5-2019

The Effects of Men's Lacrosse Protective Equipment on Thermoregulation and Perceptions During Exercise Heat Stress

Amanda Glasgow

The Effects of Men's Lacrosse Protective Equipment on Thermoregulation and Perceptions During Exercise Heat Stress

Amanda Glasgow
University of Arkansas

Chapter 1

Exertional heat stroke and other heat related illnesses are a common concern for athletic coaches and players alike. Looking to prevent injuries and heat related illnesses it is questioned whether or not athletes could consciously perceive when their body is overheating to a dangerous level. Factors that play into this perception include thirst, thermoregulation, muscle pain, and perceived overall exertion.

Thirst is important because it affects all systems in the body and helps to keep equilibrium within these systems. It's the sensation that lets an organism know of their water need at a particular moment, in order to help with these processes (Leib, Zimmerman, & Knight, 2016). Thermoregulation is another important process in regulating overall body system equilibrium. It's in charge of keeping the body's temperature within a livable range. Muscle pain helps to indicate when the body is working outside of its normal comfort zone and helps to aid in signaling when muscle fatigue is becoming too great. These factors contribute to RPE, rate of perceived exertion, how hard the body feels it is working. This RPE is what contributes to perception, letting the mind know how hard the body is working. All these factors can be affected with the addition of exercise equipment.

Previous research has explored the impact of American football and ice hockey equipment on thermoregulation and perception, but none has been done to examine lacrosse equipment. This research is important because lacrosse players are subject to thermoregulatory stresses, which may lead to heat illness. **The purpose of this study was to evaluate if reported RPE, thermal, thirst, and pain sensation were elevated in participants when exercising in lacrosse equipment compared exercising without it.** This can then be used clinically to help determine when players are becoming overheated to the point of risking heat illness.

Chapter 2

Hydration and thirst

Thirst is important when discussing fluid balance because it is the sensation that lets an organism know of their water need at a particular moment. (Leib, Zimmerman, & Knight, 2016) Dehydration is a process of losing fluid during exercise with low or nonexistent water replacement. Vomiting, diarrhea, sweat, or urine can cause this, when conditions present. Baroreceptors are responsible for detecting changes in blood pressure; equally important osmoreceptors detect changes in osmolality; in this situation, the concentration of urine or blood. Osmoreceptors detect a decrease in water levels and sends signals via afferent nerves to the hypothalamus. From here, several processes are put in action. Sympathetic nerves located in the skin stimulate eccrine glands to release acetylcholine and stimulate the release of sweat when body temperature begins to rise (Casa D. J.). As sweat rate increases, blood osmolality is increased. Osmolality is the ratio of salt to water, or concentration, in your blood. With increased sweat rates, osmolality increases as total body water decreases. Once the hypothalamus has received these messages it sends the information on to the pituitary gland via hormonal or electrical stimuli. This signals the release of arginine vasopressin (AVP), also known as antidiuretic hormone, by the posterior pituitary. AVP then acts on the collecting ducts and distal tubules of the kidneys to facilitate water reabsorption.

When water levels in the body are low, blood pressure drops, osmolality increases, and urine output decreases. Low water levels are detected by low-pressure cardiopulmonary receptors. These receptors send messages to the pituitary to increase water reuptake and decrease water loss through urine. On the opposite side, when high water levels are detected by the osmoreceptors opposing actions take effect. Blood pressure is higher; osmolality as well as urine output is increased. Baroreceptors signal messages to the hypothalamus so reabsorption is discontinued when appropriate. Both of these patterns are put in place to help create and keep equilibrium within the body's systems.

The body doesn't solely pay attention to water levels, rather it takes into account osmolality as whole to account for evaluate these levels. Although not as great, with water loss, sweat also reduces the sodium levels within the blood. Low sodium levels can lead to muscle cramping, lethargy, confusion, and when extreme, issues such as renal and heart failure (Takahashi, 2017). Aldosterone is the predominant hormone responsible for sodium reuptake. It is regulated by renin, a hormone released by the kidneys when total body water levels are decreased. Baroreceptors and sympathetic nerves control this release (Armstrong, Exertional Heat Illnesses, 2003). Renin then starts the renin, angiotensin, aldosterone system (RAAS), beginning with Renin converting to Angiotensin. Once this is done, angiotensin converting enzyme (ACE), facilitates Angiotensin 1 to Angiotensin 2. Angiotensin 2 causes indirect and direct increases in blood pressure. Directly, angiotensin 2 stimulates systemic vasoconstriction, increasing blood pressure. Indirectly, angiotensin 2 is responsible for an increase in Aldosterone, which causes reabsorption of water and sodium. Since this increases blood volume, blood pressure increases.

The goal of these processes is to balance the water/sodium ratio within the body to help minimize strain. When osmolality is high, there is less water in the blood stream, therefore a decreased total blood volume. A lower level of blood in the body leads to decreased stroke volume in the heart, causing an increase in heart rate in order to keep the same level of cardiac output as before hydration loss; this is known as cardiovascular drift. In order to further help this process, blow flow is reduced to the kidneys, GI system, and visceral organs (Cheung, Advanced

Environmental Exercise Physiology, 2010). This allows the blood to be sent to the most vital organs, the heart and the brain.

