INVESTIGATING THE EFFECTS OF PRECOOLING ON RECREATIONALLY ACTIVE INDIVIDUALS DURING A LOADED CARRIAGE FOOT MARCH IN HEATED CONDITIONS

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ABSTRACT

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Abstract

Introduction: Over the past 20 years, the literature has demonstrated that military members are prone to exertional heat illness due to a combination of heavy loads and physical exertion. Precooling is a relatively new idea where an individual ingests a substance preemptively to lower core temperature before an activity. **Purpose:** The aim of this study was to investigate the effects of a precooling protocol employing ice slurry (0±1°C) vs. cold water (4°C) on core body temperature and time to exhaustion during a simulated military full combat gear foot march in males aged 18 to 35 years. **Methodology:** The researchers used a precooling protocol of 7.5g/kg of bodyweight of both water (control) and ice-slurry (experimental) administered over a 30-minute period. Following the precooling protocol, the participants self-selected a pace from 3.0-4.0 MPH and walked for up to 90 minutes or until volitional fatigue inside a heat tent while wearing full Army combat gear. Core temperature, heart rate and RPE were collected every 5 minutes. Blood pressure was collected pre and post exercise. **Results:** There was no difference in time to exhaustion ($p = 0.227$), heart rate ($p = 0.763$) or core temperature ($p = 0.876$) between conditions. **Conclusion:** Precooling protocol was ineffective at lowering core temperature vs. control and thus did not increase time to exhaustion. Additional research on precooling with military equipment is needed to further elucidate the potential benefits of precooling on exercise performance and decreasing the risk of exertional heat illness.

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CHAPTER 1: INTRODUCTION

Load Carriage foot marches are a routine aspect of training and combat operations for both new recruits and veterans among different military disciplines. Soldiers are required to carry loads that range from 35 pounds to 50 pounds on marches that can span from a few to many miles (Smith, S., 2019). Since the 1980s, there have been over 5,000 documented cases of military members having heat related injuries (Carter et al., 2005), with most cases of exertional heat illnesses coming from both hot environments (33.5%) and temperate environments (34.6%) (Stacey et al., 2015).

Many of the heat illness cases impacted gun crewmen and infantry soldiers, two units which regularly engage in loaded carriage foot marches (Carter et al., 2005). Infantry men and gun crewmen typically aid in the mobilization of troops and execute reconnaissance missions while carrying increased loads (Smith, S., 2019; Infantryman ((11B), (2019)). Exertional heat illnesses are serious and pose a major threat to trainees' health status as they endure long treks on these loaded foot marches, especially in the heat. Increasing the carrying capacity load by wearing a pack and holding extra gear while going on long treks in the heat may further increase the risk of heat illnesses. Recently, there have been efforts to try and prevent exertional heat illnesses using pre-cooling protocols to reduce core temperature prior to physical activity.

There is evidence within the literature suggesting that the magnitude of heat can affect physiological responses within the human body (Hayes et al., 2014). In most cases heart rate will increase with heat exposure secondary to a decreased blood pressure due to a reduction in plasma volume induced by sweating (Cheung, S. S., 2010). If the exposure to the heat persists, it can lead to decreased exercise performance; this decrease in exercise performance capability is believed to be directly correlated to a mechanism in the body which signals the body to cease exercise before any thermal damage can be done (Cheung, S. S., 2010; Cheung, S. S., & McLellan, T. M., 1998; Gonzalez-Alonso et al., 1999). This mechanism is believed to occur once a certain core temperature set point has been reached, at which point; the body is signaled to shut down and the individual fatigues (Cheung, S. S., 2010). The shutdown that Cheung refers to is just the individual's will to cease exercise during the test and was characterized as the individual being heavily fatigued (Cheung, S. S., 2010). For highly fit individuals the marker is approximately 39.2°C, and for moderately fit the marker is approximately 38.8°C. Interestingly, the systemic shut down referred to by Cheung (2010) does not appear to have any long-lasting negative effects as data has demonstrated no ill effects up to 24 hours post-even in either animals or human; this suggests exhaustion occurred well before any health complications and any system failure (Cheung, S. S., 2010). The safety switch can be an issue for a military member however, if an individual cannot keep up with the rest of the unit; then the entire unit is slowed potentially risking the success of a mission.

Past literature has focused on cooling measures that are employed either during or post-exercise in relation to loaded foot marches (Nye et al., 2017). One such protocol is known as cold water immersion. Cold water immersion is when an individual sits in a tub filled with either cold water, ice or a mixture of the two to lower core temperature. This has been demonstrated to be effective in lowering heat strain post-exercise (Nye et al., 2017). Another method is known as icy sheets, where long thin ice packs are placed on the neck, head, groin and each arm pit. There is very limited research on icy sheets and it only acts to cool after exposure to the heat and or exercise (Nye et al., 2017). Nye and his team have also demonstrated that icy sheets are an ineffective method at cooling (Nye et al., 2017). Other researchers have also investigated ventilated vests which enhance convective cooling (Chinevere et al., 2008; Hadid et al., 2008). The vests incorporate an impermeable outer layer and have an ambient air blower that uses air as a convective way to cool the torso (Chinevere et al., 2008). The vest is worn under any and all equipment, it is also lightweight to minimize the additional load to the individual (Chinevere et al., 2008). Both Chinevere's (2008) team and Hadid's (2008) research has shown the cooling vests to be effective in lowering core temperature. An issue regarding post-exercise cooling interventions is that individuals are put at risk before heat stress is addressed.

The most recent applicable method that has been effective in lowering core temperature is precooling. Precooling is a useful strategy for combating the detrimental effects that heat stress has on exercise performance, and involves utilizing different mechanisms (ingestion, conductive or convective cooling) to preemptively reduce core body temperature prior to exercise (Jones et al., 2012; Pryor et al., 2014; Walker et al., 2014; Siegel et al., 2010; Zimmerman et al., 2015). Precooling is done so that core temperature is pre-emptively lowered in order to raise the heat storage capacity of an individual (Siegel et al., 2010). Heat storage capacity is the amount of thermal energy being stored in the body, and by lowering core temperature, the body has an increased heat storage capacity of an individual to be capable of holding more thermal energy (Siegel et al., 2010). Pre-cooling is typically done prior to exercise in smaller intervals (i.e. breaking down a 30-minute period of precooling into 6, 5-minute periods of precooling). One of the more recent precooling trends has been the use of an ice slurry.

Multiple researchers have demonstrated that ice slurry and crushed ice ingestion have significantly lowered core temperature both pre and during exercise (Jones et al., 2012; Pryor et al., 2014; Walker et al., 2014; Siegel et al., 2010; Zimmerman et al., 2015). However, there are still pieces of information missing, such as ingestion time and dose. There are different prescriptions of quantity, though most of the research suggests either 7.0 g/kg or 7.5g/kg of body weight; typically ingested over a 30-minute duration by drinking roughly 1.16 g/kg or 1.25g/kg of substance every 5 minutes (Siegel et al., 2010; Walker et al., 2014). The use of an ice-slurry is highly practical because it can be administered to many people and is relatively low cost. There has been ample research that shows pre-cooling is effective at lowering core temperature and thereby increasing the heat storage capacity of an individual (Jones et al., 2016; Pryor et al., 2014; Walker et al., 2014; Siegel et al., 2010; Zimmerman et al., 2015). Pre-cooling seems to have applicability to military foot marches because of its effectiveness and relatively low levels of cost.

In terms of using pre-cooling in relation to load carriage foot marches, there seems to be limited research. To the investigators' current knowledge, there was no study outlining the possible effects of using a pre-cooling method for load carriage foot marches. Pre-cooling offers a cost-effective method at reducing core temperature. Applying precooling to load carriage foot marches may offer a possible solution where there is a need to help reduce exertional heat illnesses and improve exercise performance in hot conditions.

Purpose

The aim of this study was to investigate the effects of a precooling protocol employing ice slurry (0±1°C) vs. cold water (4°C) on core body temperature and time to exhaustion during a simulated military full combat foot marches in males aged 18 to 35.

Null Hypotheses

There will be no statistically significant difference between the precooling protocol and the control on core body temperature while wearing full combat gear.

There will be no statistically significant difference in time to exhaustion between the experimental trial and control protocol while doing the load carriage foot marches.

Delimitations

1) Participants were recreationally active individuals from a University in Northeastern Pennsylvania.
2) Participants were males aged from 18-35 years.
3) Participants were physically active at least three times per week following ACSM guidelines (20-60 minutes of activity) 3-5 times per week (Garber et al., 2011).
4) Participants were apparently healthy with no prior history of heat illness injuries.

5) Participants were apparently healthy with no lower extremity injuries in the past year.

Limitations

1) Participant dropout due to illness or injury.
2) Participants level of heat acclimatization.
3) Participants adherence to pre-conditions.
4) Participants were giving maximal effort.
5) Failure to replicate pre-exercise 24-hour diet.

Operational Definitions

Combat Gear – Combat uniform, summer weight boots, a Fighting Load Carrier (FLC) vest, ruck sack (35lbs), and Army Combat Helmet. (ACH).

