EXERTIONAL HEAT ILLNESS IN INTERSCHOLASTIC FOOTBALL ATHLETES
IN THE STATE OF GEORGIA: A FOUR-YEAR PERSPECTIVE

by

JESSICA RAQUEL DYSART MILES

(Under the Direction of Michael S. Ferrara)

ABSTRACT

Exertional Heat Illness (EHI) is a deadly but preventable disease. Interscholastic football players are particularly at risk for EHI, but there are no evidence-based guidelines for safety and acclimatization to prevent morbidity and mortality. Thus, the purpose of this study was: to investigate the effect the new Georgia High School Association (GHSA) pre-season acclimatization policy implementation had on the total and significant (heat stroke/heat exhaustion (HS/HE)) injury rates (IR), over the entire season and first two weeks of data; to determine if IR’s by WBGT ranges during the first two weeks of data collection were significantly different in the time period before the policy change (Seasons 2009-11, PRE) when compared to those following change (2012 season, POST); and to determine the effectiveness of current heat stress index scales (HSIS) and which mitigate risk for EHI events. There were a total of 761 EHI cases and 259,413 Athlete Exposures (AE) for an overall EHI rate of 2.93/1000 AE (95%CI=2.73, 3.15). Risk for HS/HE was approximately 4 times greater for the entire data collection period (annual) for PRE [0.82/1000AE (95%CI=0.70, 0.95)] compared to the POST period, 0.22/1000 AE (0.12, 0.37)) and 7 times greater for the first two weeks of
participation for the PRE period [1.85/1000AE; (95%CI=1.54, 2.21)] compared to the POST period at 0.27/1000 AE (95%CI=0.09, 0.65)). The EHI risk was lower in the POST period than in the PRE period for the entire data collection period [2.24/1000AE (95%CI=1.88, 2.65)] and 3.14/1000 AE (95%CI=2.90, 3.39, respectively) and first 2 weeks of data collection [1.22/1000AE (95%CI=0.75, 1.89] and 4.48/1000 AE (95%CI=3.98, 5.02), respectively). The Pearson correlation showed an r of 0.963 and an $r^2$ value of 0.927 between WBGT and Discomfort Index (DI). The majority of the HSIS’s appeared to capture risk well. This study demonstrated mitigation in EHI risk following the policy change and that existing HSIS’s seem to adequately stratify risk.

INDEX WORDS: Exertional Heat Illness, Wet Bulb Globe Temperature (WBGT), Discomfort Index (DI), Heat Stress Index (HSI), Thermal Load Index (TLI)
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DEDICATION

This dissertation is dedicated to my best friend and loving husband, Patrick, who has been by my side during the extent of my dissertation journey – this storm was much more bearable with him by my side. Also, to our loving and beautiful gift from God, our little Ansley Grace – all it took was one glance at your smiling face and tough times magically melted away. And to this new little life that is growing within me…your quick little movements make it easier to relax after long nights. I love you three more than words will ever be able to say and I thank our gracious and loving God for putting y’all in my life…which will be much more enjoyable now that this chapter has ended 😊.
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and I can be to Ansley (and any others with whom we are blessed) what you have been to Sara, Amanda, and me. Sara and Amanda – what would life be without a duo of great sisters who are always there when I need y’all most? I love y’all dearly.

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ACKNOWLEDGEMENTS</th>
<th>v</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xi</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Significance of the Study</td>
<td>1</td>
</tr>
<tr>
<td>Purpose Statement</td>
<td>7</td>
</tr>
<tr>
<td>Hypotheses</td>
<td>8</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>8</td>
</tr>
<tr>
<td>Delimitations</td>
<td>9</td>
</tr>
<tr>
<td>Limitations</td>
<td>9</td>
</tr>
<tr>
<td>Assumptions</td>
<td>10</td>
</tr>
<tr>
<td>Definitions of Terms</td>
<td>10</td>
</tr>
<tr>
<td>2 LITERATURE REVIEW</td>
<td>12</td>
</tr>
<tr>
<td>Physiology and Etiology</td>
<td>12</td>
</tr>
<tr>
<td>Pediatric/Adolescent Population</td>
<td>16</td>
</tr>
<tr>
<td>Epidemiology</td>
<td>17</td>
</tr>
<tr>
<td>Heat Stress Indices</td>
<td>23</td>
</tr>
<tr>
<td>Chapter</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>METHODOLOGY</td>
</tr>
<tr>
<td></td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>Procedures</td>
</tr>
<tr>
<td></td>
<td>Environmental Data</td>
</tr>
<tr>
<td></td>
<td>Practice Data</td>
</tr>
<tr>
<td></td>
<td>Online Database</td>
</tr>
<tr>
<td></td>
<td>Instrumentation</td>
</tr>
<tr>
<td></td>
<td>Statistical Analysis</td>
</tr>
<tr>
<td>4</td>
<td>CHANGES IN HEAT ACCLIMATIZATION POLICY MITIGATE HEAT ILLNESS RISK IN GEORGIA INTERSCHOLASTIC FOOTBALL PLAYERS</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
</tr>
<tr>
<td></td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Methods</td>
</tr>
<tr>
<td></td>
<td>Results</td>
</tr>
<tr>
<td></td>
<td>Discussion</td>
</tr>
<tr>
<td></td>
<td>Conclusion</td>
</tr>
<tr>
<td></td>
<td>References</td>
</tr>
<tr>
<td>5</td>
<td>HEAT STRESS INDEX SCALES: AN EVIDENCE BASED APPROACH TO VALIDATION AND SUBSEQUENT CREATION</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
</tr>
<tr>
<td></td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Methods</td>
</tr>
</tbody>
</table>

viii
Results ........................................................................................................72
Discussion .....................................................................................................73
Conclusions .....................................................................................................78
References .....................................................................................................93
6 CONCLUSION ............................................................................................96
REFERENCES ..................................................................................................98
APPENDICES
A 2011-2012 GHSA Constitution & Bylaws .................................................104
B 2012-2013 GHSA Constitution & Bylaws .................................................106
C Participant Instruction Manual .................................................................110
D Web-based Data Management Site ..........................................................134
LIST OF TABLES

Table 2.1: Physical and physiological differences between children and adults affecting
thermoregulation........................................................................................................29
Table 4.1: Daily data collection variables.................................................................56
Table 4.2: Variables collected for each exertional heat illness case..........................57
Table 4.3: National Athletic Trainers’ Association definitions for heat illnesses........58
Table 4.4: School participation by school and region...............................................59
Table 4.5: Percentage of EHI’s and IR’s (95% CI) by year .......................................60
Table 4.6: Percentage of EHI, IR (95% CI) for the first 2 weeks of the pre-season
period .....................................................................................................................61
Table 5.1: Heat stress index scales and guidelines for physical activity in the heat.....80
Table 5.2: Assumptions on which the heat index is based .........................................83
Table 5.3: Heat study data collection variables .......................................................84
Table 5.4: Frequencies, percentiles, and IR’s for each heat stress index scale of
interest....................................................................................................................85
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>QuesTemp 34 Unit (QT-34; 3M Quest Technologies, Oconomowoc, WI) provided to and used by all participant schools.</td>
<td>54</td>
</tr>
<tr>
<td>4.2</td>
<td>IR’s per ACSM WBGT risk stratification category</td>
<td>55</td>
</tr>
<tr>
<td>5.1</td>
<td>Correlation between WBGT and DI</td>
<td>87</td>
</tr>
<tr>
<td>5.2</td>
<td>Injury rates per category in the American College of Sports Medicine heat stress index scale</td>
<td>88</td>
</tr>
<tr>
<td>5.3</td>
<td>Injury rates per category in the American Academy of Pediatrics heat stress index scale</td>
<td>89</td>
</tr>
<tr>
<td>5.4</td>
<td>Injury rates per category in the Department of Defense heat stress index scale</td>
<td>90</td>
</tr>
<tr>
<td>5.5</td>
<td>Injury rates per category in the Georgia High School Association heat stress index scale</td>
<td>91</td>
</tr>
<tr>
<td>5.6</td>
<td>Injury rates per category in the Discomfort Index heat stress index scale</td>
<td>92</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

Significance of the Study

Participation in high school sports has been on the rise over the past decade with the vast majority of these participants in football. Football is classified as a “fall sport”, but the pre-season period often begins in late July or early August when heat and humidity are at their highest levels, especially in the southeast region of the country. As the heat and humidity increase, the risk of suffering an exertional heat illness (EHI) event also increases due to the body’s inability to dissipate heat via evaporation. Recently, Grundstein and colleagues published an epidemiological review of heat stroke deaths in American football players. This review showed that heat stroke death rates in football have been on the rise over the past 15 years with the majority of deaths occurring in the southeast and Georgia leading the nation in heat stroke deaths. The month of August was the most common, with the greatest number of deaths occurring in those 18 years of age or younger. These two statistics alone show there to be an increase in risk for those athletes participating in high school football in the state of Georgia.

While there have only been a few epidemiological studies in the high school population, there have been numerous other studies in different settings with various methodologies. One epidemiological study concerning high school athletes was conducted by the Center for Disease Control and Prevention (CDC), which examined all sports over a five-year period, finding that football had the highest incidence of EHI, with
the majority of those illnesses occurring in August. The IR for football players was 4.5/100,000AE, much lower than that in other studies\textsuperscript{6,8,9}. The difference in EHI injury rate could be attributed to injury definition since only EHI’s that caused greater than one day of time loss from activity were counted for this study. Furthermore, the CDC study did not obtain detailed environmental data associated with it to demonstrate a possible cause and effect.

The greatest amount of research concerning EHI and environmental factors has been conducted in the military settings with the majority of these studies conducted on Marine Corps recruits in Parris Island, South Carolina by Yaglou and Minard\textsuperscript{10} who developed the wet bulb globe temperature (WBGT). The WBGT is a heat stress index (TLI) derived from the wet bulb (WB), dry bulb (DB), and black bulb (BB) that seeks to define the amount of heat stress placed on the body while performing physical activity in extreme environmental conditions. With this measure they developed a subsequent scale that set forth activity guidelines at various ranges of WBGT values that corresponded with various flag colors. The most severe was the black flag (WBGT $\geq$90°F) denoting that environmental conditions were not adequate to continue physical activity. This is the WBGT scale upon which the American College of Sports Medicine (ACSM)\textsuperscript{11-13} guidelines and recommendations for activity in the heat were based and also helped mold scales adopted by the National Athletic Trainers’ Association (NATA)\textsuperscript{14}, American Academy of Pediatrics (AAP)\textsuperscript{15}, and Georgia High School Association (GHSA)\textsuperscript{16}.

Other studies concerning EHI and environmental data have been conducted in the American collegiate football setting. Cooper \textit{et al}\textsuperscript{9} conducted an epidemiological study at 5 southeastern Division I universities in the United States and found the overall EHI rate
was 4.19/1000 Athlete Exposures (AE). Much of their data showed the same trends with EHI as the deaths reported in the Grundstein study\(^2\). The majority of EHI’s occurred in August and became nearly non-existent for the remainder of the football season. The authors used the original ACSM WBGT scale\(^{12}\) to classify in what kind of environment injuries occurred; 96% of all injuries happened in the high or extreme risk categories of the ACSM scale \([\text{WBGT}>32.2^\circ\text{C (86.0}^\circ\text{F)}]\), showing a seemingly strong correlation between environmental conditions and EHI’s. All serious injuries (heat syncope and heat exhaustion) occurred in these heat illness categories.

While the WBGT is a very commonly used TLI and utilized by many different organizations to stratify risk, it is not the only TLI that exists. While there are many others that have been developed throughout the years\(^{17}\), the discomfort index (DI) was of particular interest in this study. The DI is commonly used in parts of Europe, the Middle East and some areas of Central America. Currently, the Israeli government uses the DI to quantify risk for workers as well as their military. The DI uses the WB and DB in the following equation:

\[
\text{DI} = 0.5\text{WB} + 0.5\text{DB}\quad^{17}
\]

Unlike the WBGT, the DB does not utilize the BB in the equation. Because WBGT measurement units that measure BB can be somewhat cumbersome to transport, especially in a military setting where such units are not ideal to carry along with all other equipment that soldiers must carry, the lack of BB on a unit that measures DI may be more favorable in such settings. Furthermore, WBGT units can cost anywhere from a couple hundred dollars to more complex and accurate units that cost a couple thousand dollars, which may hinder some from purchasing/having access to such a device. The DI
may be of particular interest to recreational sporting leagues and tournament and camp sponsors who may only host events a couple times a year; use of the DI may prove to be advantageous in these settings.

As previously mentioned, the combination of heat and humidity greatly increases the risk of sustaining an EHI event\textsuperscript{18-20}. For the body to maintain its normal core body temperature (CBT) of 98.6°F, a number of physiological processes ensue in a thermoregulatory effort. The body’s greatest defense against an increase in CBT is heat loss through evaporation of sweat from the body. This mechanism works very well in dry environments but when the humidity begins to rise, as is often the case in the southeast in July and August, the body does not lose heat as readily via evaporation and must rely on other, much less efficient means of heat loss (conduction, convection, and radiation). Further complicating EHI is the extensive amount of equipment players must wear in their football practices and games. Football pads decrease the effectiveness of evaporative heat loss and also lead to a rise in CBT\textsuperscript{21}. Both the humidity and the equipment put football players at a greater risk when participating in the hot summer months.

Proper heat acclimatization is important to decrease the number of EHI’s. Heat acclimatization is defined as, “…the physiologic response [of the body] produced by repeated exposures to hot environments in which the capacity to withstand heat stress is improved.”\textsuperscript{20} These physiologic processes are numerous and ultimately allow the body to remain at a lower CBT for a longer period of time when compared to one who is unacclimatized. The processes of acclimatization become apparent as early as 5 days following consecutive exposure and, depending on which empirical evidence you consult,
continues to take place for 14 days and to up to a month\textsuperscript{20,22}. Early adaptations include an increase in total blood volume, accommodating the working muscles and allowing heat produced by these muscles to be carried to the skin by the increased volume\textsuperscript{23,24}. Other changes that occur beyond the first five days are earlier sweating (keeping the CBT lower longer), more dilute sweat, an increase in the number of active sweat glands, and many other changes in the functioning of the body that allow it to maintain a higher exercise intensity and lower CBT than before acclimatization. Overall, these physiological and adaptive changes lead to reduced EHI rate. For these changes to be optimized, individuals must be gradually introduced to the extreme environments, both in exposure and exercise duration and intensity, and the exposure should be on consecutive days. When appropriate heat acclimatization occurs, one will see an increase in exercise performance and a reduction in EHI risk.

Because of the increased risk of EHI in high school football players in the state of Georgia, it is imperative to take every measure necessary to mitigate risk and ultimately prevent death. The Georgia High School Athletic Association (GHSA) rules and regulations pertaining to preseason practices and policies for practicing in heat and humidity prior to the 2012 season were as follows\textsuperscript{25}:

Section 5D. Football practice may begin no earlier than August 1st.

1. In the first five days, at least two days must have practices with players dressed in shorts, helmets, shoulder pads, mouthpieces and shoes only. The other three days MAY include practices that have players in full pads, but no more than two consecutive days of the first five days may have full pads in use. Coaches are not required to have any practices in full pads during the first five days of practice.
2. At school workouts from the end of school in the spring until the first day of practice in the fall, players may wear no other protective football equipment except helmets and mouthpieces for all voluntary workouts and passing league games. NOTE: Any modification of this equipment rule in summer camps requires the approval of the Executive Director.

2.67 Practice Policy for Heat and Humidity:

(a) Each member school shall have a written policy for conducting practices in all sports during times of extremely high heat and/or humidity that will be signed by each head coach and distributed to all players. The policy shall include, but is not limited to:

(1) the time of day the practices are to be scheduled at various heat/humidity levels

(2) the ratio of workout time to time allotted for rest and hydration at various heat/humidity levels

(3) the heat/humidity levels that will result in outdoor practices being terminated

(b) A scientifically-approved instrument that measures the heat index must be utilized at each practice to ensure that the written policy is being followed properly.

(c) Schools may determine the heat/humidity levels using either wet bulb globe temperature readings or heat index readings.

While the GHSA had great intentions by assuring that each school have a heat policy, this rule was not adequate due to several reasons. Firstly, there were no specifications as to how long or how many times a team could practice in a single day, theoretically meaning
that a team could practice four times in a day if they desired which could place athletes at an increased risk of EHI during an acclimatization period. Secondly, while each school was required to have a heat policy, there was no guidance as to which scale would be best (ACSM, DOD, etc.) or the environmental scale (WBGT or heat index) Thus schools were left to determine the best policy with little oversight from the GHSA or the medical community.

Because of the issues associated with these rules, the GHSA changed the policy for the 2012 football preseason period. These changes came about as a result of data collected in the first three years of the current study (PRE period). Data collected were analyzed and showed under which conditions (both practice conditions (time of day, duration, etc) and environmental conditions) risk for EHI was greatest. A group of experts came together to help form the current heat acclimatization policy. Thus the rules were based both on empirical evidence and the National Athletic Trainers’ Association’s (NATA) Preseason Heat Acclimatization Guidelines for Secondary Schools. In short, the new rules mandate a five-day acclimatization period where only helmets may be worn and athletic activities (practice, conditioning, weight training, etc.) during this period may not last longer than two hours. Also mandated was that each school follow the newly created wet bulb globe temperature (WBGT) physical activity scale based on the data above and have a WBGT measuring device at the practice facility to assure values specific to their practice facility.

