AN ANALYSIS OF REGIONAL ACCLIMATIZATION OF GEORGIA HIGH SCHOOL FOOTBALL PLAYERS AND THE IMPACT OF A REVISED HEAT SAFETY POLICY.

by

SHAINA EILEEN POORE

(Under the Direction of Andrew J. Grundstein)

ABSTRACT

This thesis used data collected from a six year study of Georgia High School football players to assess if there are regional differences in exertional heat illness (EHI) rates between the Northern and Southern halves of the state and how a new heat safety policy impacted EHIs regionally. The results of this study shows geographical differences in injury rates (IR) for different WBGT categories. Northern football players experienced greater IRs, ranging from 0.32-3.07 injuries per 1000 athlete exposures, compared with those in the South with IRs of 0.03-0.88 injuries per 1000 athlete exposures. Also, the new policy greatly reduced injury rates from 50-70%, depending on the WBGT category in the South but made no statistically significant change in IRs in the North. The results suggest that regional heat safety guidelines may be needed in Georgia and other states with similarly diverse climates.

INDEX WORDS: exertional heat illness, high school football, wet bulb globe temperature, acclimatization, Georgia, United States

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DEDICATION

I wish to dedicate this thesis to all those I have lost during my time as a graduate student. I finished this project knowing how you all would have been so proud of me. You may be gone but you will truly never be forgotten. Thank you for all the encouragement and support you gave me before you passed, it has truly given me the strength to complete this thesis.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Purpose and Motivation

Football is deeply rooted in the State of Georgia's identity. In a statistical analysis of the top college recruits from 2008-2013, the state of Georgia ranked fourth in the nation with a total of 950 recruits during the six-year period (Longhorn 2013). The national recruiting class of 2018 had 14 out of the top 100 players on ESPN's Top Athletes Recruiting Database from the state of Georgia, with the number one and two recruits from high schools in Georgia (ESPN). These impressive numbers can lead to high expectations of success for high school aged football players and can put an immense amount of pressure on them (Flanagan 2014). For some, this pressure may begin as soon as they are old enough to pick up the ball; for others, it starts at the first conditioning practice of the season their freshman year of high school.

Despite all the excitement surrounding football, there is also a dangerous element, which seems to come to light in the headlines each year. This past summer the headlines read, "Ga. high school football player dies after conditioning drills" and "Riverdale player dies after suffering heat stroke at football practice" (usatodayhss.com, 2017). The overzealousness of athletes and coaches can lead to heightened risk of exertional heat illness (EHI) because football practice and competition can lead to over exertion, the dismissal of normal behavioral mitigation, and ignoring early warning signs (Cleary 2007; Lopez et al. 2011). This and many other risk factors, including environmental conditions, athletic equipment, lack of heat acclimatization, poor physical fitness, and increased body mass index have led to heat-related deaths and injuries in football players (Casa et al. 2015).

Heat has been a factor in 148 football related fatalities from 1931 to 2016, and since the mid-1990s there have been almost three heat-related football deaths per year (Kucera et al. 2017; Grundstein et al. 2012). Over a 30-year (1980-2009) period Georgia led the nation in heat-related deaths (Grundstein et al. 2012). The high incidence of heat stroke deaths in Georgia interscholastic football players and the highly-publicized death of 15-year-old Tyler L. Davis in 2006 led the Georgia High School Association (GHSA) to create a study to produce an evidence-based heat safety policy (Carvell 2011). The state previously had a policy on heat and humidity, but the rules and regulations pertaining to heat and humidity were vague to follow. There was, for instance, no guidance on the appropriate heat metric (e.g. heat index, WBGT) or activity modification thresholds. Each school was left to interpret the policy as it saw fit, with little oversight from GHSA or the medical community.