Army Combat Uniform Pattern – Army combat uniform (ACU), standard battle uniforms worn by the United States Army.

Operational Camouflage Pattern – Operational Camouflage Pattern (OCP), the United States Army main camouflage pattern on uniforms.

Foot March – Walking treadmill test where participants chose a speed ranging from 3.0-4.0 MPH and 0% grade for 90 minutes or until volitional fatigue.

Hot Conditions – A tent heated to and maintained at 33 degrees Celsius with individual heating units (Zimmerman et al., 2015).

Recreationally Active – Following ACSM guidelines, 20-60 minutes per day for at least 3-5 times per week (Garber et al., 2011).

Summary

Load Carriage foot marches are an integral part of military training. However, over the last 20 years, different forms of heat illnesses have been plaguing cadets which hinders both health and performance (Carter et al., 2005). Military branches have employed countermeasures but most of these are not used due to cost or have been demonstrated as ineffective in lowering core temperature and therefore preventing heat illnesses (Nye et al., 2017). The task at hand was to identify a cost-effective method which could lower core temperature in hot conditions in order to reduce the chance of heat illnesses and improve exercise performance for military members.

CHAPTER 2: LITERATURE REVIEW

Thermoregulation

Regulation and effector responses to thermoregulatory issues are strongly influenced by the hypothalamus, specifically a region known as the preoptic area (Cheung, S. S. 2010; Nagashima, K., 2015). There are thermos-sensitive neurons (TSN) in this preoptic area that are sensitive to any type of thermoregulation variance, whether it be hot or cold stimulation. The TSN are also distributed in the skin and other areas of the brain and is mostly regulated by the central nervous system; however, the TSN and thermoregulatory system is currently not fully understood (Cheung, S. S. 2010; Nagashima, K., 2015). There are different theories on how thermoregulation works but it is surmised that the autonomic responses due to the potential variance in core body temperature and skin temperature are from this preoptic area in the hypothalamus (Cheung, S. S. 2010).

A few autonomic responses that occur due to cold exposure in humans is that the superficial subcutaneous arterial vessels will constrict; this will limit blood flow to the skin so that heat loss will be minimalized (Cheung, S. S. 2010; Nagashima, K., 2015).

The body will also start to generate heat via shivering thermogenesis and non-shivering thermogenesis (Cheung, S. S. 2010; Nagashima, K., 2015). The former generating heat by repeatedly contracting the muscles, while the latter increases metabolic activity in brown-adipose via uncoupling of oxidative phosphorylation to increase heat production (Nagashima, K., 2015).

The autonomic responses that occur due to heat exposure is different from that of a response to a cold environment. The vessels will dilate so that blood can flow from the core to the skin freely to try and release heat from the body via either convective or conductive measures (Nagashima, K., 2015). The human body will also sweat, in hopes to alleviate heat via evaporative means (Nagashima, K., 2015).

Effect of Heat Physiology on Performance

There are three separate studies that have looked for a temperature endpoint that is associated with volitional fatigue and a request to stop exercise by the participants. In Cheung and McLellan's study done in 1998, there were four conditions: euhydrated and pre-acclimation, euhydrated and post-acclimation, hypohydrated and pre-acclimation, and hypohydrated and post-acclimation (Cheung, S. S., & McLellan, T. M., 1998). For moderately fit individuals, they found the cut-off point for core body temperature and volitional fatigue to be 38.8°C (0.3), 38.8°C (0.3), 38.7°C (0.3) and 38.6°C (0.3) respectively (the numbers in parentheses represents the standard error) (Cheung, S. S., & McLellan, T. M., 1998). For highly fit individuals they found it to be 39.2°C (0.2), 39.1°C (0.2), 39.2°C (0.1) and 39.2°C (0.1) respectively (Cheung, S. S., & McLellan, T. M., 1998).

One team of researchers had five conditions, which were precooled, control, preheated, low rate of heat storage and high rate of heat storage (Gonzalez-Alonso et al., 1999). The endpoint of core temperature for those groups were 40.1°C (0.1), 40.2°C (0.1), 40.1°C (0.1), 40.1°C (0.3) and 40.3°C (0.3) respectively (Gonzalez-Alonso et al., 1999). Two other researchers, Selkirk and McLellan, found similar results in 2001. They had four conditions, two were for highly fit individuals; trained participants and low body fat and trained participants and high body fat (Selkirk, G. A., & McLellan, T. M., 2001). The two conditions for moderately fit individuals were untrained participants with low body fat and untrained participants with high body fat (Selkirk, G. A., & McLellan, T. M., 2001). The trained participants with low body fat had an end-point core temperature of 39.5°C (0.0) (Selkirk, G. A., & McLellan, T. M., 2001), while the trained participants with high body fat had an end-point core temperature of 39.2°C (0.1) (Selkirk, G. A., & McLellan, T. M., 2001). For the moderately fit group with low body fat, the end-point core temperature was 38.6°C (0.2) (Selkirk, G. A., & McLellan, T. M., 2001). The moderately fit group with high body fat had a core temperature end point of 38.8°C (0.2) (Selkirk, G. A., & McLellan, T. M., 2001). These values are all very similar and are within 1°C of another regardless of the condition, training status and body fat percentage. Cheung theorizes that because none of the participants suffered ill effects for up to 24 hours later, that the body shuts down well before potential health risks (Cheung, S. S. 2010). It is thought that the body has an endpoint of core temperature in relation to volitional fatigue so that system integrity and function is not predisposed to injury or malfunction (Cheung, S. S. 2010). However, there is not enough information as to know how this pathway works or how the signal is sent and received.

Exertional Heat Illness

Exertional heat illness is when the body's thermoregulatory system becomes compromised due to excessive heated conditions or because of too much physical exertion; or it could arise from a combination of both (Phinney et al., 2001). There are three classifications of exertional heat illnesses, exertional heat cramps, exertional heat exhaustion and exertional heat stroke (Cheung, S. S. 2010). Usually, a core temperature of 40.5°C or greater puts an individual at a greater risk to have an exertional heat illness (Casa et al., 2015).

Exertional heat cramps are a mild form of exertional heat illness. It is the least worrisome out of the three, however, if left untreated it could potentially progress to the next stage and be detrimental. Heat cramps can occur without a direct increase in core temperature (Casa et al., 2015). It is characterized by recurring cramps usually in the lower extremity. Usually, exertional heat cramps are treatable through proper rehydration and with recovery, or by getting out of a hot environment and into a cooler one (Cheung, S. S., 2010).

Exertional heat exhaustion is the second stage of exertional heat illness. It is a stage where the body can no longer work effectively (Casa et al., 2015). The result of this could be a singular issue or a combination of multiple factors, which include cardiovascular insufficiency, hypotension, central fatigue and energy depletion (Casa et al., 2015). Heat exhaustion is typically characterized by having an increased core temperature but being lower than 40.5°C (Casa et al., 2015). At this stage, the individual could be at risk for heat syncope, organ damage (specifically renal system and possible liver damage) and significant central nervous system dysfunction (Casa et al., 2015). Some symptomology includes confusion, dizziness, headache and fatiguing (Casa et al., 2015). Using methods such as rehydration or cold-water immersion could help an individual reverse the symptomology of exertional heat exhaustion.

Exertional heat stroke is the last stage and most dangerous out of the three exertional heat illness classifications. This illness is usually brought on by a combination of metabolic heat production, environmental factors and inhibited heat loss (Casa et al., 2015). It is characterized by a core temperature of 40.5°C and greater (Casa et al., 2015). The first sign is usually CNS dysfunction, which could cause heat syncope, irritability, confusion and altered consciousness (Casa et al., 2015). This can progress into multi-organ failure and possibly death if untreated (Casa et al., 2015). The risk for mortality increases the longer the individual stays above a core temperature of 40.5°C, so getting the individual treatment as quickly as possible is of the upmost importance (Casa et al., 2015).

Exertional heat illness poses a serious threat to anyone who is physically active, works in a hot environment, or has a damaged thermoregulatory system. Added loads and equipment for work and or sports such as football or an occupation such as an active military member can even further increase the likelihood of having an exertional heat illness (Phinney et al., 2001: Pryor et al., 2018).

Different Cooling Methods

Within the literature, there are numerous methods that were used to induce a cooling effect on the body. There were four methods of cooling investigated, cold water immersion (CWI), icy sheets (IS), convective cooling vests (CCV) & precooling (Pc). The first being investigated is CWI. One group of researchers recruited 18 participants (9 male & 9 female) to walk at 4mph and 0% grade on a treadmill in a heat tent for up to 90 minutes or until core temperature reached 40°C (Nye et al., 2017). Immediately after exercise, the participant removed the military uniform and entered the CWI tank in shorts and a top. The water was between 5-10°C. Participants were immersed in the CWI tank until core temperature reached 37.5°C. CWI was effective in lowering core temperature for this study design (Nye et al., 2017).