**Purpose Statement**

There were several purposes of this study. First, to investigate the effect the new GHSA pre-season acclimatization policy implementation had on the total and significant
(heat stroke, heat exhaustion (HS/HE)) injury rates (IR), both over the entire data
collection period and in the first two weeks of data collection. Second, to determine if
IR’s at different levels of WBGT during the first two weeks of data collection were
significantly different in the time period prior to the policy change (Seasons 2009-11,
PRE) when compared to that following the policy change (2012 season, POST). Third, to
determine the effectiveness of current heat stress index scales (HSIS) and which best
mitigates the risk for an EHI event. To date, research has been conducted concerning the
WBGT scale, but other heat stress indices (TLI’s) have not been well explored – namely
DI. Thus, this study also strove to determine the relationship between WBGT and DI.

Hypotheses

1. Following the GHSA pre-season acclimatization policy change, the IR for the entire
data collection period will be lower in the POST period than in the PRE period.

2. Following the GHSA pre-season acclimatization policy change, the IR for the first
two weeks of preseason practice will be lower in the POST period than the PRE.

3. For the first two weeks of the data collection period, the IR for the PRE period will be
greater than that of the POST period for all ACSM WBGT risk categories.

4. The WBGT and DI will show a strong positive relationship with each other.

5. Each of the HSIS’s of interest will adequately define EHI risk.

Statement of the Problem

In the PRE period, heat policies required by the GHSA were not based on
scientific evidence specific to population or region. The GHSA used data from the UGA
EHI in Interscholastic Football Players study to rewrite their pre-season practice rules as
well as create a WBGT scale for practicing in the month of August. There were no
current data to support if the rules change had a beneficial or deleterious effect; thus, this study serves to answer this question and to provide evidence to either support the change or suggestions for future modifications. Furthermore, current research uses data collected on adults to determine which TLI is best suited to mitigate risk of an EHI, but this particular scale may not be best suited for the high school population; this study will help determine which TLI is best suited for the adolescent population. Moreover, WBGT is the only TLI currently used in HSIS’s in the United States, yet a scale utilizing DI may be just as advantageous. Therefore, use of the DI in an athletic setting needs to be further explored.

**Delimitations**

1. Georgia high school football players.
2. Data collected from start of the 2009-2012 seasons from the first day of practice through the month of September for each year.
3. Use of QUESTemp° 34 (QT-34; 3M Quest Technologies, Oconomowoc, WI) unit to collect environmental data.

**Limitations**

1. Athletes may not report their symptoms to the Athletic Trainer for the proper determination of an EHI.
2. Experience of ATs’ recognition of various types of EHI. If all Athletic Trainers do not classify EHI’s in the same manner according to the project definitions, this could create an under or over reporting of the data.
3. Conditions cannot be monitored in inclement weather due to the QT-34’s inability to operate in the rain, but environmental conditions in inclement weather can still result in an EHI.

4. While AT’s have been given specific instructions for reporting practice information, data may not always be accurately reported (e.g. changes in athlete demographics, athlete exposures, practice start/end times, etc).

Assumptions

1. Athletes are taking advantage of rest breaks and consuming water during designated times.

2. Athletes are adequately consuming enough food and water to replenish the energy used during the previous practice/conditioning/game session.

3. Athletic Trainers are classifying EHI cases according to the definitions provided by the investigators.

4. The AT knows how to use the QUESTemp° 34 (QT-34; 3M Quest Technologies, Oconomowoc, WI) unit and abides by the rules set forth by the researchers to obtain accurate measures.

Definitions of Terms

1. Athlete – high school football player in Georgia

2. Exertional Heat Illness (EHI) – One of several conditions that occur as a result of physical activity in extreme environmental conditions.¹⁴

3. Heat Cramp – A condition that presents during or after intense exercise sessions as an acute, painful, involuntary muscle contraction; possible causes may include fluid
deficiencies (dehydration), electrolyte imbalances, neuromuscular fatigue, or any combination of these factors\textsuperscript{14}.

4. Heat Syncope – A condition that may occur as a result of exposure to high environmental temperatures that is attributed to peripheral vasodilation, postural pooling of blood, diminished venous return, dehydration, reduction in cardiac output, and cerebral ischemia that causes an individual to faint. Also referred to as orthostatic dizziness\textsuperscript{14}.

5. Heat Exhaustion – An inability to continue exercise associated with any combination of heavy sweating, sodium loss, and energy depletion. Signs and symptoms include pallor, persistent muscle cramps, weakness, fainting, dizziness, headache, hyperventilation, nausea, decreased urine output, and a body-core temperature up to 104°F\textsuperscript{14}.

6. Heat Stroke – An elevated core temperature usually greater than 104°F associated with signs of organ system failure due to hyperthermia. Occurs when the body’s temperature regulation system is overwhelmed as a result of excessive endogenous heat production or inhibited heat loss in challenging environmental conditions. Symptoms include tachycardia, hypotension, sweating (although the skin may be warm and dry), hyperventilation, altered mental status, vomiting, diarrhea, seizures, and coma\textsuperscript{14}.

7. Heat Stress Index (TLI) – A value used to quantify the amount of heat stress placed on the body during activities performed in the heat.

8. Heat Stress Index Scale (HSIS) – A scale used to quantify and stratify risk of EHI in extreme environmental conditions.
CHAPTER 2

LITERATURE REVIEW

The amount of literature that exists concerning the physiology of exercising in the heat is vast. Many studies have been conducted in laboratories to determine what happens to the body when it is subject to temperature extremes, specifically heat. There have also been studies conducted in the field showing different physiological aspects that occur with physical activity in the heat. Epidemiological studies concerning EHI are far fewer, but do still exist; the majority of these studies have been in the football and military settings, with only two of these studies conducted in the high school setting. The majority of epidemiological data were focused on adults, college-aged and older. Concerning physiology of physical activity in the heat, there are numerous studies concerning adolescents and the pediatric population, most of which have been conducted in the laboratory setting. Furthermore, several heat stress indices have been published by different organizations, but the only one of these scales specific to adolescents was published by the ACSM in their most recent position stand concerning heat illness. The purpose of this literature review is to illustrate the physiology and etiology of EHI and to show a void in the literature concerning epidemiology and heat stress indices.

Physiology & Etiology

The temperature of the body is referred to in a variety of different manners (skin, oral, tympanic, esophageal, rectal, etc.), but during exercise the core body temperature (CBT) becomes of greatest interest. CBT is usually defined as “…the temperature of the
hypothalamus, the temperature regulatory center of the body”

Under normal circumstances, the CBT is maintained in a very narrow range, 36.5º-37.5ºC (97.7º-99.5ºF). As physical activity begins, maintenance of this CBT range becomes challenged. A complex interaction of many systems of the body, including the cardiovascular and central nervous systems, come together in an effort to maintain a reasonable CBT. To avoid injury and to achieve and sustain optimum performance this maintenance of CBT must continue, if not an EHI may ensue and performance suffers.

Exercise stresses the body’s thermoregulatory system, and in presence of extreme temperatures (in this case, heat), this combination has been said to be, “…probably the greatest stress ever imposed on the human cardiovascular system (except for severe hemorrhage)”

As muscular activity begins, metabolic heat is produced within the muscle. This heat in turn warms the blood being circulated throughout the muscles; warmed blood eventually bathes the hypothalamus, signaling it of an increase in CBT. A variety of responses from different systems of the body occur in response to this signal. To dissipate heat, the cardiovascular system shunts blood from the core to the periphery for heat loss via evaporation (other means of heat dissipation include convection, radiation, and conduction). An increase in blood to the periphery in an effort to dissipate heat via sweating lowers the central blood volume, ultimately decreasing stroke volume.

To maintain blood distribution to the tissues and the increasing demands for skin blood flow in the presence of decreased blood volume, heart rate must increase to maintain cardiac output (heart rate x stroke volume). Without ingestion of fluids and electrolyte substances (e.g. Gatorade and Powerade) to replenish that lost through sweating, the body begins to react to the signals. A decrease in blood volume increases both osmolality and
viscosity of the blood. An increase in osmolality signals release of antidiuretic hormone (ADH) from the pituitary gland, which is the primary signal to increase water reabsorption, decreasing the available blood flow to the skin and making the body less efficient in cooling itself. Likewise, osmoreceptors in the hypothalamus sense the increase in blood osmolality and signal a cascade of events. The liver releases angiotensinogen while the kidneys release renin. In the presence of renin, angiotensinogen is converted to angiotensin I. Angiotensin Convertin Enzyme (ACE) is released, converting angiotensin I to angiotensin II, ultimately releasing aldosterone. Aldosterone is the major signal for sodium reabsorption and since water follows sodium, the amount of blood available to take heat to the skin and cool the body via evaporation is decreased. This increase in CBT coupled with dehydration is the primary cause leading to heat illness.

Along with evaporation, heat is dissipated from the body in a number of different ways to minimize the rise in CBT, namely conduction, convection, and radiation. The mathematical equation for heat loss/heat gain in the body has been presented as follows¹⁹:

\[ S = M \pm R \pm C \pm K - E \]

Where \( S \) = heat storage, \( M \) = metabolic heat production, \( E \) = evaporation, \( R \) = radiation, \( C \) = convection, and \( K \) = conduction. Note that evaporation is only a means of heat loss and not heat gain, hence the “-“ sign and not “±”. The longer work is performed the more metabolic heat production that takes place, requiring an increase in heat loss via radiation, conduction, convection, and evaporation to maintain thermal balance. Again, an increase in CBT increases the risk for EHI occurs when \( M \) exceeds the sum of losses from \( R, C, K, \) and \( E \).
A special consideration that comes with football is that of protective equipment. The presence of football pads and helmets add to the amount of heat storage in the athletes and provide a barrier to evaporative cooling not present in many other athletic activities occurring during the hottest months of the year. A study by Armstrong et al\textsuperscript{21} confirmed that excess physiological stresses placed on the body under the presence of the American football uniform lead to an increase in CBT with increasing equipment worn. Three different conditions were analyzed (control, full pads, and partial pads) and perception of thirst, perception of thermal sensation, rating of perceived exertion (RPE), pain rating, sweat rate, CBT via rectal probe (CBT-R), heart rate (HR), blood pressure (BP), forearm and posterior neck skin temperature, hematocrit (HCT), hemoglobin (HGB), blood glucose (BG), lactate (LACT), and plasma osmolality (OSM) were all analyzed at various times during the up to 80-minute protocol performed in the heat chamber. As the amount of protective equipment increased (FULL – full NFL uniform including pants, pads, jersey, and helmet; PART – NFL uniform without helmet and shoulder pads; or CON – socks, sneakers, and shorts), fewer participants were able to complete the full 80-minute trial, showing that heat load provided by the protective equipment was increasingly cumbersome. Skin temperature was statistically significantly greater in the FULL group than the CON group at both the forearm and posterior neck region. CBT-R was greater in both of the uniform groups when compared to the CON group. HR at 40 minutes of physical activity and through the final measurements were again higher in the FULL and PART groups than in the CON, indicating that the heart was having to work harder to keep up with the load of the equipment groups. At time of exhaustion, RPE was statistically significantly greater for the FULL and PART groups.
than for the CON group, but all other perceptual response differences were insignificant. Overall, this study demonstrated the effects of the American football uniform on both perceptual and physiological constructs in the participants.

**Pediatric/Adolescent Population**

While heat dissipation follows the same general pathways in humans regardless of age, studies have been conducted to show the adolescent population to be less efficient at dissipating heat than their adult counterparts. Overall, physical and physiological differences between adults and adolescents and their effects on thermoregulation can be found in Table 1.1. As listed in the table, some of these differences include a greater surface-area-to-mass ratio in children, greater body density in girls vs. women, lower blood volume per body surface area, small sweat glands, greater oxygen cost of locomotion, lower maximal cardiac output (Q), lower sweat gland sensitivity, lower sweat gland anaerobic metabolism, and lower prolactin response to exercise in the heat. Several reviews of the literature regarding thermoregulation of children and adolescents in the heat have been published. The aforementioned review by Falk and an updated review by the same author and Dotan reveal some of the major points regarding thermoregulation in children in the heat. The greater surface-area-to-mass ratio in children versus adults leads to an increase in heat gained through convection and radiation when air temperature is greater than skin temperature, placing children at a greater risk. The authors also point out differences in metabolism during activity. Because children are not as efficient, they consume a higher amount of oxygen during activity, causing as much as a 10-15% increase in heat production over their adult counterparts, lending to an overall higher CBT.
Another crucial difference between the pediatric and the adult population concerns the cardiovascular system. This is likely the greatest contributor to children’s decreased exercise heat tolerance when compared to adults. In a study concerning prepubertal girls and college women exercising in the heat conducted by Drinkwater et al., a clear difference between the two groups was noted. While subjects had relatively the same VO₂max and were working at the same relative workload, the girls’ faces were flushed, had increased signs of distress, and some reported being dizzy. Overall, the girls were exercising at a higher percent of heart rate reserve, at a lower cardiac index, and had a higher Tskin than adults. The authors’ thoughts were that the cardiovascular system was not able to keep up with the shift from blood in central circulation to peripheral circulation required to dissipate heat in order to maintain a lower CBT.

**Epidemiology**

While EHI has not been studied in great detail in football at the interscholastic level, there have been many studies conducted in various different activities at a variety of different levels, some of which include the military, cycling events, collegiate football, and high school sports.

In 2005, Carter et al published an article concerning heat related hospitalizations and deaths in the military from the years 1980-2002, the largest epidemiological study of its kind concerning the military to date. The authors specifically looked at incidences by heat illness type, concurrently taking into account personal characteristics such as age, gender, race, type of injury (training, off duty, on duty, etc.) and home of record (the recruit’s home state). Data from this study were obtained from the U.S. Army Research Institute of Environmental Medicine. The definition of injury was those individuals
hospitalized for heat illness, but not those who were treated and released. The total number of hospitalizations for the 22-year period was 5,246, 86% of which were men. The vast majority (67%) of those admitted were Caucasian, followed by African Americans (23%), Hispanics (4%), Asian/Pacific Islanders (2%), Alaskan/Native Americans (<1%), and other (2%). The greatest number of these hospitalizations occurred in those 17-21 years of age (40%). Remaining statistics showed the majority of incidences occurred while on duty (84%), to those on a scheduled training activity, and to those who had been enlisted in the military one year or less (44%). Overall, the majority of EHI’s hospitalized were heat exhaustion/syncope (61%) followed by heat stroke (18%). Another interesting finding from the study was that those recruits with origin in northern states were just over 1.5 times more likely to be hospitalized for an EHI than those from southern states (44.5/100,000 and 27.5/100,000 cases, respectively).

Townes, Bersotti, and Cromeans conducted a study concerning overall injury and illness (not solely EHI) during a multiday recreational bicycling tour. Unlike in the military, anyone was allowed to compete in this particular event, indicating that the increased likelihood of unacclimatized, weekend warriors participation was great. The race occurred in the month of July and was a multiday, 520 miles ride from Minneapolis, MN to Chicago, IL lasting 6 days. Of particular note was that this was a ride supporting AIDS awareness and many of the participants either had HIV or other chronic conditions that may have predisposed them to heat illness. The overall injury rate was calculated to be 116/1,000 riders or 22/100,000 person miles. Of those treated at medical stops (N=244), the greatest incidences of injury/illness were dehydration (n=86, 35%) and orthopedic injuries (n=65, 27%). Over the 6 days, the temperatures ranged from 81°F to
88°F with a humidity between 60% and 90%, with the greatest number of dehydrations (n=41, 48% of dehydrations) occurring on the first day of the race with the temperature at the lower range at 81°F days. Specific relation between ambient temperature and relative humidity were not recorded for each day, thus it is unclear whether the events occurred on humid days or drier days. Furthermore, as the race proceeded, the number of individuals treated for dehydration decreased (n=49, 15, 10, 8, 4, and 0 for days 1-6, respectively). This is somewhat curious in that you would expect individuals to not hydrate themselves appropriately at the end of each ride, thus leading to a higher incidence of dehydration on the following day. Contrarily, this decrease in dehydration incidences may support the body’s ability to acclimatize very quickly, showing that even little exposure to hot environments can decrease EHI. Another theory behind this may be survivor bias – those susceptible to an EHI even fall early in the race. Overall, due to a lack of details on actual dehydration events and environmental conditions for the specific days, it is hard to draw concrete conclusions from this study.

A more detailed and complete study concerning 5 Division I Universities in the Southeast was conducted by Cooper et al. This study looked at environmental conditions and EHI’s during practice sessions over a period lasting from August to October. The overall injury rate was 4.19/1000 Athlete Exposures (AE; and athlete exposure is defined as each time an athlete is exposed to practice/games/conditioning) with trends showing the majority of EHI’s occurred in the month of August (n=122, 88% of cases, IR=8.95/1000AE); there was a marked decrease in the number of EHI’s in September (IR=1.70/1000AE) and by October, there were no EHI’s reported by the 5 participating schools. This period in August corresponds with the time where the players would be
going through acclimatization. Further breakdown of the month of August shows the
greatest number of EHI’s occurring in the first week (n=49) and decreasing over the
remaining three weeks in August (n=35, 32, and 6, respectively). As mentioned in the
etiology section, the greatest amount of acclimatization occurs within the first 5 days of
exposure and continues anywhere from 14 days to a month and this data supports that
notion. Because the authors also recorded environmental factors, WBGT values, for these
practice sessions they were able to portion out practices according to the ACSM Heat
Stress Index\textsuperscript{32}. The highest injury rates occurred during practices in the High (WBGT 23-
28°C) and Extreme (WBGT >28°C) ACSM risk categories, 6.13 and 5.75/1000AE,
respectively. This data indicates that there seems to be a strong relationship between EHI
events and the WBGT value.