In response to this lack, the GHSA sponsored a three-year (2009-2011) study to monitor Exertional Heat Illness (EHI) among Georgia high school football players and the factors (environmental conditions, practice start time, length of practice, etc.) that may contribute to heat- related injuries. As a result of the study, a new GHSA heat and humidity policy was put in place prior to the 2012 pre-season. The findings from the initial study resulted in a uniform, evidence-based heat safety policy with requirements for acclimatization and activity modification based on the WBGT. The new policy implemented a higher standard for all high school athletic teams during times of physical outdoor exertion. The original study that prompted the policy was continued for three years following the policy change from 2012-2014 to assess the impact of the new policy on EHI incidence.

The GHSA instituted a uniform policy across the state. Some states like Georgia, however, have diverse climates where athletes may have different degrees of acclimatization and exposure to particular climatic conditions. Studies suggest that regional acclimatization is an important factor in understanding the incidence of EHIs and thresholds at which injuries occur (e.g. Carter et al. 2006; Grundstein et al. *In press*). A study of U.S. soldier recruits, for instance, indicates that regional acclimatization is important in determining risk to potential EHIs (Carter et al. 2006). Recruits from northern states had an incidence rate of 44.5 cases per 100,000 solders, while recruits from the southern states had 27.5 cases per 100,000 solders (Carter et al. 2005). Soldiers from cooler climates experienced more heat-related illnesses than those from warmer climates. What should we make of these disparate outcomes?

The six year GHSA dataset provides a unique source of information to examine the potential for differences in EHIs among high school football players for given weather conditions in different regions of the state and if region-based heat safety guidelines are needed. In addition, the information on EHIs pre- and post-policy can be used to see the degree to which the new policy mitigated EHI risk in different regions.

1.2 Literature Review

1.2.1 What is an Exertional Heat Illness?

Exertional heat illnesses (EHI) is an umbrella term encapsulating injuries associated with physical activity in a hot and humid environment (Casa et al. 2015). These injuries range from mild, such as a, exercise-associated muscle cramps (EAMC) —a painful acute involuntary muscle contraction present during or after intense exercise sessions (Armstrong et al. 2007; Casa et al. 2015)—to more debilitating, such as heat syncope and heat exhaustion. Heat syncope, also referred to as orthostatic dizziness, is a condition that occurs during an 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 (Armstrong et al. 2007; Casa et al. 2015). Heat exhaustion occurs when an individual is unable to continue to exercise due to a combination of heavy sweating, sodium loss, and energy depletion while showing signs and symptoms of persistent muscle cramps, weakness, fainting, dizziness, headache, decreased urine output, and a body-core temperature of up to 104°F (Armstrong et al. 2007; Casa et al. 2015). Finally, the deadliest among the various forms of EHI is heat stroke, occurring when an individual has an elevated core temperature usually greater than 40.5°C (104°F) and has signs of organ failure and neurological deficit due to hyperthermia (Armstrong et al. 2007; Casa et al. 2015). The longer the individual's core body temperature is elevated above 40.5°C (104°F) the greater the risk of morbidity and mortality, therefore it is critical to promptly and efficiently lower the body temperature (Adams, 2015). Heat stroke is especially dangerous, because it is one of the few medical emergencies that must be treated first before being transported to a hospital (Cooper et al. 2016).

1.2.2 Prevalence of EHI in Athletes

There has been a substantial amount of research looking at heat-related mortality and morbidity of football players (e.g. Kerr et al. 2013; Nelson et al. 2011; Grundstein et al. 2012; Boden et al. 2013; Kucera et al. 2017; Yeargin et al. 2016; Cooper et al. 2006). Heat-related injuries are seen in a variety of high school athletics. A study by Kerr et al. (2013) found that 14 sports reported EHI incidents, with football being the most prevalent and girls' field hockey and girls' lacrosse being right behind. It is estimated that at least 1.1 million student athletes in grades 9-12 participate in high school football annually (Kucera et al. 2017), and more than nine thousand high school athletes in the United States suffer from exertional heat illnesses (EHI) ranging from EAMC to heat stroke (Kerr et al. 2013; Nelson et al. 2011). Heat safety policies have been implemented at professional and collegiate levels for some time but have only recently been implemented for interscholastic sports (KSI 2016). The National Collegiate Athletic Association (NCAA), for instance, adopted heat acclimatization guidelines in 2003 and the NFL did so in 2011 (Blackwell 2002, KSI 2016).