Walker et al. (2014) also looked at CWI. There were 74 total participants in their research design, which were split into three groups: one CWI group, one control group and one iced slush ingestion group. This study was a simulated search and rescue for firefighter, where the participants had to perform two 20-minute simulated searches in a 40.5°C chamber. Each 20-minute search was split in half, where at the halfway point the participants would exit the chamber, remove their jackets, and change their breathing apparatus. This was to emulate the exact protocol that firefighters use in actual firefighting scenarios. After the simulation was complete, the participants exited the chamber and stripped down to shorts and entered a CWI tank which was set to 15°C. The tank was in the shade and participants stayed in the tank for up to 15 minutes. The water level went up to the individual’s umbilicus while their arms stayed out of the tank. Both the crushed ice ingestion and CWI were effective in returning core temperature back to baseline values within 15 minutes (Walker et al., 2014).

CWI has been demonstrated to be effective in returning core temperature back to normal range, however there are two concerns with this method. If the individual stays immersed for too long, the individual could be put at risk of hypothermia. The other concern, especially in a military setting, is that it requires time and equipment. It may be practical for trainees, but overseas or in a combat setting, time and space may not be available. It also cannot be applied to multiple people at one time. While CWI is the gold standard for cooling, it still has some limitations to it.

Icy sheets are a method of cooling that are used by placing ice sheets on the head, neck, groin and each armpit. The temperature of the icy sheets are typically 5-10°C. One group of researchers used icy sheets for individuals after walking for up to 90 minutes of exercise at 4mph and 0% grade on a treadmill in a heat chamber (38.5±0.5°C) (Nye et al., 2017). The participants walked to a separate room and stripped to shorts and a top. The ice sheets were placed on the participants on the head, neck, groin and each armpit. The sheets were replaced every three minutes to ensure the cooling temperature of 5-10°C was maintained. The cooling protocol used was the same as CWI where the cooling method was continued until normal core temperature was reached. This cooling method was not effective in reducing core temperature to within normal limits in a reasonable amount of time (within 15 minutes) when compared to the CWI protocol. (Nye et al., 2017).

Convective cooling vests (CCV) are a relatively new method to try and cool the body during exercise or physical activity. CCV's are worn under any clothes or equipment around the bare chest of the individual. It takes ambient air through a small tube and shuttles it towards the trunk, in hopes to help evaporate heat that may be contained under the heavy equipment being used by the individual. One team of researchers used a type of CCV which simulated a ruck-march (Chinevere et al., 2008). The treadmill protocol was 1.34 meters per second and 0% grade to elicit a metabolic rate of ~200 watts. There were 7 participants who had 9 separate sessions. Each session was in a different environment and the CCV had a different use. The three environments were -40°C and 20% relative humidity, 30°C and 50% relative humidity and finally 35°C and 75% relative humidity. The three different settings for the CCV were CCV turned on, CCV turned off, and no CCV. What was demonstrated at the end of this design was that heart rate, core temperature and sweating rates were significantly lower in the different environments with the system being on versus off (Chinevere et al., 2008).

Hadid et al. (2008)looked at CCV in 2008 as well. He had 12 participants walk on a treadmill for up to 115 minutes followed by a 70-minute recovery window. There were two environmental conditions, 40°C and 40% relative humidity and 35°C and 60% relative humidity. There were two conditions where the participants had a CCV equipped or no CCV equipped. The CCV was effective in lowering core temperature and skin temperature compared to no CCV being equipped in both environments. Heart rate was not significantly lowered for the CCV group in both conditions. The vests were demonstrated to be effective in lowering core temperature during exercise in heated conditions (Hadid et al., 2008). There are a few limitations to the vests, however. One is that they add weight, and when you add any extra weight to a military member who is already carrying upwards of 40 lbs. of equipment, there can be added risk for load bearing injuries. Another potential limitation in terms of using them with military members is the cost of the vests. Each military member would need a vest and that could add up in costs compared to other methods that are cheaper such as precooling with a slurry.

Precooling is a technique to preemptively cool the body prior to exercise or certain heated conditions (Cheung, S. S., 2010). There has been research done to support the claims that precooling via ingestion of an ice slurry has lowered core temperature and in turn increased an individual's heat storage capacity (Siegel et al., 2010). However, there is also research that demonstrates the ice-slurry ingestion increased heat storage capacity but did not improve physical performance. (Zimmerman et al., 2015). The use of an ice-slurry presents a practical and easily implemented precooling protocol at a very low cost. It is still being used and researched as a method of precooling to try and lower core body temperature.

One researcher used a precooling protocol that administered 7.5g/kg of bodyweight of ice slurry over a 30-minute period (Siegel et al., 2010). There were 10 male participants who either ingested a control cold water 4°C or an experimental 0°C ice slurry before running a ventilatory threshold test in heated conditions (34°C) (Siegel et al., 2010). Before exercise, core body temperature was lower in the ice slurry condition when compared to the control (Siegel et al., 2010). Ice slurry ingestion also helped to increase the duration of the submaximal running activity in the heated conditions (Siegel et al., 2010).

One group of researchers recruited 9 moderately trained females to perform a cycling protocol in 33°C heat (Zimmerman et al., 2015). The cycling protocol imitated games that include a halftime such as soccer and field hockey and involved the completion of 2x36 minute halves on a cycler ergometer (18x 4 second sprints with 96 seconds of recovery, and 5x2 second repeated spring efforts after the 8^{th} and 16^{th} sprint) (Zimmerman et al., 2015). There was a control water precooling protocol and an experimental precooling crushed ice ingestion protocol. The protocol was the same for either condition, only the substance was different; the participants were administered 6.8g/kg of bodyweight or either crushed ice or water over a 30-minute period where they were seated for the duration of the protocol. The crushed ice ingestion protocol did lower core body temperature significantly before exercise compared to the control water protocol, and it also lowered the perception of thermal stress (Zimmerman et al., 2015). However, there was no improvement in performance with ice ingestion compared to control (Zimmerman et al., 2015).

One group of researchers had 10 male firefighters use the same precooling ingestion protocol as Siegel et al. (2015), (7.5g/kg of bodyweight), and had them walk on a treadmill in 38.8°C and full fire fighter gear. There were two conditions, an experimental precooling slurry (0.1°C) and a precooling control beverage (20°C). The researchers collected gastric temperature, skin temperature, heart rate, perceiving of thermal sensation, ratings of perceived exertion, comfort and sweating. The researchers found a modest difference between gastric temperatures that demonstrated a slight decrease in the ice slurry protocol however it was not statistically significant. However, the difference did not persist for the 45-minute duration of the exercise protocol.

The precooling ice-slurry and crushed ice ingestion have been demonstrated to be effective in lowering core temperature but need further investigation. Precooling seems to be a reliable method to lower core temperature prior to exercise, however, it is not clear if it will improve performance in both sports and occupational fields (fire fighters). It would seem likely that precooling may be influenced by occupation, environment, mode of exercise, type of precooling protocol and many other potential variables. Despite the potential variability in its effectiveness, precooling poses a possible solution to lower core temperature prior to exercise and may also have other yet to be determined benefits.

Fluid Replacement

One of the proposed treatments for an exertional heat illness is to rehydrate. It is known that dehydration can exacerbate the effects of an exertional heat illness (Casa et al., 2015), making rehydration a critical component in the prevention of heat illness. There are two studies that looked at rehydration, one that had an ad-libitum policy for a simulated army ruck march (Hailes et al., 2016); while the other simulated a military red flag condition (wet-bulb globe temperature of 31.5-33.2°C) and had them consume either water or ice-slurry every 10 minutes (2g/kg of bodyweight) (Nolte et al., 2010).

Hailes' (2016) team had 12 participants walk for up to 3 hours in military red flag conditions on a treadmill, and every 10 minutes the participants were hydrated with either

2g/kg bodyweight of either ice slurry or water (Hailes et al., 2016). The speed and grade were set to 40% of the individuals VO2 peak from preliminary testing, the speed and grade was lowered if the participant had trouble completing the testing procedures. The slurry was 0°C and the water was above ambient temperature, roughly 35.5°C (Hailes et al., 2016). Hailes team found no difference in core temperature and heart rate between the water and ice slurry protocol (Hailes et al., 2016). It was discussed that this could possibly be due to the gear that is involved as there is little to no breathability in military gear thereby confounding cooling (Hailes et al., 2016).

Nolte et al. (2010) had 15 (13 male and 2 female) South African National Defense Force soldiers conduct a 16.4km march outdoors on a track, during which the participants were instructed to drink ad-libitum. Dependent variables were core temperature, total body water, serum sodium concentration and plasma osmolality (Nolte et al., 2010). The mean hourly ad-libitum water intake was 383mL, and average total body weight was roughly 1kg (Nolte et al., 2010). Despite the changes in weight, there were no differences seen in total body water, serum sodium concentrations and plasma osmolality (Nolte et al., 2010). There was also no relationship observed between percent body mass lost and core temperature values at the end of testing (Nolte et al., 2010). Core temperature was maintained throughout the duration of this test (Nolte et al., 2010).

Balancing Protection and Health

One of the major issues that concerns military members is that it is a physically taxing job to execute while wearing full gear and a combat uniform. The gear that is being carried can differ in weight depending on what division a military member is in, however, the infantry and gun-men crews usually carry an extra 33-45 kg of gear (Hunt et al., 2016). Two different researchers both had study designs that examined the physiological stress that load can cause during an extended march (Hunt et al., 2016; Taylor et al., 2016).