Recently, Grundstein and colleagues\textsuperscript{2} published an epidemiological review of
hyperthermia deaths in American football players of all ages from 1980-2009, showing
trends similar to the Cooper study. Over the period analyzed, 58 deaths were reported,
with an increase in deaths over the last 15 years of the study. This study showed the
majority of deaths occurred in the southeastern portion of the United States, with the
greatest amount occurring in the state of Georgia. As in the Cooper study, the majority of
hyperthermia deaths occurred in the month of August (n=37), and more specifically
within the first 15 days of the month (n=27); again, this is most often during the time of
early acclimatization in athletes as well as a period of two-a-day preseason
practices/workouts. Forty-eight of the 58 recorded deaths occurred in athletes 18 years
old or younger. Forty-two of the cases reported BMI for the athletes who died – 40 of
these were classified as overweight or obese. Not surprisingly, 32 of the 37 known
positions for those who died were linemen, the biggest/heaviest athletes on the football
field. The authors were able to obtain WBGT values for 33 of the recorded deaths; all 33
of these deaths occurred in the ACSM High or Extreme risk categories. Again, this study
shows trends in time of year (August), season (preseason practices), environmental
conditions (ACSM High or Extreme risk categories), as well as in region (southeast), age
(≤18 years old) and BMI (≥25). This study validates that deaths are on the rise and they
are centered in the southeast region of the country and that, ultimately, some sort of
intervention needs to take place to decrease the number of hyperthermia deaths.

The CDC published a report of EHI’s specifically in the high school setting⁵. This
study gathered data from 100 schools across the United States, 8 different sports, and
covered school years from 2005-2009 (4 school years). A “time-loss heat illness” for this
study was defined as, “…dehydration or heat exhaustion/heatstroke that 1) resulted from
participation in a school-sanctioned practice or competition, 2) was assessed by a medical
professional (with or without treatment), and 3) resulted in ≥1 day of time loss from the
athletic activity.”⁵ All 100 schools employed a full time athletic trainer who reported all
injuries and other data collected during the study. Over the four-year period, for all
sports, only 118 time-loss illnesses were reported, a rate much lower than that of the
Cooper study⁸. The majority of these illnesses occurred during football (70.7%,
4.5/100,000AE) and, as with the Cooper⁸ and Grundstein² studies, the vast majority of
these happened in August (66.3%). Furthermore, 76.7% of these illnesses were reported
to occur during the preseason period, again, in-line with the other studies mentioned and
during the time of acclimatization. This study also considered other characteristics of
those football players sustaining heat illnesses: 83.6% occurred during practice; 58.2%
were Varsity players; 64.7% had a BMI greater than 25 (considered overweight or obese); and 63.1% returned to activity within 1-2 days of the event. This study, however, did not list environmental conditions under which the events occurred.

Most recently in 2013, Kerr et al\textsuperscript{3} published an epidemiological study of EHI’s among high school athletes across the United States. High schools from across the U.S. were recruited to assure equal representation from predetermined geographical regions. Nine sports were initiated in the surveillance study (football included) in the 2005/2006 school year and another 11 sports were added in 2008/2009. Just as with the CDC study, an EHI was defined as a heat illness event that resulted in $\geq 1$ day of time loss from sport activity, as well as the other three aforementioned criteria. For football, the EHI rate was 0.044/1000 AE for the 2005/2006 to 2010/2011 academic years. Of all EHI events, 60.3% of these events occurred in the month of August, a time when we know heat and humidity is at its highest; of these, 90.4% occurred during the preseason period. In terms of region of the country, the states of Alabama, Florida, and New Hampshire reported the highest IR’s over the period of the study, slightly different than those deaths reported by Grundstein et al\textsuperscript{2}. Also of interest were the suggestions for improvement of surveillance of EHI events, which included: including EHI events that were less than 1 day of time loss; collecting additional data including, but not limited to time of onset of EHI, environmental conditions, body mass index, healthcare professional who treated EHI event, and sport setting; incorporating weather patterns across study; tracking treatment of EHI; and increasing heat illness education concerning prevention and treatment strategies\textsuperscript{3}. 

22
Heat Stress Indices

Currently, the two most widely used heat stress indices in the United States are the WBGT Heat Stress Index and Heat Index (HI). The American College of Sports Medicine (ACSM), National Athletic Trainers’ Association (NATA), American Academy of Pediatrics (AAP), Georgia High School Association (GHSA), and Department of Defense (DOD) have developed WBGT scales to determine safe practices for physical activity in the heat. The ACSM has used the research conducted by the DOD to establish their WBGT scales.

The American College of Sports Medicine (ACSM) came out with its original position stand concerning heat illnesses in 1975\(^{33}\) and came out with subsequent revisions in 1987\(^{34}\), 1996\(^{12}\), and 2007\(^{18}\). The first three versions of the position stand were aimed toward distance running, with the most current version covering a broader scope of “training and competition”. The original position stands were meant to be used as a safety measure during marathons, giving race sponsors and participants an index for when the risk of heat illness begin to rise using WBGT measures. Information for this scale was developed primarily from data collected from adult runners and the DOD. The 1996 position stand used different color flags to denote different levels of heat illness risk, while subsequent position stands stopped using the difference color flags, but created different activity and rest levels for both unacclimatized (high risk) and acclimatized (low risk) individuals as well as a pediatric scale. For adults, the point at which EHI becomes a risk is at a WBGT of 18.4°C for unacclimatized and 22.3°C for acclimatized individuals; the most severe risk, where practice or competitions should be canceled or delayed, occurs when the WBGT reaches 30.1°C for unacclimatized individuals and >32.3°C for
acclimatized individuals. Between the least severe and most severe environmental conditions are various levels where different actions should be taken depending on the amount of risk present. For the pediatric population, once the WBGT reaches 24°C, longer rest periods are encouraged with emphasis on fluid consumption at least every 15 minutes; with a WBGT >29°C, all activities are advised to be canceled. In a study conducted by Cooper et al\textsuperscript{8}, the environmental conditions for five division one Universities in the Southeast were collected over a period of four weeks in August. Average WBGT’s for the four weeks’ 2 PM practices were 29.97, 29.71, 30.06, and 31.75; if these schools were to follow the ACSM index scale, they would have never practiced because all of these values are classified as extreme and delaying or canceling activity is advised. This scale is obviously not conducive to having practice in the Southeast region of the country.

The Department of Defense (DOD) created the other WBGT index scale that currently exists. Research for this scale was conducted by Yaglou and Minard at the Paris Island Marine Corps Compound in 1957\textsuperscript{10}. Data collection was conducted during Marine Corps Training Camp at Paris Island. This location was chosen because of its hot, humid climate that was thought to be comparable to conditions where Marine Corps recruits would be stationed and involved in combat. This study showed when risk factors for experiencing an EHI increased and determined that a drastic increase in EHI occurred when the WBGT was >27°C. Like the 1996 ACSM scale, the DOD used flags to indicate the threat level, with the initial increase of threat occurring when the WBGT reached 26.7°-29.4°C indicated by a green flag and denoting that the recruits should exercise with caution; and the most severe threats occurring at WBGT >32.2°C, indicated by a black
flag and denoting that risks are extreme and all activities should be suspended. According to the same study by Cooper et al\textsuperscript{8}, WBGT values for the 2 PM practice would be classified moderate to high indicating that practice should either be suspended for “novice recruits” (in this case, likely first year football players) or suspended for all recruits (athletes). Once again, it is plain to see that this scale is not conducive to conducting practice in August in the Southeast either.

As can be seen by the current indices, there is some variation in scales. The ACSM Heat Stress Scale shows that risk increases at WBGT 18.4°C (unacclimatized individuals), while the DOD Heat Stress Index shows that caution should be exhibited when the WBGT reaches 26.7°C. On the other extreme, the ACSM shows risk to be extreme (comparable to the DOD black flag) and consideration to reschedule or delay the event should be considered at WBGT >30.1°C. The DOD’s scale is similar in that it suggests risks are extreme (also a black flag) and all activities should be suspended at WBGT >32.2°C. If interscholastic football teams in Georgia were to adhere to the WBGT on the current scales, they would almost never practice because the environmental conditions in their state are near the extremes determined by these scales. Furthermore, these scales were created using data collected from EHI occurrence among adults, yet there is currently no evidence to support that these scales are adequate for use in an adolescent population. Considering the information at hand, the need for a scale specific to adolescents exercising in Georgia is necessary to accurately determine risk.

While the WBGT HSIS’s have been more widely accepted by the medical and military populations, the general public, and many interscholastic and recreational institutions most often turn to the HI to determine the course of action for activity in the
heat. Prior to the GHSA rule change, the vast majority of heat policies for Georgia High Schools were written according to the HI. The HI (originally humiture) was originally developed in 1978 by George Winterling and was shortly adopted thereafter by the United States Weather Service. Much of the work of Winterling concerning HI was based off of the work of Steadman in studies concerning sultriness. To this day, the HI is one of the most recognizable ways in the United States to establish “how it feels” outdoors. While the basic premise of the HI seems fit to use for physical activity, a more in depth look at how HI was develops shows this to not be the case. Many assumptions are made when calculating the HI, some of which are as follows: dry-bulb temperatures from 20-50°C (68-122°F); vapor pressure from 0-4.6 kPa; a typical adult human measuring 1.7m, with a mass of 67kg; significant body diameter of 15.3 cm; wearing long pants and a short sleeve shirt or blouse; CBT of 17°C (98.6°F); walking outdoors in the shade at a rate of 1.4 m/s (3.1 mph); wind speed of 5knots; sweat is uniform and not dripping from the body; and many others that are beyond the scope of this paper.

Changes in any of the variables listed above have the ability to significantly change the HI. As is apparent, football players do not fit the majority of the listed criteria, thus using the HI as a means of indicating physical activity in the heat is not adequate.

While the WBGT and the HI are the most widely used and recognized scales in the United States, Epstein and Moran recently published a review of the various heat stress indices of past and present, some used more frequently than others. In their review, 40 different heat stress indices were referred, but the authors state that there are likely many more that are not alluded to. These authors categorize the indices into one of three groups: “rational indices; “empirical indices”; and “direct indices”. The WBGT is an
example of a direct index and is simple to use and come to. One of the other direct indices mentioned that is commonly used in other countries, especially Israel, is the Discomfort Index (DI). Several versions of the Discomfort Index have been proposed (Thom\(^38\), Tennenbaum et al\(^39\), and others), with different modifications to the equation. In 1998, Moran et al\(^40\) published a comparison of the WBGT and the Modified Discomfort Index (MDI; MDI = 0.30 dry bulb + 0.75 wet bulb) showing the correlation coefficient of the two to be 0.94 in the United States, 0.95 in Israel (reached by using a correction factor of 2 for measures taken in the sun), and 0.83 in Egypt. This study showed the DI to be strongly correlated with the WBGT, indicating that this may be a worthwhile alternative to the WBGT. Yet, no actual studies have been conducted to show where risk levels lie when using the MDI.

While not commonly used in the U.S., the DI is used in various parts of the world, including parts of Australia\(^41\), Europe\(^42-45\), Central America\(^46\), Africa\(^47\), and Israel\(^48\). The DI was presented in 1959 by Thom\(^38\) to evaluate workplace thermal load, using the WB and the DB in the following equation:

\[
DI = 0.4 \times (DB + WB) + 1538
\]

With temperatures measured in Fahrenheit, resulting in a “unit” of DI. This scale was developed to determine the degree of discomfort for those in the workplace. In short, humans will begin to feel uncomfortable at a DI of 70°F and all individuals will feel a level of discomfort when he DI reaches a level of 79°F. Since creation of this TLI, others have created modified versions of the DI. In 1978 Sohar et al\(^49\) conducted research regarding the DI in Tel Aviv, presenting a modified DI using the following equation:

\[
DI = 0.5WB + 0.5DB^{49}
\]
The DI using this equation was employed in a study by Hansen\textsuperscript{41} to determine the DI’s association with physiological responses of the body, including core temperature, heart rate, and sweat loss in indoor squash and basketball players. The indoor DI correlated highly with the outdoor DI (p<0.001), thus indicating that results are applicable to both indoor and outdoor values. All physiological values were significantly correlated with DI, indicating that this TLI may be a good alternative to the WBGT. Yet, no studies have been conducted in conjunction with EHI, thus showing a void in the literature. Currently, the only HSIS that uses DI is that of the Israeli government, which denotes four levels of risk.
Table 2.1 - Physical and physiological differences between children and adults affecting thermoregulation\(^{27}\)

<table>
<thead>
<tr>
<th>Difference</th>
<th>Effect on thermoregulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
<td></td>
</tr>
<tr>
<td>Greater surface-area-to-mass ratio</td>
<td>Increased heat gain in hot environments</td>
</tr>
<tr>
<td>Greater body density (in girls vs women)</td>
<td>Increased heat loss in warm and cold environments</td>
</tr>
<tr>
<td>Lower blood volume per body surface area</td>
<td>Higher specific heat of the body</td>
</tr>
<tr>
<td>Smaller sweat glands</td>
<td>Possible compromise in perfusion of periphery, muscles or central nervous system</td>
</tr>
<tr>
<td><strong>Physiological</strong></td>
<td></td>
</tr>
<tr>
<td>Greater oxygen cost of locomotion</td>
<td>Greater metabolic heat production per kg body mass</td>
</tr>
<tr>
<td>Lower maximal cardiac output</td>
<td>Possible compromise in perfusion of periphery, muscle or central nervous system</td>
</tr>
<tr>
<td>Lower sweat gland sensitivity</td>
<td>Higher sweating threshold</td>
</tr>
<tr>
<td>Lower sweat gland anaerobic metabolism</td>
<td>Longer time to sweating onset, Lower sweating rate</td>
</tr>
<tr>
<td>Lower prolactin response to exercise in the heat</td>
<td>Lower sweating rate</td>
</tr>
<tr>
<td></td>
<td>Possible effect on sweat electrolyte consumption</td>
</tr>
</tbody>
</table>
CHAPTER 3

METHODOLOGY

There were several purposes of this study. First, to investigate the effect the new GHSA pre-season acclimatization policy implementation had on the total and significant (heat stroke, heat exhaustion (HS/HE)) injury rates (IR), both over the entire data collection period and in the first two weeks of data collection. Second, to determine if IR’s at different levels of WBGT during the first two weeks of data collection were significantly different in the time period prior to the policy change (Seasons 2009-11, PRE) when compared to that following the policy change (2012 season, POST). Third, to determine the effectiveness of current heat stress index scales (HSIS) and which best mitigates the risk for an EHI event. To date, research has been conducted concerning the WBGT scale, but other heat stress indices (TLI’s) have not been well explored – namely DI. Thus, this study also strove to determine the relationship between WBGT and DI. To create the best heat policy/practice guidelines possible for high schools in the state of Georgia and to determine player characteristics for those sustaining an EHI, a thorough study including player characteristics (demographics, position, history of EHI, etc), school characteristics, practice information, environmental data, and EHI specifics needed to be performed. A multi-year study (2009-2012) to evaluate EHI risk, conditions, and player characteristics associated with EHI and the associated environmental conditions was conducted to address the aims of this study. The first three years of data
collection represented conditions prior to the GHSA rule change (2009-2011, PRE) and
the fourth year represented conditions post-rule change (2012, POST).

Participants

This study was a 4-year prospective observational study. High Schools across the
state of Georgia who employed full-time athletic trainers were identified for the study.
The state of Georgia was then subdivided into 5 different geographical regions (North,
Metro-Atlanta, Central, Southwest, and Southeast) to assure equal representation across
the state. A convenience sample of five schools from each region was selected to
participate in the study. All institutions had a full-time AT licensed in the state of Georgia
present at all football conditioning, practice, and competition sessions. Non-identifiable
demographic information was recorded such as height, weight, age, position and playing
status on the team (starter, substitute, non-player) Also collected from each participating
institution were data relating to the school (size, region), the number of years of
experience for the head coach, athletic trainer, and team physician (if the school had one).
Since the project was an observational epidemiological design and there was no
individually identifiable data for the participants, the project was determined to be
exempt by the Institutional Review Board.

Procedures

Prior to the data collection period, an informational meeting with all AT’s from
the participating schools was conducted. During this meeting, data collection procedures
were explained to ATs. Each AT was given a manual detailing all procedures for the
study, as well as definitions for EHI types, facilitating uniform classification of EHI’s by
Athletic Trainers. Instructions on the use of the QuestTemp 34 environmental monitor
and its corresponding software were also given to the participant schools’ ATs and they were instructed on the proper operation of the device, how to save the data and transferring the data to the project coordinator at UGA. All data for all schools, athletes, daily practice specifics, and EHI injury profiles were uploaded to an online database and monitored throughout the study by the project manager. Specific data parameters and the sample instruction manual can be found in Appendix C. Annual meetings to refresh Athletic Trainers of the guidelines and inform them of any procedural changes were conducted prior to each data collection season.

**Environmental Data**

Each day the AT was instructed to put the QuestTemp 34 in a central area to the practice field in a sunny area and shielded from shade. The unit was not to be near any structures (such as the field house, other buildings, stadiums, cars, etc.) that may cause black bulb values to be different that those on the playing surface. To assure proper calibration, the unit was to be set out at least 15 minutes prior to the beginning of the scheduled practice/game and shut down 15 minutes following the activity to assure that a final reading was obtained.