When sweating increases osmolality, it is also increasing extracellular pressure. These two things are detected by osmoreceptors and baroreceptors. They send this message to the subfornical organ and organum vasculosum of the lamina terminalis, both of which are located in the blood brain barrier (Zimmerman, Lieb, & Knight, 2016). These messages are then translated to the hypothalamus where the beginning of physiological responses is started. These responses are what make the body feel thirsty. By drinking water the body improves these symptoms and in turn no longer feels thirsty.

As sweating occurs, fluid is lost, therefore decreasing overall blood volume. Blood pressure is a product of the blood volume and cardiac contractility. Baroreceptors detect this change in blood pressure and send signals to the brain. The medulla of the brain then sends directions to the heart to increase cardiac contractility intensity in order to get the lower amount of blood volume circulated throughout the body in an effort to raise blood pressure. Hemoglobin in blood is the carrier for oxygen and because there is less blood circulating in the body there is also less hemoglobin reaching all the major organs and muscles. Cells in the carotid body alert the medulla of the brain to send messages to the lungs to breathe faster and harder in order to pull in oxygen as quickly as possible in an effort to keep up with the demand. These simultaneous processes occur in order to maintain body temperature, limit heat storage and prevent dangerous levels.

Thermoregulation

Thermoregulation is the process of maintaining body temperature; the body's homeostasis point is 37ºC. Thermoregulation allows the body to respond to environmental changes to maintain internal temperature at a level that allows our body's processes to continue.

The pre-optic area of the anterior hypothalamus (POAH) is the section of the brain responsible for setting the body's internal temperature and, therefore, dictating when and how we react to temperature changes. (Casa D. J.) The POAH consistently receives peripheral feedback from the body so it can make changes when needed. These messages come primarily from receptors in the skin and blood. When body temperature increases, sympathetic thermoreceptors in the skin send messages to the brain indicating that body temperature is rising. Vasodilation of the skin occurs to allow heat to dissipate via convection. Heat is transferred between the body and air in an effort for the two temperatures to reach equilibrium. Sweat glands are also perfused with blood to increase sweat rates. (Johnson, Ganio, Lee, & et, 2010)

To aid in this effort, sweat rises to the surface of the skin it begins to evaporate and dispels heat from the body. Evaporation is the most effective (80-90% heat loss) method of heat dissipation.

Heat storage is calculated by the following equation:

$$Heat\ Storage = Metabolic\ Heat \pm Conduction \pm Convection\ \pm Radiation - Evaporation.$$

Metabolic heat is the heat naturally created within your body due to muscular contraction. The Conduction of heat is heat transfer when objects make direct contact with one another, such as a player's helmet and their head. Convection is heat transfer through air. If hot air builds up underneath the player's pads, it keeps circulating back on itself acting as an oven, increasing temperature with time. Radiation is natural heat transferred between the human body and its' surroundings. Evaporation is the rate your body is cooling due to the evaporation of sweat from your skin. (Johnson, Ganio, Lee, & et, 2010) All of these factors contribute to changing body temperature within the body when muscles contract.

Strain caused by exertion is increased when protective equipment is added. Protective equipment is a blockade to heat transfer and evaporation, acting as an insulator continually inhibiting convection, evaporation, and radiation. (Gavin, 2003) The inability to dissipate heat causes the body's internal temperature to rise and the process of thermoregulation to protract. The systems responsible for thermoregulation have to increase their efforts in order to compensate for the added heat stress. This overall increase in the workload of the thermoregulation system puts further strain on the body that would not occur with a lack of protective equipment.

Perceptual Responses

Perception is important in everyday life to provide information about the environment that can be acted upon. It allows information about what is going on around and in the body to be evaluated. Some common perceptions include, thermal perception, pain perception, and perception of exertion. Regarding thermal perception, thermoreceptors throughout the body detect temperature and send messages concerning the body's current temperature to the POAH. (Christmann, 2015) The hypothalamus of the brain receives the physical parts of the messages but it is the cortex that is responsible for the conscious evaluation of these messages. This is where perception comes in, it is the body's mental ability to identify and describe the messages being processed. Pain perception is also transmitted by neurons, specifically nociceptors. These receptors attach to fibers that innervate the dorsal horn of the spine. When a stimulus is applied, the message of pain is sent along these neurons and up the spinal cord. They travel through the spinothalmic tract to the hypothalamus, where the messages are interpreted and an action in response is started. (Garland, 2012)

When discussing perception of exertion specifically, the Borg RPE (rate of perceived exertion) scale is used to rate how hard an individual feels like they are working based on their subjective opinion. This scale consists of a 6-20 range, from no exertion at all to maximal exertion. Through testing it has been found that this scale is accurate when working with healthy individuals (Wilmore, Costill, & Kenney, 2008). This method is used by showing the individual the scale and asking them to correlate how hard they feel they are working to a number on the scale. This rating is affected by an array of factors ranging from physical pain to hydration levels.

But the question regarding lacrosse athletes is: when they practice in the heat while wearing full equipment, are they getting the most out of their workouts? If they practice in extremes and wear equipment they will feel overly worked and not put in as much effort. If they work in normal conditions with equipment they are able to acclimatize to wearing the extra layers. So it would be assumed, when conditions are extreme, to get the most out of athletes it is best to remove the factor of equipment.