In the United States, there have been 148 football heat-related fatalities at all levels of competition (organized youth, high school, college and professional) from 1931 to 2016 (Kucera et al. 2017). The trend of heat-related fatalities has been almost three heat-related football deaths per year since the mid-1990's (Kucera et al. 2017; Grundstein et al. 2012). During a 30-year study (1980-2009) conducted by Grundstein et al. (2012), Georgia led the nation in football heat-related deaths during the time of the study. Exertional heat stroke (EHS) accounts for about 2% of all sport-related deaths and is among the top three causes of fatalities among football players (Boden et al. 2013). More specifically, EHS is responsible for about 15% annually of all football related deaths (Kucera et al. 2017; Yeargin et al. 2016). Over the past decade there has been a 133% increase in EHI emergency room reports, with 48% of those visits being youth and adolescent males (≤19 years) participating in football at the time (Nelson et al. 2011). High school aged athletes are particularly vulnerable for an increased risk of EHI's due to physiological differences compared to adults and the likelihood of participating in physical exertion during times of elevated heat and humidity (American Academy of Pediatrics, 2000).

Also, high schools begin fall preseason conditioning and practices during times of elevated heat and humidity, typically late July and August (Cooper et al. 2006; Grundstein et al. 2012).

1.2.3 Risk factors for EHI

There are many intrinsic and extrinsic factors that increase an individual's risk for exertional heat-related illnesses (Casa et al. 2015). Intrinsic conditions include obesity, low physical fitness, non-heat acclimation, dehydration, sleep deprivation, overzealousness, and sunburn (Casa et al. 2015; Brocherie et al. 2015). Environmental conditions, previous history of exertional heat-related injury, practice environment, peer or organizational pressure, and lack of education and awareness of heat illness are all extrinsic factors that can lead to an increased risk of EHI (Casa et al. 2015; Brocherie et al. 2015). In a case study of fatal EHSs of six, healthy, highly motivated, young (19±0.6 years), male, active duty soldiers Rav-Acha et al. (2004) found that both extrinsic and intrinsic factors were prominent predisposing aspects that lead to EHS. The researchers found that there were 15 predisposing factors and a combination of these factors lead to EHS fatalities. Seven of these 15 factors were most common, occurring in over 80% of the EHS deaths. Of these factors, two of them (i.e. physical effort unmatched to physical fitness and lack of proper medical treatment) were prevalent in all six fatalities. The other predisposing factors there were common were poor physical fitness, sleep deprivation, WBGT of 27°C or greater, training during the hottest hours, and high solar radiation occurred in five out of the six EHS fatalities (Rav-Acha et al. 2004).

1.2.4 Nonenvironmental Risk Factors among American Football Players

Several studies have investigated EHI risk factors associated with American football. An important non-environmental factor is the role of acclimatization (Cooper et al. 2016). Heat acclimatization is a biological function that allows the body to be adapted to stressful weather condition, such as high WBGT, allows the body to adapt to stressful weather conditions. (Cooper et al. 2006; Ingram et al. 1975). For an athlete to become acclimatized, the individual needs to be exposed to a hot environment repeatedly to increase both core and skin temperatures and invoke the sweat response (Casa et al. 2015; Cooper et al. 2016). An acclimatization period of 7 to14 days has been recommend by the National Collegiate Athletic Association (NCAA), although, some studies have shown that full acclimatization may take between two and three months (Casa et al. 2015; Binkley et al. 2002). The prevalence of EHI's may be attributed to an athlete's improper acclimatization to climatic heat stress (Cooper et al. 2016). Grundstein et al. (2012) found that 71% of heat-related football deaths occurred in the first two weeks of practice when athletes are not acclimatized properly. Similar results in EHI occurred in collegiate football players. After the first two weeks of practice there is a decline in EHI injury rate and occurrence and is plausibly related to acclimation (Cooper et al. 2016).