One group of researchers had 37 Royal Australian infantry soldiers march for up to 10km at a pace of 5.5km per hour on a flat outdoor surface (Hunt et al., 2016). The test was conducted outdoors, and participants were given ques about pace at every 2.5km mark (Hunt et al., 2016). The average temperature over the course of the testing was 23.1±1.8°C (Hunt et al., 2016). The participants wore full combat military gear and equipment that weighed 41.9 ±3.6kg (Hunt et al., 2016). Core temperature and heart rate were monitored continuously, and there was a heat illness symptomatic survey that the participants completed after the march (Hunt et al., 2016). If anyone exhibited signs of an exertional heat illness or had a core temperature greater than 39°C, they were removed from the experiment (Hunt et al., 2016). Only 23 participants completed the race, 9 participants were removed due to exertional heat illness symptomology, and 5 due to having a core temperature greater than 39°C (Hunt et al., 2016). What Hunt and his team of researchers concluded was that the equipment that is being used might be preventing some soldiers from completing their assignments. 14 out of the 37 infantrymen were unable to complete the task at hand, representing ~38% of the group (Hunt et al., 2016). If this were an actual mission, the group would not be able to function as well as it could have if every member was healthy. Having the right equipment for any scenario is important, but if a culmination of physical activity and too much external load inhibits a military member from completing his or her mission; there is reason to either eliminate some external load or to devise a physiological solution to aid in maintaining homeostasis.

A team of researchers looked at the physiological strain that is caused by the ballistic gear that military members wear (Taylor et al., 2016). They investigated these effects in both a jungle terrain and then four separate trials in an urban environment as well (Taylor et al., 2016). One trial was unloaded, and the other was loaded walking at 4km per hour for a duration of 90 minutes (Taylor et al., 2016). The 3rd and 4th trials were also loaded and unloaded respectively, but this time the participants walked at 6km per hour for up to 30 minutes or volitional fatigue (Taylor et al., 2016). What Taylor and his team of researchers found was that throughout all experimental trials, work tolerance was reduced as ballistic protection increased (Taylor et al., 2016). Taylor proposed that there can be a balance between the appropriate amount of gear and the intensity at which the soldiers are working, but the calculation of this balance has yet to be elucidated.

CHAPTER 3: METHODOLOGY

Participants

Approval for the current study was obtained from the Institutional Review Board of East Stroudsburg University (Appendix A). Participant participation was voluntary, and each participant underwent an orientation session where written informed consent (Appendix B) was completed. Participants were recruited from graduate level exercise science courses at a University in Northeastern Pennsylvania. This study was limited to male participants due to potential confounding effects of the menstrual cycle associated variations in core temperature and thermoregulation in females (Nagashima, K, 2015).

Participant Characteristics

The values (mean and SD ±) in Table 2 represent the participants (n = 6) characteristics for demographic data (height, weight & age) as well as their activity status. All six participants were recreationally active males. Initially 10 participants were recruited, however, three dropped out before attending any testing sessions; and 1 participant dropped out after attending the first session due to an inability to commit to participation in the entire study.

Table 1. Subject characteristics

Subjects	Height (cm)	Weight (kg)	Age (years)	Recreation Status
1	178	87.2	24	Active
2	188	83.3	25	Active
3	185	103.7	22	Active
4	183	97.7	23	Active
5	170	77	23	Active
6	196	97.3	24	Active
Mean	183.3	91	23.5	
SD (±)	8.1	9.3	1	

Values were rounded to 1 significant figure.

Inclusion and Pre-Participation Requirements

To participate in this study, the participants were required to adhere to the following set of guidelines. The participants were free from any previous heat illness and any injury in the past year. The participants completed a Par Q, the principal investigator added in the following question to the Par Q. "Have you ever suffered a heat illness/injury? If yes, please list below" (Appendix C). A list of injuries that would exclude participants can be found below (Table 2). Participants were recreationally active at least three times per week following ACSM guidelines, 20-60 minutes of activity 3-5 times per week (Garber et al., 2011). Prior to experimentation, participants gave their written informed consent and became familiarized with the protocol which is further described below.

Table 2. List of lower extemity injuries that would exclude subject participation

List and descirption of injuries
Any broken bone in the lower extemity (foot, ankle, knee, femur)
Any sprained ligaments in the lower extremity
Any strained muscles or tendons in the lower extremity
If the participant had surgery on the lower extremity in the past year
Shin Splints
Any injury/surgery that occurred around the lower portion of the back/spine

Hydration Status

Before each session began, hydration status was assessed using urine refractometry (Atago Hand-held Refractometer, Japan). The participants could proceed with the protocol if they had a specific urine gravity of 1.020 or below which is indicative of euhydration (How to Maximize Performance Hydration, NCAA., 2013). If the participants were dehydrated, they were hydrated on site and a re-test of urine refractometry was done to ensure hydration status. A description of rehydration can be found below. Urine specific gravity was also assessed post-test, and if the scores were reflective of dehydration, participants would ingest fluid and remain in the laboratory until they were euhydrated as indicated by urine refractometry.

Hydration and Pre-conditions

Participant hydration status was monitored pre and post data collection through urine refractometry. For this study design, any value 1.020 or below was considered euhydrated, and anything above was considered dehydrated. If the test results were indicative of dehydration, then the researchers gave the participant 16 ounces of water to drink within 30 minutes. A second urine refractometry test was then administered after an additional 30 minutes (How to Maximize Performance Hydration, NCAA, 2013). To ensure hydration, participants were told to drink 16 ounces 2-3 hours before the session, and they were advised to drink another 8 ounces of water 15 minutes before the session (How to Maximize Performance Hydration, NCAA., 2013). Participants were asked to refrain from heavy exercise (any type of cardio-endurance, interval training or lower-body resistance training), alcohol, caffeine and any sort of stimulants one day prior to testing. Two days before a testing session, the principal investigator would contact the participant to remind them of their session time and date, as well as to remind them about abstaining from heavy lower body resistance training the day prior.

Precooling Protocol

There was a 30-minute window to ingest 7.5 g/kg body mass (-1 ˚C or 0 ˚C) of ice slurry or water (1 ˚C) before the exercise commenced (Siegel et al., 2010). At every 5-minute window the participant ingested 1.25g/kg of bodyweight. Shortly after finishing the precooling protocol the exercise commenced. The ice-slurry flavor the participants consumed was blue raspberry (Snappy Popcorn Co, Breda, IA). One serving was 8oz and contained 5 calories, 1mg of sodium 1g of carbohydrates and 1g of sugar.

Experimental Conditions

The participants were asked to complete three total sessions. Session 1 which was familiarization, and sessions two and three which were either the experimental or control trial. The order of sessions was randomized and counterbalanced for each participant before the trials began. In every trial, the recreationally active individuals wore military grade equipment.

Experimental Design

Visit one consisted of informed consent, measuring demographic data, orientation, and familiarization. The participants completed and signed an informed consent (Appendix B) prior to any testing sessions. The participants were oriented with the study procedures and equipment prior to any testing, following which the participants height and body mass were measured using a Detecto Stadiometer (Detecto, Webb City, Missouri). Participants then underwent a familiarization trial which was designed to orient the participants with the gear and equipment that were going to be utilized during testing sessions. Full gear consisted of a combat uniform either ACU or OCP, summer weight boots, a fighting load carrier vest (FLC), a ruck sack (15.8 kg) and a US Army combat helmet.

Participants practiced walking on a treadmill at 4 mph and 0% grade for 15 minutes in order to become familiarized with the experimental protocol. If the pace was too difficult, it was lowered until it could be kept at a challenging yet comfortable speed (Nye et al., 2017). The exercise protocol originally was set to 4 mph and 0% grade, but it proved to be too difficult for the participants in this study design. The exercise protocol was then changed to a self-selected pace where the treadmill was set to 3.5 mph and 0% grade. From there, the participants were instructed that they could increase or decrease the speed from 0.1-0.5 mph in either direction. The screen was covered meaning the participants were blinded to the speed. The investigator instructed the participants to select a speed that was comfortable enough to sustain for a long period but would also be challenging towards the end. Once the participant selected the speed, they felt was best, the investigator recorded on the data sheet and started the timer to signal the start of the test. The same speed was used during the participants next session still while being blinded. All sessions occurred inside of a 10x10 Eurmax canopy tent (Eurmax 10x10 Canopy Tent, El Monte, California) at 33˚C, with full combat gear on and full lab equipment on. The tent was heated to 33˚C using four space heaters (TPI 188 Portable Heater, Gray, Tennessee), which took approximately 45 minutes to heat up to the correct temperature. Visit two and three began with assessing hydration levels via the handheld urine refractometer (Atago Hand-held Refractometer, Japan). If the participants were euhydrated, they equipped the polar heart rate monitor, watch (Polar FT1, Beijing, China) and the rectal thermistor (Measurement Specialties Model 701, Andover, Minnesota). Once the equipment was put on, all resting variables were recorded which included heart rate, core temperature, blood pressure and rating of perceived exertion (RPE). Afterwards, the participants put on the full Army combat gear.