Uniforms and Protective Equipment

Football and hockey players are at increased risk for heat related illnesses due to the equipment they wear. Due to the material and thickness of the pieces, their equipment acts as insulation. (Noonan, Mack, & Stachenfeld, 2007) Although this insulation is good for preventing traumatic injury, it is not helpful for sweat release. Sweating, coupled with evaporation, is the body's most efficient method of cooling down. Insulated padding is not breathable, inhibiting evaporation and facilitating heat storage. (Davis, Laurent, Allen, & et, 2017) Specifically, football uniforms inhibit heat loss by 42%. (McCullough & Kenny, 2003) This extra heat builds and increases body temperature. Microenvironments are created underneath the padding, allowing minimal heat to escape (Sullivan & Mekjavic, 2019). An inability to rid sweat through evaporation creates 100% humidity underneath sports padding. This also prevents airflow and convection to facilitate heat dissipation. This means that there is enough water vapor underneath the padding to saturate the air completely. This furthers convection and without the dissipation of heat, this saturated air keeps circulating, continually increasing in temperature as strain persists. (Clapp, Bishop, & Gu, 2000)

Compensable heat stress is when the body is able to maintain equilibrium temperature despite increasing heat stress. The real danger comes during uncompensable heat stress. This is when the strain becomes too much for the body to handle (K.K. & R. R., 1991). This happens because the evaporation needed to keep the body at thermal steady state exceeds evaporative capacity. This can lead to continuous heat storage until physical impairment shuts down the body or the environmental factors reduce the strain put on the individual (Cheung, McLennan, & Tenaglia, The Thermophysiology of Uncompensable heat stress, 2000)

Although the body emits key signals to indicate change, the mind does not always follow suit. Perception is the ability of your mind to process what is going on in or around it. (Aque, 2007) If this perception is off, it can affect how well one responds to their environment. Certain scales can be used to measure players' perception of their workload, or temperature. One common scale is a rating of perceived exertion (RPE) scale. The RPE scale ranges from 6-20, 6 being no perceived exertion and 20 being the greatest perceived exertion (Wilmore, Costill, &

Kenney, 2008). The Borg RPE (rate of perceived exertion) is a scale used to subjectively rate the intensity at which work is being performed. This scale consists of a 6-20 range, from no exertion at all to maximal exertion. Through testing it has been found that this scale is accurate when working with healthy individuals (Wilmore, Costill, & Kenney, 2008)**.** This method is used by showing the individual the scale and asking them to correlate how hard they feel they are working to a number on the scale. The perception of how stressful an environment is can be assessed using the thermal sensation (THS) scale, which indicates the level of heat or cold the athlete feels. The THS ranges from 0-8. Zero being 'unbearably cold' and 8 being 'unbearably hot.' (Suleyman, Gorkem, Muzaffer Colakoglu, & Tahsin Basaran, 2017)

Previous Sports Equipment Research

Although the effects of equipment on lacrosse players has yet to be studied, similar research has been done on sports with comparable demands. A 2012 study of football players working out in the heat while wearing protective equipment vs. without showed and increase in heart rate, a lower time to fatigue and an overall decrease in performance ability, worsening with time. (Mohr, Nybo, Grantham, & Racinais, 2012) Football and hockey players were tested, using these scales, while working out in light uniforms and with full uniforms. Skin and rectal temperatures as well as RPE increased while in full the uniform more than when players wore light uniforms. Players did not report a thermal sensation difference in this study. (Johnson, Ganio, Lee, & et, 2010) Another study, evaluating specifically hockey players, showed that when performing intermittent exercise players' RPE rankings increased 30-55% when wearing protective sports equipment. Although the exercise protocol didn't change between the trials with and without the sports equipment, athletes reported an increase in workload and fatigue with the addition of equipment. (Noonan B. C., 2006) This showed that athletes were not able to feel the difference in their rising temperatures when wearing full football uniforms with protective equipment. Lack of perception is attributed to the sensory neurons lying close to the body's surface. (Armstrong, Johnson, Casa, & et, 2010) This makes it harder for the brain to perceive how hot the body's internal temperature is. The danger behind this is, if the mind is not able to tell how hot the rest of the body is getting, players may not know when to stop working before reaching dangerous levels. The more layers a player has on, the less tolerable they are to the rising heat, and the greater the risk is of potential exertional heat stroke. (Moutain, Sawka, Cadarette, Quidgley, & McKay, 1994)

Not unlike football and hockey players, lacrosse teams wear an array of equipment. A typical men's lacrosse uniform consists of a helmet, gloves, arm pads, the crosse (stick), and shoulder pads. The helmet includes a facemask and a pad to protect the chin. It is recommended that rib pads be attached to the shoulder pads. The goalie is also required to wear a throat and chest protector in addition to the other equipment. This equipment puts them, too, at a risk for heat-induced illnesses.

Purpose of this study

In the last 10-year period, 18 exertional heat stroke (EHS) fatalities occurred among high school and college athletes (Association, 2015). Exertional heat stroke is an illness defined by a significantly elevated body temperature and central nervous system dysfunction. Although it can be fatal, EHS is survivable without long- term complications when appropriate treatment is administered. (Casa et al., 2015) Prevention strategies for EHS revolve around limiting the rise of body temperature during exercise through appropriate hydration, moderating exercise intensity based on the environment, and considering the impact of clothing and equipment on heat dissipation. (Casa et al., 2015) Athletes that wear protective equipment as part of their sport may be at particular risk of heat illness, although only American football and hockey equipment have been investigated. This study of the impact of lacrosse equipment will provide necessary information about lacrosse athletes so that appropriate safety guidelines can be implemented. Our overarching research question was whether or not wearing protective equipment increases perceptual responses when wearing protective equipment compared to not. Our hypothesis was that the added equipment would create a significant increase in reported RPEs.