Individuals acclimatize to the environments in which they train. Carter et al. (2005) found that acclimatization of soldiers from northern states (i.e. Washington, Montana, Minnesota, New York, and Massachusetts), were presumed to have lower degrees of acclimatization, and had noticeably greater rates of EHIs than those from southern states (i.e. Arizona, Texas, Georgia, and Louisiana) during training at Paris Island, South Carolina. Their findings show that recruits from northern states were almost 1.7 times more susceptible to heat illness than those from the south when exposed to increased environmental conditions (Carter et al. 2005). Grundstein et al. (2015) identified that there were differences in warm season WBGTs between geographical regions in the contiguous United States. These differences would help explain why individuals from cooler climates would have different degrees of acclimatization.

Additionally, a recent study of regional heat safety guidelines found that football heat-related deaths tended to occur at lower WBGT values in the northern states verses deaths in the southern states which occurred at normal to below normal WBGT (Grundstein et al. *In Press*). The researchers observed that fatal EHSs occurred at lower WBGTs in cooler climates and deaths in cooler climates occurred under very extreme conditions by local conditions standards. But, fatal EHSs in hotter climates often occurred under near-normal conditions as these WBGT were already sufficiently high to cause heat stress (Grundstein et al. *In Press*). This demonstrates that current uniform heath safety policies may not be suitable for all regions in the country (Grundstein et al. *In Press*). Currently, there is not a recommendation for a modified WBGT activity guidelines based on climatological data for any of organizations with heat safety guidelines (i.e. ACSM, OHSA and the U.S. Military) (Grundstein et al. *In Press*).

Football players also tend to have physical characteristics, such as increased muscle mass and higher body fat percentages, that generally increase heat storage (Godek et al. 2014). These characteristics make athletes less efficient at dissipating heat and regulating their body temperature, which and can lead to heat-related injuries (Godek et al. 2014; Cleary 2007; Casa et al. 2015). Heat exhaustion often affects individuals who are not acclimatized or dehydrated with a body mass index greater than 27 kg/m (Armstrong et al. 2007). In an epidemiological study by Kerr et al. (2013), he looked at EHI rates among U.S. high school athletes and found that overall 37.1% of students sustaining EHI were obese (≥95th percentile) and that within the sport of football the proportion was much higher for obese students (47.1 %) reporting EHIs (Kerr et al. 2013). Additionally, Grundstein et al. (2012) found that lineman made up a majority (86%) of the heat-related deaths and a large proportion (87%) of them were classified as obsess (BMI >30). In a study of Division I college football players, Noel et al. (2003) found that players are larger and have higher BMIs than they did in the 1980s and early 1990s. There has been an increase of body size for football players, particularly linemen (Wang et al. 1993; Noel et al. 2003; Secora et al. 2004; Kraemer et al. 2005).

Furthermore, high school football players are more likely to overexert themselves and dismiss early warnings signs of EHI putting themselves more at higher risk for EHI (Cleary, 2007; Lopez et al. 2011a). An athlete's lack of acknowledgment of their body's normal adaption to regulate their core body temperature could lead to dehydration and improper fluid replacement (Casa et al. 2015). Intense exercising in the heat can result in large deficits in hydration and fluid loss from practice session that is not adequately replenished prior to the next practice increases an athletes risk for EHI (Stofan et al. 2005; Bergeron et al. 2005; Casa et al. 2000). Having proper hydration can help reduce an individual's core body temperature, and improve performance (Lopez et al. 2011b; Casa et al. 2010; Stearns et al. 2009).

Heat-related injuries and deaths can occur in all sports due to the metabolic heat exerted during play; however, football players are especially susceptible to heat-related injuries, because their use of additional padding and helmets amplifies metabolic heating and prevents cooling (e.g. Fox et al. 1966; Mathews et al. 1969; Kulka and Kenney 2002; McCullough and Kenney 2003; Brothers et al. 2004; Armstrong et al. 2010). Football helmet and pads can cover about 50% of the skin surface area of a player and other clothing (shorts/pants) can account for covering an additional 2% (Armstrong 0 et al. 2010). Football players in full uniform may block up to 70% of evaporative heat loss (Mathews et al. 1969) restricting the body's ability to thermoregulate (Casa et al. 2015).

