Impact of Excessive Clothing During Exercise in a Thermo-Neutral Environment

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Fall Term 2023

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Abstract

During exercise in warm environments, the cardiovascular system is challenged to simultaneously provide sufficient blood flow to the working skeletal muscles and to provide sufficient blood flow to the skin to dissipate heat. This leads to the physiological phenomenon of cardiovascular drift, which is defined as the progressive increase in heart rate paired with a decrease in stroke volume, while cardiac output remains constant. This study was designed to explore the impact of layering clothing to induce cardiovascular drift, which indicates the possibility of heat acclimation. Specifically, this study was undertaken to determine if the results of exercise in excess layers match the traditional, well-researched method of exercise in an environmental chamber.

Methods: Five female athletes performed three separate randomly assigned trials: one in an environmental chamber (95°F), one in a thermo-neutral environment with no added heat stress, and one in a thermo-neutral environment with excess layers of clothing. Each trial consisted of forty minutes on a cycle ergometer, at a moderate workload. Measures included heart rate, rating of perceived exertion, and sweat response.

Chapter 1

Title:
Impact of excessive clothing during exercise in a thermo-neutral environment.

Introduction:
It is widely acknowledged that exercise performed under heat stress can pose a considerable challenge for athletes. Endurance sports such as running, cycling, triathlons, and rowing are primarily conducted in outdoor environments. For many athletes, exposure to the elements is a part of the appeal to their sport, despite the potential risks. The impact of heat on sporting competition is greater than ever as climate change produces more cases of extreme weather. Since the 1950's, heatwaves have increased in intensity, frequency, and duration, with these trends expected to accelerate under enhanced climate change (14). Extreme heat is already the number one weather-related cause of death in the United States. Current climate projections suggest the planet could warm by 7.2°F by 2100, which would impose major ramifications on athletes: from recreational runners to elite athletes.

Exertional heat-related illness refers to a spectrum of heat illnesses that occur during exercise due to high ambient temperatures and humidity levels. The most serious heat-related illness, exertional heat stroke, is one of the leading causes of sudden death in athletes. Furthermore, the number of sports-related exertional heat stroke deaths in the United States has doubled since 1975 (12). The incidence of exertional heat illness in endurance athletes raises the importance of developing a tolerance to the heat through practical and effective heat mitigation practices.

Heat acclimation (HA) and heat acclimatization (HAz) have shown to be effective heat mitigation strategies that enhance athletic performance and readiness during exercise in hot conditions (2). HA refers to training in an artificial, controlled environment, whereas HAz refers to training in a natural, outdoor environment. Both HA and HAz involve repeated and systematic exercise in hot environments, which induces physiological adaptations, ultimately enhancing performance and reducing the risk of exertional heat illnesses. Adaptations include decreases in heart rate, rating of perceived exertion (RPE), skin (T_{sk}) and core (T_c) temperature, and sweat electrolyte concentration; as well as increases in plasma volume and sweat rate (20). Heat acclimation generally requires 10 days of 90-minute moderate-intensity exercise in 86°F wet-bulb globe temperature (13).

The benefits to heat acclimation are appealing to athletes of all levels who are looking to improve performance in hot conditions. Many athletes, however, live and train in temperate climates and do not have access to the necessary resources (i.e. environmental chambers) to adequately acclimate. There are other promising heat acclimation strategies for athletes that include post-exercise hot tub or sauna bathing (24); however, wearing excess clothing in temperate conditions may be the most realistic, simplest, and cost-effective method.

Statement of Purpose:
To determine if exercise in excess clothing in a thermo-neutral environment can promote heat acclimation.

Significance of the Study:

This study has significance on determining if HA is possible through the practical method of layering clothing during exercise. There has been noteworthy research highlighting the benefits of resting in hot-dry or hot-humid conditions (15) as well as post-exercise hot water immersion (24), however, the most effective HA methods require heat stress during exercise. Most exercise-based research is completed within controlled environmental chambers, which is not logistically or financially feasible for most of the population. A practical, proposed method for inducing HA is to wear excessive clothing, which restricts heat loss during exercise.

As the investigator, this study is significant to me because I have always been involved in outdoor sports and recreational activities. Also, I have family members who frequently participate in outdoor events such as triathlons and running races. We currently live in Indiana which is a temperate climate, meaning the winters are cool to cold and the summers are mild to warm. Most of the year, the temperatures are relatively cool, however, in the peak of summer, the temperatures can reach dangerously hot conditions. I find it fascinating that it could be possible to prepare for the summer heat by layering clothing during training in the weeks leading up a race. With this exposure, I hope to find a practical way to prepare for athletic events in hot conditions, as well as improve the safety of myself and others by limiting the risk of exertional heat-related illnesses.

Delimitations:

The focus of this study was to determine if limiting heat loss by layering clothing can achieve the same degree of cardiovascular drift as imposing heat in the environmental chamber. The independent variables were the environmental chamber and the thermo-neutral room, as well as the layers of clothing. The dependent variables were heart rate, rating of perceived exertion (RPE, 6-20), sweat response, and a thermal comfort rating (1-7).

Each participant underwent four different sessions. The first was an orientation, followed by three separate, randomly assigned trials: one took place in the environmental chamber set to 95°F and two took place in a thermo-neutral room: one with the subject dressed in light clothing, the other with the subject in layers of clothing.

The trials were 40-minute sub-maximal sessions on the cycle ergometer. Each subject performed the trials at a workload that allowed them to reach 70% of their max heart rate during a 15-minute cycle ergometer test. Before and after each trial, the subject's weight was taken to determine the sweat response. During each trial, the heart rate was recorded every minute and the RPE was recorded every two minutes.

Five female college athletes, ages 20-21 years old, served as subjects. The subjects were tested in isolation to ensure no distractions were affecting the variables. Each subject was instructed to fast and refrain from vigorous exercise for at least 12 hours prior to testing. Additionally, subjects were advised to be well-hydrated prior to each session.

Limitations:

This study was limited in the number of subjects. External validity due to the use of young, healthy, conditioned, female athletes also limited the study. The timing between sessions varied slightly, due to having to be scheduled when the subject, researcher, and laboratory were free. Due to logistical reasons, an accurate core body temperature measurement was unable to be measured, so results are based on the subject's heart rate. Also due to logistical reasons, hydration levels of subjects were unable to be controlled, so it was assumed that each subject was well-hydrated.

Assumptions:

It was assumed that…

1. Participants were not acclimated to the heat prior to the experiment.
2. Participants did not exercise for at least 12 hours prior to testing.
3. Participants fasted for at least 12 hours prior to testing.
4. Participants received at least 7 hours of sleep the night prior to testing.
5. Participants were well hydrated prior to each session.
6. Participants refrained from caffeine intake for 12 hours prior to testing.
7. Increases in heart rate were due to heat stress, not dehydration.
8. Equipment was effective in obtaining the desired data.
9. Data was reliable.

Hypotheses:

It was hypothesized that when exercising in a thermo-neutral environment and comparing results with exercising in thermo-neutral environment wearing excessive clothing:

1. Heart rate will be lower
2. Rating of perceived exertion will be lower
3. Sweat response will be lower

It was hypothesized that when exercising in a thermo-neutral environment and comparing results with exercising in a thermo-hostile environment:

4. Heart rate will be lower
5. Rating of perceived exertion will be lower
6. Sweat response will be lower

It was hypothesized that when exercising in a thermo-neutral environment wearing excessive clothing and comparing results with exercising in a thermo-hostile environment:

7. Heart rate will be the same
8. Rating of perceived exertion will be the same
9. Sweat response will be the same

Definition of Terms:

Acclimation: Artificially induced adaptations
Acclimatization: Naturally induced adaptations
Adaptations: Process of change by which an organism becomes better suited to its environment
Cardiac output: Quantity of blood pumped by the heart in a given period of time
Cardiovascular drift: Increase in heart rate that occurs with little to no change in pace
Conduction: Transfer of heat through direct contact with an object or surface
Convection: Transfer of heat by the movement of air or water
Endotherm: Organisms that use internally generated heat to maintain body temperature
Evaporation: A form of cool in which liquid, secreted from sweat glands, evaporates from the skin

Heart rate: Number of times the heart beats per minute
Homeotherm: Organism that maintains a stable internal body temperature
Humidity: Amount of water vapor in the air
Hypothalamus: Structure that maintains homeostasis within the body
Radiation: Transfer of heat in the form of waves
Shivering: Involuntary muscle spasms to produce heat
Stroke Volume: Amount of blood ejected with each heartbeat
Sweating: Release of liquid from the body's sweat glands
Thermoreceptors: Sensory nerve that detects changes in temperature
Thermoregulation: Ability of an organism to maintain a steady internal body temperature despite changes in external conditions
Vasodilation: Dilation of blood vessels
Vasoconstriction: Constriction of blood vessels

Operationally defined terms:

Cycle ergometer: Stationary exercise bike that measures the amount of work done by pedaling the bike
Endurance training: Activities that increase your breathing and heart rate such as walking, jogging; increase energy and stamina by increasing aerobic capacity
Environmental chamber: System that enables users to manipulate the environmental conditions of an enclosed space to run controlled tests on a subject
Sub-maximal: Physical activity with increasing intensity but does not exceed 85% of your maximum heart rate
Thermo-neutral: Environment where normal body temperature can be maintained while minimizing energy expenditure and oxygen consumption

Chapter 2

Background:

Introduction

Human bodies are remarkably well-adapted to acclimate to heat stress under the right circumstances, if given sufficient time and adequate amounts of water. Heat stress on the body is the result of a combination of environmental conditions, physical work rate, and the wearing of clothing that hinders heat loss. Environmental heat stress and physical exercise interact simultaneously to increase strain on physiological systems, specifically the cardiovascular system. If physical exercise is conducted in warm to hot conditions, it results in an elevated body temperature, increased cardiovascular strain, and ultimately, impaired aerobic performance. Overtime, with repeated exposure to hot conditions, the body adjusts to reduce the negative effects of heat stress, through heat acclimation (HA) or heat acclimatization (HAz). These adjustments or adaptations that occur greatly reduce the strain that heat places on the body during exercise. Both HA and HAz elicit analogous responses, so the terms will be used interchangeably.

A variety of methods have shown to be effective in inducing heat adaptations, some of which include, exercise in a naturally warm environment (HAz), exercise in an artificially warm environment (HA), or post-exercise hot water immersion. These approaches would be useful for athletes who reside and train in a cool climate but compete in a hot climate. The changes in the big ten conference for 2024 provides a good example of when HA or HAz would be beneficial. If the University of Minnesota's football team goes to Los Angeles to play UCLA in mid-November, they would automatically be put at a disadvantage due to the heat. The players in Minnesota would likely have been practicing in 30-40°F temperatures for several weeks, while it is still 80-85°F in Los Angeles. If the players from Minnesota do not follow any type of acclimatization protocol prior to the game at UCLA, they would likely notice a decrease in their performance. If found to be effective, overdressing as a mechanism to acclimate to the heat would be the most financially and logistically feasible mechanism, especially for large athletic teams and recreational athletes.

Thermoregulatory control

Living organisms can survive in a variety of biomes due to their diverse abilities to adapt to fluctuating external environmental conditions. An organism's ability to maintain a consistent internal environment in a variety of conditions is attributed to many physiological processes that work to maintain homeostasis. Living organisms can be categorized into two primary groups based on their response to fluctuating ambient temperatures: poikilothermy and homeothermy. Those two terms, poikilotherm and homeotherm, refer to if the body temperature remains constant. Poikilotherms lack the physiological means to generate their own body heat, so their body temperature tends to match that of their surrounding environment. In contrast, homeotherms can maintain a relatively constant body temperature through physiological mechanisms, even when the environmental temperature varies (11).

Furthermore, animals can be categorized into two more groups, endothermic or ectothermic, depending on where they receive heat from. Endotherms can regulate their own body temperature through a variety of metabolic processes. They are often referred to as 'warm-blooded' and include mammals and reptiles. A benefit to being endothermic is the ability to inhabit a wide variety of climates, however, a limitation is that generating heat is energetically costly, so there are high nutritional and caloric requirements. In contrast, ectotherms receive their heat from the surrounding environment. They are often referred to as 'cold-blooded' animals and include reptiles and amphibians. A benefit to being ectothermic is that the energetic requirements are low, so they can survive with a lower caloric intake. A drawback is that ectotherms are limited in the climates they can inhabit; they often require a warm environment that provides sufficient heat.