Chapter 3

Participants

In this study, 12 healthy males ages 18-27, with heights ranging from 173.1 cm – 191.2 cm, and body fat percentages from 6.4%-20.2% were recruited to complete our randomized crossover study. They were to have more than one year of high school or college lacrosse (competitive season) or football experience.. Exclusionary criteria for the study involved a history of heat stroke or heat exhaustion within the past three months, current musculoskeletal injury, diagnosed sickle cell trait, cardiovascular problems, diabetes, the use of nutritional supplements, medications, alcohol, tobacco, or stimulants that may influence thermoregulation or fluid balance. All participants were asked to refrain from vigorous exercise and alcohol for 24 hours and caffeine for 12 hours before the test.

Familiarization Session

After participants were identified, they visited the experimental lab to complete a familiarization session. The purpose of this session was to inform the experimental procedures and associated risks; and to obtain baseline measures. Age, height, and body mass were recorded during the session, and correct sizing of the uniform and protective equipment was determined. Dual-energy X-ray absorptiometry (DEXA) also was administered to assess an accurate body composition. The participants were instructed to consume 591 mL (20oz) of water the night before and the morning of body mass assessment days.

Experimental Procedures

The study was designed to simulate a lacrosse game performed partially on a treadmill in the environmental chamber. The chamber was maintained at 30°C dry bulb, and 50% relative humidity. Two experimental trials were completed in a controlled, randomized, and counterbalanced order. In one trial, participants wore a lacrosse jersey, a t-shirt, shorts, mid-calf socks, and athletic shoes. (CON). In the other trial, participants wore all the clothing in the CON condition plus full lacrosse protective equipment, which consists of a helmet, shoulder/chest pads, arm pads, and gloves (FULL). For each participant, the time of day of the two experiments were consistent (within 1 hour) to minimize circadian effects on thermoregulation. Each participant completed two 60-minute laboratory tests.

Before entering the heat chamber, nude body mass was measured on a digital scale (Health-o-meter; LOCATION), and participants inserted a rectal probe 15cm past the anal sphincter (Miller, Hughes, Long, Adams, & Casa, 2017). If a participant had a fever (resting rectal temperature >37.8°C), the trial was rescheduled for another day.

Participants wore either CON or FULL clothing, entered the chamber, and sat for 10 minutes to get acclimated. Then we administered baseline measurements, which included total body mass (including all the clothing), heart rate via cardiotachometer (Polar; LOCATION), rectal temperature via the rectal thermistor (Physitemp; LOCATION), (Tango; LOCATION), lateral calf, deltoid, chest, and thigh skin temperatures (Maxim Integrated; T_{MWSK}) (Ramanathan, 1964). Then, participants completed four subjective perceptual rating scales. Rating of perceived exertion (RPE) was obtained by using Borg's 15-point scale (Borg, 1970). Thermal perception was obtained using the 17-point scale ranging from 0 (unbearably cold) to 8 (unbearably hot) (Young, Sawka, Epstein, Decristofano, & Pandolf, 1987). Perception of thirst was obtained using the 9-point scale ranging from 1 (not thirsty at all) to 9 (very, very thirsty) (Engell, Maller, Sawka, Francesconi, & Young, 1987). Perception of muscle pain was obtained by using the 13-point incremental scale ranging from 0 (no pain at all) to 10 (extremely intense pain, almost unbearable), with additional values of 0.5 and an optional point beyond 10 to denote unbearable pain (Cook, O'Connor, Eubanks, Smith, & Lee, 1997).

The exercise protocol consisted of 5 minutes of warm-up (jogging) and 60 minutes of simulated lacrosse exercises, which was separated into four 12 minute-workout sessions. Between the sessions, participants rested for 4 minutes. Each 12 minute-session was comprised of three 4 minute-interval cycles. A cycle included 2-minute intermittent running followed by 45-second standing rest, 15-second agility exercise (side shuffling side-to-side as fast as possible on a 4-meter line), 15-second standing rest, five explosive push-ups (3 sec/a push-up), and 30-second standing rest. The intermittent running was a modification of a soccer-simulated intermittent running protocol established by Drust et al (Drust, Reilly, & Cable, 2000). The detailed trial timeline is presented in Figure 1.

- **Session 1 (12 min.)**

Jog 7 mph 40 sec	Run 9 mph 30 sec	Sprint 12 mph 20 sec	Walk 2 mph 20 sec	Rest 40 sec	Agility 15 sec	Rest 30 sec	Push-ups 15 sec	Rest 30 sec

(Repeat 3 times)

- **Rest 1 (4 min.)**
- **Session 2 (12 min.)**

Jog 7 mph 40 sec	Run 9 mph 30 sec	Sprint 12 mph 20 sec	Walk 2 mph 20 sec	Rest 40 sec	Agility 15 sec	Rest 30 sec	Push-ups 15 sec	Rest 30 sec

(Repeat 3 times)

- **Rest 2 (4 min.)**
- **Session 3 (12 min.)**

Jog 7 mph 40 sec	Run 9 mph 30 sec	Sprint 12 mph 20 sec	Walk 2 mph 20 sec	Rest 40 sec	Agility 15 sec	Rest 30 sec	Push-ups 15 sec	Rest 30 sec

(Repeat 3 times)

- **Rest 3 (4 min.)**
- **Session 4 (12 min.)**

Jog 7 mph 40 sec	Run 9 mph 30 sec	Sprint 12 mph 20 sec	Walk 2 mph 20 sec	Rest 40 sec	Agility 15 sec	Rest 30 sec	Push-ups 15 sec	Rest 30 sec

(Repeat 3 times)

Figure 1.