1.2.5 Environmental Risk Factors

Meteorological conditions are one of the main extrinsic factors that can influence an athlete's risk for a heat illness. Hot and humid environmental conditions during active engagement in physical activity can stress an individual's ability to regulate their core body temperature (Yeatgin et al. 2017; Casa et al. 2011; Epstein et al. 2011; Kenny 2010; Sawka et al. 2011; Armstrong 2003). There are many ways to measure and assess heat exposure (Epstein and Moran 2006). The heat index is used by the National Weather Service as a metric for assessing heat hazards for the general public. It is even used by some states such as New York, Kentucky, and Oregon, in their heat safety policies (KSI 2017). However, it is not the best estimator for assessing conditions for athletes due to the many assumptions made by the computation. For instance, it assumes that an individual is of an average height, dressed lightly, located in the shade, and doing a minimal amount of activity (Rothfusz 1990).

The gold standard for measuring environmental stress in athletic, occupational, and military setting is the wet bulb globe temperature (WBGT; Casa et al. 2015). The WBGT calculation 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 determined by the following equation:

$$WBGT = 0.7WB + 0.2BB + 0.1DB$$

WBGT considers the influence of air temperature, wind speed, humidity, and solar radiation on human comfort in its calculation (Yaglou and Minard 1957; Thom 1959). The American College of Sports Medicine (ACSM) provides recommendations and guidelines for all athletes participating in hot environmental conditions to use the WBGT as a metric for heat intensity, as seen in Table 1 (Armstrong et al. 2007).

Athletes in Georgia are particularly vulnerable for EHIs and the state is currently the highest in nation in the number of heat-related fatalities over a 30 year period (Grundstein et. al 2012). In Alabama, a neighboring state and climatologically similar to Georgia, a climate study of optimal practice times found there were no suitable times for outdoor practices in full uniform in August (Francis et al. 1991).

In a geographical study of extreme heat hazards and American football players, Grundstein et al. (2014) found that in the 58 heat-related football deaths that occurred from 1980-2009 almost half (47%) occurred at locations with average WBGT values greater than 28°C and 81% of deaths occurring at locations with values averaging greater than 26°C. Furthermore, an extensive study of heat and injury occurrence among collegiate-level football players at five Division I universities in the Southeastern United States during a 90-day period in late summer and early fall, Cooper et al. (2006) observed that most of the EHIs (87%) and more serious EHI's (e.g. heat syncope and heat exhaustion) occurred with WGBTs were ≥ 23°C and the greatest incidence of heat exhaustion (57%) occurred during WBGT's over 28°C (Cooper et al. 2006). In a similar study, Cooper et al. (2016) conducted a four year study of 60 universities and colleges representing five geographic regions in the United States (US), and a found that the EHI rate was six times higher for WBGT's 27.8-28.9°C compared to rates during lower WBGTs of 24.5-25.6°C (Cooper et al. 2016). Extensive research of environmental conditions among high school athletes are more limited. In a one year study of high school football players in Florida Tripp et al. (2015) showed that 73.7% of EHI occurred during time periods that were considered high or extreme risk by the ACSM guidelines (Tripp et al. 2015).

1.3 Heat Safety Policy

There are several governmental agencies and professional organizations that have uniform WBGT activity guidelines regardless of climate of the area. These include American College of Sports Medicine (ACSM), the U.S. military, and Occupational Safety and Health Administration (OHSA). The ACSM developed an activity modification guidelines that have been adopted as a guide for many athletic heat safety policies, including the National Athletic Trainers' Association (NATA).