As both endotherms and homeotherms, humans can regulate their own body temperature and maintain that temperature within a narrow range, even when the environmental conditions fluctuate.

Humans have the capacity to confront variable environmental changes to maintain homeostasis through behavioral and physiological changes. Behavioral thermoregulation is dependent upon voluntary decisions. Changes in skin temperature are detected by the afferent pathway and a signal is sent to the cerebral cortex, where the decision is made to gain or lose heat. The level of perceived comfort is influenced with fluctuations in skin temperature, which leads to thermoregulating behaviors. One of the most basic thermoregulating behaviors includes searching for hot or cold habitats that allow the organism to alter its rate of heat loss or gain. More complex thermoregulating behaviors include making burrows, huddling in groups, and human behaviors like altering clothing or adjusting the air conditioner (10). Physiological thermoregulation is involuntary, and it involves either thermogenic (heat production) or thermolytic (heat loss) responses. The main physiological responses to heat and cold stress include vasodilation, vasoconstriction, sweating, and shivering (13).

Homeostatic Control

Humans core body temperature is regulated by a part of the brain called the hypothalamus. The anterior hypothalamus stimulates heat loss, while the posterior hypothalamus stimulates heat gain. The body has peripheral (skin) and central (brain, spinal column, large vessels) thermal receptors that constantly provide afferent input to the hypothalamus. Thermoregulation is conducted through a homeostatic control system and every homeostatic control system consists of three components. The first component is the afferent sensor, which for thermoregulation are the thermal receptors. Those receptors, located on the skin and in the hypothalamus, sense temperature changes and send a signal to the central control, which in this case is the hypothalamus. The hypothalamus takes that information and initiates a response, which is called the efferent control. In this case, if the body needs to lose heat, the anterior hypothalamus will initiate a primary response of vasodilation and a secondary response of sweating. If the body needs to gain heat, the posterior hypothalamus will initiate a primary response of vasoconstriction and a secondary response of shivering.

Shell and Core Temperature

Typically, the body's core temperature is around 98.6°F, however, it can fluctuate between a narrow range of 97-99°F. Small fluctuations in core body temperature occur naturally due to sleeping patterns, physical work, hydration status, food intake, and environmental conditions. In contrast to core temperature, the temperature of your skin can vary much more. The average skin temperature is 93°F, but it can range from 92.3-98.4°F. This is because your skin is exposed to the environment and your body regulates its core temperature by changing the amount of blood flow to the skin, referred to as vasodilation and vasoconstriction. This temperature difference between the two is called the temperature gradient. This gradient is vital for our survival because it is the pathway in which we can lose body heat. According to the second law of thermodynamics, heat always flows from areas of hot to cold, unless work is exerted to make it flow in the other direction (1). Since the core temperature is warmer than the skin temperature, heat will move from the core out to the skin.

Mechanisms of Heat Loss

Heat is transferred down the thermal gradient, from hot to cold, through the processes of radiation, convection, and/or conduction. With a core body temperature of 98.6°F humans are often the warmer than their surrounding environment, meaning heat is usually transferred from the body to the surroundings. Radiation is the mechanism that releases the most heat, accounting for about 60% of the body's heat loss. It is the process where heat waves are emitted and either absorbed or transmitted as infrared waves. One strategy to support heat loss through radiation would be to expose more skin to the environment, while a strategy to gain heat would be to sit near a fire or in direct sunlight. The second most effective mechanism of heat loss is convection, which is the exchange or movement of heat from your skin to the surroundings. This accounts for 10-15% of all heat lost by the body. A strategy to support convection as a heat loss mechanism would be to sit in front of a fan or pour cool water over the skin. A strategy to limit convection would be to wear a windbreaker to prevent any breeze from contacting the skin. The least effective form of heat loss is conduction, which is heat exchange through direct contact with an object or surface. This only accounts for about 2% of the body's heat loss.

If those three mechanisms of heat loss are not enough, the body will resort to the final mechanism, which is sweating. Sweating is the last resort because your body does not want to lose water. At rest, about 20% of the body's heat loss occurs through sweating but during exercise it can increase to account for up to 85% of heat loss. Therefore, as core temperature rises, heat loss through evaporation becomes the primary mechanism of heat dissipation. Sweat droplets are derived from interstitial fluid, then produced by the eccrine glands. The drop of sweat is converted from a liquid to a gas, using the heat energy on the skin to complete the process. After the drop of sweat rises, it leaves the area of skin cooler because the heat was used as energy for the process.

The amount of sweat vaporized from the skin depends on the following three factors: the surface area exposed to the environment, the temperature and relative humidity of ambient air, and convection air currents around the body. The surface area exposed to the environment is a factor because the larger the exposed surface area of skin, the more molecules will vaporize and escape into the air. Temperature and relative humidity are both factors because the warmer the air is, the more active the air molecules will be, leaving more open space for moisture to accumulate. In contrast, the lower the humidity is, the more effective evaporation will be because the air is able to hold more water molecules. Finally, convection currents around the body influence the degree of evaporation because as air surrounds the body, it warms up, rises, and is replaced by cooler air. If there is more air flow, the process will continue at a quicker rate.

Heat Balance Equation

The following heat balance equation addresses the internal and external factors that contribute to thermal balance and the maintenance of core temperature:

$T_c = M \pm C_v \pm C_d \pm R - E - W$

The heat balance equation shows that core temperature equals the combination of metabolism, convection, conduction, radiation, evaporation, and work. $T_c = M$ will always be constant no matter what is going on in the environment. C_v, C_d, and R will be either positive or negative depending on the temperature of the surroundings. If the surrounding air is above the skin temperature of 93 degrees, then the body will gain heat from the surroundings, so it would be positive. On the other hand, if the surrounding air is cooler than the skin temperature of 93 degrees then the body would lose heat into the environment, so it would be negative.

Heat balance equation for thermo-neutral conditions:

$T_c = M - C_v - C_d - R - E - W$

Heat balance equation for thermo-hostile conditions:

$T_c = M + C_v + C_d + R - E - W$

E is always negative because humans can only lose heat through evaporation, never gain it. Even though your body doesn't lose heat through work, W is always negative because while exercising some of the metabolic processes are transferred to support the work, rather than ending up as heat. At rest the body is 0% efficient because all metabolic processes end up as heat. During exercise on the cycle ergometer, the body is 20% efficient with the other 80% going to heat production. Prolonged exercise in hot conditions imposes a challenge on the cardiovascular system, as the heart must circulate blood to the working muscles as well as the skin to dissipate heat. Overtime, this leads to a gradual increase in heart rate known as cardiovascular drift.

Cardiovascular Drift

Cardiovascular drift is the natural increase in heart rate during an extended period of cardiovascular exercise, such as running or biking, despite the intensity remaining the same. A more complex definition is the upward drift of heart rate over time, coupled with a progressive decline in stroke volume and maintenance of cardiac output, while exercise intensity remains constant. It occurs after approximately 10-15 minutes of moderate-intensity exercise and it is associated with decreased maximal oxygen uptake, particularly during heat stress. Cardiovascular drift indicates an increased relative metabolic intensity during exercise in the heat, which has implications for exercise prescription (22).

Cardiac Output

*Q = Heart rate * Stroke volume*

Cardiac output (Q) is defined as the amount of blood that the heart circulates per minute. It is the limiting factor during exercise because if there is not enough blood being circulated to the working muscles, then they will fatigue very quickly. At rest, the average cardiac output is 5L/min and it is dependent on size and body composition, not physical fitness. The two variables that work together to form cardiac output are heart rate and stroke volume. Heart rate and stroke volume work inversely of each other to maintain cardiac output. If you are a highly fit person and have a high stroke volume, then you will have a low resting heart rate to compensate. In contrast, if you are unfit and have a low stroke volume, your heart will have to beat much quicker to maintain cardiac output.

Heart rate is defined as the number of times the heart beats per minute, and it is typically directly related to the workload being placed on the heart. The average resting heart rate is between 60 to 100 beats per minute. If the resting heart rate is over 100 bpm, it is known as tachycardia and if it is below 60 bpm, it is known as bradycardia. An exception for bradycardia is if the individual is very fit with a well-trained cardiovascular system.

Stroke volume is the amount of blood ejected from the left ventricle with each beat. It is influenced by venous return, which is the amount of blood that gets circulated back to the heart. There are three factors that help blood move back to the heart: one-way valves, muscle pumps, and pulmonary pumps. One-way valves work to prevent backflow of blood. Muscle pumps squeeze on the veins to help blood move against gravity. Pulmonary pumps squeeze down on the abdomen to help push blood back up to the heart. If more blood flows into the heart, the end diastolic volume will increase, so more blood must be ejected from the ventricles, ultimately meaning stroke volume will increase. This idea is known as the Frank-Starling law which states that the heart will eject a greater stroke volume if it is filled to a greater volume at the end of diastole (23). In relation to exercise, if you are a fit individual, you will have a higher stroke volume, meaning you can perform a given workload at a lower heart rate.

Autonomic Nervous System

The body's autonomic nervous system is a part of the peripheral nervous system and it controls our involuntary physiological responses such as heart rate, respiration rate, and blood pressure. There are two components to the autonomic nervous system: the sympathetic and the parasympathetic nervous systems. The sympathetic nervous system is involved in the "fight or flight" response and prepares our body to respond to dangerous or stressful situations. When activated, the sympathetic nervous system speeds up your heart rate, widens bronchial passages, decreases movement of the large intestine, constricts blood vessels, and raises blood pressure. In opposition to the sympathetic nervous system, the parasympathetic nervous system is involved in the "rest and digest" response. When activated, the parasympathetic nervous system calms the body down by decreasing heart rate, relaxing muscles, and increasing movement of large intestine to aid digestion.

At rest, the sympathetic and parasympathetic nervous systems are at equilibrium. When a stressful event is experienced or at the beginning of exercise, there is a depression of the parasympathetic nervous system and a stimulation of the sympathetic nervous system. This results in a rapid increase in heart rate, which lasts for about one to two minutes, with the degree of increase relating to the exercise intensity. During light exercise in thermo-neutral conditions, the heart rate will plateau within a few minutes, but during high intensity exercise or moderate intensity exercise in thermo-hostile conditions, the heart rate will continue to drift upward. The gradual increase in heart rate is matched by a reduction in stroke volume, which enables cardiac output to be preserved (3).

Causes of Cardiovascular Drift

There have been two prevailing hypotheses surrounding the cause of cardiovascular drift. The traditional hypothesis links the peripheral displacement of blood volume (i.e. increased blood flow to skin) to a decrease in stroke volume (16). As core body temperature increases, more blood gets sent to the skin, which is accompanied by a reduction in venous pressure, ventricular filling pressure, and end-diastolic volume, leading to a reduction in stroke volume. It was thought that an increase in heart rate was a response intended to maintain cardiac output in the wake of decreased stroke volume. A more recent hypothesis argues that an increased heart rate lowers the ventricular filling time, ultimately lowering stroke volume (4).

Nonetheless, it is widely acknowledged that there are two reasons for the occurrence of cardiovascular drift: thermoregulatory stress and dehydration (22). During exercise, especially in the heat, body temperature increases because approximately only 20% of the energy produced in contracting muscles is used for muscle contraction, with the remaining 80% being converted to heat energy. An increased heart rate is associated with an increased core body temperature, partially because blood flow to the skin is increased to promote heat loss. As core body temperature increases during exercise, fluids are lost through sweat. This fluid loss directly decreases the plasma volume of the blood. Returning to the concept of stroke volume, when the plasma volume decreases, there is less blood circulating through the vessels, meaning end-diastolic volume is less. Consequently, the left ventricle is only partially filled during the contraction, which is reflected in the decrease in stroke volume. As stroke volume drops, the sympathetic nervous system kicks in to increase heart rate to maintain cardiac output.

Depending on the environmental conditions, as well as the individual's sweat rate, it is normal to see an upward drift of up to 15% in heart rate during exercise under thermal stress. The effects of exercise in the heat could be reduced through the process of heat acclimation or acclimatization.

Heat Acclimation

Heat acclimation refers to a complex series of beneficial changes or adaptations that occur in response to heat stress over the course of 7-14 days. There are three main adaptations that occur to help reduce the effects of heat on the body: increased plasma volume, quicker sweat response, and a greater sweat production. An increased plasma volume allows the heart rate to decrease because there is a higher volume of blood to pump to the skin and muscles. A quicker sweat response allows for heat to be lost via evaporation before it builds up. Furthermore, a greater sweat production allows more heat to be lost through evaporation.