Throughout our trials, the Wet-Bulb Globe Temperature (WBGT) was consistently assessed using a WBGT weather monitor (Kestrel), and rest periods are allocated according to the NATA guidelines to sustain appropriate work-to-rest ratio (Casa, DeMartini , & Bergeron, 2015). At rest periods, all baseline measurements were administered, and perceptual questions were asked. Three hundred mL (10.1oz) of water was provided at the rest period between session 1 and 2. At the rest periods between session 2 and 3, and between 3 and 4, the amount of fluid replacement was individualized depending on the weight loss. The goal was to prevent more than 1% body mass deficit at the end of the exercise. Fluid consumption was matched between trials based on tolerance from trial 1.

Immediately after the cessation of exercise, physiological and perceptual measures were recorded, and participants jogged for 5 minutes and then remained seated for 10 minutes of recovery. Participants then left the environmental chamber and removed all clothing to record nude body mass. Whole body sweat rate was calculated by subtracting the post-exercise nude body mass from the pre-exercise value.

Assumptions

While performing this experiment we were under the impression that after going through all the testing steps, the participants would be honest about whether or not they understood what we were doing and whether or not they had any questions. We are also assuming that during the experiment they understood the questions we were asking them and answered honestly. Along with getting reliable information from our participants, we also expected to get reliable feedback from the instruments we use. We assumed they were going to work within the margin of reasonable doubt. We also assumed that all participants' sessions were run in exactly the same way without any delays or researcher errors in timing.

Delimitations

When performing these tests, there were a few things we decided not to do. One being, we decided not to test regular athletes but rather stick to testing students that played lacrosse or football. This was chosen in order to make the testing more accurate. We wanted to test how lacrosse specific players, who were already trained in the sport, reacted to the equipment they are wearing. We also chose to test a specific age range. We did this because we wanted to make our study more specific. By not including a large range of ages we could get more accurate results as to how a certain group of people responded. Narrowing the age range let us test people who were similar. The last thing we chose not to incorporate into our testing was random exercises. Instead we chose to create a test that mimicked how a lacrosse game would run. We chose to have breaks and different exercises. Lacrosse games aren't just straight sprinting the entire time, rather they include slowing down, breaks, and other muscle movements. By incorporating specific exercises we hoped to create a test that would give us the most accurate results.

Statistical analyses

Upon completion of data collection, we quantified mean ± standard deviation (SD) for all independent and dependent variables at each time point. For variables with only 1 time point (pre-trial urine specific gravity) for comparison, we utilized a paired-samples t-test to compare trials. For other variables with multiple time points (RPE, THS, etc.) we first assessed for normal distribution. If abnormal, Greenhouse-Geisser corrections were used. We assessed trial and time-point differences utilizing repeated measures analysis of variance. If a significant interaction was identified, subsequent post-hoc analyses with Bonferroni correction were used to determine specific time-point or trial differences.

Results

For our trial, diet and water intake were matched resulting in no significant difference between trials with first morning urine osmolality ($p=.128$).

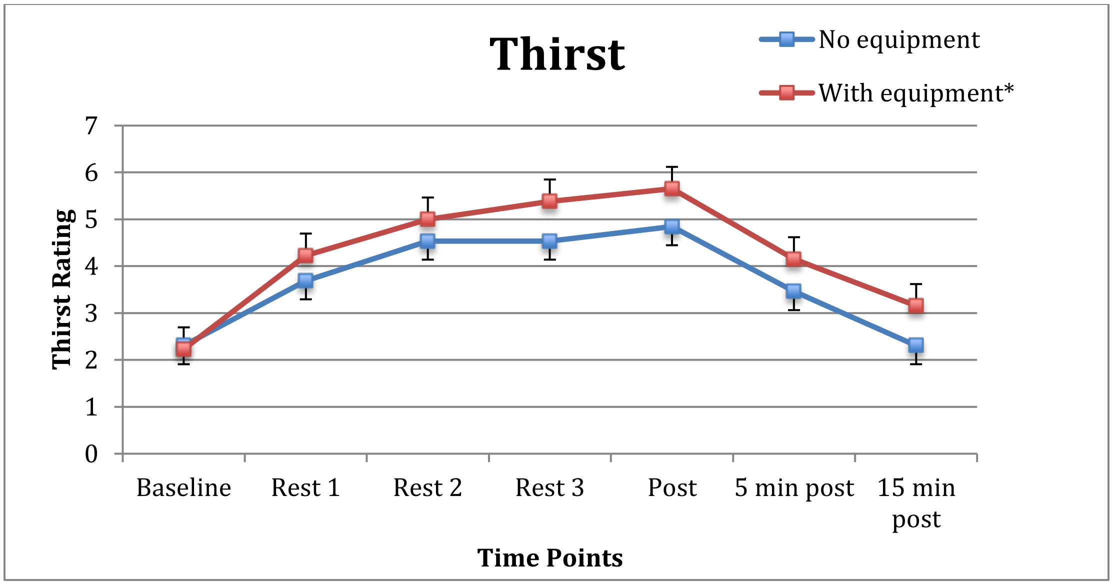

Figure 2. Thirst ratings during trials.
*Regardless of time point, thirst sensation was greater in the equipment trial compared to the no equipment trial ($p=.001$).
Regardless of trial, thirst was greater at Rest 2, 3 and post-exercise than both rest 1 and post-exercise ($P \leq .025$).

