sacroiliac pain
- Pain radiating from back down limbs

Please give details for any items checked (when, severity, treatment):

Other

Have you ever passed out during or after exertion?

 Yes No

Name: _____

Medical History, page 4

Do you have a family history of coronary artery disease? Yes No

If yes, who? _____

Do you use (complete the information if your answer is yes):

| | | | | | |
|---------|------------------------------|-----------------------------|------------|-------|--------------|
| Tobacco | <input type="checkbox"/> Yes | <input type="checkbox"/> No | Cigarettes | _____ | per day_____ |
| | | | Smokeless | _____ | per day_____ |
| | | | Pipe | _____ | per day_____ |
| | | | Cigars | _____ | per day_____ |

ALLERGIES

Please list all allergies you have (include pollen, drugs, alcohol, food, animals, etc.):

Check this box if you have no allergies

1. _____
2. _____
3. _____
4. _____

.....
I, _____, have completed this medical/health history questionnaire honestly and completely as possible.

Participant Signature

Date

Reviewed and approved for participation:

Principal or Student Investigator

Date

TABLE 2. AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health needs by marking all *true* statements.

History

You have had:

- a heart attack
- heart surgery
- cardiac catheterization
- coronary angioplasty (PTCA)
- pacemaker/implantable cardiac defibrillator/rhythm disturbance
- heart valve disease
- heart failure
- heart transplantation
- congenital heart disease

If you marked any of the statements in this section, consult your healthcare provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Symptoms

- You experience chest discomfort with exertion.
- You experience unreasonable breathlessness.
- You experience dizziness, fainting, blackouts.
- You take heart medications.

Other health issues:

- You have musculoskeletal problems.
- You have concerns about the safety of exercise.
- You take prescription medication(s).
- You are pregnant.

Cardiovascular risk factors

- You are a man older than 45 years.
- You are a woman older than 55 years or you have had a hysterectomy or you are postmenopausal.
- You smoke.
- Your blood pressure is $>140/90$.
- You don't know your blood pressure.
- You take blood pressure medication.
- Your blood cholesterol level is >240 mg/dL.
- You don't know your cholesterol level.
- You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
- You are diabetic or take medicine to control your blood sugar.
- You are physically inactive (ie, you get <30 minutes of physical activity on at least 3 days per week).
- You are >20 pounds overweight.

If you marked 2 or more of the statements in this section, consult your healthcare provider before engaging in exercise. You might benefit by using a facility with a professionally qualified exercise staff to guide your exercise program.

- None of the above is true.

You should be able to exercise safely without consulting your healthcare provider in almost any facility that meets your exercise program needs.

AHA/ACSM indicates American Heart Association/American College of Sports Medicine.

Appendix E
Borg RPE Chart

BORG SCALE OF PERCEIVED EXERTION

| | |
|----|------------------|
| 6 | |
| 7 | Very, Very Light |
| 8 | |
| 9 | Very Light |
| 10 | |
| 11 | Fairly Light |
| 12 | |
| 13 | Somewhat Hard |
| 14 | |
| 15 | Hard |
| 16 | |
| 17 | Very Hard |
| 18 | |
| 19 | Very, Very Hard |
| 20 | |

Appendix F
Gagge Thermal Sensation Scale

| | |
|-----|-----------------------|
| 0.0 | Unbearably Cold |
| 0.5 | |
| 1.0 | Very Cold |
| 1.5 | |
| 2.0 | Cold |
| 2.5 | |
| 3.0 | Cool |
| 3.5 | |
| 4.0 | Neutral (Comfortable) |
| 4.5 | |
| 5.0 | Warm |
| 5.5 | |
| 6.0 | Hot |
| 6.5 | |
| 7.0 | Very Hot |
| 7.5 | |
| 8.0 | Unbearably Hot |

Gagge, A.P., A.J. Stolwijk, and J.D. Hardy. Comfort and thermal sensations associated with physiological responses at various ambient temperatures. *Environmental Research*.1: 1-20, 1967.

Appendix G
HSIRB Approval Letter

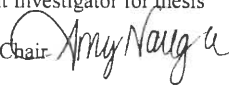
WESTERN MICHIGAN UNIVERSITY



Human Subjects Institutional Review Board

Date: January 15, 2014

To: Christopher Cheatham, Principal Investigator
Afton Seeley, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair 

Re: HSIRB Project Number 13-12-10

This letter will serve as confirmation that your research project titled "Effects of Various Partial Body Cooling Techniques on Core Temperature during Recovery from Prolonged Cycling-Induced Heat Stress" has been **approved** under the **full** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study."*** Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: December 18, 2014