The precooling protocol was then initiated, which was to consume 7.5g/kg of bodyweight in either ice slurry or water over a 30-minute period (Siegel et al., 2010).

Every 5 minutes, the participant consumed 1.25g/kg of bodyweight of either cold water or ice slurry and this continued until 30 minutes had elapsed. Once the precooling protocol was complete, the participants entered the heat tent and began the actual experimental protocol which had a maximum test length of 90 minutes or until volitional fatigue (Nye et al., 2017). The speed was a self-selected pace that ranged from 3.0 - 4.0 mph and 0 % grade (Nye et al., 2017) in a heat tent at 33±2˚C (Zimmerman et al., 2015). The treadmill was set to 3.5 mph and the participant, not able to see the speed, was instructed to increase or decrease the speed until they found a pace that was challenging. Once the participant selected a speed the principal investigator recorded the pace on top of the data sheet, as well as started the timer to indicate the start of the data collection process. The same speed that the participant selected was replicated in the second experimental trial. All variables were collected in 5-minute intervals which included, heart rate (Polar H10, Beijing, China), core temperature (Measurement Specialties, Andover, Minnesota; Cole-Parmer Instrument Co, Vernon Hills, Illinois) and RPE (RPE, Borg, 1998) (Walker et al., 2015).

Heart rate, core temperature and RPE were collected every 5 minutes in both the familiarization session as well as session two and session three (Walker et al., 2015). The data collected during familiarization was not used and was discarded. Blood pressure was collected pre and post testing via a stethoscope and sphygmomanometer. Heart rate was collected through a polar heart band and polar heart rate watch. Core temperature was collected via a rectal thermistor and was read through a tele-thermometer. RPE was collected on a 6-20 Borg scale. Physiological strain index (PSI) was calculated after the test using the data collected every 5 minutes. PSI is the indication of heat stress by considering both metabolic (heart rate) and thermal (temperature) strain. The equation for PSI is as follows: PSI = 5(Tret - Tre0). (39.5 - Tre0)-1 + 5(HRt - HR0). (180 - HR0)-1, where Tret and HRt are any measures at a given interval and Tret0 and HR0 are the given resting measurements (Cheung, S. S., 2010; Moran et al., 1998). The time points used in calculating PSI for this study design were post dose consumption and recovery.

Heart rate and core temperature were monitored continuously for safety purposes. The exercise trial was terminated either at participant request or if the participant met termination criteria, listed below. The participant was immediately removed from the heat tent and instructed to remove the US Army helmet, rucksack, jacket, boots, FLC and pants. The participants then sat quietly for 5 minutes at which point post-exercise measures were obtained. After the test was terminated, participants were removed from the heat tent to return to normal resting heart rate and core temperature. A re-test of urine refractometry was conducted, and if the participants were dehydrated, the researchers administered fluids using the same hydration protocol found above until euhydration was achieved.

Absolute Test Termination Criteria

1) Core temperature greater than or equal to 39.5 ˚C, (2) HR greater than 10 bpm over age predicted maximum heart rate, (3) Unsteady gait making it unsafe to continue walking, or (4) participant request (Hailes et al., 2016)

Keeping the participants safe was of the highest priority and if any of the participants reached any one of the above criteria cut off points, the test would be terminated. If the participant was unable to walk steadily on the treadmill with the extra load carriage, the participants would be at risk of a fall. After one warning of an unsteady gait, with a second occurrence resulting in test termination. Age predicted maximum heart rate was calculated by the following: 220 – Age (Physical Activity Basics – CDC, 2018). No participant throughout the duration of the study design had a test terminated due to one of the criteria above.

Statistical Analysis

Statistical analysis was performed using SSPS Version 24 for Windows (SSPS., Chicago, IL). The means and standard deviations were calculated for all variables that were recorded during testing. T-tests was used to test the main effect of precooling on time to volitional fatigue for each protocol. A series of one-way repeated measure analysis of variance (ANOVA) were used to test the statistical significance of the precooling protocol on core temperature and heart rate for both conditions. A Tukey *post hoc* analysis was conducted to determine which precooling condition differed from each other. Statistical significance was accepted with a p-value of $p < 0.05$. The smallest worthwhile change was also calculated for the main effects of time to exhaustion and core temperature using the explanation as done by Hopkins (Hopkins, W. G, 2016).

CHAPTER 4: RESULTS

Kinetic Results

The average time to exhaustion for the control condition was 26.33±8.22 minutes. The average time to exhaustion for the experimental condition was 28.23±11.03 minutes. The results of the paired sample t-test on time to exhaustion between conditions demonstrated no significant difference ($p = 0.227$; $t = -1.37$). Figure 3 displays the mean values for time to exhaustion per individual participant, across the two separate conditions.

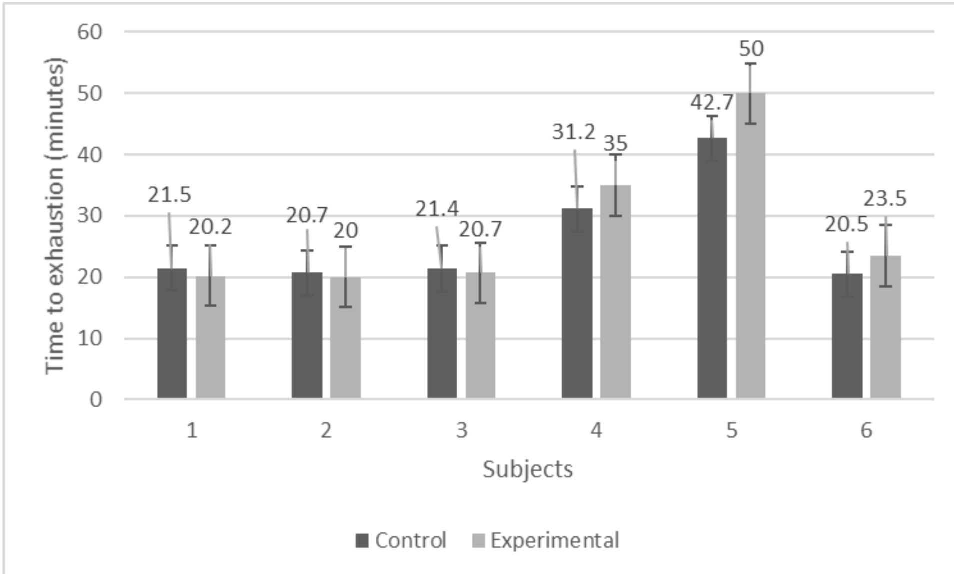

Figure 1. Mean time to exhaustion per participant by condition

*Indicates significance ($p < 0.05$) compared to the control condition

Table 3. Mean (SD) values for both conditions of all subjects per variable

	Cooling Type							
	Control				**Experimental**			
	Core Temp (˚C)	**HR (BPM)**	**RPE**	**TTE (minutes)**	**Core Temp (˚C)**	**HR (BPM)**	**RPE**	**TTE (minutes)**
Mean	37.4	133.6	12.4	26.3	37.4	135.7	12.2	28.2
SD (±)	0.4	13.4	0.8	8.2	0.4	16.2	0.8	11

***Significant difference from control condition ($p < 0.05$); TTE = time to exhaustion (minutes); HR = heart rate (beats per minute); RPE = rating of perceived exertion (on Borg's 6-20 scale). Figures were rounded to 1 significant figure.**

Metabolic and Physiological Results

There was no statistical significant difference for core temperature (p = 0.876; f = 0.20) between the two conditions. The mean core temperature for control sessions was 37.36± 0.39˚C. The mean core temperature for the experimental group was 37.42± 0.39 ˚C.

There was no statistical significant difference for heart rate (p = 0.763; f = 0.001) between the two conditions. The control had a mean heart rate of 133.59±13.36 BPM across all sessions and time intervals. For the experimental trials, the mean heart rate was 135.71±16.2 BPM. Figure 3 demonstrates the differences seen in heart rate between the two conditions. The average temperature and humidity respectively in the control sessions was 32.6 ˚C. and 29% relative humidity. For the experimental session, the average temperature and humidity respectively was 32.5 ˚C. and 30% relative humidity. The temperature of the environment and humidity for each participant respectively was not significantly different (p = 0.741; p = 0.597).

Physiological strain index (PSI) was calculated and was then compared by condition using a paired sample t-test. There was no significant difference found between the experimental and control conditions (p = 0.604; t = -4.09). Mean PSI for the control was 2.92±1.85 Mean PSI for the experimental condition was 2.46±1.10. Only one individual reaching a score greater than 4 for both session 2 and session 3. Every other individual was below a score of 4 which is considered minimal strain.

All averages from the figures included the baseline core temperature measurements, post-dose (post precooling consumption) measurements, all data from the 5-minute intervals, and the recovery measurements.