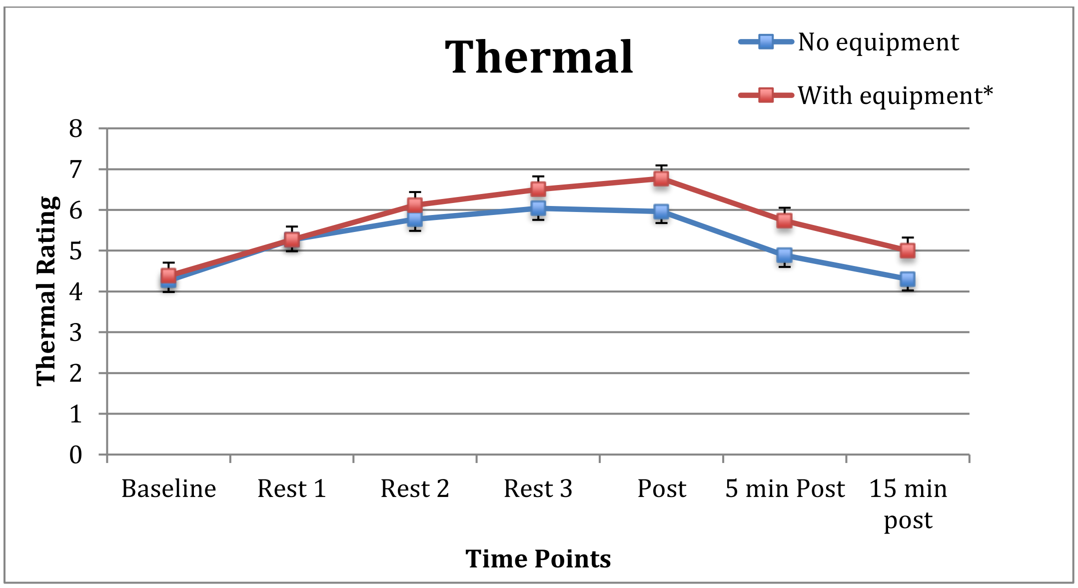

Figure 3. Thermal ratings during trials.
*Thermal sensation was significantly greater during the equipment trial versus the no equipment trial ($p<.001$). Thermal sensation was significantly elevated at rest 2,3 and post-exercise compared to rest 1 ($p<.001$). Rest 2,3 and post-exercise thermal sensation were not significantly different ($p \geq .145$). Rest 1 and 15-min post-exercise were similar ($p=.249$).

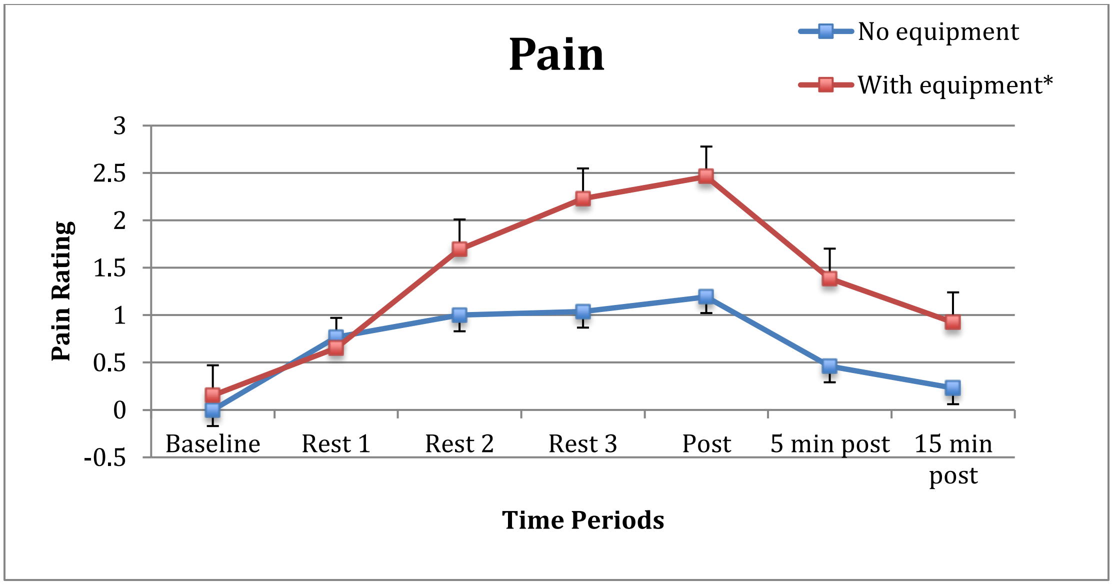

Figure 4. Pain ratings during trials.
*Muscle pain was significantly greater throughout trials, regardless of time point (P=.006). Due to multiple comparisons, muscle pain did not demonstrate significant time point differences (p≥.030).