The extent of biological adaptations from heat acclimation depends on the intensity, duration, and number of heat exposures. Even resting in the heat allows one to gain limited heat adaptations, however, frequent exercise in the heat is the most effective method to develop and maximize adaptations. Optimal heat acclimation requires a minimum of 90-minutes of heat exposure daily, for 7-14 days. Furthermore, it is recommended that athletes perform aerobic exercise in the heat rather than resistance training (9).

Heat Illness

Given sufficient water and shade, healthy individuals can survive extreme exposures to hot conditions. The ability to survive in extreme conditions is only possible assuming the individuals can transfer heat from their core to the environment. If the body heats up too rapidly or if excessive fluid or salt is lost through sweat, heat-related illness could be experienced. Often, the first sign of heat-related illness is heat syncope, which is when an individual feels faint and dizzy while exercising. If it is not addressed, then heat cramps could be experienced. These are painful muscle spasms that occur due to dehydration and a loss of electrolytes. As electrolytes are lost, an imbalance occurs between the cell and the interstitial fluid, causing an electrical current to stimulate muscular contraction. The next stage is heat exhaustion which includes heavy sweating, weakness, cool, pale, and clammy skin, rapid HR, and nausea or vomiting. The final and most dangerous stage is heat stroke. This occurs when the body can no longer control its temperature, so the body temperature rises rapidly, sweating mechanisms fail, so sweating stops, and the body is unable to cool down. If this stage is reached, medical attention is needed immediately, as the body temperature can rise to 106°F or higher within 10 to 15 minutes.

Pertinent Literature:

There have been many studies conducted to investigate the effects of heat on endurance performance, however, very few studies have examined different methods of heat acclimation to improve performance. Furthermore, this study is unique because it is using all young, female athletes. This section provides previous literature that is pertinent to this study. The following research either supports or refutes the hypotheses of this study.

There were two studies conducted that have many similarities to this study. The first is titled "Physiological responses to overdressing and exercise-heat stress in trained runners" by Brett Ely et al (6). It was conducted and funded by the University of Oregon department of human physiology as well as funded by the United States Army research institute of environmental medicine. This study was published in *Medicine and Science in Sports and Exercise* in 2018. Their statement of purpose for the study was to compare physiological and cellular responses to exercise in a hot environment with minimal clothing and in a temperate environment with overdressing in both men and women. The significance of their study was to determine if overdressing in well-trained men and women elicits the same physiological, perceptual, and cellular responses to standard heat acclimation conditions. It was not known how effective overdressing would be in well-trained endurance athletes who can produce extremely high heat loads for prolonged periods of time and who rely heavily on evaporative heat loss. Additionally, they wanted to observe the effects of overdressing in men compared to women. Women have a higher body surface area to mass ratio and potentially reduced sudomotor function, which indicates overdressing might be less effective for women than men. They hoped to determine whether overdressing can create a local environment sufficient to raise core body temperature, thereby inducing heat acclimation. They were also looking to gain insight on possible clothing designs and work rates sufficient to achieve heat acclimation.

The researchers hypothesized that overdressing during exercise would cause similar increases in core temperature, skin temperature, heart rate, and sweating rate in both men and women. In addition, they hypothesized that the eHSP72 would increase in both conditions pre to post exercise. The subjects in this study consisted of 13 well-trained distance runners: seven males and 6 females. Well-trained was defined as performing over 7 hours per week of aerobic exercise and exceeding the 85^{th} percentile for VO_{2max} for age and sex. They were also young (24±6), healthy, and not heat acclimated. Each subject underwent VO_{2max} testing prior to study participation. The overall average VO_{2max} was 58±10.7, which indicates highly fit subjects. The experimental sessions were scheduled to begin at least 48 hours after VO_{2max} testing. Each subject participated in two experimental sessions separated by at least seven days. The HOT trial took place in an environmental chamber set to 40°C and 30% relative humidity. The overdressed trial took place in the same environmental chamber set to 15°C and 50% relative humidity. The clothing in the overdressed session consisted of two midweight wicking lose sleeve shirts, another long sleeve shirt and a coat with a heat retaining liner, rain jacket, mittens, short running tights, long running tights, track pants, and waterproof rain pants. For the sessions, the subjects ran on a treadmill at 1% grade and a speed to elicit 50-60% of VO_{2max} for 60 minutes. T_{re}, T_{sk}, and HR were measured continuously throughout the session. Metabolic measurements including VO_2, VCO_2, and RER were measured in three-minute increments, every ten minutes (minute 7-10, 17-20, etc). Perceptual ratings including RPE, thermal sensations, and sweat sensations were assessed every five minutes.

All subjects completed both trials, but one subject stopped due to volitional fatigue at 40 minutes and four subjects stopped due to an attainment of T_{re}>39.9°C at 50 minutes. Results showed that T_{re} increased throughout both HOT and CLO but was significantly higher in HOT compared to CLO. Heart rate and mean T_{sk} values were not significantly different between trials. In both men and women, it was found that heat production, evaporative heat loss, and evaporative efficiency was higher in HOT than CLO. Due to the presence of key acute physiological responses (elevated T_{re}, T_{sk}, sweating rate, heart rate) overdressing may be adequate for heat acclimation if repeated over a period of 5-14 days. However, the lower change in T_{re} and the modest cellular responses found in CLO suggest that it could be delayed or less robust compared with classic heat acclimation protocols.

The second study with similarities to this study was titled "Training wearing thermal clothing and training in hot ambient conditions are equally effective methods of heat acclimation" (8). It was conducted by Carsten Lundby et al., and it was funded by the Innland University of applied sciences in Norway, as well as the Norwegian Olympic and paralympic committee and confederation of sports. It was published in the *Journal of Science and Medicine in Sport* on June 7th, 2021. Their statement of purpose was to compare the efficacy of three different heat acclimation protocols to improve exercise performance in the heat.

Their study had 34 (30 males, 4 females) well-trained cyclists divided into three different ten-day intervention groups. The subjects were an average of 21±4 years old, 68±7.6 kg, 179±6 cm, and had an average VO_{2max} of 77.4±8.5. Furthermore, all subjects were young, healthy, and not fully heat acclimated. One group performed 50 minutes of cycling per day in 35°C (HEAT), another group performed 50 minutes of cycling per day wearing thermal clothing (SUIT) in 19.5°C, and the final group performed 50 minutes of cycling per day wearing thermal clothing plus an additional 25 minutes of hot water immersion ($SUIT_{HWI}$). It was hypothesized that the effects of training in HEAT and SUIT exert similar effects on exercise performance and that $SUIT_{HWI}$ training would exert greater effects on exercise performance.

Researchers conducted preliminary testing, which consisted of a graded cycle ergometer test in temperate conditions to determine VO_{2max} and power output at a blood lactate level of 4.0 mmol/L. Then they conducted testing before and after the ten-day intervention to determine whether there was a change in the dependent variables. This test consisted of 15-minutes of submaximal cycling at 60% of individual power output at a BLa of 4.0mmol/L, then a five-minute rest period, then into a 30-minute maximal time trial in 35°C with 60% humidity. The ten-day intervention consisted of 50-minute sessions every afternoon for ten consecutive days. Subjects cycled at ~45% (HEAT) and ~51% (SUIT) of individual power output at 4mmol/L. SUIT clothing consisted of a wool layer on both the upper and lower body, a wool hat, down jacket, and a nylon rain jacket and pants. For the hot water immersion group, following the heat training sessions they were immersed in a bath heated to 40°C within five to ten minutes of training completion. They remained submerged up to their necks for 25 minutes.

The results of this study showed no significant difference between groups in the 15-minute sub-maximal trial, however when the three groups were combined, there was a small decrease in baseline core temperature, end core temperature, and heart rate. There was also no significant difference between the three groups in the 30-minute all out trial, however, each group had a 9.5-9.9% improvement in mean power output from pre to post testing, indicating that heat acclimation was achieved in each group, but it was no significant differences were found between groups.

They concluded that ten days of heat acclimation via daily training sessions in 35°C, wearing thermal clothing in 19.5°C, and wearing thermal clothing combined with HWI are all equally effective in improving exercise performance in the heat in highly trained cyclists. It is important to note that a potential downside to SUIT vs HEAT training is a higher work rate might be needed in SUIT compared to the heat chamber. This study did not see a significant difference in core temperature, but power output differed slightly between SUIT and HEAT (158±22W vs 134±17W, respectively).

- The effects of training in HEAT and SUIT exert similar effects on exercise performance. **ACCEPTED.**
- $SUIT_{HWI}$ training would exert greater effects on exercise performance. **REJECTED.**

<u>Hypothesis #1: When exercising in a thermo-neutral environment the heart rate, RPE, and sweat response will be lower than when exercising in a thermo-neutral environment with excessive clothing.</u>

Supportive

Willmott, A. G., Gibson, O. R., James, C. A., Hayes, M., & Maxwell, N. S. "Physiological and perceptual responses to exercising in restrictive heat loss attire with use of an upper-body sauna suit in temperate and hot conditions." <u>Temperature</u>, 52: 162-174, 2018.

Stevens, C. J., Plews, D. J., Laursen, P. B., Kittel, A. B., & Taylor, L. "Acute physiological and perceptual responses to wearing additional clothing while cycling outdoors in a temperate environment: a practical method to increase the heat load." <u>Temperature</u>, 44: 414-419, 2017.

Non-supportive

Stevens, C. J., Heathcote, S. L., Plews, D. J., Laursen, P. B., & Taylor, L. "Effect of Two-Weeks Endurance Training Wearing Additional Clothing in a Temperate Outdoor Environment on Performance and Physiology in the Heat." <u>Temperature</u>, 53: 267–275, 2018.

Summary

The studies conducted by Ashley Willmott et al. (21) and Christopher Stevens et al. (18) support the hypothesis that heart rate, RPE, and sweat response will be lower in a thermo-neutral environment than in a thermo-neutral environment with excessive clothing. The study by Ashley Willmott et al. (21) found that when exercising in temperate conditions whilst wearing an upper-body sauna, there is a greater physiological strain and a larger sweat response when compared to exercise without a sauna suit. The study by Christopher Stevens et al. (18) found that training in winter garments is an effective strategy to increase the thermo-physiological strain, which was measured by an elevated core temperature, sweat rate, and heart rate.

The study conducted by Christopher Stevens et al. (18) did not support the hypothesis that heart rate, RPE, and sweat response will be lower in a thermo-neutral environment than in a thermo-neutral environment with excessive clothing. They found that when wearing additional clothing while cycling and running outdoors in a temperate environment, there was an increased thermo-physiological strain and hotter thermal sensations. Despite that, following the two-week training period in additional clothing, no evidence of heat acclimation or improved cycling performance was found. There was not a reduction in core temperature, heart rate, or sweating rate during exercise.

Hypothesis #2: When exercising in a thermo-neutral environment the heart rate, RPE, and sweat response will be lower than when exercising in a thermo-hostile environment.

Supportive

de Korte, J. Q., Bongers, C. C., Hopman, M. T., & Eijsvogels, T. M. "Exercise performance and thermoregulatory responses of elite athletes exercising in the heat: Outcomes of the Thermo Tokyo Study." Sports Medicine, 51(11), 2423-2436, 2021.

Galloway, S. D., & Maughan, R. J. (1997). Effects of ambient temperature on the capacity to perform prolonged cycle exercise in man. Medicine and Science in Sports and Exercise, 29(9), 1240-1249, 1997.

Summary

The studies conducted by Johannus de Korte et al. (5) and SD Galloway and RJ Maughan (7) both support the hypothesis that when exercising in a thermo-neutral environment the heart rate, RPE, and sweat response will be lower than when exercising in a thermo-hostile environment. The study by Johannus de Korte et al. (5) compared exercise in hot conditions that would be experienced in the 2020 Olympics to a cool environment (31.6°C, 15.9°C, respectively). The researchers observed a quicker time to exhaustion, increased core and skin temperatures, and overall lower performance. The study by SD Galloway and RJ Maughan (7) found that in a hot environment (31°C) the VO2 was lower, heart rate was higher, and time to exhaustion was quicker than in 4, 11, and 21°C environments.