**Practice Data**

The AT was instructed to keep track of the following data for each session so he/she could upload them to the online database at a later time:

- Practice date
- Practice start and end-time
- Session number
- Team level
• Equipment worn
• Practice session type
• Number of participants
• Number of team rest/water breaks
• Intensity of practice session
• Whether or not an EHI occurred

If an EHI occurred in any session, the Athletic Trainer was instructed to obtain the following data to be uploaded to the database:

• Player ID
• Team Level
• Date and time of Injury
• Date and time of Return
• Session Number
• Practice Session Type
• Return during same practice/game
• Period of EHI
• EHI Type
• Evaluation by Physician
• Treatment Administered

EHI type was determined using the definitions from the National Athletic Trainers Association. Data were collected on the first official practice session to September 30th for each data-reporting year. The same instructions were maintained for the four-year collection period.
Online Database

An online database was developed so each individual school could upload their data onto their own “site”. Each athletic trainer was given a log in name and password that was specific to their individual school. AT’s were given instructions on how to upload data onto the web site during the pre-study informational meeting. The web site consisted of the following headings: School Information; Sport Related; Roster Entry; Roster List; Daily Calendar; EHI Information; Open EHI Cases; and View All EHI Info (Appendix D). Participants were instructed to upload data to the web site on a weekly basis so the project coordinator could monitor data input and ask questions as the data collection period progressed.

Instrumentation

The environmental unit used in this study was the QuesTemp° 34 Thermal Environment Monitor (Quest Technologies, a 3M Company, Oconomowoc, WI). The monitor has the ability to preset many different functions. Prior to the data collection period, the unit was set to record in Fahrenheit, at 15 minute intervals. Readings from the unit included wet bulb, dry bulb, globe, WBGT in, WBGT out, Humidity, and Heat Index Readings and were recorded and stored internally at each 15-minute interval. Following practice/games, data were uploaded to the computer using the QuestSuite Professional II Software (3M Quest Technologies, Oconomowoc, WI) and saved as a comma-separated values (CSV) file. This data was then uploaded to the reporting web site along with the practice data. Again, environmental data was checked and verified regularly by the project coordinator.
Statistical Analysis

Hypothesis 1 - Following the GHSA pre-season acclimatization policy change, the IR for the entire data collection period will be lower in the POST period than in the PRE period.

- Injury rates (IR) were calculated for both the PRE and POST periods for the entire data collection period. To determine the IR the total number of EHI’s for the variable of interest were summed and divided by the total number of athlete exposures (AE) for the same variable of interest; this number was then multiplied by 1000 to determine the injury rate per 1000 AE. Visually, the equation appears as follows:

\[
\text{Injury Rate (IR)} = \frac{\text{sum of EHI's}}{\text{sum of AE's}} \times 1000
\]

Risk Ratios (RR) were also calculated to determine the magnitude of change between the PRE and POST conditions and were determined by dividing the PRE rate by the POST rate\(^5\). As defined by Dick et al\(^5\), “Rate ratios indicate the increased rate of injury associated with [one condition] relative to [another condition]” – in the case of this study, PRE vs POST. A z-test was performed to determine the difference between PRE and POST conditions with an alpha level of 0.01 to determine statistical significance.

Hypothesis 2 - Following the GHSA pre-season acclimatization policy change, the IR for the first two weeks of preseason practice will be lower in the POST period than the PRE.

- IR’s, RR’s and z-tests as outlined for hypothesis 1 were calculated for the first two weeks of the data collection period. Again, an alpha level of 0.01 was used to determine significance.
Hypothesis 3 - For the first two weeks of the data collection period, the IR for the PRE period will be greater than that of the POST period for all ACSM WBGT risk categories.

- Data from the first two weeks of the data collection period was divided into risk categories using the ACSM HSIS for both the PRE and POST period. IR’s were calculated for each category and then a z-test was performed to determine the difference between the two periods. An alpha level of 0.05 was used to determine statistical significance.

Hypothesis 4 – The WBGT and DI will show a strong positive relationship with each other.

- A Pearson Correlation coefficient was used to determine the strength of relationship between WBGT and DI. Points were charted and a line of best fit was placed to visually show the strength of relationship between the two variables.

Hypothesis 5 – Each of the HSIS’s of interest will adequately define EHI risk.

- Hypothesis 5 was first approached graphically and then by describing injuries by the various scales that exist (DOD, ACSM, American Academy of Pediatrics (AAP), GHSA WBGT scale, and the DI Scale). A DI value was calculated for all injuries using the following equation:

\[
DI = 0.5T_a + 0.5T_w
\]

Values for \(T_a\) and \(T_w\) were obtained from raw data collected from the QuestTemp34 units. Descriptive data (mean and standard deviation) were calculated for environmental data (WBGT and DI) associated with all EHI injuries that occurred in the 2009, ’10, and ’11 seasons. All individual injuries from the first three years of data collection were used. IR’s were calculated for
each of the risk categories of the HSIS’s (DOD, ACSM, AAP, GHSA, DI) and were charted using an area chart. Data from the study were divided into 1° F increments and IR’s were calculated for each of these increments. This data was plotted as a line graph atop the area charts for each of the HSIS’s of interest. Because this line was not smooth, an exponential trendline using Excel chart editor was created to better understand the IR trends of the 1° F increments when compared to IR’s for each of the HSIS risk categories. If the exponential trendline fell within the area of each of the risk categories of the HSIS interest, the scale was considered to adequately define EHI risk.
CHAPTER 4

CHANGES IN HEAT ACCLIMATIZATION POLICY MITIGATE HEAT ILLNESS RISK IN GEORGIA INTERSCHOLASTIC FOOTBALL PLAYERS¹

¹Miles, JD, Baumgartner, TB, Brown, CN, Ferrara, MS, Grundstein, AJ, and Schmidt, MS. To be submitted to *Journal of Athletic Training*
ABSTRACT

Context: Exertional heat illness (EHI) is a potentially life-threatening condition, but limited information exists on how preseason heat acclimatization policies moderate risk. The Georgia High School Association (GHSA) changed its preseason acclimatization policy in 2012 (POST) based on data collected from 2009-2011 (PRE).

Objectives: To evaluate how a change in the GHSA preseason acclimatization policy affected the EHI injury rate (IR) in Georgia high school football players before and after the policy change. Further, to determine how the wet bulb globe temperature (WBGT) may have affected IR’s in the PRE vs POST periods.

Design: Prospective Observational Study.

Setting: Georgia Interscholastic football activities.

Participants: Georgia Interscholastic football players.

Intervention: Environmental data and injury data were collected from 22 interscholastic football teams in the state of Georgia for all training and competition sessions from the first day of pre-season practice to the last day in September for the 2009-2012 seasons. The 2009-2011 seasons were combined to form the PRE group and 2012 formed the POST group. PRE indicated years prior to the GHSA policy change and POST, following the change.

Main Outcome Measures: EHI cases ((cramps and Heat Stroke/Heat Exhaustion (HS/HE)) and WBGT values collected daily throughout data collected period. Injury Rates (IR) per 1000 athlete exposures (AE) were calculated. Seasons were compared using a z-test with an \( \alpha \) level of 0.01. Data for the PRE and POST periods were partitioned into the ACSM WBGT risk stratification categories and a z-test was
performed (alpha level of 0.05) to determine if there was a difference in IR in terms of environmental conditions for the PRE vs POST period.

**Results:** There were a total of 761 EHI cases recorded and 259,413 AE for an overall EHI rate of 2.93/1000AE (95%CI=2.73, 3.15). Risk for significant injuries (heat syncopes and heat exhaustions; HS/HE) was approximately 4 times greater for the PRE period compared to the annual entire data collection period (0.82/1000AE (95%CI=0.70, 0.95) and 0.22/1000AE (0.12, 0.37), respectively) and 7 times greater for the first two weeks of participation (1.85/1000AE (95%CI=1.54, 2.21) and 0.27/1000AE (95%CI=0.09, 0.65)). The risk was lower in the POST period than it was in the PRE period for both the entire data collection period (2.24/1000AE (95%CI=1.88, 2.65) and 3.14/1000AE (95%CI=2.90, 3.39), respectively) and first 2 weeks of data collection (1.22/1000AE (95%CI=0.75, 1.89) and 4.48/1000AE (95%CI=3.98, 5.02), respectively).

In terms of WBGT, the IR for the PRE period was statistically greater (p=0.03) than that of the POST period in the 86-90°F ACSM risk stratification category. No other risk category showed a statistically significant difference between the PRE and POST periods.

**Conclusions:** Risk of EHI was greater in the PRE period than in the POST period, with the greatest risk seen within the first two weeks of the data collection period. The only ACSM risk stratification category in which there was a statistically significant difference was in the 86-90°F category, confirming the notion that EHI is multifaceted. Overall, the study demonstrated that a change in heat acclimatization policy was advantageous in the reduction in EHI risk.

**Key Words:** exertional heat illness, wet bulb globe temperature, Georgia interscholastic football, heat acclimatization policy
INTRODUCTION

Exertional heat illness (EHI) has been identified as a life-threatening condition in physically active individuals and ranks among one of the top killers in high school athletics\textsuperscript{1-3}. EHI studies have been conducted on cyclists,\textsuperscript{4} military personnel,\textsuperscript{3,5} and collegiate\textsuperscript{6} and high school athletes\textsuperscript{7-8}. In American football alone, there were 58 deaths between the years of 1980 and 2009 due to hyperthermia, mainly caused by heat stroke\textsuperscript{8}; 81\% of the deaths reported in this study were high school athletes 14-18 years old. This statistic and age group are of paramount importance because high school sport participation has increased over the past decade, currently estimated at approximately 7.7 million athletes\textsuperscript{10}.

Organizations such as the National Athletic Trainers’ Association (NATA)\textsuperscript{11-12}, American College of Sports Medicine (ACSM)\textsuperscript{13-15}, American Academy of Pediatrics (AAP)\textsuperscript{16}, Department of Defense (DOD)\textsuperscript{17}, and recently, the Georgia High School Association (GHSA)\textsuperscript{18}, have taken measures to mitigate the risk of heat illness. All of these organizations have established heat stress index scales (HSIS’s) to guide respective groups’ participation in intense activities in the heat. All of these organizations base their HSIS on the wet-bulb globe temperature (WBGT), a composite measure using wet bulb (WB), dry bulb (DB) and black bulb (BB) to determine the heat stress placed on the body during physical activity. The most commonly accepted formula for WBGT is as follows:

\[
\text{WBGT} = 0.7\text{WB} + 0.2\text{BB} + 0.1\text{DB}\textsuperscript{19}
\]

The WB temperature (humidity) has the greatest influence on the WBGT, mainly due to the body’s decreased efficiency in dissipating heat via evaporation\textsuperscript{19-20}, followed by the BB (radiant heat), and of least impact, the DB (ambient temperature).
Following a study conducted on division I and division III intercollegiate universities\textsuperscript{21}, the southeast US showed the greatest risk of EHI, resulting in focused research in Georgia interscholastic football players. The results demonstrated the risk for EHI was greatest in the first two weeks of pre-season activity. Based on these data, a prospective epidemiological investigation was developed and implemented to measure EHI in GA high school football players. Furthermore, the previous GHSA by-laws (Appendix A) provided no absolute guidelines for pre-season activities, leaving schools to develop their own standards, which were not evidence-based\textsuperscript{22}. Data from the current study showed the following for the first 3 years of data collection: EHI risk was greatest in the first two weeks of activity; there was a dose response – as practice duration and number of practices per day increased, so did the EHI rate; and the more equipment worn, the higher the injury rate (IR). Following completion of data collection for the first 3 years of the study, the GHSA board members and experts in the field of EHI and environmental conditions developed and implemented a new policy.

The GHSA policy implemented was evidence-based and also used expert opinion from scientists, administrators, and coaches (Appendix B)\textsuperscript{18} in its development. The new pre-season policy required that student-athletes were required to participate in a 5-day acclimatization period where sessions were not to exceed 2 hours and no equipment except a football helmet and mouthpiece were to be worn or used. Also introduced was a rule limiting two-a-days where two-session practice days were to be followed by a one-session practice day. Further, all GHSA member schools were required to purchase a WBGT monitoring device and conduct practices according to the newly created WBGT heat stress index (TLI) scale, thus assuring that all schools were using the same evidence-
based scale. While these were some of the revisions, the new policy included many other facets in an effort to mitigate risk such as cooling zones, altered work to rest ratios, and an approved WBGT device.

The purpose of this study was to determine the effectiveness of the newly implemented pre-season acclimatization policy by comparing IR prior to the policy change (2009-2011) with IR’s following the policy change (2012). We also wanted to determine if there was a significant difference in the EHI rate and environmental conditions during the first two weeks of data collection, typically the period related to the pre-season period and prior to the start of the academic year before and after the policy change. This information could help determine contributing factors to EHI. We hypothesized the IR’s would significantly decrease following the policy change, both for the entire data collection period and during the first two weeks of participation and that IR would be higher for each ACSM WBGT risk stratification category in the PRE period when compared to the POST period.

**METHODS**

The state of Georgia was divided into five geographic regions: North (N), Metro (M), Central (C), Southeast (SE), and Southwest (SW) to assure equal representation across the state. A convenience sample of twenty-five interscholastic institutions, five from each region, agreed to participate. All institutions invited to participate had a full-time athletic trainer (AT) licensed in the state of Georgia present at all football conditioning, practices and competition sessions. Approval for this study was obtained from the University of Georgia institutional review board. The data collection period began the first official day of practice as determined by the GHSA (August 1 prior to the
policy change and 5 business days prior to August 1 following the policy change) until the last day in September for each of the years. AT’s were required to record and report characteristics of daily practice/game sessions (Table 4.1). In the event of an EHI, data specific to the injury were also recorded (Table 4.2). AT’s were responsible for WBGT equipment set-up to monitor weather conditions and logging all data related to practice sessions and EHI’s. Data recorded were then uploaded to a secure web portal (for which each AT had his/her own logon and password) which was monitored daily for presence and accuracy of entries. Prior to the beginning of the study, and in each subsequent year of the study, AT’s attended an orientation meeting to review in detail project criteria, including injury definition, equipment set-up, and data entry. A handbook with detailed instructions was provided to the AT’s. EHI cases were defined using the NATA position statement on Exertional Heat Illnesses11 (Table 4.3).

Participants

School retention and distribution per year can be found in Table 4.4. On average, about 20 schools participated per year. Fourteen of the schools were common to all four years of the study.

Instrumentation

A QUESTemp° 34 (QT-34; 3M Quest Technologies, Oconomowoc, WI) environmental monitoring device (Figure 4.1) was provided to each AT at participating schools. All participants were given instructions on how to use the unit as well as how to upload data using the QuestSuite Professional II software (Quest Technologies, Oconomowoc, WI). Units were preset to record environmental data every 15 minutes in Fahrenheit (and later converted to Celsius for analysis purposes). Each QT-34 was
mounted on a tripod with the unit five feet off the ground and placed in an area adjacent
to the playing surface, in direct sunlight, and away from any structures that may interfere
with environmental measures (e.g. buildings). AT’s were instructed to begin recording 15
minutes prior to the start of a session to assure the unit had time to reach current
environmental conditions. In the event that a unit malfunctioned during the data
collection period, a loaner was sent to the school until the respective unit had been
repaired.

**Data Processing**

Data were checked daily throughout each data collection period to assess quality
and accuracy of entries. Entered data were converted to a comma-separated values (CSV)
document by the web developer and transmitted to the research team. Data were assessed
twice by members of the research team for accuracy. All data were checked to assure that
dates and times entered by the AT matched the recorded dates and times from the QT-34
units, that athlete exposure (AE; number of participants for each session) values were
accurate by verification with the AT, session numbers were recorded appropriately using
practice start times, and that duplicate environmental data were removed.

**Data Analysis**

Due to the low rate of heat syncopes (HS) and heat exhaustions (HE), these two
injuries were combined to form the significant injury group (HS/HE), as reported by
Cooper *et al.*\(^2^1\). Data were labeled as either PRE (data collected in years 2009-2011) or
POST (2012 year) according to policy change date. Injury rates (IR) were used to assess
risk of EHI. To determine the IR, the total number of EHI’s for the variable of interest
were summed and divided by the total number of athlete exposures (AE; the number of
participants per session) for the same variable of interest; this number was then multiplied by 1000 to determine the injury rate per 1000 AE, using the following equation:

\[
Injury \ Rate \ (IR) = \frac{\text{sum of EHIs}}{\text{sum of AEIs}} \times 1000^{23}
\]

Descriptive statistics (frequency, percentage, AE) were calculated for each year of data collection. An IR was calculated for the entire data collection period using both the PRE and POST data. Rate Ratios (RR) were also calculated to determine the magnitude of change between the PRE and POST years. RR’s were determined by dividing the PRE rate by the POST rate. As defined by Dick et al\textsuperscript{23}, “Rate ratios indicate the change in injury rate associated with [one condition] relative to [another condition]” – in the case of this study, a z-test was used to determine the difference between the PRE and POST periods\textsuperscript{24}, with an alpha level of \textit{p}<0.01 to determine the effect the policy change had on the IR. Each of these calculations was then performed again for only the first two weeks of the preseason practice periods. Data from the first two weeks of the data collection period were divided into risk categories using the ACSM HSIS\textsuperscript{15} for both the PRE and POST period. IR’s were calculated for each category and then a z-test was performed to determine the difference between the two periods. An alpha level of 0.05 was used to determine statistical significance.

**RESULTS**

Over the four years of data collection, there were 761 EHI’s recorded, with 630 EHI’s in the PRE period (mean 210 EHI’s per year) and 131 EHI’s in the POST period (Table 4.5). The 2010 season showed the greatest number of EHI’s as well as the greatest number HS/HE; the fewest number of HS/HE were recorded in 2012. For all years,
cramps represented the highest percentage of EHI’s (Table 4.5) with a 3:1 ratio between Cramp:HS/HE.