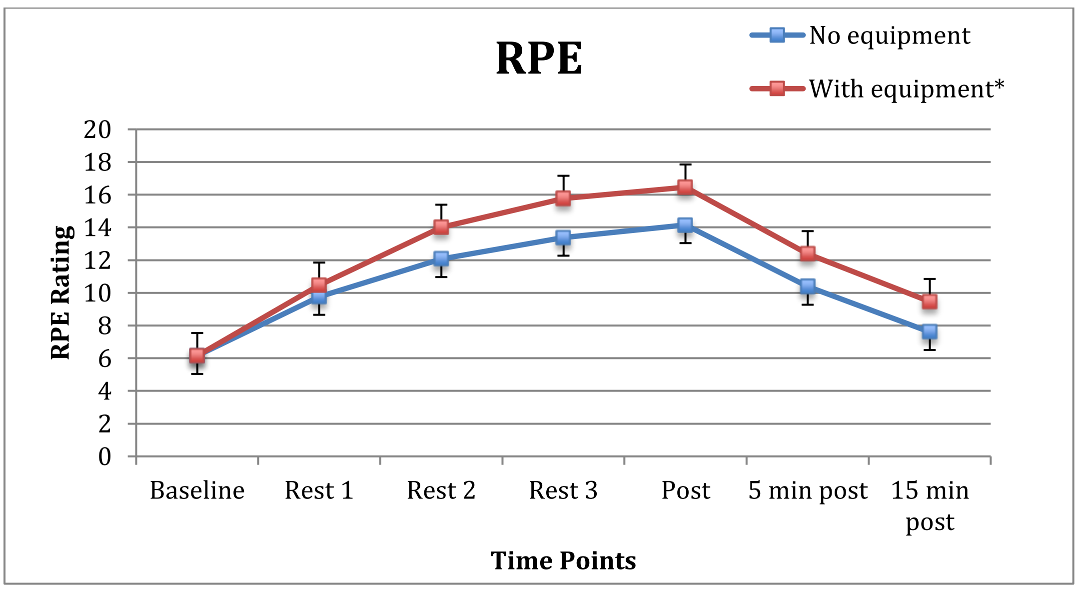

Figure 5. RPE responses during trials.
*In terms of equipment, RPE was significantly greater with equipment throughout trials (p<.001). For time point differences, rest 1 was significantly less than all other time points (p<.001). Rest 2 was significantly greater than rest 1 and less than rest 3 and 4 (p≤.003). Rest 3 and 4 were not significantly different from each other (p=.498).

Discussion

The purpose of this study was to evaluate if reported RPE, thermal, thirst, and pain sensation were elevated in participants when exercising in lacrosse equipment compared to exercising without it. The hypothesis was that ratings on all scales would increase with the addition of exercise equipment. Our results supported this hypothesis. It was shown that there was a steady increase in RPE, thermal, and thirst sensation while exercising with and without equipment. With the addition of equipment, these scales were rated higher. When evaluating the cool down period following the exercise protocol, it is shown that while wearing equipment RPE, thermal, and thirst ratings still remained higher in trials where participants were wearing equipment. When evaluating the rating of pain sensation, pain was rated significantly higher in trials where participants were wearing equipment, this higher elevation continuing in the cool down period. These results show that excess strain is put on the body while exercising while wearing lacrosse equipment. Using this data clinically, lacrosse athletes are under excess stress while wearing sports equipment and this should be taken into account.

Previous research with football and hockey players concurs with our findings. It is shown that high humidity and temperatures coupled with exercising while wearing protective equipment, increase players' perceived exertion, thermal strain, and reported thermal comfort (Nichols, 2014). These factors have played a role in increasing players' risks for heat related illnesses. From these studies it is shown that the best method to keep players safe is to gradually add on protective equipment to allow ample time for acclimatization (Casa D. J.).

Conclusion

In conclusion, when athletes exercise in protective equipment, their reported RPE, thermal, thirst, and pain sensation were elevated when exercising in lacrosse equipment compared exercising without it. This increase in effort puts further strain on the body and decreases the work effort an athlete is able to perform. It is best to be aware of these responses to help prevent heal illness injuries in athletes.

Bibliography

Aque, C. (2007). *Perception.* University of Chicago.

Armstrong, L. E. (2003). *Exertional Heat Illnesses.* Champaign, IL: Human Kinetics Publishers, Inc.

Armstrong, L. E., Johnson, E. C., Casa, D. J., & et, a. (2010). The American football uniform: uncompensable heat stress and hypothermic exhaustion. *Journal of athletic training , 45* (2), 117-127.

Association, T. N. (2015). *Executive Summary of National Athletic Trainers' Association Position Statement on Exertional Heat Illnesses: An update to the 2002 NATA Guidelines.* Journal of Athletic Training.

Borg, G. (1970). Percieved exertion as an indicator of somatic stress. *Scand J Rehabil Med , 2* (2), 92-98.

Casa, D. J. *Sport and Physical Activity in the Heat Maximizing Performance and Safety.* Storrs, CT: Springer.

Casa, D. J., DeMartini , J. K., & Bergeron, M. F. (2015). National athletic trainers' association position statement: exertional hear illness. *J Athl Train , 50* (9), 986-1000.

Cheung, S. S. (2010). *Advanced Environmental Exercise Physiology.* Champaign, IL: Human Kinetics Publishers.

Cheung, S. S., McLennan, T. M., & Tenaglia, S. (2000). The Thermophysiology of Uncompensable heat stress. *Sports Med , 29* (5), 329-359.

Cheuvront, S. N., Kenefick, R. W., & Zambraski, E. J. (2015). Spot urine concentrations should not be used for hydration assessment: a methodology review. *Int J Sport Nutr Exerc Metab , 25* (3), 293-297.