Hypothesis #3: When exercising in a thermo-neutral environment the heart rate, RPE, and sweat response will be the same as exercise in a thermo-hostile environment.

Supportive

Ely, B. R., Blanchard, L. A., Steele, J. R., Francisco, M. A., Cheuvront, S. N., & Minson, C. T. "Physiological responses to overdressing and exercise-heat stress in trained runners." Medicine and Science in Sports and Exercise, 50(6), 1285-1296, 2018.

Lundby, C., Svendsen, I. S., Urianstad, T., Hansen, J., & Rønnestad, B. R. "Training wearing thermal clothing and training in hot ambient conditions are equally effective methods of heat acclimation." Journal of Science and Medicine in Sport, 24(8),763-767, 2021.

Summary

The studies conducted by Brett Ely et al. (6) and Carsten Lundby et al. (8) both support the hypothesis that when exercising in a thermo-neutral environment with excessive clothing the heart rate, RPE, and sweat response will be the same as exercise in a thermo-hostile environment. The study by Brett Ely et al. (6) found that overdressing during exercise induces elevated core and skin temperature, heart rate, and sweat response. However, core temperature was lower compared to the hot environment which indicates that exercise intensity might need to be increased when overdressed to achieve the same benefits as training in the heat. The study by Carsten Lundby et al. (8) found no significant differences in heart rate, RPE, or sweat loss between the HEAT and SUIT groups and both groups achieved similar levels of acclimation at the end of the 10-day intervention. However, it is important to note that the researchers adjusted exercise intensity for the SUIT group during training to a slightly higher intensity.

Those two studies found that overdressing during endurance exercise increases physiological strain, however, more research is needed to determine how much the workload must increase in comparison to a hot environment to reach the adequate core temperature necessary for acclimation.

Chapter 3

Methodology:

Introduction

The purpose of this study was to determine if exercise in excess clothing in a thermo-neutral environment can promote heat acclimation. The subject selection, research design, testing equipment, testing procedures, and testing protocol are discussed in this chapter.

Subject selection

Five subjects participated in this study. The participants were female college-aged athletes ranging from 19-21 years old. The subjects had a history of endurance training and weight training, but none of the subjects had a history of cycling. Furthermore, none of the subjects had previously followed intentional acclimatization protocol. Before any trials were performed, all subjects gave their consent to participate in the study by signing a consent form.

Research design

Each participant underwent four different sessions. The first session was an orientation session conducted in the exercise physiology lab. The purpose of the orientation was to get the subject accustomed to the equipment and find a workload that got their heart rate to 140 over a 15-minute period. The next three sessions were randomly assigned for each subject to avoid the ordered effect. Each of the three sessions consisted of 40-minutes on the cycle ergometer, at a pre-determined submaximal workload. One of the sessions was a control session, which took place in the thermo-neutral exercise physiology lab with no added heat stress. Another session took place in the environmental chamber set to 95°F where the subject wore light clothing. The final session took place in the physiology lab and the subject wore excess layers of clothing to induce heat stress on the body. Body weight was measured before and after each trial to determine the amount of sweat lost. There were 48 hours of rest between the three testing sessions.

Reliability was determined for the polar heart rate monitor by two 10-minute increments on the cycle ergometer. The subject sat in a chair until a resting heart rate measurement was obtained, then the subject worked at a constant, self-determined workload for 10 minutes, with their heart rate being recorded each minute. The subject then got off the cycle ergometer and rested in a chair until their resting heart rate was reached. Then they got back on the cycle ergometer and did 10 minutes of cycling at the same workload, and heart rate was recorded each minute again. The subjects heart rate stayed within one to two beats between the two sessions. Additionally, the heart rate measured by the polar monitor was identical to the heart rate measured by the cycle ergometer and it stayed within one to two beats of the heart rate measured by the subject’s apple watch. For those reasons, it was determined that the polar heart rate monitor was highly reliable. Reliability was also determined for the mechanical scale by the subject having two identical weight measurements taken consecutively.

Equipment

- Monark cycle ergometer
- Polar heart rate monitor

- Health O Meter Professional Dual-Reading Beam Scale
- Towel (for drying sweat after session)
- Borg Rating of perceived exertion scale
- Thermal comfort scale

Pre-test Protocol

When the subject reported for each testing session, it was assumed they would have done the following:

- Were well-hydrated
- Did not eat 12 hours prior to session
- Did not partake in vigorous exercise 12 hours prior to session
- Slept at least 7 hours the previous night
- Did not consume caffeine 10 hours prior to the session

Procedures

Procedure for determining workload on cycle ergometer

1. Subject positioned the heart rate monitor, so it fit snugly just below the sternum. They also tightened the watch firmly around their wrist.
2. Subject sat in a chair until a stable resting heart rate was recorded.
3. While the subject rested, the researcher adjusted the seat height on the cycle ergometer.
4. Subject got on the cycle ergometer and began pedaling at a self-determined pace.
5. About every 5 minutes or as needed, the pace was adjusted to get their heart rate to 140 bpm.
6. Once an adequate workload was reached, it was recorded and used for each of the three subsequent sessions.

Procedure for measuring sweat response

1. Subject was instructed to arrive at the exercise physiology lab wearing shorts and a t-shirt or sports bra and to bring an extra set of clothing to wear on the cycle ergometer.
2. Subject stood on mechanical scale to get a pre-trial weight.
3. Subject was then instructed to change into the clothing they were going to wear on the cycle ergometer.
4. Subject completed the 40-minute cycle ergometer session.
5. Immediately at the conclusion of the session, the subject was given a hand towel to dry the sweat off, then they changed back into the shorts and t-shirt or sports bra they arrived in.
6. Subject stood on the mechanical scale again to record a post-trial weight.
7. The difference in body weight from pre to post testing was used as their sweat response.

Subjects were not permitted to consume any fluids between pre and post weight measurements

Procedure for clean-up

1. Wiped down the heart rate monitor and the cycle ergometer with a paper towel and cleaning spray.
2. Removed the weights from the tray on the cycle ergometer and placed the cycle ergometer back in its original position.
3. Placed the heart rate monitor back in the cabinet with the other monitors.

<u>Orientation session</u>

1. Subject arrived at the exercise physiology lab wearing athletic clothing.
2. Subject was shown the cycle ergometer that the sessions would be conducted on.
3. Subject was introduced to the rating of perceived exertion scale and the thermal comfort scale that would be used during the trials.
4. Subject was briefed on the pre-test protocol they were to follow prior to starting the sessions.
5. The *Procedure for determining workload on cycle ergometer* was followed.
6. The *Procedure for clean-up* was followed

<u>Environmental chamber session</u>

1. Subject arrived at the exercise physiology lab wearing shorts and a t-shirt or sports bra.
2. A pre-trial weight was recorded on the mechanical scale.
3. Subject was instructed to change into clothing for the session in the environmental chamber. Researcher informed the subject to wear light-weight shorts or spandex and a sports bra (if comfortable) or a lightweight t-shirt.
4. Researcher gathered materials needed for the session and led the subject to the environmental Schamber located on the first floor of the science center. Materials included the heart rate monitor and watch, the rating of perceived exertion scale, the thermal comfort scale, appropriate amount of weight needed for resistance, and a pen.
5. Subject placed the heart rate monitor around their chest, so it fit snug. The watch was turned on to record a resting heart rate.
6. The researcher set up the cycle ergometer in the environmental chamber.
7. The subject got on the cycle ergometer and began the 40-minute session.
8. Heart rate was recorded every minute, while RPE and a thermal comfort rating was recorded every 5-minutes.
9. At the conclusion of the 40-minute session, the subject got off the cycle ergometer.
10. The cycle ergometer was moved out of the environmental chamber into the hallway and the researcher gathered materials that were brought down.
11. The subject and researcher went back up to the second floor to the exercise physiology lab.
12. The subject removed the heart rate monitor and used a towel to dry the sweat off, then they changed into the same clothing they used to get a pre-trial weight.
13. Subject stood on the scale to record a post-trial weight. The difference in their body weight from pre to post testing was used to determine their sweat response.
14. The *Procedure for clean-up* was followed.

<u>Thermo-neutral with added layers of clothing session</u>

1. Subject arrived at the exercise physiology lab wearing shorts and a t-shirt or sports bra.
2. A pre-trial weight was recorded on the mechanical scale.
3. Subject placed the heart rate monitor around their chest, so it fit snug. The watch was turned on to record a resting heart rate.
4. Subject was instructed to change into their clothing for the overdressed session. Clothing consisted of a base layer long-sleeve shirt, a hoodie with the hood up, a heat-retaining puffy jacket, a pair of gloves, thermal leggings, sweatpants, long socks, and tennis-shoes.

5. The seat was adjusted, so it fit the subject comfortably.
6. The subject got on the cycle ergometer and began the 40-minute session.
7. Heart rate was recorded every minute, while RPE and a thermal comfort rating was recorded every 5-minutes.
8. At the conclusion of the 40-minute session, the subject got off the cycle ergometer.
9. The subject removed the heart rate monitor and used a towel to dry the sweat off, then they changed into the same clothing they used to get a pre-trial weight.
10. Subject stood on the scale to record a post-trial weight. The difference in their body weight from pre to post testing was used to determine their sweat response.
11. The *Procedure for clean-up* was followed.

Thermo-neutral with no added heat stress session

1. Subject arrived at the exercise physiology lab wearing shorts and a t-shirt or sports bra.
2. A pre-trial weight was recorded on the mechanical scale.
3. Subject placed the heart rate monitor around their chest, so it fit snug. The watch was turned on to record a resting heart rate.
4. Subject was instructed to change into their clothing for the control session. Clothing consisted of lightweight shorts or spandex and a sports bra (if comfortable) or a lightweight t-shirt.
5. The seat was adjusted, so it fit the subject comfortably.
6. The subject got on the cycle ergometer and began the 40-minute session.
7. Heart rate was recorded every minute, while RPE and a thermal comfort rating was recorded every 5-minutes.
8. At the conclusion of the 40-minute session, the subject got off the cycle ergometer.
9. The subject removed the heart rate monitor and used a towel to dry the sweat off, then they changed into the same clothing they used to get a pre-trial weight.
10. Subject stood on the scale to record a post-trial weight. The difference in their body weight from pre to post testing was used to determine their sweat response.
11. The *Procedure for clean-up* was followed.

Pilot Data

Overview

Pilot data was collected at Hanover College in room 252 and in the environmental chamber located on the first floor of the Science Center. The pilot subject performed the orientation session, followed by the three experimental sessions in a randomized order. Each session began at 8am and they were separated by exactly 48 hours to allow the subject to rest and rehydrate. The subjects body weight was measured before and after each session to determine sweat response. While cycling the subjects heart rate was measured each minute and their RPE was measured every two minutes. Pilot data was collected prior to extending the study to include a thermal sensation scale. After collecting pilot data, it was determined that a thermal rating would be collected from the subject every 5-minutes and RPE would be collected every 5-minutes, rather than every two minutes.

Subject Description

The subject used for pilot data was a highly fit, female collegiate basketball player from Hanover College. She was 20 years old with a height of 69.5 inches and a weight of 154 lbs. For the control session, the subject wore spandex and a t-shirt. For the overdressed session, the subject wore a long sleeve wicking shirt, windbreaker, heat retaining puffy coat (with hood up), thermal leggings, sweatpants, long socks, and gloves. In the environmental chamber, the subject wore spandex and a sports bra. The subject cycled at a workload that allowed her heart rate to reach 70% of her maximal heart rate using the equation 200-0.67(age-20). That equated to a heart rate of 140 and the workload used was 2.5 kg of resistance at a speed of 48-50 rpm, which equals 750 kgm/minute.