**All Years PRE vs POST Injury Rates**

Annually, for the entire data collection period, the PRE period IR was greater than that of the POST period \( z=3.54, \ p<0.01 \) (Table 4.5). For cramps, the PRE period IR was greater than that of the POST period (Table 4.5). HS/HE were greater in the PRE period than the POST \( z=4.87, \ p<0.05 \). PRE period IR’s were greater than POST period IR’s for all years of data collection and in all categories (total (all injuries), cramps, and HS/HE).

**Analysis By Year, Entire Data Collection Period**

The IR’s for the POST year were lower for total (where total is cramps and HS/HE combined), cramps and HS/HE than for any individual year of the PRE period (Table 4.5). For the PRE years, the highest total IR was observed in 2010, while the lowest total IR occurred in 2009. The highest IR for HS/HE occurred in 2010, while the lowest IR for HS/HE occurred in 2009.

**Risk Ratio Analysis**

RR for all injuries for the entire data collection period for PRE versus POST was 1.45 \( z=3.54, \ p<0.01 \); for HS/HE the RR for PRE versus POST was 3.95 \( z=4.87, \ p<0.01 \).

**First 2 Weeks PRE vs POST**

For all injuries during the first 2 weeks of data collection, the PRE period IR was greater than that of the POST period (Table 4.6). For cramps, the PRE period IR was greater than that of the POST period (Table 4.6). HS/HE were greater in the PRE period
than the POST. PRE period IR’s were greater than POST period IR’s for all years of data collection and in all categories (total (all injuries), cramps, and HS/HE).

First 2 Weeks Individual Year Comparison

The IR’s for the POST year were lower for total, camps and HS/HE than for any individual year of the PRE period (Table 4.6). For the PRE years, the highest total IR was observed in 2010, while the lowest total IR occurred in 2009. The highest IR for HS/HE occurred in 2010, while the lowest IR for HS/HE occurred in 2009.

First 2 Weeks Risk Ratios

RR for all injuries for the first 2 weeks for PRE versus POST was 3.67 ($z=5.74$, $p<0.01$); for HS/HE the RR for PRE versus POST was 6.85 ($z=4.39$, $p<0.01$).

First 2 Weeks WBGT Z-test

A z-test was run to determine difference between PRE and POST IR’s at the different ACSM risk category levels. The only level at which there was a statistically significant difference ($z=1.90$, $p<0.05$) was at the 86-90°F category. For the POST period, the IR was 0 for the <78°F, 86-90°F, and >90°F categories.

DISCUSSION

The most important finding was that following the GHSA pre-season acclimatization policy change, the EHI rate decreased by a factor of 1.45 and, most importantly, risk of HS/HE decreased by a factor of 3.95. Significant injuries in the POST year were almost 25% lower than the pre-policy years. Analysis of both the PRE and POST data show the policy appears to be successful in mitigating risk of EHI’s. Our hypothesis regarding environmental conditions PRE vs POST was not supported. The POST period only showed a statistically significantly lower IR in the ACSM 86-90°F risk
category, where we thought all risk categories would be lower for the POST period. Thus, we cannot be sure the decrease in IR was due to the policy change. We believe the mitigation in risk to be multifaceted, just as the occurrence of EHI is not related to just one variable. The policy implemented a change in the environmental conditions, measured by WBGT, under which athletes could participate, and also included rules regarding the number and duration of rest/water breaks, practice durations, time between practices, equipment worn as seen in Appendix B. However, our findings demonstrated that this multifactorial approach to EHI mitigated risk and reduced EHI’s

We determined that the GHSA policy change was effective in moderating risk and our results indicate it did reduce the EHI rate in 2012. Other states may apply the GHSA pre-season heat policy as a guide in creating their own evidence-based guidelines. The NCAA mandated major changes in pre-season football practice policies in 2003 regarding practice duration, equipment, and two-a-day practice restrictions to mitigate risk of EHI\(^25\). New Jersey and Texas were among the first states to adopt pre-season interscholastic football exertional heat policies in 2011 to mitigate EHI risk; as did the National Football League. North Carolina, Georgia, Arkansas, Florida, and Arizona\(^26\) followed in 2012. The Korey Stringer Institute reports there are only 13 states in the U.S. that have pre-season practice guidelines that follow their recommendations\(^26\). Thus 37 states, as well as the District of Columbia, have not implemented guidelines that match current recommendations..

Our IR’s were different than those previously recorded in the literature. In 2010, the Center for Disease Control and Prevention (CDC) published a 4-year report for EHI from a sample of 100 schools across the United States focusing on eight different sports –
football, wrestling, men’s soccer, baseball, men’s basketball, women’s basketball, women’s volleyball, and women’s soccer. In this report, the authors reported 118 total EHI’s over the 4-year period with an IR of 0.016/1000 AE, an injury rate much lower than that of the total rate for either the PRE (3.24/1000 AE) or POST (2.24/1000 AE) in the present study. In this study, the authors only considered EHI’s with time loss of ≥1 day, while we considered all EHI’s removing athletes from any period of participation. A more appropriate comparison would likely be to that of HS/HE, in which our rates were still much higher than those reported in the CDC study (0.87 and 0.22/1000 AE for PRE and POST, respectively). The difference was hard to account for and merits further investigation. One possible explanation was that the CDC recorded information from high schools across the United States, while our study focused on players in the state of Georgia where environmental conditions were more extreme compared to other regions of the country. A retrospective study on hyperthermic deaths in American football players conducted by Grundstein et al. showed the greatest risk for death in the Southeast United States, specifically the state of Georgia. Additionally, the CDC study utilized several sports, but indicated that football had an IR 10 times higher than the average rate of the other eight sports combined, confirming the significance of EHI risk in high school football players. Another study with similar methods conducted by Kerr et al. showed football to have a risk 11.4 times greater than all other sports, very similar to that of the CDC study. Thus, our rates were likely elevated based of an increase risk to football in the hot, humid climate of the southeastern U.S.

Another study on high school athletes in a variety of sports defined EHI as illnesses resulting in 1 or more days of time lost from activity. This study reported injury
proportion ratio for all sports as 0.0120/1000AE and 0.0442/1000AE for football alone. Arizona, Kentucky, Alabama, Florida, and New Jersey reported the greatest number of EHI’s, not Georgia. While our rates were far higher than those reported in this study, the risk of EHI at the high school level was confirmed with this study. Furthermore, this study also showed that about 60% of all EHI’s reported occurred in August, with 90% of those hown during the preseason period.

While IR’s in our study were higher than those reported by others, the total IR’s were lower than those published by Cooper et al, which focused on five Division I collegiate institutions in the southeast United States. The total IR reported in that study was 4.19/1000 AE, about 0.95/1000 AE higher than that reported in the PRE period and 1.95/1000 AE than that of the POST period. Their HS/HE IR, 1.01/1000 AE, was greater than our HS/HE IR’s, 0.87 and 0.22/1000 AE. Yet their IR and our PRE HS/HE IR were still 0.24/1000 AE different. Because there was such a small difference between this study and ours, we consider the findings to be consistent. This study was more similar to ours in geographic location, but the collegiate athletes in this study were adults who could dissipate heat more readily and maintain a lower core body temperature during activity in the heat than interscholastic participants (youth) in our study. Some of the difference in the rates could be due to the increased intensity at which the collegiate athletes were practicing. Additionally, the collegiate study included data from practices only and not games, while ours analyzed practices and games. In both studies, cramps accounted for the majority of EHI’s. Furthermore, these collegiate players were likely better acclimatized as they had required/suggested practice and conditioning year round where high schools did not.
The magnitude of the impact of WBGT for this study was not easily discernable. Our data do show that IR’s for the POST period were statistically significantly lower than that of the PRE period in the 86-90°F risk stratification category of the ACSM WBGT scale\textsuperscript{11}. The risk for EHI at WBGT’s in this range is considered severe and this is the final category before which cancellation or postponement of activity is advised. The new GHSA policy limited practice duration, decreased the amount of equipment worn, and implemented more and longer rest/water breaks at WBGT’s of this level. Thus, we can assert that the lower IR in the POST period may have been partly attributed to the increased caution and preventative measures taken at WBGT’s of this extreme. Although, we are aware that EHI is multifactorial and mitigation of such cannot be attributed to just one variable.

A major limitation for the current study was the comparison of three years of data collection to one year of data collection. Additional years are required to truly determine if the policy is decreasing risk of EHI. Additionally, while the risk was decreased, it was not entirely eliminated, and the policy may need to be revisited as additional data are collected and analyzed. Another limitation of the study was the variation in the number of schools each year. Schools from whom no data or limited data were received were not used in the analysis and ideally all schools would have participated in all four years of the data collection period. Each year we began with 23 schools participating in the study, with anywhere from two to five schools not submitting adequate data at the end of the season.
CONCLUSION

The risk of EHI was mitigated following the change of the pre-season policy in 2011. The EHI rate was decreased by a factor of 1.45 and, most importantly, risk of HS/HE decreased by a factor of 3.95 for the PRE or POST reporting periods. In terms of ACSM WBGT risk stratification, the only level at which there was a statistically significant difference was at the 86-90°F category, which could have been contributed to the great deal of caution added at WBGT’s of this level in the GHSA heat acclimatization policy. Ultimately, this study confirms the risk of EHI to be multifaceted and schools and health care providers should take the necessary precautions to prevent and adequately treat EHI’s.
Figure 4.1 – QuesTemp 34 Unit (QT-34; 3M Quest Technologies, Oconomowoc, WI) provided to and used by all participant schools.
Figure 4.2 – IR’s per ACSM WBGT risk stratification category. An * indicates that there was a statistically significant difference between the PRE and POST IR.
Table 4.1 – Daily data collection variables

| Environmental Data (WBGT, WB, DB, Globe, HI) | Environment Worn (Full Pads, Shells, Helmet Only, Shorts & T-Shirt) |
| Practice Date | Session Type (Conditioning, Split Practice, Regular Practice, Scrimmage, Game) |
| Session Number (if there were multiple sessions in a single day) | Number of Team Rest/Water Breaks |
| Start and End Time of practice | Intensity of Session |
| Athlete Exposures (AE) (number of athletes participating in any portion of practice) | Did an EHI Occur |
| Session Level (Freshman, Junior Varsity, Varsity) |  |
### Table 4.2 – Variables collected for each exertional heat illness case

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Level</td>
<td></td>
</tr>
<tr>
<td>Date of Injury</td>
<td></td>
</tr>
<tr>
<td>Time of Injury</td>
<td></td>
</tr>
<tr>
<td>Session Number</td>
<td></td>
</tr>
<tr>
<td>Date of Return</td>
<td></td>
</tr>
<tr>
<td>Time of Return</td>
<td></td>
</tr>
<tr>
<td>Practice Session Type</td>
<td></td>
</tr>
<tr>
<td>Whether or not athlete returned in the session</td>
<td></td>
</tr>
<tr>
<td>EHI Type</td>
<td></td>
</tr>
<tr>
<td>If EHI was evaluated by physician</td>
<td></td>
</tr>
<tr>
<td>Acute Treatment</td>
<td></td>
</tr>
<tr>
<td>EHI Condition</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Exercise-Associate Muscle (Heat) Cramps</td>
<td>Heat cramps represent a condition that presents during or after intense exercise sessions as an acute, painful, involuntary muscle contraction</td>
</tr>
<tr>
<td>Heat Syncope</td>
<td>Heat syncope, or orthostatic dizziness, can occur when a person is exposed to high environmental temperatures. This condition is attributed to peripheral vasodilation, postural pooling of blood, diminished venous return, dehydration, reduction in cardiac output, and cerebral ischemia. Usually occurs during the first five days of acclimatization, before the blood volume expands, or in persons with heart disease or those taking diuretics. It often occurs after standing for long periods of time immediately after cessation of activity or after rapid assumption of upright posture after resting or being seated.</td>
</tr>
<tr>
<td>Exercise (Heat) Exhaustion</td>
<td>Exercise (Heat) Exhaustion is the inability to continue exercise associated with any combination of heavy sweating, dehydration, sodium loss, and energy depletion. Other signs and symptoms include pallor, persistent muscular cramps, urge to defecate, weakness, fainting, dizziness, headache, hyperventilation, nausea, anorexia, diarrhea, decreased urine output, and a body-core temperature that generally ranges between 36 degrees C (97F) and 40C (104F)</td>
</tr>
<tr>
<td>Exertional Heat Stroke</td>
<td>Exertional heat stroke is an elevated core temperature (usually &gt;40C [104F]) associated with signs of organ system failure due to hyperthermia. The central nervous system neurologic changes are often the first marker of exertional heat stroke.</td>
</tr>
</tbody>
</table>

Table 4.3 – National Athletic Trainers’ Association definitions for exertional heat illnesses\textsuperscript{14}
<table>
<thead>
<tr>
<th>Region</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Metro</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Central</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Southeast</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Southwest</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td><strong>21</strong></td>
<td><strong>20</strong></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>
Table 4.5 – Percentage of EHI’s and IR (95% CI) by Year.

<table>
<thead>
<tr>
<th></th>
<th>EHI’s</th>
<th>Injury Rate (per 1000 AE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cramps</td>
<td>HS/HE</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>PRE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>65182</td>
<td>144</td>
</tr>
<tr>
<td>2010</td>
<td>68175</td>
<td>163</td>
</tr>
<tr>
<td>2011</td>
<td>67475</td>
<td>158</td>
</tr>
<tr>
<td>Total</td>
<td>200832</td>
<td>465</td>
</tr>
<tr>
<td>POST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>58494</td>
<td>118</td>
</tr>
<tr>
<td>TOTAL</td>
<td>259413</td>
<td>583</td>
</tr>
</tbody>
</table>

PRE: years of data collection prior to the policy change, 2009-2011; POST: years of data collection following the policy change, 2012
AE: Athlete Exposures
Table 4.6 - Percentage of EHI and IR (95% CI) for the first two weeks of the pre-season period.

<table>
<thead>
<tr>
<th></th>
<th>EHI's</th>
<th>Injury Rate (per 1000 AE)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cramps</td>
<td>HS/HE</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>AE</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>PRE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>20803</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>21111</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>22400</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>64314</td>
<td>169</td>
</tr>
<tr>
<td>POST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>14767</td>
<td>14</td>
<td>77.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>79081</td>
<td>183</td>
<td>59.8</td>
</tr>
</tbody>
</table>

| RISK RATIO | 2.77 | 6.85 | 3.67 |

PRE: years of data collection prior to the policy change, 2009-2011; POST: years of data collection following the policy change, 2012

AE: Athlete Exposures


** indicates a statistically significant difference from the POST period with p<0.01

***indicates a statistically significant difference from the POST period with p<0.001
REFERENCES


22. GHSA. *Constitution and By-Laws*. 2011.


CHAPTER 5

THE USE OF WET BULB GLOBE TEMPERATURE AND DISCOMFORT INDEX HEAT STRESS INDICES TO MITIGATE EXERTIONAL HEAT ILLNESS RISK IN GEORGIA HIGH SCHOOL FOOTBALL PLAYERS

ABSTRACT

Context: The wet bulb globe temperature (WBGT) is a commonly used thermal load index (TLI; an alternate to heat stress index in other publications) in the United States, but can be difficult to obtain. The discomfort index (DI) is commonly used in Israel and Europe, is easier to obtain, and may be a good alternative TLI in the mitigation of exertional heat illness (EHI) risk within the athletics setting. Various scales exist using these TLI’s, but no studies have been conducted to confirm their usefulness in Georgia interscholastic football players.

Objectives: To determine the strength of relationship between WBGT and DI and to assess existing HSIS’ ability to stratify EHI risk.

Design: Three-year prospective observational study.

Setting: Georgia Interscholastic football conditioning, practice sessions, and games.

Participants: Georgia Interscholastic football players.

Intervention: Environmental data and injury data were collected and reported for all conditioning sessions, practices, and games in the months of August and September for the years 2009-2011.

Main Outcome Measures: Mean DI and WBGT values were calculated for each session in which an injury occurred. Injury rates (IR) were calculated for each of the selected EHI Heat Stress Index Scales (HSIS’s) to determine if said scales adequately defined risk. IR’s for risk categories of each HSIS of interest were plotted. Within this chart was plotted a line graph demonstrating IR’s for the collected data in 1º increments; an exponential trendline was applied to this data to smoothly represent it.
**Results:** A Pearson correlation showed an $r$ of 0.963 and an $r^2$ value of 0.927. All existing HSIS’s showed the lowest risk of EHI in the least extreme environmental conditions and the highest risk of EHI in either the most extreme or second most extreme category. All current HSIS’s, except the DI scale, appeared to define EHI risk well.

**Conclusions:** The DI shows a very strong positive correlation with WBGT, demonstrating that it may be a good alternative TLI when WBGT is not a feasible option. Furthermore, all of the current HSIS’s, except the DI scale, appear to adequately define EHI risk levels for Georgia interscholastic football players. Further analyses of the data should be conducted to create a scale specific for this population.

**Key Words:** exertional heat illness, heat stress index, wet bulb globe temperature, discomfort index
INTRODUCTION

To mitigate risk of exertional heat illness (EHI), many organizations employ the use of heat stress index scales (HSIS) based on various environmental measures\textsuperscript{1-7}. One of the most widely used and accepted environmental measures is the wet bulb globe temperature (WBGT)\textsuperscript{1-3}. The WBGT is a heat stress index (TLI) that was developed by Yaglou and Minard\textsuperscript{8} in 1957 through research conducted on Marine Corps recruits during training in Parris Island, South Carolina. The WBGT takes into account the dry bulb (DB; ambient temperature), wet bulb (WB; amount of moisture in the air), and black bulb (BB, radiant heat) and is calculated using the following equation:

\[ \text{WBGT} = 0.7\text{WB} + 0.2\text{BB} + 0.1\text{DB} \]

The WB has the greatest bearing on the WBGT value, which is important because evaporation is the most efficient means for heat to escape the body\textsuperscript{9-10}. If the environmental conditions are too humid, with high WB, the body will not dissipate heat as effectively, increasing the risk of EHI. From this research, a HSIS was created and implemented in the military shortly thereafter using the WBGT (Table 5.1).