Christmann, B. (2015, May 13). *Breaking Research: How the brain recognizes hot and cold.* Retrieved 10 9, 2018, from Fly on the Wall: https://blogs.brandeis.edu/flyonthewall/breaking-research-how-the-brain-recognizes-hot-and-cold/

Clapp, A., Bishop, P., & Gu, D. (2000). Climate under impermeable protective clothing. *International Journal of Industrial Ergonomics , 25* (3), 233-238.

Cook, D. B., O'Connor, P. J., Eubanks, S. A., Smith, J. C., & Lee, M. (1997). Naturally occuring muscle pain during exercise: assessment and experimental evidence. *Med Sci Sports Exerc , 29* (8), 999-1012.

Davis, J. K., Laurent, M. C., Allen, K. E., & et, a. (2017). Influence of clothing on termoregulation and comfort during exercise in the heat. *Journal of strength and conditioning research , 31* (12), 3435-3443.

Drust, B., Reilly, T., & Cable, N. T. (2000, 18 11). Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise. *J Sports Sci* , 855-892.

Engell, D. B., Maller, O., Sawka, M. N., Francesconi, R. N., & Young, A. J. (1987). Thirst and fluid intake following graded hypohydration levels in humans. *Physiol Behav , 40* (2), 229-236.

Garland, E. L. (2012). Pain Processing in the Human Nervous System: A Selective Review of Nociceptive and Biobehavioral Pathways. *Primary Care , 39* (3), 561-571.

Gavin, T. P. (2003). Clothing and thermoregulation during exercise. *Sports Medicine , 33* (13), 941-947.

Johnson, E. C., Ganio, M. S., Lee, E. C., & et, a. (2010). Perceptual responses while wearing an american football uniform in the heat. *Journal of athletic training , 45* (2), 107-116.
K.K., K., & R. R., G. (1991). Physiological consequences of intermittent exercise during compensable and uncompensable heat stress. *Journal of Appl. Phys. , 71* (6), 2138-2145.
Leib, D. E., Zimmerman, C. A., & Knight, Z. A. (2016). Thirst. *Current Biology Magzaine* (26), 1260-1265.
McCullough, E. A., & Kenny, L. W. (2003). Thermal insulation and evaporative resistance of football uniforms. *Med. Sci. Sports Exerc. , 33* (5), 832-837.
Miller, K. C., Hughes, L. E., Long, B. C., Adams, W. M., & Casa, D. J. (2017). Validity of core temperture measurements at 3 rectal depths during rest, exercise, cold-water immersion, and recovery. *J athl Train , 52* (4), 332-338.
Mohr, M., Nybo, L., Grantham, J., & Racinais, S. (2012). Physiological Responses and Physical Performance during Football in the Heat. *PloSONE , 7* (6), 1-10.
Moutain, S. J., Sawka, M. N., Cadarette, B. S., Quidgley, M. D., & McKay, J. M. (1994). Physiological tolerance to uncompensable heat sress: effects of exercise intensity, protective clothing, and climate. *Journal of Appl. Physiology , 77* (1), 216-222.
Nagashima, K., Tokizawa, K., Uchida, Y., Nakamura-Matsuda, M., & Lin, C.-H. (2012). Exercise and thermoregulation. *Journal of Physical Fitness and Sports Medicine , 1* (1), 73-82.
Nichols, A. W. (2014). Heat-related illness in sports and exercise . *Curr Rev Musculoskelet Med , 7* (4), 355-365.
Noonan, B. C. (2006). *THE PHYSIOLOGICAL EFFECTS OF HOCKEY PROTECTIVE EQUIPMENT ON HIGH INTENSITY INTERMITTENT EXERCISE.* Yale University, School of Medicine. EliScholar.
Noonan, B., Mack, G., & Stachenfeld, N. (2007). The effects of hockey protective equiptment on high intensity intermittent exercise. *Med. Sci. Sports Exerc , 39* (8), 1327-1335.
Ramanathan, N. L. (1964). A new weighting system for mean surface temperature of the human body. *J Appl Physiol , 19* (3), 531-533.
Suleyman, Z., Gorkem, A., Muzaffer Colakoglu, C., & Tahsin Basaran, B. (2017). *Associations between Thermal and Physiological Responses of Human Body during Exercise.* Multidisciplinary Digital Publishing Institute.
Sullivan, P. J., & Mekjavic, I. (2019). *Temperature and Humidity within the clothing microenvironment: determenants of heat strain.* Canada: Simon Fraser University.
Takahashi, P. Y. (2017, July 15). *Low Blood sodium in Older Adults: A Concern?* Retrieved April 11, 2019, from Mayo Clinic: https://www.mayoclinic.org/diseases-conditions/hyponatremia/expert-answers/low-blood-sodium/faq-20058465
Wilmore, J. H., Costill, D. L., & Kenney, L. W. (2008). *Physiology of Sport and Exercise Fourth Edition.* Champaign, IL: Human Kinetics.
Young, A. J., Sawka, M. N., Epstein, Y., Decristofano, B., & Pandolf, K. B. (1987). Cooling different body surfaces during upper and lower body exercise. *J Appl Physiol , 63* (3), 1218-1223.
Zimmerman, C. A., Lieb, D. E., & Knight, Z. A. (2016, December 19). *Thirst.* Retrieved April 10, 2019, from Current Biology: https://www.cell.com/current-biology/fulltext/S0960-9822(16)31344-6?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0960982216313446%3Fshowall%3Dtrue