Results

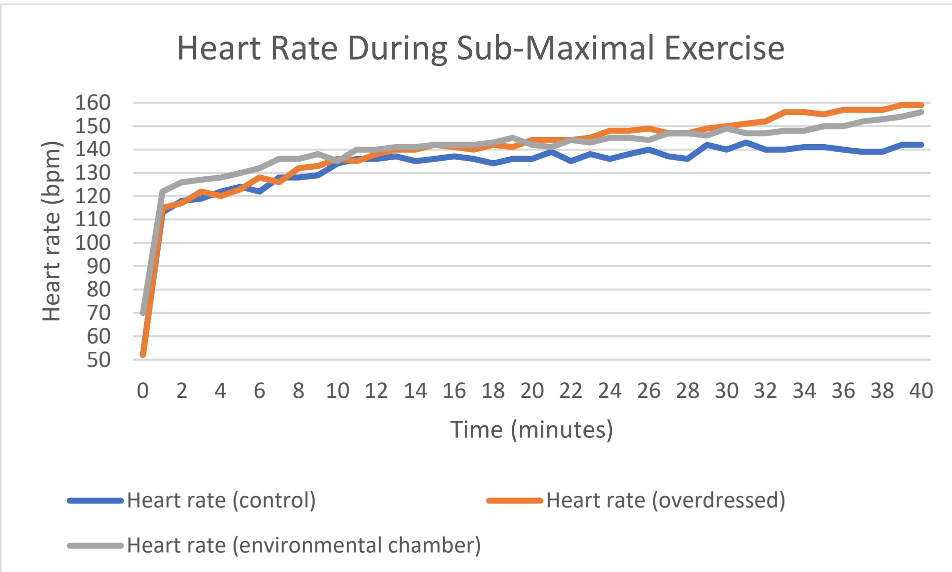

Figure 1. Heart rate measured each minute for the 40-minute sub-maximal cycling session. Heart rate was measured and recorded every minute, on the minute for the duration of the 40-minute sub-maximal cycling session. There was a large increase in heart rate during the first minute of cycling for all three conditions. In the control session, the heart rate began at 52 bpm and ended at 142 bpm. In the overdressed session, the heart rate began at 52 bpm and ended at 159 bpm. In the environmental chamber, the heart rate began at 70bpm and ended at 156 bpm.

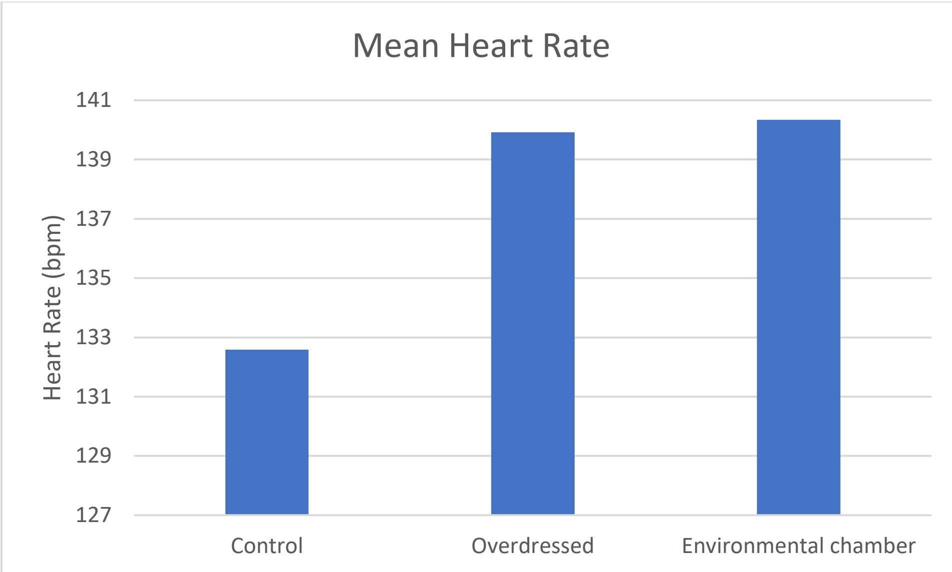

Figure 2. Mean heart rate for the 40-minute sub-maximal cycling session.
This figure illustrates the mean heart rate (HR) in beats per minute (bpm) recorded each minute. Heart rate was averaged for the 40-minute sub-maximal cycling session for each condition. For the control session, the average heart rate was 133 bpm. For the overdressed and environmental chamber session, the average heart rate was 140 bpm. The percent difference between the mean HR of the overdressed environmental chamber sessions compared to the control session was 5.5% and 5.8%, respectively. A significant difference ($p<0.05$) was found between the control group and the two interventions. The difference between the two interventions was not statistically significant ($P>0.05$). Therefore, exercise while overdressed as a mechanism to induce heat acclimation was found to be effective, but not quite as effective as the traditional method of exercise in a warm environment.

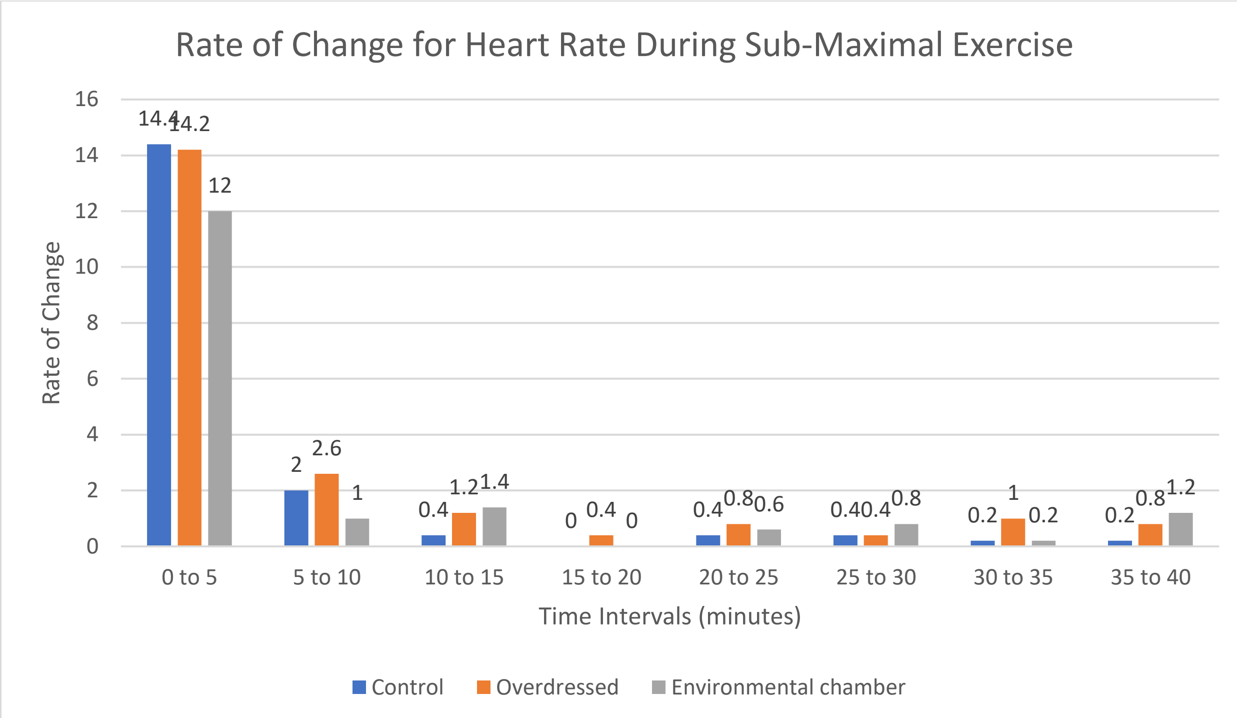

Figure 3. Rate of change for heart rate in 5-minute intervals for the 40-minute sub-maximal cycling session.

This figure represents the rate of change or slope for heart rate in 5-minute intervals throughout the 40-minute sub-maximal cycling session for each condition. For the first five-minutes, the control and overdressed session had the highest rate of change at 14.4 and 14.2 beats/minute, respectively. The session in environmental chamber showed the lowest rate of change in the first five minutes at 12 beats/minute, likely due to the subject having a higher resting heart rate in that session. Over the last 30-minutes the control session had the lowest rate of change. The session in the environmental chamber had the highest rate of change in the last 5-minutes, which would be expected to continue to increase with more time due to dehydration beginning to add to the heat stress on the subject.

Hypothesis 1, 4, 7

1. When exercising in a thermo-neutral environment the heart rate will be lower than when exercising in a thermo-neutral environment wearing excessive clothing. **ACCEPTED.**
4. When exercising in a thermo-neutral environment the heart rate will be lower than when exercising in a thermo-hostile environment. **ACCEPTED.**
7. When exercising in a thermo-neutral environment wearing excessive clothing the heart rate will be the same as exercising in a thermo-hostile environment. **ACCEPTED.**

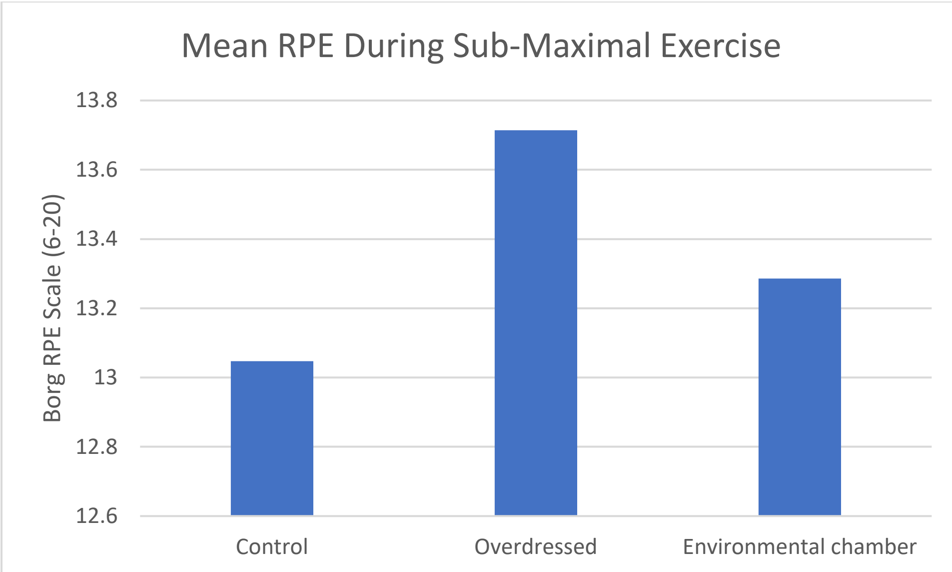

Figure 4. Mean RPE for the 40-minute sub-maximal cycling session.
A Rating of Perceived Exertion from the Borg's RPE scale was taken every two minutes for the duration of the 40-minute test. The average RPE in the control session was 13.05. The average RPE in the overdressed session was 13.7 and the average in the environmental chamber was 13.3. For all conditions the RPE began at six at minute 0. In the control session the RPE ended at 14. In both the overdressed and environmental chamber sessions, the RPE ended at 16, however, it reached 16 sooner in the overdressed session.

Hypotheses 2, 5, and 8

2. When exercising in a thermo-neutral environment the RPE will be lower than when exercising in a thermo-neutral environment wearing excessive clothing. **ACCEPTED.**
5. When exercising in a thermo-neutral environment the RPE will be lower than when exercising in a thermo-hostile environment. **ACCEPTED.**
8. When exercising in a thermo-neutral environment wearing excessive clothing the RPE will be the same as exercising in a thermo-hostile environment. **ACCEPTED.**

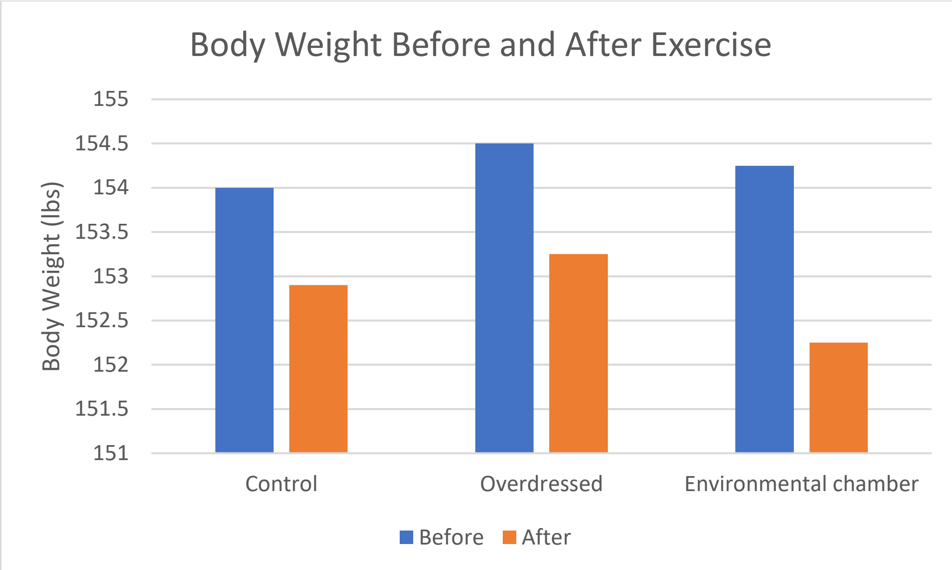

Figure 5. Body weight before and after the 40-minute sub-maximal cycling session.
Body weight was recorded pre and post exercise for all three conditions. For the control session the pre body weight was 154 lbs and the post body weight was 152.9 lbs. In the overdressed session the pre body weight was 154.5 lbs and the post body weight was 153.25 lbs. In the environmental chamber the pre body weight was 154.25 lbs and the post body weight was 152.25 lbs. The body weight varied slightly between each session, but in all three sessions, a decrease in body weight due to sweat loss was experienced.