Since then, a variety of organizations have published HSIS’s for different populations performing different physical activities, in an effort to mitigate EHI risk\textsuperscript{1-3,5,11-13}. However, they have been based on expert opinion and not epidemiologic evidence. Published scales are specific to the pediatric population\textsuperscript{3}, military personnel\textsuperscript{5}, runners\textsuperscript{11,14}, and Georgia high school football athletes\textsuperscript{12} (Table 5.1). In addition to WBGT, the heat index (HI) has been used as a HSIS. While it is easily obtained, it was never designed to evaluate safety for intense physical activity\textsuperscript{35-16}, especially not football players dressed in full equipment in the heat of August (Table 5.2).
Another TLI employed is the discomfort index (DI). While seldom used in the U.S., it is widely used in Europe and Israel\textsuperscript{17}. To date, there are many different versions of the DI, the majority of which use $T_a$ (ambient temperature) and $T_w$ (wet bulb) imputed into a mathematical equation\textsuperscript{18-19}. The DI, much like the WBGT, has been shown to be effective in measuring heat stress\textsuperscript{18, 20-25} and has been in use for more than 40 years. Furthermore, researchers have found the DI to be highly correlated with WBGT with an $r^2$ value of 0.95\textsuperscript{4}. With its high correlation with the WBGT and effectiveness in measuring heat stress, a DI HSIS may be a sound alternative to WBGT S’s. Furthermore, the DI may be advantageous for recreational events such as youth camps and youth tournaments where a WBGT measurement device may not be available. Thus, the purpose of this study was two-fold: 1) to validate the strength of relationship between WBGT and DI; and 2) to evaluate the ability of current HSIS’s (Table 5.1) to stratify risk. We hypothesized that the WBGT and DI would have a strong positive correlation with one another and that current HSIS’s would adequately stratify EHI risk.

**METHODS**

This study was a 3-year prospective observational study. GHSA member High Schools with football teams across the state of Georgia who employed full-time certified athletic trainers (AT’s) were identified for the study. The state was then subdivided into 5 different geographic regions (North, Metro-Atlanta, Central, Southwest, and Southeast) to assure equal representation across geographical areas. Non-identified demographic information was recorded such as height, weight, age, position and playing status on the team (starter, substitute, non-player). Each participating institution reported size and region and the number of years of experience for the head coach, AT, and team physician.
(if the school had one). Because the study was an epidemiological, observational study and researchers were blinded to identifiable participant data, the Institutional Review Board determined minimal risk, and therefore no informed consent was necessary.

Participants

On average, about 20 schools participated per year. Fourteen of the schools were common to all three years of the study. Approximately three schools per years did not complete the data collection process and thus were not used.

Procedures

Prior to the data collection period, an informational meeting with all AT’s from the participating schools was conducted. During this meeting, data collection procedures were detailed. Each AT received a manual containing all procedures for the study, as well as definitions for EHI types (from the NATA EHI position statement\(^2\)), assuring that each AT would classify injuries in the same manner. Instructions on the use of the QuestTemp-34 environmental monitor and its corresponding software were also given to the participants and they were instructed on the proper operation and how to save and transfer the data to the secure website. All data for all schools, athletes, daily practice details, and EHI injury profiles were updated to an online database and monitored throughout the study by the project manager. Annual meetings to refresh participants of guidelines and inform them of any changes were conducted prior to each data collection season.

The AT was instructed to place the QuestTemp-34 adjacent to the field, away from other structures, in direct sunlight 15 minutes prior to the start of practice to allow calibration. Other structures such as a field house, buildings, stadiums, cars, etc. may
cause BB values to be different than those on the playing surface. The unit was shut down 15 minutes after the end of activity. The AT recorded descriptive data for each practice/game session (Table 5.3). If an EHI occurred in any session, the AT uploaded data specific to each case (Table 5.4). Data were collected on the first official practice session (August 1st) to September 30th for each data-reporting year (2009-2011). The same instructions were maintained for the three-year collection period.

**Instrumentation**

The environmental unit used in this study was the QuesTemp 34 Thermal Environment Monitor (QT-34; Quest Technologies, 3M, Oconomowoc, WI). The monitor has the ability to preset temperature type (F or C), recording increments (in minutes), humidity and time. Prior to the data collection period, the unit was set to record in Fahrenheit, at 15-minute intervals. Readings from the unit included WB, DB, BB, WBGT in (for recordings inside), WBGT out (for recordings outside), Humidity, and Heat Index and were recorded and stored internally at each 15-minute interval. Following practice/games, data were uploaded from the unit to a computer using the QuestSuite Professional II Software (3M Quest Technologies, Oconomowoc, WI) and saved as a comma-separated values (CSV) file. These data were then uploaded to the project’s website along with the practice information. A member of the research team checked environmental data and verified it regularly. The project manager would assure that practice intervals matched recorded environmental data, inquire as to missing data, and confirm all data were entered accurately.
Data Reduction and Analysis

All daily environmental data were averaged to obtain a mean value for each session. From these averages, a DI value was calculated for the session during which an EHI occurred using the following equation:

\[ DI = 0.5T_a + 0.5T_w^4 \]

Values for \( T_a \) and \( T_w \) were obtained from raw data collected from the QT-34 units. Descriptive data (frequency, mean, standard deviation (SD)) were calculated for environmental data (WBGT and DI) associated with all injuries that occurred in the 2009, ’10, and ’11 seasons. All individual injuries with environmental data from the data collection period were used in the analysis. Due to the low number of heat syncopes (HS) and heat exhaustions (HE), these two injury types were combined to form the significant injury group (HS/HE).

A Pearson correlation between daily mean DI and daily mean WBGT values was applied to determine strength of association between the two variables. Injury rates (IR) were calculated according to the risk stratification categories delineated by existing HSIS’s: Department of Defense (DOD); American College of Sports Medicine (ACSM) unacclimatized and acclimatized; American Academy of Pediatrics (AAP); GHSA; and DI and then placed in tabular format to determine if any of the existing HSIS’s adequately captured where injuries were occurring. IR’s were calculated by dividing the number of EHI’s by the number of athlete exposures (AE; the number of participants) and multiplying by 1000 to obtain an IR per 1000 AE. IR”s were also calculated for all injury data at 1°F increments and plotted as a line graph on each HSIS chart; an exponential trendline was applied to this data to smoothly represent it. If a portion of the
line fell within the IR for each risk category, the HSIS was determined to adequately stratify risk.

RESULTS

Strength of Relationship Between WBGT and DI

A Pearson correlation between WBGT and DI (Figure 5.1) showed a strong positive relationship with an $r$ value of 0.963 ($p<0.001$) and $r^2$ value of 0.927.

Descriptive Statistics

There were 460 EHI’s that had corresponding environmental data, of which 349 were cramps and 111 HS/HE. The average WBGT for all injuries was 27.3°C (81.2°F) (SD±3.3°C (5.8°F)). The average DI was 27.2°C (80.9°F) (SD±2.6°C (4.8°F)). Three-hundred forty-three of the injuries occurred in August and 116 of them occurred in September. Overall IR for the three-year period was 2.43/1000AE, for cramps was 1.84/1000AE, and for HS/HE was 0.59/1000AE.

Injury Rates by Heat Stress Index Scale

The ACSM Unacclimatized and Acclimatized Scale showed the highest overall IR (by 0.02/1000 AE) in the $\leq 25.6$ºC (78ºF) category and highest HS/HE in the 30-32.2ºC (86.01-90.0ºF) range (Table 5.4, Figure 5.2). The lowest overall IR for this HSIS was noted in the $\geq 32.21$ºC (90.01ºF) category and the lowest HS/HE in the $\leq 25.6$ºC (78ºF) category. Some portion of the exponential trendline fell within each risk stratification category of this scale (Figure 5.2).

The AAP Scale showed the highest overall IR in the 24.0-25.9ºC (75-78.6ºF) range and highest HS/HE in the $\leq 29$ºC (85ºF) range (Table 5.4). The lowest overall IR for this HSIS was noted in the $\leq 24$ºC (75ºF) range and the lowest HS/HE in the 24.0-
25.9°C (75-78.6°F) range. Some portion of the exponential trendline fell within each risk stratification category of this scale, except in the 24.0-25.9°C (75.01-78.6°F) category where the IR trendline was higher than that of the category (Figure 5.3).

The DOD Scale showed the highest overall IR in the 31.1-32.2°C (88-89.9°F) range and highest HS/HE in the same range (Table 5.4, Figure 5.4). The lowest overall IR for this HSIS was seen in the 27.8-29.4°C (82-84.8°F) range and the lowest HS/HE in the 25.6-27.7°C (78-81.9°F) range. Some portion of the exponential trendline fell within each risk stratification category of this scale (Figure 5.4).

The GHSA Scale showed the highest overall IR in the 30.6-32.2°C (87-89.9°F) range and highest HS/HE in the same range (Table 5.4, Figure 5.5). Both the lowest overall IR and lowest HS/HE for this HSIS was seen in the ≥33.31°C (92.01°F) range. Some portion of the exponential trendline fell within each risk stratification category of this scale (Figure 5.5).

The Israeli DI Scale showed both the highest overall IR and highest HS/HE in the ≥28.01°C (82.41°F) range (Table 5.4, Figure 5.6). Both the lowest overall and lowest HS/HE for this HSIS was seen in the ≤24°C (75.2°F) range. The only category in which the exponential trendline fell within the DI scale data was in the ≥28.01°C (82.41°F) category (Figure 5.6).

**DISCUSSION**

Overall, the study showed DI and WBGT strongly correlated with one another (Figure 5.1), indicating that DI may be a good alternative TLI when obtaining WBGT is not a feasible option. Furthermore, our data showed current HSIS’s to stratify risk well (Table 5.4) – as WBGT and/or DI increase, so does the IR. While the existing HSIS’s
seem to be a good indicator of risk by virtue of IR values, they are not based on evidence collected in an athletic setting. Therefore our data may be helpful in future creation of an HSIS based on data collected in the athletic setting.

**Agreement between WBGT and DI**

WBGT was significantly (p<0.0001) and positively correlated with DI (Figure 5.1), supporting our hypothesis. Our r value is comparable to the correlation between WBGT and the modified discomfort index (MDI) as shown by Moran *et al*\textsuperscript{15, 24} in a study conducted by the U.S. Army Research Institute of Environmental Medicine. The MDI was presented by Moran *et al* as a more easily attainable alternative to WBGT for use in the military (as a WBGT measuring device can be cumbersome for military personnel) and is calculated as follows:

\[
MDI = 0.30T_a + 0.75T_w
\]

Our study confirms that a measure not using the BB is still highly correlated with WBGT and can be used in situations where use of a WBGT monitor is not ideal or available. This confirmation could be paramount in establishing a new scale using DI as opposed to WBGT because of the strong relationship with each other and evidence based off of data collected in an athletic setting. Furthermore, a research study conducted by Hansen\textsuperscript{26} showed the DI able to predict physiological strain in basketball and squash players. Data from his study showed DI to have a statistically significant correlation with core body temperature, heart rate, and sweat rate. This is of utmost importance because some may discount the DI because it does not take into account radiant heat (BB), but this study confirms that there is some physiological significance associated with DI.
The WBGT has been the primary criterion for establishing HSIS's\textsuperscript{1-3, 5, 12}, but a simpler environmental measure could make the values more accessible and potentially increase compliance by members if organizations employ policies using DI. Currently, the WBGT is not easily accessible unless a WBGT monitor is in use. Many WBGT monitors are available on the market, but to date, there have been no studies published confirming the validity of these instruments with the recommendation scientific specifications for WBGT measurement. Furthermore, the seemingly more reliable instruments can cost several thousand dollars, money that many organizations, especially smaller ones such as high schools and parks and recreation leagues, don’t have at their disposal. WBGT values are not available from the National Weather Service, the National Oceanic and Atmospheric Association (NOAA), or other well-known and readily accessible organizations. Because the DI is solely based off of ambient temperature and humidity, it would be easily reported by meteorological societies. Therefore, a HSIS using DI may be easily implemented by organizations and institutions across the U.S and other countries who may not have access to a WBGT monitor. Furthermore, this scale may be of special interest to entities that may not have access to a WBGT monitor, such as recreational organizations and those who host athletics camps and tournaments that only occur a few times annually.

**Evaluating Risk by HSIS**

All current HSIS’s evaluated showed some promise for mitigation of risk in Georgia high school football players except for the DI scale. The DI HSIS showed the least potential for use in Georgia interscholastic football players, as the risk categories were wide and did not appear to stratify risk. Furthermore, the 20-fold increase in risk
between the 24-28°C (75.21-82.39°F) and ≥28°C (82.40°F) risk levels indicate that, should DI be used, several more levels of risk need to be added to adequately mitigate risk in this population.

Each HSIS of interest, except for the Israeli DI scale showed a drop in the IR in the most extreme risk category (Table 5.4); we hypothesize that this decrease is due to the decrease in AE during extreme conditions and feel this indicates that teams are taking appropriate measures to mitigate risk during intense environmental conditions. Another explanation for the decrease in IR may be due to the alteration in activity. For instance, at the most extreme risk category in the GHSA HSIS, practice is limited to one hour with no protective equipment and no conditioning and requires 20 minutes of water breaks throughout that time period\textsuperscript{12}. These are preventative measures that contribute to a decrease in the number of EHI’s.

We expected to see the IR increase as environmental risk factors increased when applied to existing HSIS’s. However, our data reflect there is not an upward trend in IR throughout the entire HSIS, except in the DI. This is likely due to total IR being driven by heat cramps, an event that some may argue is not significant because it is not life threatening. Exertional cramping, however, is often considered a marker of dehydration which is potentially a marker for decreased cardiovascular function\textsuperscript{27}. Furthermore, cramps occur in a wide array of environmental conditions, even in well-controlled internal environments such as basketball arenas\textsuperscript{28}. When eliminating cramps and examining solely HS/HE (significant injuries), the Unacclimatized ACSM, Acclimatized ACSM, and DOD HSI’s all show upward trends until the category of greatest risk, where the IR falls off. This, in all likelihood, is due to a vast decrease in the AE’s at those
extremes, leading us to believe that the majority of participant schools in our study, likely in response to policies and oversight by a full time AT, were not conducting practices during times of extreme risk. The GHSA HSIS shows an upward trend through the first three categories and a subsequent drop in the remaining two categories. The GHSA HSIS allows participation up to 33.3°C (92°F), beyond the upper limit recommended by ACSM and DOD\textsuperscript{1,5}. Practices at this level are limited to 1 hour, with no protective equipment worn, no conditioning allowed, and at least 20 minutes of rest breaks throughout the hour. Moreover, just as with the previously mentioned scales, athlete exposures were very low at these levels showing minimal activity in extreme conditions.

The AAP HSIS shows similar IR’s in the 2 lowest risk categories and a gradual upward trend for the remaining two risk categories. Unlike the previously mentioned scales, there is no drop-off at the end. This is likely due to the low upper limit of the extreme risk category. In like manner, the Israeli DI HSIS shows essentially a flat-line for the first two risk categories, likely due to their low environmental values. From the second to the third category there is a twenty-fold increase (0.07 to 1.46/1000 AE). Again, the upper limit DI is set to 28°C (82.4°F), extremely low in comparison to the upper limits of the Unacclimatized and Acclimatized ACSM and the DOD Scale. Thus, for both scales, there are undoubtedly more injuries occurring with less stringent environmental conditions and greater numbers of athletes participating, both of which contribute to the 20-fold increase from the second category to the third.

Our hypothesis that current HSIS’s capture risk well was confirmed by our data. Overall, current scales seem to capture risk well. Many of the scales show the lowest risk in the least extreme environmental conditions and a drop-off in IR at the most extreme
conditions, which our data show is a mathematical anomaly as a result of fewer AE”s in these ranges. Thus, we conclude that use of any of the existing scales will aid in the mitigation of EHI risk.

Limitations

Because there is no existing literature on the construction of current HSIS’s, we had to use our best judgment via graphs and exponential trendlines to determine if current HSIS’s stratify risk well. A more scientific method of comparison is needed to better answer our research questions. Further research needs to be conducted to best mitigate EHI risk in Georgia interscholastic football players.

Future Research

With our data showing the strong relationship between WBGT and DI, creation of a DI scale specific to football could prove to be useful to organizations across the world. More in-depth study is necessary to create the soundest scale to be put into practice.