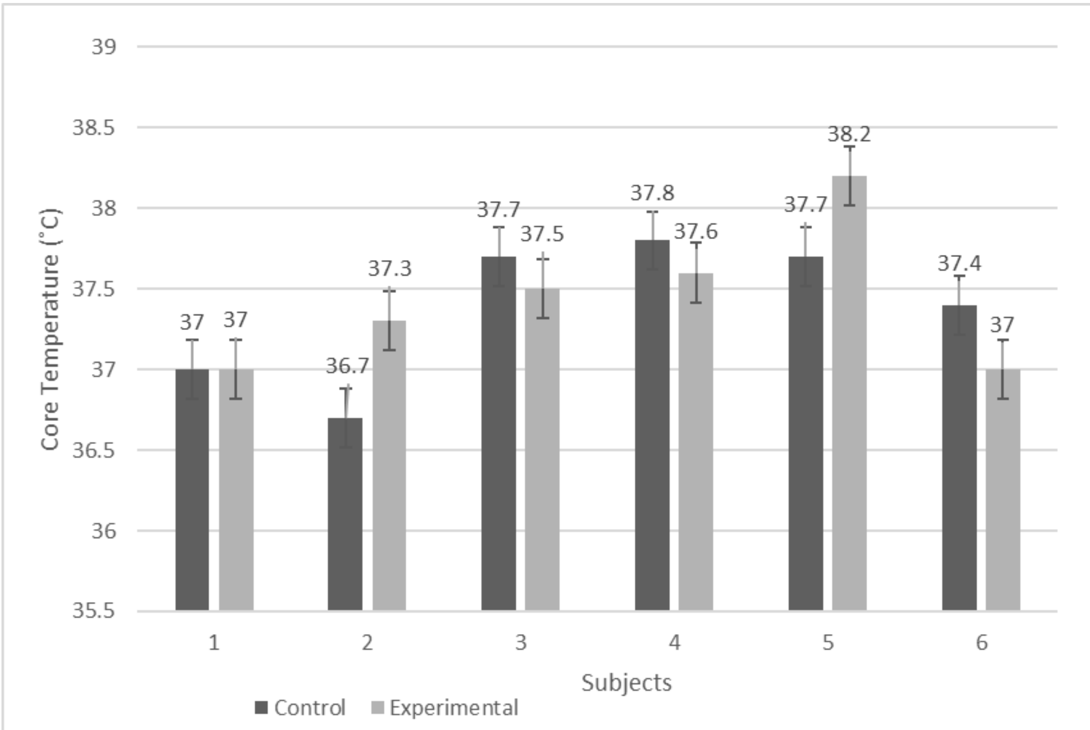

Figure 2. Mean core temperature per participant by condition

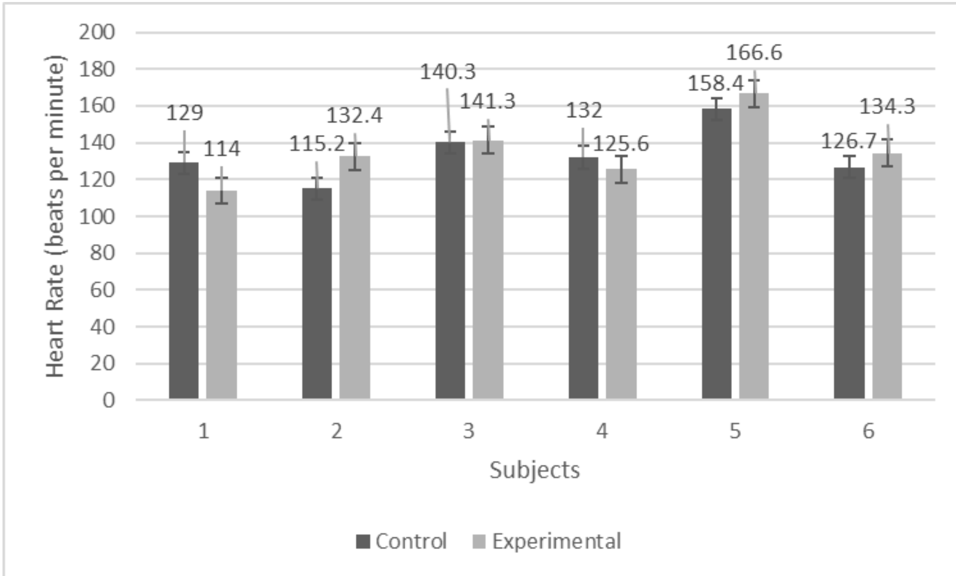

Figure 3. Mean heart rate per participant by condition

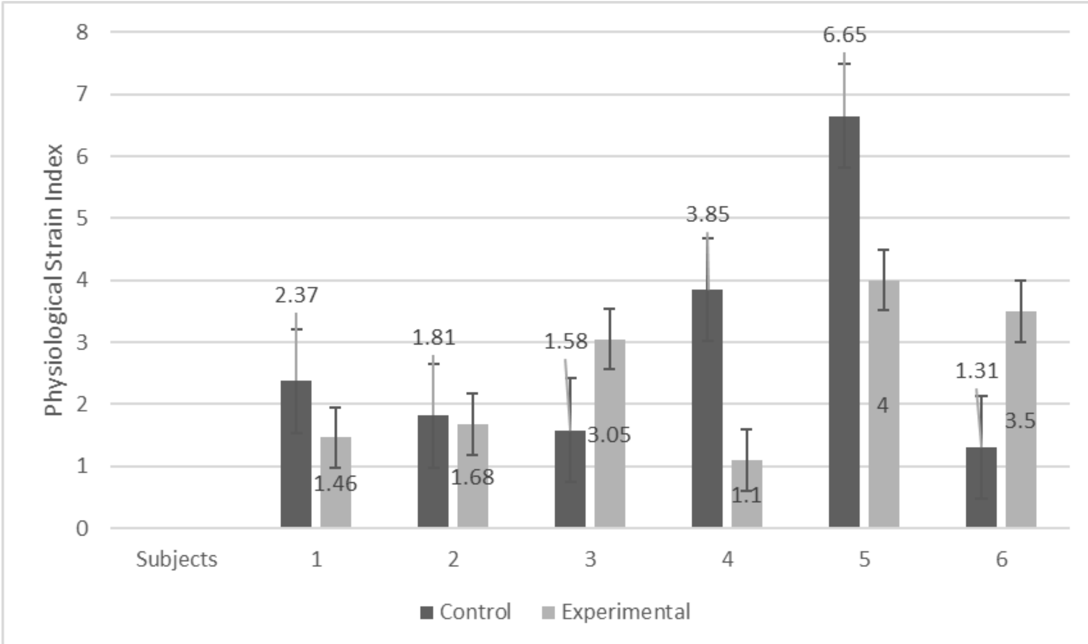

Figure 4. Physiological strain index for all participants for both conditions

Smallest Worthwhile Change

The smallest worthwhile change was calculated to see if there were any meaningful differences, since there were no statistically significant differences. The standard deviation from the control condition was taken and multiplied by 0.2 to get the smallest worthwhile change. If the experimental trial differed by the smallest worthwhile change calculated from the control (per specific variable), then it was considered a smallest worthwhile change. The smallest worthwhile change for core temperature in the control sessions was 0.078 ˚C. For time to exhaustion, the smallest worthwhile change in the control trial would be a difference of 1.644 minutes.

To make things simpler, the smallest worthwhile change was only looked at for baseline measures, post-dose measurements and the recovery measures in participants 1, 4 and 5. These participants were chosen because of the differences observed in certain variables throughout the study design. Participant 1 had positive smallest worthwhile changes for core temperature, but not for time to exhaustion.

Participant 4 exhibited positive smallest worthwhile changes in both core temperature and time to exhaustion. Participant 5 demonstrated no positive smallest worthwhile changes for values of core temperature. Participant 5 did however, demonstrate a positive smallest worthwhile change in time to exhaustion.