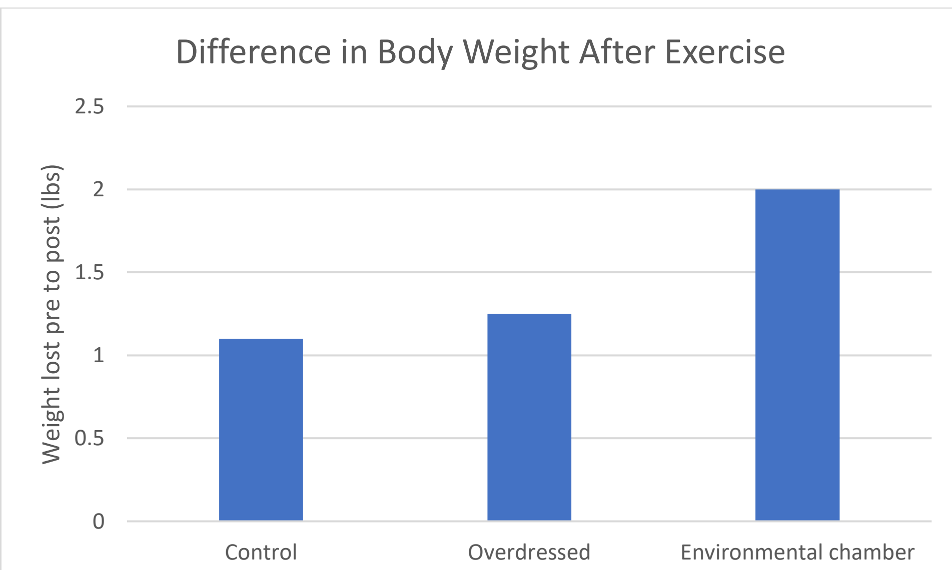

Figure 6. Difference in body weight from pre to post exercise.
The difference in body weight was calculated from pre exercise to post exercise for the 40-minute sub-maximal cycling session. The control session had the smallest change in body weight with a decrease of 1.1 lbs. The overdressed session had a decrease of 1.25 lbs and the environmental chamber had the largest sweat response with a decrease of 2 lbs. A decrease in 1

pound of body weight equals 1 pint of sweat lost. This equates to a sweat rate of 0.746 L/hr in the control session; 0.91 L/hr in the overdressed session; and 1.358 L/hr in the environmental chamber session.

Hypotheses 3, 6, and 9

3. When exercising in a thermo-neutral environment the sweat response will be lower than when exercising in a thermo-neutral environment wearing excessive clothing. **ACCEPTED.**
6. When exercising in a thermo-neutral environment the sweat response will be lower than when exercising in a thermo-hostile environment. **ACCEPTED.**
9. When exercising in a thermo-neutral environment wearing excessive clothing the sweat response will be the same as exercising in a thermo-hostile environment. **REJECTED.**

Summary

Figure 1 and **Figure 2** show that heart rate increased in both the environmental chamber session and the overdressed session. For the 40-minute sub-maximal cycling session, the mean heart rate for the environmental chamber session was slightly higher than the overdressed session, however, it was not statistically significant ($P>0.05$). There was a statistically significant ($P<0.05$) difference between both intervention groups when compared to the control session. These results were expected, as it is widely acknowledged that exercise in hot conditions place an exception strain on the cardiovascular system. The normal range of cardiovascular drift due to endurance exercise in hot conditions can reach up to a 15% increase in heart rate. In the overdressed session, at the highest heart rate reached, the subject experienced a 12% increase in heart rate compared to the control. In the environmental chamber session, at the highest heart rate reached, the subject experienced a 10% increase in heart rate compared to the control. It is predicted that in the overdressed session, the heart rate would increase more if there were more layers of clothing added, or if the current layers had higher thermal qualities.

Figure 3 shows the rate of change of the heart rate in 5-minute intervals. As expected, the highest rate of change occurred within the first 5-minutes of exercise. This occurs because when exercise begins the sympathetic nervous is stimulated and the parasympathetic nervous is suppressed. This response by the autonomic nervous system allows the heart to circulate enough oxygen and nutrients to the working muscles. During light exercise the heart rate levels off, as seen in the control session. During exercise in warm conditions, the heart rate continues to drift upwards as the body tries to get rid of the excess heat. The anterior hypothalamus initiates a response to dilate the blood vessels, causing more subcutaneous blood flow, meaning less blood is returning to the heart, so the heart rate must increase to compensate. Cardiovascular drift also occurs due to dehydration during prolonged exercise (>45 minutes).

Figure 4 shows the rating of perceived exertion from the Borg's RPE scale. The rating of perceived exertion scale goes from 6-20 and it is supposed to equate to ten times the subjects heart rate. The overall mean RPE was similar for all three trials, due the RPE starting at a low value and slowly increasing. In the control session the heart rate ended at 142 bpm and the final RPE was 14. In the overdressed and environmental chamber session, the heart rate ended at 159 and 156, respectively, with the RPE ending at 16 for both. This indicates the RPE scale was accurate and effective. The pilot subject was educated on the RPE scale from a previous course, but to limit bias, the heart rate was covered on the cycle ergometer and the subject was instructed to avoid looking at the watch.

Figure 5 and **Figure 6** show the sweat response. A sweat rate was calculated for each condition. In the control session the sweat rate was 0.746 L/hour; in the overdressed session the sweat rate was 0.91 L/hour; and in the environmental chamber session the sweat rate was 1.358 L/hour. These responses were expected because the body does not need to sweat as much in the thermo-neutral conditions. In the environmental chamber, the subject had a lot of skin exposed and a there was a low humidity, allowing a lot of sweat to be evaporated. The average sweat rate is 0.8 to 1.4 L/hour, so these rates were within the normal range. One of the adaptations that occurs with heat acclimation is an increased sweating rate and an increased sweating efficiency. In response to heat acclimation, one can expect an increase in sweat rate by 10-20%.

These results found from the pilot data indicate that heat acclimation could be induced by layering clothing. A stronger heart rate response, RPE response, and sweat response in the overdressed session could be generated by altering the layers of clothing. The layers of clothing used in the pilot data collection included a long sleeve wicking shirt, a windbreaker, a puffy coat, leggings, sweatpants, and gloves. In future sessions, the layers of clothing will be altered to include a thermal long sleeve shirt, a sweatshirt with the hood up, a puffy coat, thermal leggings, sweatpants, long socks, and gloves. Furthermore, in future sessions, a thermal comfort scale will be added to determine the subjects comfort level in the two hot conditions.

Chapter 4

This chapter contains relevant data collection following pilot data. The data was analyzed using ANOVA single factor variance testing and a simple paired t-test, which were deemed appropriate for a multiple trial study. Significance was defined as $P < 0.05$.

Results

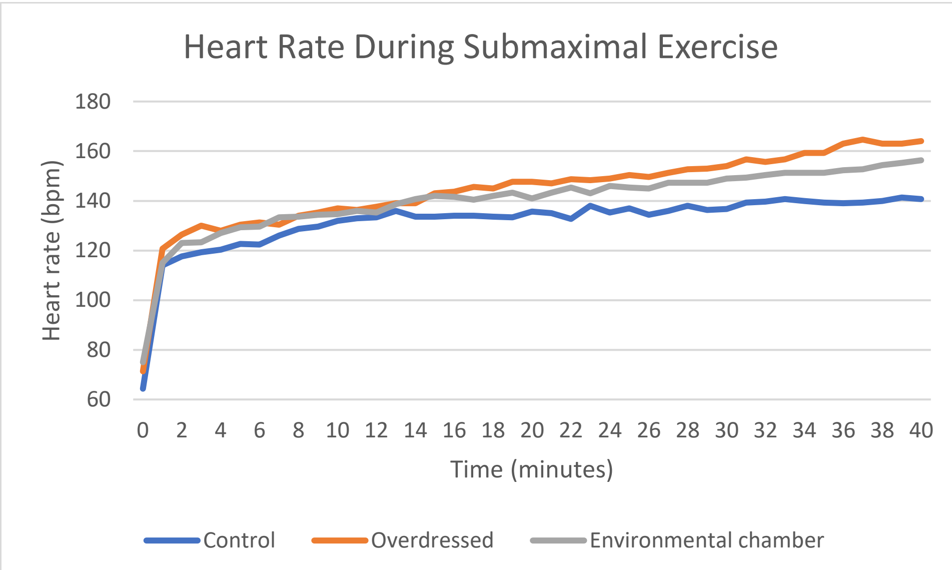

Figure 7. Heart rate measured each minute for the 40-minute sub-maximal cycling session. Heart rate was measured and recorded every minute, on the minute for the duration of the 40-minute sub-maximal cycling session. Mean heart rate was calculated for the five subjects for each condition. There was a large increase in heart rate during the first minute of cycling for all three conditions. In the control session, the mean heart rate began at 64 bpm and ended at 141 bpm. In the overdressed session, the mean heart rate began at 71 bpm and ended at 164 bpm. In the environmental chamber, the heart rate began at 75 bpm and ended at 156 bpm. Significance was found amongst the three conditions ($P=0.0006$). A t-test found a significant difference ($p<0.05$) was found between the control group and the two interventions. The difference between the two interventions was not statistically significant ($P>0.05$). Therefore, exercise while overdressed as a mechanism to induce heat acclimation was found to be effective, but not quite as effective as the traditional method of exercise in a warm environment.

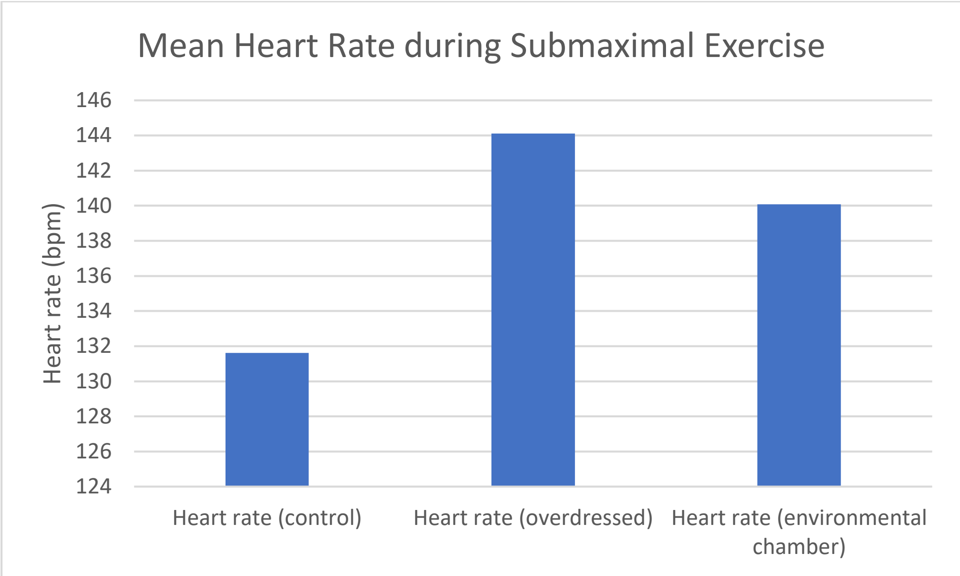

Figure 8. Mean heart rate for the 40-minute sub-maximal cycling session.
This figure illustrates the mean heart rate (HR) in beats per minute (bpm) recorded each minute. Heart rate was averaged for the 40-minute sub-maximal cycling session for each condition. For the control session, the mean heart rate was 132 bpm. For the overdressed session the mean heart rate was 144 bpm. For the environmental chamber session, the mean heart rate was 140 bpm. The mean heart rate was higher in the overdressed session than in the environmental chamber, which indicates that overdressing is an effective mechanism to induce heat acclimation.