CONCLUSION

This study confirmed that WBGT and DI are strongly correlated with each other and that DI may be a good alternative TLI when WBGT is not readily available. Based on IR’s from this 3-year study, the majority of the existing scales do a clinically acceptable job at capturing where EHI risk occurs and likely help mitigate risk for activities that take place in the heat. However, evidence-based scales may mitigate risk further. Because of the strong correlation between WBGT and DI, and the DI being a simpler and more easily obtainable measure, it may be an acceptable alternative in settings where a WBGT monitor is not feasible. Further studies are needed to determine
if the DI is an appropriate measure and if its use would be appropriate in the athletic setting.
Table 5.1 – Heat stress index scales and guidelines for physical activity in the heat. Department of Defense WBGT Stages and Guidelines for Hard Work Load

<table>
<thead>
<tr>
<th>Temperature Range (WBGT)</th>
<th>Work/Rest Cycle</th>
<th>Water Intake Qt/Hr</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤27.7°C (81.9°F)</td>
<td>40/20 min</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>27.71-29.4°C (82 – 84.9°F)</td>
<td>30/30 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>29.41-31.1°C (85 – 87.9°F)</td>
<td>30/30 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>31.2-32.2°C (88 – 89.9 ºF)</td>
<td>20/40 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>≥32.3°C (90°F)</td>
<td>10/50 min</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

American College of Sports Medicine levels for modification or cancellation of workouts or athletic competition in healthy adults

<table>
<thead>
<tr>
<th>Unacclimatized</th>
<th>WBGT</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤10.0°C (50°F)</td>
<td>Normal Activity</td>
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</tr>
<tr>
<td>10.0-18.3°C (50.1-65.0°F)</td>
<td>Normal Activity</td>
<td></td>
</tr>
<tr>
<td>18.4-22.2°C (65.1-72.0°F)</td>
<td>Increase the work:rest ratio. Monitor fluid intake</td>
<td></td>
</tr>
<tr>
<td>22.3-25.6°C (78.0°F)</td>
<td>Increase the rest:work ratio and decrease total duration of activity</td>
<td></td>
</tr>
<tr>
<td>25.7-27.8°C (78.1-82.0 °F)</td>
<td>Increase the rest:work ratio, decrease intensity and total duration of activity</td>
<td></td>
</tr>
<tr>
<td>27.9-30°C (82.1-86.0 °F)</td>
<td>Increase the work:rest ratio to 1:1, decrease intensity and total duration of activity. Limit intense exercise. Watch at-risk individuals carefully.</td>
<td></td>
</tr>
<tr>
<td>30.1-32.2°C (86.1-90.0 °F)</td>
<td>Cancel or stop practice and competition.</td>
<td></td>
</tr>
<tr>
<td>≥32.3°C (90.1 °F)</td>
<td>Cancel exercise</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acclimatized</th>
<th>WBGT</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤10.0°C (50°F)</td>
<td>Normal Activity</td>
<td></td>
</tr>
<tr>
<td>10.0-18.3°C (50.1-65.0°F)</td>
<td>Normal Activity</td>
<td></td>
</tr>
<tr>
<td>18.4-22.2°C (65.1-72.0°F)</td>
<td>Normal Activity</td>
<td></td>
</tr>
<tr>
<td>22.3-25.6°C (72.1-78.0°F)</td>
<td>Normal activity. Monitor fluid intake.</td>
<td></td>
</tr>
<tr>
<td>25.7-27.8°C (78.1-82.0 °F)</td>
<td>Normal activity. Monitor fluid intake.</td>
<td></td>
</tr>
<tr>
<td>27.9-30°C (82.1-86.0 °F)</td>
<td>Plan intense or prolonged exercise with discretion, watch at-risk individuals carefully</td>
<td></td>
</tr>
<tr>
<td>30.1-32.2°C (86.1-90.0 °F)</td>
<td>Limit intense exercise and total daily exposure to heat and humidity, watch for early signs and symptoms</td>
<td></td>
</tr>
<tr>
<td>≥32.3°C (90.1 °F)</td>
<td>Cancel exercise, uncompensable heat stress exists for all athletes</td>
<td></td>
</tr>
</tbody>
</table>
### American Academy of Pediatrics restraints on activities with heat stress

<table>
<thead>
<tr>
<th>WBGT</th>
<th>Restraints on Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤24°C (75°F)</td>
<td>All activities allowed, but be alert for prodromes of heat-related illness in prolonged events</td>
</tr>
<tr>
<td>24.0-25.9°C (75.01-78.6°F)</td>
<td>Longer rest periods in the shade; enforce drinking every 15 minutes</td>
</tr>
<tr>
<td>26-29°C (79-84.99°F)</td>
<td>Stop activity if unacclimatized persons and other person with high risk; limit activities of all others (disallow long-distance races, cut down further duration of other activities)</td>
</tr>
<tr>
<td>≥29°C (85°F)</td>
<td>Cancel all athletic activities</td>
</tr>
</tbody>
</table>

### Georgia High School Association guidelines for activities in the heat

<table>
<thead>
<tr>
<th>WBGT</th>
<th>Activity and Rest Break Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤27.8°C (82 °F)</td>
<td>Normal activities – Provide at least three separate rest breaks each hour with a minimum duration of 3 hours each during each workout</td>
</tr>
<tr>
<td>27.8-30.5°C (82.01-86.9 °F)</td>
<td>Use discretion for intense prolonged exercise, watch at-risk players carefully. Provide at least 3 separate rest breaks each hour with a minimum duration of 4 minutes each</td>
</tr>
<tr>
<td>30.6-32.1°C (87.0-89.9°F)</td>
<td>Maximum practice time is 2 hours. For Football: players are restricted to helmet, shoulder pads, and shorts during practice, and all protective equipment must be removed during conditioning activities. For All Sports: Provide at least four separate rest breaks each hour with a minimum duration of 4 minutes each</td>
</tr>
<tr>
<td>32.2-33.3°C (90.0-92.0 °F)</td>
<td>Maximum practice time is 1 hours. For Football: no protective equipment may be worn during practice and there may be no conditioning activities. For All Sports: There must be 20 minutes of rest breaks distributed throughout the hour of practice</td>
</tr>
<tr>
<td>≥33.3°C (92.01°F)</td>
<td>No outdoor workouts. Delay practice until a cooler WBGT is reached</td>
</tr>
<tr>
<td>DI</td>
<td>Level</td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
</tr>
<tr>
<td>≤24°C (75.2°F)</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>24-28°C (75.21-82.39°F)</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>≥28°C (82.40°F)</td>
<td>Severe</td>
</tr>
</tbody>
</table>
Table 5.2 – Assumptions on which the heat index is based\textsuperscript{15-16}

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual measuring 1.7m and with a mass of 67kg</td>
<td>Skin resistance to moisture transfer</td>
</tr>
<tr>
<td>Effective radiation area between 0.79 and 0.85</td>
<td>Clothing resistance to heat transfer</td>
</tr>
<tr>
<td>Clothed in long pants and a short sleeve shirt</td>
<td>Clothing resistance to moisture transfer</td>
</tr>
<tr>
<td>Core body temperature of 37°C (98.6°F)</td>
<td>Surface radiation</td>
</tr>
<tr>
<td>Walking at 1.4 m s\textsuperscript{-1} Base wind speed of 2.5 m s\textsuperscript{-1}</td>
<td>Surface convection</td>
</tr>
<tr>
<td>Heat loss accounted for by the lungs (ventilation)</td>
<td>Surface resistance to heat transfer</td>
</tr>
<tr>
<td>Skin resistance to heat transfer</td>
<td>Surface resistance to moisture transfer</td>
</tr>
</tbody>
</table>
Table 5.3 – Heat study data collection variables

**Variables Collected Daily by Athletic Trainers**

<table>
<thead>
<tr>
<th>Environmental Data (WBGT, WB, DB, Globe, HI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice Date</td>
</tr>
<tr>
<td>Session Number</td>
</tr>
<tr>
<td>Start and End Time</td>
</tr>
<tr>
<td>Athlete Exposures (AE)</td>
</tr>
<tr>
<td>Session Level (Freshman, Junior Varsity, Varsity)</td>
</tr>
<tr>
<td>Equipment Worn (Full Pads, Shells, Helmet Only, Shorts &amp; T-Shirt)</td>
</tr>
<tr>
<td>Session Type (Conditioning, Split Practice, Regular Practice, Scrimmage, Game)</td>
</tr>
<tr>
<td>Number of Team Rest/Water Breaks</td>
</tr>
<tr>
<td>Intensity of Session</td>
</tr>
<tr>
<td>Whether or Not an EHI Occurred</td>
</tr>
</tbody>
</table>

**Variables Collected for Each Exertional Heat Illness Case**

<table>
<thead>
<tr>
<th>Team Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Injury</td>
</tr>
<tr>
<td>Time of Injury</td>
</tr>
<tr>
<td>Session Number</td>
</tr>
<tr>
<td>Date of Return</td>
</tr>
<tr>
<td>Time of Return</td>
</tr>
<tr>
<td>Practice Session Type</td>
</tr>
<tr>
<td>Whether or not athlete returned in the same session</td>
</tr>
<tr>
<td>EHI Type</td>
</tr>
<tr>
<td>If EHI was evaluate by physician</td>
</tr>
<tr>
<td>First Aid Treatment</td>
</tr>
</tbody>
</table>

*Where the following abbreviations indicate:*

- WBGT = wet bulb globe temperature
- WB = wet bulb
- DB = dry bulb
- HI = heat index
- EHI = exertional heat illness*
Table 5.4 – Frequencies, Percentiles, and IR’s for each heat stress index scale of interest.

<table>
<thead>
<tr>
<th>Heat Stress Index Scale</th>
<th>Cramps</th>
<th>HS/HE</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AE n</td>
<td>%</td>
<td>IR n</td>
</tr>
<tr>
<td><strong>Department of Defense Risk Scale</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBGT&lt;sup&gt;61&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤27.7ºC (81.9ºF)</td>
<td>100028</td>
<td>221</td>
<td>88.0</td>
</tr>
<tr>
<td>27.71-29.4ºC (82 – 84.9ºF)</td>
<td>37233</td>
<td>43</td>
<td>66.2</td>
</tr>
<tr>
<td>29.41-31.1ºC (85 – 87.9ºF)</td>
<td>27822</td>
<td>52</td>
<td>60.5</td>
</tr>
<tr>
<td>31.2-32.2ºC (88 – 89.9 ºF)</td>
<td>11282</td>
<td>20</td>
<td>54.1</td>
</tr>
<tr>
<td>≥32.3ºC (90ºF)</td>
<td>12579</td>
<td>13</td>
<td>61.9</td>
</tr>
</tbody>
</table>

| **American College of Sports Medicine Scale for Unacclimatized and Acclimatized Individuals** |        |       |       |       |       |       |
| WBGT<sup>11</sup>        |        |       |       |       |       |       |
| ≤25.6ºC (78.0ºF)         | 100028 | 157   | 94.0  | 2.80  | 10    | 6.0   | 0.18  | 167   | 2.98  |
| 25.7-27.8ºC (78.1-82.0 ºF) | 58305  | 64    | 76.2  | 1.45  | 20    | 23.8  | 0.45  | 84    | 1.91  |
| 27.9-30ºC (82.1-86.0 ºF) | 18243  | 67    | 63.2  | 1.38  | 39    | 36.8  | 0.81  | 106   | 2.19  |
| 30.1-32.2ºC (86.1-90.0 ºF) | 6800   | 48    | 58.5  | 1.70  | 34    | 41.5  | 1.20  | 82    | 2.90  |
| ≥32.3ºC (90.1 ºF)        | 5779   | 13    | 61.9  | 1.03  | 8     | 38.1  | 0.64  | 21    | 1.67  |

| **American Academy of Pediatrics Scale** |        |       |       |       |       |       |
| WBGT<sup>15</sup>        |        |       |       |       |       |       |
| ≤24ºC (75ºF)              | 31732  | 54    | 90.0  | 1.70  | 6     | 10.0  | 0.19  | 60    | 1.89  |
| 24.0-25.9ºC (75.01-78.6 ºF) | 33956  | 113   | 96.6  | 3.33  | 4     | 3.4   | 0.12  | 117   | 3.45  |
| 26-29ºC (79-84.99 ºF)     | 71489  | 97    | 70.8  | 1.36  | 40    | 29.2  | 0.56  | 137   | 1.92  |
| ≥29ºC (85ºF)              | 51951  | 85    | 59.0  | 1.64  | 59    | 41.0  | 1.14  | 144   | 2.77  |

| **Georgia High School Association Risk Scale** |        |       |       |       |       |       |
| WBGT<sup>16</sup>        |        |       |       |       |       |       |
| ≤27.8ºC (82 ºF)          | 100028 | 221   | 88.0  | 2.21  | 30    | 12.0  | 0.30  | 251   | 2.51  |
| 27.8-30.5ºC (82.01-86.9 ºF) | 58305  | 81    | 65.3  | 1.39  | 43    | 34.7  | 0.74  | 124   | 2.13  |
| 30.6-32.1ºC (87.0-89.9ºF) | 18243  | 34    | 53.1  | 1.86  | 30    | 46.9  | 1.64  | 64    | 3.51  |
| 32.2-33.3ºC (90.0-92.0 ºF) | 6800   | 10    | 66.7  | 1.47  | 5     | 33.3  | 0.74  | 15    | 2.21  |
| ≥33.3ºC (92.01ºF)        | 5779   | 3     | 50.0  | 0.52  | 3     | 50.0  | 0.52  | 6     | 1.04  |

| **Israel Guidelines**<sup>17</sup> |        |       |       |       |       |       |


<table>
<thead>
<tr>
<th>DI</th>
<th>n</th>
<th>%</th>
<th>IR</th>
<th>n</th>
<th>%</th>
<th>IR</th>
<th>n</th>
<th>%</th>
<th>IR</th>
<th>n</th>
<th>%</th>
<th>IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤24°C (75.2°F)</td>
<td>34933</td>
<td>48</td>
<td>88.9</td>
<td>1.37</td>
<td>6</td>
<td>11.1</td>
<td>0.17</td>
<td>54</td>
<td>1.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-28°C (75.21-82.39°F)</td>
<td>82207</td>
<td>183</td>
<td>83.2</td>
<td>2.24</td>
<td>37</td>
<td>16.8</td>
<td>0.45</td>
<td>220</td>
<td>2.69</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥28°C (82.40°F)</td>
<td>71988</td>
<td>118</td>
<td>63.4</td>
<td>1.63</td>
<td>68</td>
<td>36.6</td>
<td>0.94</td>
<td>186</td>
<td>2.57</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Where WBGT is wet bulb globe temperature, DI is discomfort index, n is number of injuries in that range, % is percent of injuries in that category (cramps or heat syncope/heat exhaustion (HS/HE), and IR is injury rate per 1000 athlete exposures (AE).
Figure 5.1 – Correlation between WBGT and DI. $r=0.963$, $r^2=0.927$, $p=0.00$. 

$R^2$ Linear $= 0.927$
Figure 5.2 – Injury rates per category in the American College of Sports Medicine heat stress index scale. The - - - line represents the incremental data line smoothed to an exponential trendline.
Figure 5.3 - Injury rates per category in the American Academy of Pediatrics heat stress index scale. The - - - line represents the incremental data line smoothed to an exponential trendline.
Figure 5.4 - Injury rates per category in the Department of Defense heat stress index scale. The - - - line represents the incremental data line smoothed to an exponential trendline.
Figure 5.5 - Injury rates per category in the Georgia High School Association heat stress index scale. The - - - line represents the incremental data line smoothed to an exponential trendline.
Figure 5.6 - Injury rates per category in the Israeli heat stress index scale. The --- line represents the incremental data line smoothed to an exponential trendline.
REFERENCES


12. GHSA. *Constitution and By-Laws.* 2012.


19. Sohar E, Tennenbaum J, Robinson N. A comparison of the cumulative discomfort index (Cum DI) and cumulative effective temperature (Cum ET), as obtained by meteorological data. *Biometeorol, Tromp SW (Ed.)*. 1962: 395-400.


CHAPTER 6

CONCLUSION

The overarching theme of our aims was to help mitigate the risk of EHI in interscholastic football players in the state of Georgia. Data and results from this study have and will continue to help mitigate risk in this population. Furthermore, we are confident that results from the current study will assist other associations and organizations in endeavors to mitigate risk in the respective populations for whom they are responsible. Data from the first three years of this study were the driving factor for heat acclimatization policy development and adoption by the Georgia High School Athletic Association. The data driven scale was the beginning of mitigation of EHI risk and safer participation for high school athletes across the state.

Our data demonstrated a lower incidence of EHI for the POST period of data collection (2012) when compared to the PRE period. The EHI rate was decreased by a factor of 1.45 and, most importantly, risk of HS/HE decreased by a factor of 3.95 from the PRE period. A statistically significant difference was only seen in the 86-90°F ACSM WBGT HSIS, but it is impossible to assign cause of the mitigation of risk to this one variable. Ultimately, this study confirms the risk of EHI to be multifaceted and schools and health care providers should take the necessary precautions to prevent and adequately treat EHI’s.

Furthermore, our study confirmed that WBGT and DI are strongly correlated with each other and that DI may be a good alternative TLI when WBGT is not readily available. Based on IR’s from this 3-year study, the majority of the existing scales do a
clinically acceptable job at capturing where EHI risk occurs and likely help mitigate risk for activities that take place in the heat. However, evidence-based scales may mitigate risk further. DI was highly correlated to WBGT, and is a simpler and more easily obtainable measure. DI may be an acceptable alternative in settings where a WBGT monitor is not feasible. Further studies are needed to determine if the DI is an appropriate measure and if its use would be appropriate in the athletic setting.

Ultimately, we feel that continued research and endeavors to establish the best possible HSIS and adopt the best practices in relation to heat acclimatization policies will continue to mitigate risk of EHI. Our study also served to verify that EHI risk is multifaceted and the other facets of the injury need to be studied in further details along with environmental factors in an endeavor to further mitigate risk.
REFERENCES


16. GHSA. *Constitution and By-Laws.* 2012.


25. GHSA. *Constitution and By-Laws.* 2011.


75. Sohar E, Tennenbaum J, Robinson N. A comparison of the cumulative discomfort index (Cum DI) and cumulative effective temperature (Cum ET), as obtained by meteorological data. *Biometeorol, Tromp SW (Ed.).* 1962:395-400.


APPENDIX A

2011-2012 GHSA Constitution & Bylaws

Section 2 (pg 38)

2.67 Practice Policy for Heat and Humidity:

(a) Each member school shall have a written policy for conducting practices in all sports during times of extremely high heat and/or humidity that will be signed by each head coach and distributed to all players.