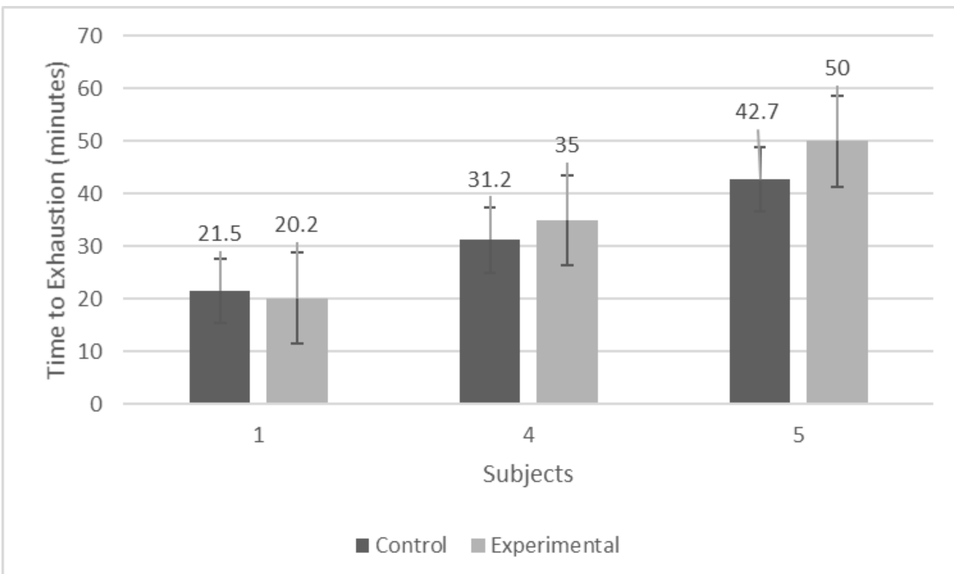

Figure 5. Time to exhaustion for three participants in both trials

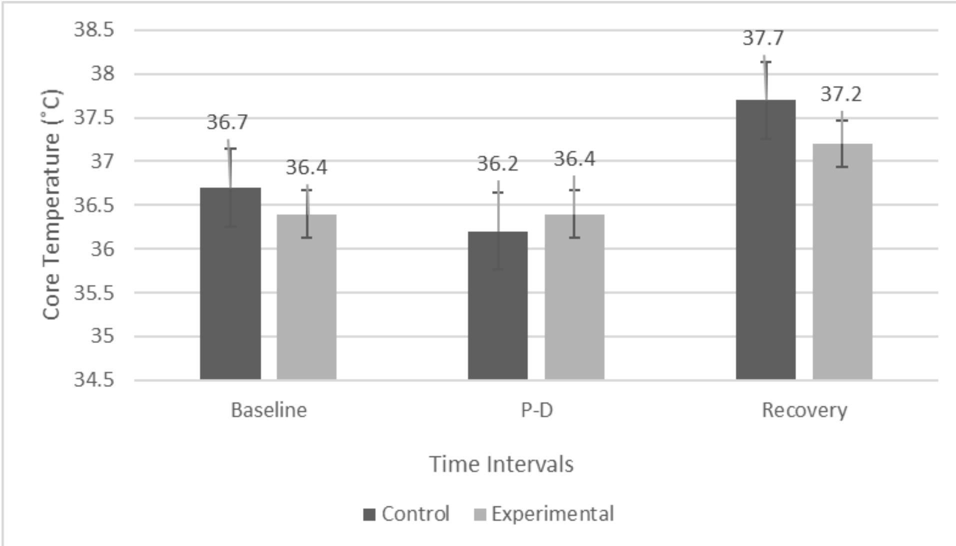

Figure 6. Core temperature values separated by condition at different time intervals for Participant 1

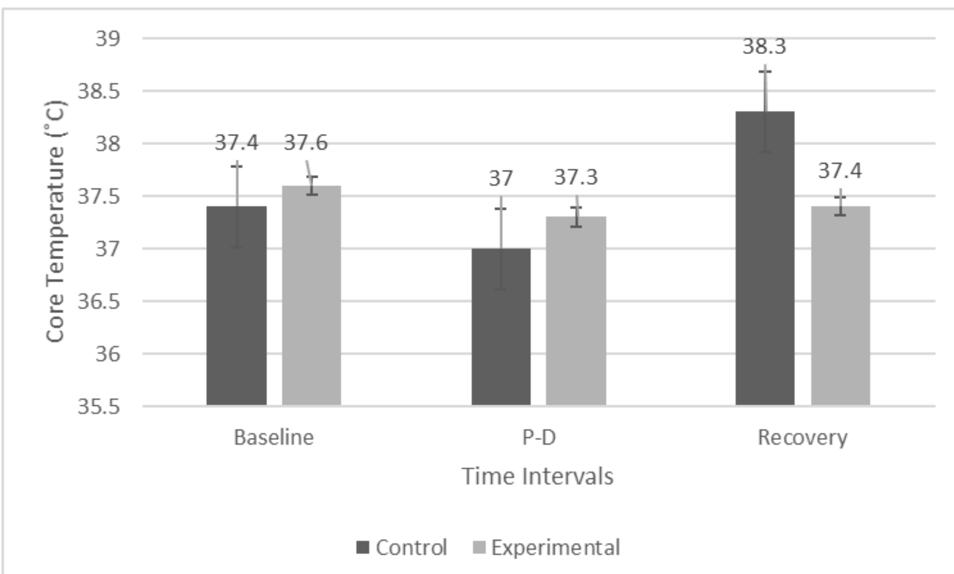

Figure 7. Core temperature values separated by condition at different time intervals for Participant 4

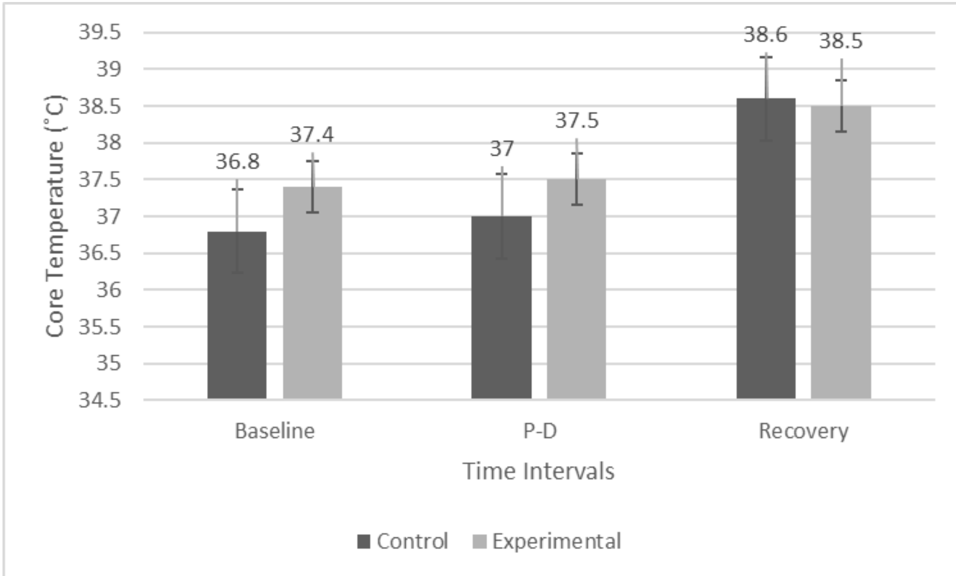

Figure 8. Core temperature values separated by condition at different time intervals for Participant 5

CHAPTER 5: DISCUSSION & CONCLUSION

Precooling Protocol and Statistics

The current investigation found no significant difference ($p > 0.05$) between conditions for time to exhaustion. A control water supplement and experimental ice slurry supplementation had similar results and ice slurry ingestion was ineffective in increasing time to exhaustion. Siegel et al., (2012), examined the effects of a pre-exercise precooling ice slurry as well as CWI compared to a precooling control water in 8 male endurance runners. Running time was significantly longer in CWI and ice slurry compared to control, however, there was no statistical difference between CWI and ice slurry for time to exhaustion. This demonstrates that an ice slurry can be effective in increasing time to exhaustion in certain performance tasks, and can even be compared to have the same effect to that of a CWI cooling method.

Marino, F. E. (2002), reviewed 12 articles concerning precooling and its effects on exercise performance. Out of the 12 articles in review, 7 found precooling with either cold air at 0°C, 5°C, or water immersion at 24°C had increased performance in terms of time to exhaustion or duration (Marino, F. E. 2002). One issue that Marino (2002) addresses is that precooling is difficult to evaluate because of the multiple types of exercise protocols employed. He states that various exercise protocols have been used, but that very few of those protocols are actual measures of exercise performances. He suggests that precooling is more beneficial for endurance events from 30-40 minutes, and that precooling with higher intensity events are less well understood (Marino, F. E. 2002). The possibility exists that although that the exercise protocol could be considered light endurance work, the added equipment mixed with task inexperience may have resulted in relatively higher intensity for the participants and possibly ameliorated the effects of the precooling protocol. This is further supported by the fact that the average times to exhaustion for each condition were less than the 30 minute minimum exercise duration suggested by Marino as benefiting from the precooling protocol (Marino, F. E., 2002).

The results from the current study demonstrated no significant ($p > 0.05$) difference between the separate conditions of control versus experimental for core temperature. The precooling ice slurry ingestion was found to be ineffective at lowering core temperature pre-exercise, which is in contrast to the findings of Siegel et al. (2010), who investigated the effects of precooling with a slurry on running performance in the heat and found that the precooling protocol with an ice slurry was effective in decreasing core temperature and in turn increasing heat storage capacity. Zimmerman et al., (2015), demonstrated that a pre-exercise crushed ice ingestion effectively lowered core temperature in women cycling in 33°C heat, although it did not improve performance measures. One of the potential limiting factors that may have affected these outcomes is the low subject pool. If there were more subjects participating in the current study design, these findings may have been more similar to that of Siegel et al. (2010) & Zimmermann et al. (2015). Another possible limiting factor is that the control condition may have been too similar to that of the experimental condition. The temperature of the two different beverages from each condition were only 4°C apart. It is possible that both conditions had worked to precool the individuals, and therefore no major difference was found between the conditions.

The current investigation found no significant difference on the secondary effects of heart rate, PSI & RPE compared amongst the two separate conditions ($p > 0.05$). These findings were in contrast to that of Cotter et al., (2001) regarding heart rate and PSI. Heart rate and physiological strain were significantly lower amongst the cold air precooling group and ice vest group compared to control (Cotter et al., 2001). The current study design had similar findings for RPE relative to the results found by Zimmermann et al. (2015). Zimmermann imitated half time sports such as field hockey and soccer by having 9 female participants execute 18 four second sprints in a heated environment (33°C) (Zimmermann et al., 2015). Although the crushed ice ingestion did work to significantly lower core temperature, it did not improve performance nor RPE which were similar to the findings of this current study design (Zimmermann et al., 2015).