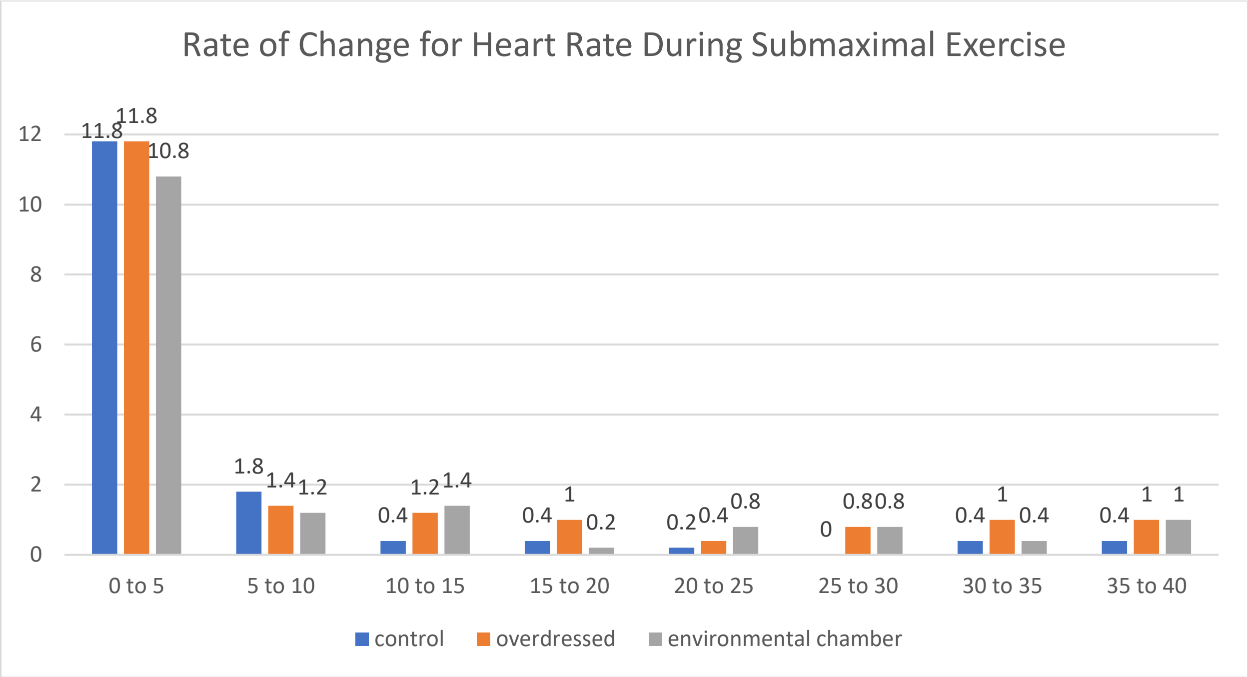

Figure 9. Rate of change for heart rate in 5-minute intervals for the 40-minute sub-maximal cycling session.

This figure represents the rate of change or slope for heart rate in 5-minute intervals throughout the 40-minute sub-maximal cycling session for each condition. For the first five-minutes, the control and overdressed session had the highest rate of change at 11.8 beats/minute. The session in environmental chamber showed the lowest rate of change in the first five minutes at 10.8 beats/minute, likely due to the subject having a higher resting heart rate in that session. Over the last 30-minutes the control session had the lowest rate of change. The overdressed and the environmental chamber sessions had the highest rate of change in the last 5-minutes, which would be expected to continue to increase with more time due to dehydration beginning to add to the heat stress on the subject.

Hypothesis 1, 4, 7

1. When exercising in a thermo-neutral environment the heart rate will be lower than when exercising in a thermo-neutral environment wearing excessive clothing. **ACCEPTED.**
4. When exercising in a thermo-neutral environment the heart rate will be lower than when exercising in a thermo-hostile environment. **ACCEPTED.**
7. When exercising in a thermo-neutral environment wearing excessive clothing the heart rate will be the same as exercising in a thermo-hostile environment. **ACCEPTED.**

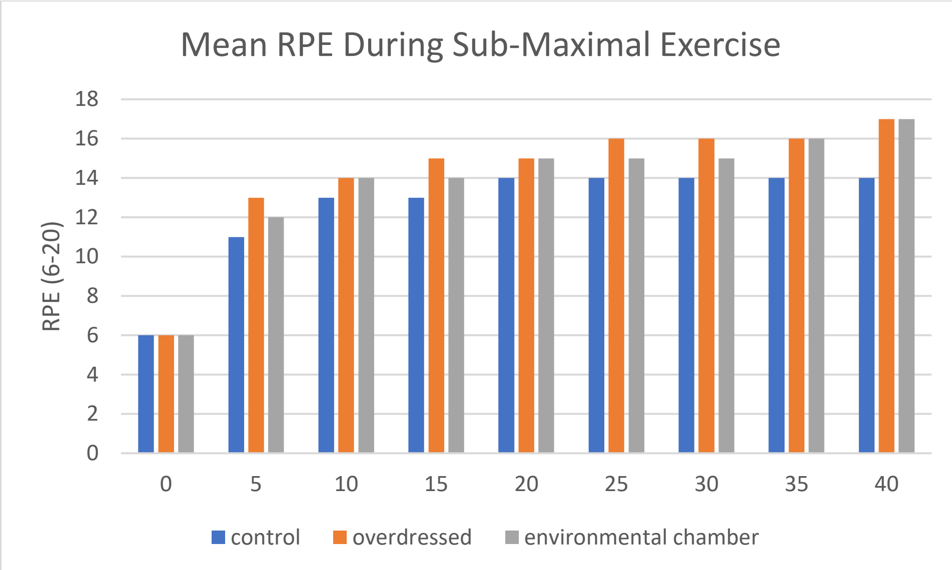

Figure 10. Mean RPE for the 40-minute sub-maximal cycling session.
A Rating of Perceived Exertion from the Borg's RPE scale was taken every five minutes for the duration of the 40-minute test. The average RPE in the control session was 12.56. The average RPE in the overdressed session was 14.22 and the average in the environmental chamber was 13.78. For all conditions the RPE began at six at minute 0. In the control session the RPE ended at 14. In both the overdressed and environmental chamber sessions, the RPE ended at 17, however, it reached 17 sooner in the overdressed session. The difference between the three conditions was found to not be statistically significant (P=0.5).

Hypotheses 2, 5, and 8

2. When exercising in a thermo-neutral environment the RPE will be lower than when exercising in a thermo-neutral environment wearing excessive clothing. **ACCEPTED.**
5. When exercising in a thermo-neutral environment the RPE will be lower than when exercising in a thermo-hostile environment. **ACCEPTED.**
8. When exercising in a thermo-neutral environment wearing excessive clothing the RPE will be the same as exercising in a thermo-hostile environment. **ACCEPTED.**

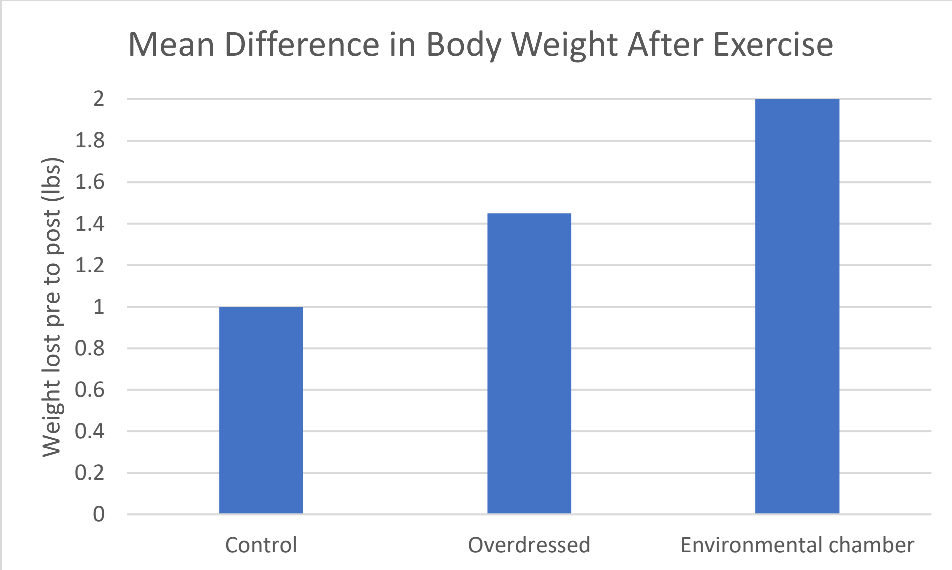

Figure 11. Difference in body weight from pre to post exercise.
The difference in body weight was calculated from pre-exercise to post exercise for the 40-minute sub-maximal cycling session and the mean was found for the five subjects. The control session had the smallest change in body weight with a decrease of 1.0 lbs. The overdressed session had a decrease of 1.45 lbs and the environmental chamber had the largest sweat response with a decrease of 2 lbs. A decrease in 1 pound of body weight equals 1 pint of sweat lost. This equates to a sweat rate of 0.68 L/hr in the control session; 0.98 L/hr in the overdressed session; and 1.36 L/hr in the environmental chamber session.

Hypotheses 3, 6, and 9

3. When exercising in a thermo-neutral environment the sweat response will be lower than when exercising in a thermo-neutral environment wearing excessive clothing. **ACCEPTED.**
6. When exercising in a thermo-neutral environment the sweat response will be lower than when exercising in a thermo-hostile environment. **ACCEPTED.**
9. When exercising in a thermo-neutral environment wearing excessive clothing the sweat response will be the same as exercising in a thermo-hostile environment. **REJECTED.**

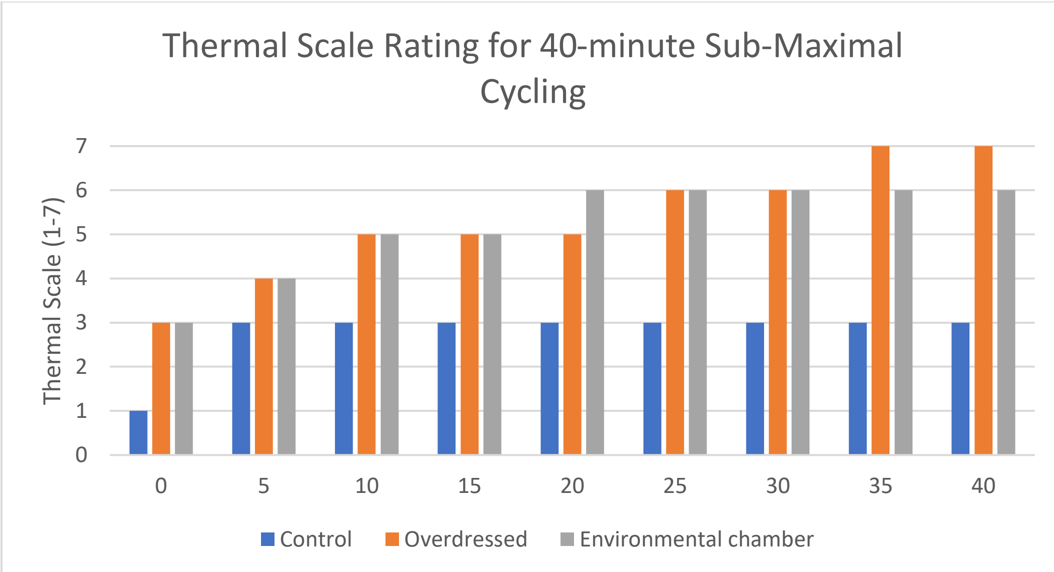

Figure 12. Mean Thermal Scale Rating for the 40-minute Sub-Maximal Cycling Session. A thermal scale rating was taken every five minutes during the 40-minute sub-maximal cycling session. The scale ranged from 1(cool) to 7(unbearably hot). In the control session, the first mean rating was 1 and ended at 3. In the overdressed session, the first mean rating was 3 and ended at 7. In the environmental chamber session, the first mean rating was 3 and ended at 6. The mean thermal rating was higher in the overdressed session than in the environmental session, which indicates that the layers of clothing provided sufficient heat stress.