The policy shall include, but is not limited to:

(1) The time of day the practices are to be scheduled at various heat/humidity levels

(2) The ratio of workout time to time allotted for rest and hydration at various heat/humidity levels

(3) The heat/humidity levels that will result in outdoor practices being terminated

(b) A scientifically approved instrument that measures the heat index must be utilized at each practice to ensure that the written policy is being followed properly.

(c) Schools may determine the heat/humidity levels using either wet bulb globe temperature readings or heat index readings.

Section 5 (pg 65)

D. Football practice shall begin no earlier than August 1st.

1. In the first five days, at least two days must have practice with players dressed in shorts, helmets, shoulder pads, mouthpieces and shoes only. The other three days MAY
include practices that have players in full pads, but no more than two consecutive days of
the first five days may have full pads in use. Coaches are not required to have any
practices in full pads during the first five days of practice.

2. At school workouts from the end of school in the spring until the first day of practice
in the fall, players may wear no other protective football equipment except helmets and
mouthpieces for all voluntary workouts and passing league games. NOTE: Any
modification of this equipment rule in summer camp requires approval of the Executive
Director.
APPENDIX B

2012-2013 GHSA Constitution & Bylaws

2.67 Practice Policy for Heat and Humidity

(a) Schools must follow the statewide policy for conducting practices and voluntary conditioning workouts in all sports during times of extremely high heat and/or humidity that will be signed by each head coach at the beginning of each season and distributed to all players and their parents or guardians. The policy shall follow modified guidelines of the American College of Sports Medicine in regards to:

1. The scheduling of practices at various heat/humidity levels
2. The ratio of workout time to time allotted for rest and hydration at various heat/humidity levels
3. The humidity levels that will result in practice being terminated.

(b) A scientifically-approved instrument that measures the Wet Bulb Globe Temperature must be utilized at each practice to ensure that the written policy is being followed properly (Table 1)
Table 1 – GHSA WBGT Scale

<table>
<thead>
<tr>
<th>WBGT</th>
<th>ACTIVITY GUIDELINES AND REST BREAK GUIDELINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNDER</td>
<td></td>
</tr>
<tr>
<td>82.0</td>
<td>Normal activities – Provide at least three separate rest breaks each hour with a minimum duration of 3 hours each during each workout</td>
</tr>
<tr>
<td>82.0-86.9</td>
<td>Use discretion for intense prolonged exercise, w/At-risk players carefully. Provide at least 3 separate rest breaks each hour with a minimum duration of 4 minutes each</td>
</tr>
<tr>
<td>87.0-89.9</td>
<td>Maximum practice time is 2 hours. For Football: players are restricted to helmet, shoulder pads, and shorts during practice, and all protective equipment must be removed during conditioning activities. For All Sports: Provide at least four separate rest breaks each hour with a minimum duration of 4 minutes each</td>
</tr>
<tr>
<td>90.0-92.0</td>
<td>Maximum practice time is 1 hour. For Football: no protective equipment may be worn during practice and there may be no conditioning activities. For All Sports: There must be 20 minutes of rest breaks distributed throughout the hour of practice</td>
</tr>
<tr>
<td>Over 92.0</td>
<td>No outdoor workouts. Delay practice until a cooler WBGT is reached</td>
</tr>
</tbody>
</table>

(c) Practice are defined as: the period of time that a participant engages in a coach-supervised, school-approved sport or conditioning related activity. Practices are timed from the time the players report to the practice or workout area until players leave the area.

(d) Conditioning activities include such things as weight training, wind-sprints, timed runs for distance, etc., and may be a part of the practice time or included in “voluntary workouts.”

(e) A walk-through is not a part of practice time regulation, and may last no longer than one hour. This activity may not include conditioning activities or contact drills. No protective equipment may be worn during a walk-through.
(f) Rest breaks may not be combined with any other type of activities and players must be given unlimited access to hydration. These breaks must be held in a “cool zone” where players are out of direct sunlight.

Section 5 (pg 66-67)

D. Football practice may begin five consecutive weekdays prior to August 1st.

1. In the first five days of practice for any student, the practice may not last longer than two (2) hours, and the student may wear no other protective football equipment except helmet and mouthpieces. NOTE: The time for a session shall be measured from the time the players report to the practice or workout area until they leave that area.

2. Beginning August 1st, any student may practice in full pads and may practice a maximum of two times in a single calendar day under the following stipulations:
   
   (a) A student must have participated in five conditioning practices wearing no other protective football equipment except helmet and mouthpieces before being allowed to practice in full pads.

   (b) If two workouts are held in a single calendar day:

   (1) No single session may last longer than three (3) hours.

   (2) The total amount of time in the two practices shall not exceed five (5) hours.

   (3) There must be at least a three-hour time of rest between sessions.

   (4) There may not be consecutive days of two-a-day practice sessions. All double-session days must be followed by a single-session day or a day off.

   (c) These procedures are derived from recommendations created by the Inter-


3. From the end of school in the spring until the first day of preseason practice, players may wear no other protective football equipment except helmets and mouthpieces for all voluntary workouts and passing league games. Institutional heat policies are also in effect for voluntary workouts supervised by school personnel.
APPENDIX C – Participant Instruction Manual

The Risk of Exertional Heat Injuries in Interscholastic Football

Funded by the NATAREF

Instruction Manual
I. Quest Environmental Monitor – Set-up

a. **Prior to using the unit make sure your unit’s battery is fully charged** A discharged battery requires an overnight charge of 16 hours. Leaving the AC adapter plugged in for extended lengths of time or when operating the unit will not harm the rechargeable batteries.

b. Fill the reservoir with distilled water and the unit should be ready to collect data.

c. Place the unit on a tripod which is approximately 3.5 feet off of the ground. Schools are responsible for purchasing their own tripod.

d. The monitor is to be set in a location close to the practice field. The location should be near where most of the practice is taking place. **Allow unit to stabilize for 10 minutes prior to starting data collection.**

e. Set recording program to record environmental data at 15-minute intervals.

   a. Press and hold the I/O or Enter button to turn on unit

   b. Use and to select setup

   c. Press I/O or Enter

   d. Scroll through options with and until you see “log rate”

   e. Press I/O or Enter until you see “15 min”
f. Press **Run/Stop** to exit to the main screen

f. Start recording environmental data 15 minutes prior to starting practice and stop when the team leaves the field (everybody is in the locker room).

   a. Begin a session by pressing the **Run/Stop** key from either the menu or **VIEW** mode. An asterisk in the lower right corner indicates the run mode.

   b. To end a session, press the **Run/Stop** key again

   c. To shut off the monitor, press and hold **I/O** until a countdown is seen and it expires, shutting off the unit.

g. Environmental data is to be recorded during practice and games

h. **For any technological assistance please call one of the following:**
   a. Jake Resch 706.542.3273 or e-mail at jeresch@uga.edu
   b. Mike Ferrara 706.542.4801 or e-mail at mferrara@uga.edu
   c. Bud Cooper 706.542.6463 or e-mail at cooperb@uga.edu

   For any further technological assistance call Randy Sleggs at Quest Technologies at 1.800.245.0779 at ext. 123

II. **Computer Software:**

d. Insert the **QuestSuite Pro II** disk into your computer CD-ROM

e. If an installation screen does not appear automatically, click on **My Computer** and then click on the **CD-ROM Drive**

f. Click “**OK**” to choose **English** as your default language

g. Click “**NEXT**”

j. **Enter Organization (Optional)**

h. **I ACCEPT THE TERMS IN THE LICENSE AGREEMENT”**

i. Enter a User Name
k. Choose whether “anyone” may use this software or “only for me”

l. Enter your serial number (YOUR SERIAL NUMBER IS LOCATED ON THE CD CASE AND STARTS WITH “CP”)

m. Click “Next”

n. Click “Install”

o. Click “Finish”

p. Restart your computer

III. Creating A Practice Session
   File

a. Connect the included computer cable to your Quest Unit via the Data Port

b. The other end of the computer cable needs to be attached to a COM1 port on the back of your computer.

c. Open QuestSuite Professional II located on your desktop

d. Click on HEAT
e. Click on the QT -34/36 Tab

f. Double Click on the name of your device (If you named it or its serial number
g. Next Click on **Retrieve Data**

h. After data has been retrieved it should appear in the **Downloaded** section on the left side of your screen

i. After clicking on the (+) next to **Downloaded** the data of your session or sessions should appear, double click on it.
j. Your screen should now look like this

k. Click on the (+) sign next to the data of your practice session

l. Click on the subtitle **Study**
m. Next click on the screen with a green (+) next to it in the upper right corner of your screen and choose **LOGGED DATA TABLE**

n. Your screen should now look like this
o. Click on the following variables in the order suggested by the website under the daily calendar category. (Click on the ? to see the instructions)

p. It is EXTREMELY IMPORTANT TO CLICK ON THE VARIABLES IN THE ORDER SUGGESTED. DATA AND TIME WILL AUTOMATICALLY BE THE FIRST VARIABLE

q. Click OK

r. Your screen should now have a box titled Logged Data Table
q. Right click on your mouse and choose to **Export All** data

r. Please save this file as the data of the session with an underscore between each number and with a final number referring to the practice session such as a 1 or 2.
For example: 4_10_2009_1

This session took place on April 10th, 2009 and was the 1st session. Click SAVE
t.

This series of steps needs to be completed for EACH session. This process can wait until you are finished with the final practice of the day. Every time the Quest unit is shut off it will automatically start a new session when turned back on.

IV. Website Data Entry

a. Open your internet browser (i.e. Explorer, Firefox)

b. Type: “http://www2.matrix.msu.edu/~hsehi/add_school.php” into the address c.

You should see the following screen:

d. Enter your e-mail and password

    a. My password is: _______________
e. The next screen is considered the homepage

f. Click on Roster Entry

g. Click on your school

h. Click on School Information and enter the requested information
i. Next, click on **Sport Related** and once again enter the requested information

j. Make sure to click the appropriate submission key (**update, add entry, etc**...) after entering

k. Click on **Roster Entry**
<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Name</td>
<td></td>
</tr>
<tr>
<td>Last Name</td>
<td></td>
</tr>
<tr>
<td>Date of Birth (MM/DD/YYYY)</td>
<td>12/12/1991</td>
</tr>
<tr>
<td>Height (in inches)</td>
<td></td>
</tr>
<tr>
<td>Weight (in lbs)</td>
<td></td>
</tr>
<tr>
<td>Academic Year</td>
<td>Fresh</td>
</tr>
<tr>
<td>Is this athlete a &quot;NON&quot; player?</td>
<td>Yes</td>
</tr>
<tr>
<td>Primary Allergies</td>
<td></td>
</tr>
<tr>
<td>Primary Medical Conditions</td>
<td></td>
</tr>
<tr>
<td>Special Teams</td>
<td></td>
</tr>
<tr>
<td>Player Status</td>
<td></td>
</tr>
<tr>
<td>Eligible</td>
<td></td>
</tr>
<tr>
<td>Conditional Heart Comp</td>
<td>No</td>
</tr>
<tr>
<td>Heart Squeeze</td>
<td>No</td>
</tr>
<tr>
<td>Heart Enlargement</td>
<td>No</td>
</tr>
<tr>
<td>Heart Defect</td>
<td>Yes</td>
</tr>
<tr>
<td>Hysterectomy</td>
<td>No</td>
</tr>
</tbody>
</table>

This athlete may have a health condition that could affect their performance.
1. Enter each member of your roster and click add player. Do this for each member of your roster.

m. Review your roster before continuing by clicking roster list

V. Calendar Data

a. Click on daily calendar

b. To upload data click Browse
c. Click on your C: Drive

d.
e. Next, click on Program files
f. Open the folder named **Quest Technologies**

g. Next, click on the practice session file for that day and click **OPEN**
i. The file selected should appear in the window which was previously blank.

j. Continue to fill in the remaining data and click Add session.
VI. EHI Data

a. Click on **Enter EHI information**

b. Fill in all pertinent information for the EHI and click **Add EHI**.

c. **PLEASE BE SURE TO REVIEW YOUR ENTRIES TO MAKE SURE ALL CATEGORIES ARE FILLED IN.**

d. Click **Log Out** and you are finished for that day
ILLNESS DEFINITION – ANY EVALUATION OR ACTION THAT YOU TOOK RELATED TO THE EVALUATION OR TREATMENT OF EHI.

k. NATA Position Statement “Exertional Heat Illnesses” (JAT 2002). The relevant definitions and common signs and symptom of EHI are included at the end of the instruction document. You can find the entire position statement at:


We will gladly send you a PDF file of the article if requested.

l. The categories for EHI are: exercise associated muscle (heat) cramps, heat syncope, exercise (heat) exhaustion, exertional heat stroke and exertional hyponatremia with the associated signed and symptoms. (See below)

**Illness Symptoms – These are drop down boxes (yes or no) for common symptoms related to EHI. Please answer Yes to those symptoms that were present at time of injury**

i. Persistent muscle cramps of the major muscle groups which required intervention or treatment

ii. Fainting/syncope

iii. Elevated body core temperature (100°F -104°F or 37°C -40°C)

iv. High body core temperature (>104°F or 40°C)

v. Pallor

vi. Cool, Clammy skin

vii. Central nervous system changes (some definitions or examples are: convulsions, altered or loss of consciousness, coma, inability to thinking clearly and rationally, etc.)

viii. Tachycardia (100-120 bpm)

ix. Hypotension

x. Please briefly describe the acute treatment for this EHI or any other pertinent signs and symptoms of this EHI
Definitions


Exercise-Associated Muscle (Heat) Cramps: Exercise-associated muscle (heat) cramps represent a condition that presents during or after intense exercise sessions as an acute, painful, involuntary muscle contraction.

Heat Syncope: Heat syncope, or orthostatic dizziness, can occur when a person is exposed to high environmental temperatures. It often occurs after standing for long periods of time, immediately after cessation of activity, or after rapid assumption of upright posture after resting or being seated.

Exercise (Heat) Exhaustion: Exercise (heat) exhaustion is the inability to continue exercise associated with any combination of heavy sweating, dehydration, sodium loss, and energy depletion and a body-core temperature that generally ranges between 36ºC (97ºF) and 40ºC (104ºF).

Exertional Heat Stroke: Exertional heat stroke is an elevated core temperature (usually >40ºC [104ºF] at time of incident as measured by rectal temperature and CNS changes. Note that the CNS may not be instantaneously present.

Exertional Hyponatremia: Exertional hyponatremia is a relatively rare condition defined as a serum-sodium level less than 130 mmol/L. Two, often-additive mechanisms are proposed: an athlete ingests water or low-solute beverages well beyond sweat losses (also known as water intoxication), or an athlete’s sweat sodium losses are not adequately replaced.

Exercise-associated muscle (heat) cramps
Dehydration
Thirst
Sweating
Transient muscle cramps
Fatigue
Heat
syncope
Dehydration
Fatigue
Tunnel vision
Pale or sweaty skin
Decreased pulse
rate
Dizziness
Lightheadedness
Fainting

Exercise (heat) exhaustion
Normal or elevated body-core temperature
Dehydration
Dizziness
Lightheadedness
Syncope
Headache
Nausea
Anorexia
Dizziness
Diarrhea
Decreased urine output
Persistent muscle cramps
Pallor
Profuse sweating
Chills
Cool, clammy skin
Intestinal cramps
Urge to defecate
Weakness
Hyperventilation
**Exertional heat stroke**
High body-core temperature (>40°C [104°F])
Central nervous system changes
Dizziness
Drowsiness
Irrational behavior
Confusion
Irritability
Emotional instability
Hysteria
Apathy
Aggressiveness
Delirium
Disorientation
Staggering
Seizures
Loss of consciousness
Coma
Dehydration
Weakness
Hot and wet or dry skin
Tachycardia (100 to 120 beats per minute)
Hypotension
Hyperventilation
Vomiting
Diarrhea

**Exertional hyponatremia**
Body-core temperature <40°C (104°F)
Nausea
Vomiting
Extremity (hands and feet) swelling
Low blood-sodium level
Progressive headache
Confusion
Significant mental compromise
Lethargy
Altered consciousness
Apathy
Pulmonary edema
Cerebral edema
Seizures
Coma
*Not every patient will present with all the signs and symptoms for the suspected condition.
APPENDIX D – Web-based Data Management Site

1. School Home Page

![School Home Page Image]
2. School Information Page
### Sport Related Page

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of years of experience of the Head Football Coach at all schools</td>
<td>13</td>
</tr>
<tr>
<td>Total number of years of experience of Head Football Coach at current school</td>
<td>1</td>
</tr>
<tr>
<td>Does the football team travel away from school for pre-season camp?</td>
<td>No</td>
</tr>
<tr>
<td>Does the team have voluntary conditioning practices prior to the start of the season?</td>
<td>Yes</td>
</tr>
<tr>
<td>Enter approximate total number of sessions prior to the start of official team practice</td>
<td>28</td>
</tr>
<tr>
<td>What time were these sessions held?</td>
<td>16:00:00</td>
</tr>
<tr>
<td>Typical duration of session</td>
<td>3</td>
</tr>
<tr>
<td>Primary method of hydration of players during practice</td>
<td>Garden Hose</td>
</tr>
<tr>
<td>Type of fluids available for typical practice</td>
<td>Water</td>
</tr>
</tbody>
</table>
4. Roster Entry Page
5. Roster List Page

![Roster List for School: Cooper HS](image)

Select a season: 2014
Select a player level: Varsity

**Varsity 2009**

- [ ] [ ]
- [ ] [ ]
- [ ] [ ]
6. Daily Calendar Entry Page
7. EHI Information Entry Page