From the precooling of the slurry, it was assumed that there would be a visible difference in core temperature from the baseline reading (B), to the post-dose measurement (PD; completion of precooling protocol). However, what was found was that core temperature was significantly different between B and recovery (R) which is expected after physical exertion in the heat. The core temperature was not significantly lowered from B to PD as was expected, and the core temperature was significantly higher from B to R which was expected. There was also a significant difference between PD and R, and since the precooling protocol was ineffective for this study design; it makes sense that if core temperature did not change from B to PD, that it would also see a significant increase in core temperature after physical exertion in the heat. If the precooling protocol was effective, it would be anticipated that core temperature would be significantly lower from B to PD, and significantly higher from PD to R. Siegel et al., (2010) demonstrates that change from B to PD, where the ice slurry was effective and lowered core temperature by 0.66°C compared with cold water ingestion which only lowered it by 0.25°C (Siegel et al., 2010).

Physiological Strain Index

One interesting point was that participants 4 and 5 were the only participants who exercised beyond 30 minutes, and while their PSI scores were reflective of being in higher strain than the other participants, all participants were classified as having minimal strain. Cheung (2010) describes minimal strain as any value under 7, with a value over 7 being considered severe strain. Some participants only had PSI scores as high as 3 and were usually below a value of 2. This could mean that potentially the exercise protocol did not cause enough strain or that the participants chose an unchallenging pace.

Core Temperature End Point

The current study design found no significant difference ($p > 0.05$) between core temperature end points amongst the separate conditions. The mean core temperature end point for the control protocol was 37.8°C and for the experimental protocol 37.9°C ($p = 0.932$). One of the potential theories behind this study design was that the precooling protocol could increase heat storage capacity from PD to R. Siegel et al. (2010) mentioned by lowering core temperature before exercise, rectal temperature could increase over a longer period of time and end at a similar temperature Cheung, S. S., & McLellan, T. M., (1998), & Gonzalez-Alonso et al., (1999) demonstrated this to be true. Cheung, McLellan and Gonzalez-Alonso found very similar core temperature end points for both highly fit individuals and moderately fit individuals, who completed various exercise protocols and fatigued around similar core temperature measurements. One of the thoughts behind the design of the current study was to apply this to military members, by allowing for a greater heat storage capacity. Theoretically the military members should be able to increase their time to exhaustion, while at the same time; potentially reducing the risk for exertional heat illness, but this was found to be untrue.

Future Considerations

Another issue with overheating and military members in general is the equipment being worn. Convective, conductive and evaporative means of heat loss offer various avenues for heat to leave the body, but it seems that the gear being worn by military members inhibits evaporative heat loss (Nagashima et al., 2015). While the relative humidity can also limit heat loss via evaporation, the long sleeve and pant leg design do not offer much bare skin exposure for the sweat to evaporate. This lack of evaporative ability may have been part of the impetus for the design of the CCV. A suggestion for the future might include a potential redesign with either the length of the garment or material of the equipment.

Some things to consider for future works would to try and increase the dose of the slurry and to increase the number of participants. The small sample size that was used in this study had an impact on the results and broadening the sample size can help with this problem in the future. Also, if the participants have no experience with load carriage and military gear, it is also suggested to have multiple familiarization sessions. Additionally, it may be beneficial to collect measurements of local fatigue if utilizing participants inexperienced with marching. In this study design, there were multiple participants who described that the local fatigue of the lower extremity was a limiting factor and much higher than overall fatigue. Another consideration is the fact that the self-selected speed protocol may have not strained the participants adequately. The participants may have selected a speed that was too easy, therefore not putting enough strain on the system to see any changes. In the future, it might be beneficial once again to have experienced marchers who can keep up with higher paces with increased loads.

Implications

In the current study, no participants had prior experience with load carriage. In theory, this could have interfered with their normal gait kinetics and potentially change the true time to exhaustion. These results differ from other studies in that the precooling protocol that was employed was not effective. It may still be possible to lower the chances of having an exertional heat illness and improve endurance performance in military members with a precooling ice slurry, however, it was not so during this study design.

Conclusion

The aim of this study was to investigate the effects of a precooling protocol ice slurry (0±-1°C) compared to a control cold water (4°C) on military foot marches in regard to core body temperature and time to exhaustion while wearing full combat gear and a loaded pack in males aged 18 to 35. The results of this study found no statistically significant difference on the main effects of core temperature and time to exhaustion; nor was a difference observed for heart rate, RPE or PSI.

Continued research is warranted on not just precooling but any type of cooling that can potentially increase heat storage capacity to increase time to exhaustion, while at the same time reducing the chances of having an exertional heat illness. More research is needed concerning the effects of the precooling protocol with military gear and using actual military members with experience marching compared to recreationally active individuals.

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APPENDICES

APPENDIX A: Institutional Review Board Approval

200 Prospect Street
East Stroudsburg, PA
18301-2999

East Stroudsburg University Institutional Review Board
Human Research Review
Protocol # **ESU-IRB-051-1819**

EAST STROUDSBURG UNIVERSITY

Date: **April 2, 2019**
To: **Christopher Esposito and Chad Witmer**
From: **Shala E. Davis, Ph.D., IRB Chair**
Proposal Title: **"Investigating the effects of precooling on recreationally active individuals during loaded carriage foot marches in heated conditions"**

Review Requested:	Exempted	Expedited	Full Review **X**
Review Approved:	Exempted	Expedited	Full Review **X**

FULL RESEARCH

_X__ Your full review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your full review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your full review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit.

EXEMPTED RESEARCH

____ Your exempted review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your exempted review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your exempted review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

EXPEDITED RESEARCH

____ Your expedited review research proposal has been approved by the University IRB (12months). Please provide the University IRB a copy of your Final Report at the completion of your research.

____ Your expedited review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

____ Your expedited review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

Please revise or submit the following:

East Stroudsburg University of Pennsylvania
A Member of Pennsylvania's State System of Higher Education
An Equal Opportunity/Affirmative Action Employer

APPENDIX B

<u>Informed Consent for Scientific Study</u>

Title of Investigation: *Investigating the Effects of Precooling on recreationally active individuals during a Loaded Carriage Foot March in Heated Conditions*

EAST STROUDSBURG UNIVERSITY
Exercise Science

<u>Principal Investigator</u>

Christopher Esposito

Overview of the study

Load Carriage foot marches are an integral part of military training. However, over the last 20 years, different forms of heat illnesses have been plaguing cadets which hinders both health and performance. Military branches have employed countermeasures but most of these are not used due to cost or have been demonstrated as ineffective in lowering core temperature and therefore preventing heat illnesses. The task at hand was to identify a cost-effective method which can lower core temperature in hot conditions in order to lower the chance of heat illnesses for military members. The purpose of the present investigation is to gauge whether or not this precooling slurry protocol increased heat storage capacity and increases time to exhaustion.

Testing Sessions

There will be three total sessions during this study. The first session will occur in the Human Performance Lab (HPL) and end in the Research Laboratory. During that session, you will learn about what is going to take place in the study. If you wish to participate, you will get your height and weight recorded. A 15-minute familiarization trial will occur immediately after.

The next two sessions are roughly the same except the drink you will intake beforehand is different. In one session you will drink 7.5g/kg of ice slurry (either blue raspberry or cherry), and the other protocol you will drink 7.5g/kg of water. After ingestion, you will enter a 93 ˚F heat tent with full combat gear and a rucksack on and walk on a treadmill for up to 90 minutes. The speed of the treadmill is 4mph and the grade is at 0%.

You will be undergoing physical activity inside of a heat tent with full combat gear on and a rucksack, although be it slight, there are still some risks involved. Any individual information obtained from this study will remain confidential. Non-identifiable data will be used for scientific presentations. You may withdraw from the study at any time. If you have any questions you may contact the principal investigator or Dr. Chad Witmer before signing this consent form. If you have any additional questions during or after this study, Dr. Witmer can be contacted at:

cwitmer@po-box.esu.edu Tel: (570) 422 3362

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT OYU HAVE READ THE INFORMATION PROVIDED AND YOU HAVE DECIDED TO PARTICPIATE IN THE STUDY.

I have read and understood the above explanation of the purpose and procedures for this study and agree to participate. I also understand that I am free to withdraw my consent at any time.

____

Print Name

____________________ ____________________ ____________________

Signature Witness Signature Date

APPENDIX C

Physical Activity Readiness Questionnaire (PAR-Q) and You

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:

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> 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 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 <u>any other reason</u> why you should not do physical activity?
☐	☐	8.	Have you ever suffered a heat illness/injury? If yes, please list below.

If you answered:

Talk to 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.

Delay becoming much more active:

- If you are not feeling well because of a temporary If you answered NO honestly to <u>all</u> PAR-Q illness such as a cold or a fever – wait until you feel questions, you can be reasonably sure that you can: better; or