Chapter 5

Discussion

Heat stress on the body is the result of a combination of environmental conditions, physical work rate, and the wearing of clothing that hinders heat loss. Environmental heat stress and physical exercise interact simultaneously to increase strain on physiological systems, specifically the cardiovascular system. If physical exercise is conducted in warm to hot conditions, it results in an elevated body temperature, increased cardiovascular strain, and ultimately, impaired aerobic performance. Overtime, with repeated exposure to hot conditions, the body adjusts to reduce the negative effects of heat stress, through heat acclimation (HA) or heat acclimatization (HAz). These adjustments or adaptations that occur greatly reduce the strain that heat places on the body during exercise. Mechanisms of HA or HAz include both passive and active methods. Passive methods include post-exercise hot water immersion, while active methods include exercising in the heat. Research has shown both passive and active heat acclimation to be effective. This is particularly useful for athletes who reside and train in a cool climate but compete in a hot climate. If you have a football team from Minnesota and they have to compete in Texas in November, they would automatically be put at a disadvantage due to the heat. The players in Minnesota would likely have been practicing in 30-40°F temperatures for several weeks, while it is still 80-85°F in Texas. If the players from Minnesota do not follow any type of acclimatization protocol prior to the game in a warm climate, they would likely notice a decrease in their performance. If found to be effective, overdressing as a mechanism to acclimate to the heat would be the most financially and logistically feasible mechanism, especially for large athletic teams and recreational athletes.

Figure 7 and **Figure 8** show that heart rate gradually increased in both the environmental chamber session and the overdressed session, more than in the control session. For the 40-minute sub-maximal cycling session, the mean heart rate for the overdressed session was slightly higher than the environmental chamber session, however, it was not statistically significant ($P>0.05$). There was a statistically significant ($P<0.05$) difference between both intervention groups when compared to the control session. These results were expected, as it is widely acknowledged that exercise in hot conditions place an exception strain on the cardiovascular system. The normal range of cardiovascular drift due to endurance exercise in hot conditions can reach up to a 15% increase in heart rate. In the overdressed session, at the highest heart rate reached, the subject experienced a 16% increase in heart rate compared to the control. In the environmental chamber session, at the highest heart rate reached, the subject experienced a 11% increase in heart rate compared to the control. In the overdressed session, the subject wore heat retaining clothing that included a thermal long sleeve shirt, a sweatshirt, a heat retaining coat, thermal leggings, sweatpants, and gloves. This differs from the layering the subject used in the pilot data because they did not wear a thermal shirt and leggings and they wore a windbreaker instead of a sweatshirt.

Figure 7 also shows the hearts initial response to exercise. When exercise begins, the parasympathetic nervous, involved in ‘rest and digest’, gets suppressed, while the sympathetic nervous system, involved in ‘fight or flight’, gets stimulated. This leads to a jump in heart rate, which also allows the heart to circulate oxygen and nutrients to the working muscles. As shown, the increase in heart rate lasts for about one to two minutes, with the degree of increase relating to the exercise intensity. During light exercise in thermo-neutral conditions, the heart rate will plateau within a few minutes, but during high intensity exercise or moderate intensity exercise in thermo-hostile conditions, the heart rate will continue to drift upward. The gradual increase in heart rate is matched by a reduction in stroke volume, which enables cardiac output to be preserved.

Figure 9 shows the rate of change of the heart rate in 5-minute intervals. As expected, the highest rate of change occurred within the first 5-minutes of exercise. This occurs because when exercise begins the sympathetic nervous is stimulated and the parasympathetic nervous is suppressed. This response by the autonomic nervous system allows the heart to circulate enough oxygen and nutrients to the working muscles. During light exercise the heart rate levels off, as seen in the control session. During exercise in warm conditions, the heart rate continues to drift upwards as the body tries to get rid of the excess heat. The anterior hypothalamus initiates a response to dilate the blood vessels, causing more subcutaneous blood flow, meaning less blood is returning to the heart, so the heart rate must increase to compensate. Cardiovascular drift also occurs due to dehydration during prolonged exercise (>45 minutes). It would be expected that if exercise were to continue past 40-minutes, the rate of change would gradually increase as dehydration compounds with the effects of the sub-maximal exercise in the heat.

Figure 10 shows the rating of perceived exertion from the Borg’s RPE scale. The rating of perceived exertion scale goes from 6-20 and it is supposed to equate to ten times the subjects heart rate. The overall mean RPE was similar for all three trials, due the RPE starting at a low value and slowly increasing. In the control session the heart rate ended at 141 bpm and the final RPE was 13. In the overdressed and environmental chamber session, the mean heart rate ended at 164 and 156, respectively, with the mean RPE ending at 17 for both. This indicates the RPE scale was somewhat accurate and effective. It was found to be more accurate with the pilot subject, however, the pilot subject was educated on the RPE scale from a previous course. To limit bias, the heart rate was covered on the cycle ergometer and the subject was instructed to avoid looking at the watch. The other subjects had not been previously educated on the RPE scale, but their heart rate was still covered with tape on the cycle ergometer.

Figure 11 shows the sweat response. A sweat rate was calculated for each condition. In the control session the sweat rate was 0.68 L/hour; in the overdressed session the sweat rate was 0.98 L/hour; and in the environmental chamber session the sweat rate was 1.36 L/hour. These responses were expected because the body does not need to sweat as much in the thermo-neutral conditions. In the environmental chamber, the subject had a lot of skin exposed and a there was a low humidity, allowing a lot of sweat to be evaporated. The average sweat rate is 0.8 to 1.4 L/hour, so these rates were within the normal range. One of the adaptations that occurs with heat acclimation is an increased sweating rate and an increased sweating efficiency. In response to heat acclimation, one can expect an increase in sweat rate by 10-20%. It would be expected that if the subjects were acclimated to the heat, that they would sweat more, leading to a higher sweat rate.

Figure 12 shows the mean thermal rating for the five subjects. The subjects used a scale from 1 to 7 to indicate how warm they were feeling every five minutes during exercise. The scale ranged from ‘cool but fairly comfortable’ to ‘unbearably hot’. In the control session, the thermal rating was at a 3 for all subjects for the duration of the 40-minute sub-maximal exercise. In both the overdressed and environmental chamber session, the thermal rating started at a 3, indicating the subjects were ‘warm but fairly comfortable’ prior to starting exercise. In the overdressed session, the mean end rating was 7, which indicated the subjects were ‘unbearably hot’. The mean end rating in the environmental chamber session was lower, ending at a 6, indicating the subjects were ‘very hot’. There could be a variety of explanations for why the rating was higher in the overdressed session than in the environmental chamber session. It could have been due to discomfort experienced by the subjects from the excess layers of clothing. It could have also been due to the limited evaporative heat loss, causing the body to retain more heat.

Conclusion

This study concludes that sub-maximal exercise in excess layers of clothing may be effective in promoting heat acclimation. This provides a cost-effective and simple way for athletes of all levels to acclimate to the heat to improve performance and reduce the risk of exertional heat related illness.

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Informed Consent

Title of Research:
Impact of Excessive Clothing During Exercise in a Thermo-neutral Environment.

Investigator:
Maddi Sears

Purpose of Study
This statement describes the purpose and procedures associated with this study, the risks and discomforts, and the precautions taken to ensure safety. Also described are your personal responsibilities. It is important to emphasize that you have the right to withdraw from the study at any time and for any reason. No guarantees or assurances can be made as to the results of this study.
This study is undertaken to fulfill the Senior Thesis requirement for the Kinesiology & Integrative Physiology Department at Hanover College. This study has been approved by the Hanover College Internal Review Board for use of human subjects in research. Dr. Bryant A. Stamford is the supervisor for this project. The purpose of this study is to determine if exercise in excess clothing in a thermo-neutral environment can promote heat acclimation.

Explanation of Procedures
Within this study, there are four separate sessions:

1. Orientation
    a. You will come into the exercise physiology lab and get comfortable with the heart rate monitor and cycle ergometer.
    b. You will perform a 15-minute test on the cycle ergometer to determine a workload that gets your heart rate to 70% of your calculated max heart rate.

The following three trials will be randomly assigned:

2. Control
    a. You will come into the exercise physiology lab wearing light exercise clothing.
    b. After getting your weight recorded, you will perform 40 minutes on the cycle ergometer at a constant, moderate workload.
    c. Following the 40-minute session, you will get a post-weight taken.
3. Environmental chamber
    a. You will report to the exercise physiology lab to get a weight recorded and put on the heart rate monitor.
    b. You will then go down to the environmental chamber with light clothing on to perform the 40-minute cycle ergometer test at a constant, moderate workload.
    c. Following the 40-minute session, you will get a post-weight taken.
4. Overdressed
    a. You will come into the exercise physiology lab, get your weight recorded, and place the heart rate monitor.
    b. You will then put on your layers of clothing including a long sleeve dri-fit shirt, windbreaker, puffy coat, gloves, leggings, sweatpants, and long socks.
    c. You will perform the 40-minute cycle ergometer test at a constant, moderate workload.

d. Following the 40-minute session, you will remove the layers of clothing and get a post-weight taken.

Your participation can be summarized as follows:

- You will arrive at the exercise physiology lab and get a baseline weight taken with dry clothes on. After recording a weight, you will change into your exercise attire.
- You will place a Polar chest strap monitor directly under the breast line to obtain a heart rate during the test. At this time the researcher will prepare the cycle ergometer.
- You will then relax until a steady resting heart rate can be recorded.
- You will begin exercising at a predetermined workload and maintain that workload throughout the 40-minute test. The researcher will record a heart rate measurement every minute and ask for your rating of perceived exertion every two minutes.
- At the end of the 40-minute test, you will immediately remove the heart rate monitor, wipe any sweat off your skin, and put your dry clothes back on to get the post-weight measurement.
- It is imperative that you prepare for testing by:
    - Not exercising for at least 12 hours prior to testing
    - Fast for at least 12 hours prior to testing
    - Receive at least 7 hours of sleep the night prior
    - Being well-hydrated
    - Refrain from caffeine intake for 12 hours prior to testing
    - Refraining from alcohol for 24 hours prior to testing
    - Refraining from smoking for 24 hours prior to testing

Risks and Discomforts

As with any exercise test, there are certain risks and discomforts that must be addressed. These include, but are not limited to, abnormal blood pressure, fainting, dizziness, and disorders of heart rhythm. There are also heat-related risks that need to be addressed. The first stage of heat illness is heat cramps; if cramping occurs at any point during the test, the subject should alert the researcher and the session will stop. The next stage of heat illness is heat exhaustion, which occurs when the body temperature reaches 101°F to 104°F. Signs and symptoms of heat exhaustion may include:

- Rapid heartbeat
- Fast breathing
- Heavy sweating
- Dizziness
- Fainting
- Nausea or vomiting
- Headache
- Weakness
- Muscle cramps
- Mild, temporary confusion
- Dehydration
- Low blood pressure

If the subject experiences any of the above symptoms, the test will immediately be stopped, the subject will be moved to a cooler area, and measures will be taken to cool the subject off. The subject would be given water and electrolytes and their condition would be monitored until symptoms subside. Subjects can minimize their risk by being well-hydrated prior to the test and wearing minimal, light clothing in the environmental chamber. If at any time, you feel uncomfortable during exercise, please inform the researcher and the session will be stopped immediately. You are free to terminate your participation at any time and for any reason.

Due to the physical aspects of this research study, it is imperative that risks are reduced to a minimum. It is therefore assumed that as far as you are aware, you are in good health, and you do not have any of the following conditions:

- High blood pressure
- Heart murmur
- Diabetes
- Any heart or artery surgery
- Asthma
- Any illness of fever within the last week
- Currently taking prescription medications
- Any history of heat illness

In signing this form, you acknowledge your understanding of the procedures outlined above and are willing to participate in this study and assume the indicated potential risks. Therefore, you agree to participate regardless of risks involved and your signature below indicates that you agree to absolve the researcher and Hanover College of any responsibility for any injury or discomfort that may occur.

Confidentiality

All information gathered from the study will remain confidential. The participants' names will only be disclosed to the experimenter to organize measured heart rate, RPE, and sweat response. The results of this study may be published for scientific purposes, and participants' identity will not be revealed in any way. Each participant will receive a detailed report of their individual results if requested.

Questions

Any questions concerning participation in this research project should be addressed to Maddi Sears at (317) 671-6013 or searsm24@hanover.edu or Dr. Bryant Stamford at stamford@hanover.edu.

Agreement

____

Subject name, please print

____ __________________

Signature of Subject Date