1.3.1 National Athletic Trainers' Association

Heat and safety policies need to take into account all the intrinsic and extrinsic risk factors that could contribute to an athlete susceptibility to an EHI. The National Athletic Trainer's Association (NATA) provides 14 evidence based recommendations for prevention and treatment. The first recommendation is to identify individuals who are at an increased risk for an EHI (i.e. obese, lack of physical fitness, recent illness, prior EHI) (Clearly 2007; Casa et al. 2012 and 2013). By objectively identifying athletes that are predisposed for an increased risk for EHI and implement appropriate monitoring is critical in EHI prevention (Clearly 2007). Next, a heat acclimatization period of 7 to 14 days is recommended to allow an individual to become accustomed to the environmental conditions they will be practicing in (Casa et al. 2015; Cooper et al. 2016). The first two to three weeks of practice typically have the highest risk of EHI, with football players being particularly susceptible due to the added equipment typically worn during practice (Casa et al. 2005; Bergon et al 2005; Kerr et al. 2013; Yeargin et al. 2006). Furthermore, athletes who are currently sick with fever, viral infection, or serious skin rash, should abstain from practicing until they are no longer ill; and then should be monitored closely following their return to practice (Armstrong et al. 2007; Casa et al. 2015).

The NATA continues its recommendations, which include, making sure an athlete is maintaining hydration, sodium intake, at least seven hours of sleep in a cool environment, well-balanced diet, and discourage the use of dietary supplements (Casa et al. 2015). NATA notes that all relevant personnel (i.e. coaches, administrators, emergency medical staff, athletes, parents) involved with the athlete should be educated on prevention and recognition of EHI's (Casa et al. 2015). If an EHI does occur, appropriate medical care needs to available and those aforementioned need to capable of actuate treatment procedures. However, certified athletic trainers and medical stuff are the primary providers of treatment for athletes experiencing any sort of EHI (Casa et al. 2015). Due to the fact that EHS is one of the few conditions that need to be treated before transported to a hospital (Cooper et al. 2006), the availability of an ice tub and towels are critical to an individual showing signs of an EHI. Cooling an individual's body temperature is essential for treating EHI's, but especially EHS (Casa et al. 2015).

Finally, NATA recommends activity modification. A preseason heat acclimatization policy should be developed for organized sports for hot and humid conditions based on activity level and WBGT (Casa et al. 2015). During conditions of elevated heat stress, particularly the first two to three weeks of practice, they advocate that practice should be shorted, delayed or rescheduled to help reduce the risk of an EHI (Casa et al. 2015). The ACSM has recommendations for activity modifications for nonacclimatized and acclimatized individuals based on WBGT values. For example, the ACSM suggests that when it is 25.7- 27.8°C nonacclimatized individuals should, "increase the rest:work ratio and decrease total duration of activity" (Armstrong et al. 2007).

CHAPTER TWO

GEORGIA HIGH SCHOOL ASSOCIATION AND HEAT SAFETY

2.1 Georgia High Schools Association

In the past decade there has been a high incidence of heat stroke deaths among Georgia interscholastic football players. And in 2006 the highly-publicized death of 15-year-old Tyler L. Davis of Metro-Atlanta in 2006 lead the Georgia High School Association (GHSA) to create a study to produce an evidence-based pre-season heat acclimatization policy (AJC 2011). To gain a better understanding of the susceptibility of Georgia high school football players to heat injuries, the Georgia High Schools Association (GHSA) initiated a study of heat injuries to develop a set of heat safety guidelines geared specifically to their younger athletes (under 18). Data were collected from an average of 25 high schools over a six year period (2009-2014); the first three years of data were used to guide a statewide policy development (pre-policy period), and the second three years of data were used to assess the effectiveness of newly implemented guidelines (post-policy period). The GHSA study collected data on all interscholastic football players during the study period, including characteristics such as age, height, weight, academic year, ethnicity, position, and amount of equipment worn during practice. Table 2 provides a complete list of data obtained by the athletic trainer (AT) during each session. If an EHI occurred during the session, the AT was instructed to record the player ID, the time of the occurrence, the EHI type, and when they returned back to the session. See Table 3 for a complete list of the data recorded.

Prior to the 2012, the GHSA did have a policy on heat and humidity, but the rules and regulations pertaining to heat and humidity were very ambiguous in nature. Players were only given a short 5-day period to acclimatize to their environment. Also, while each high school was required to have a heat policy in place, there was little guidance on the content of the heat policy or the temperature thresholds used for activity modification. Each school was left to interpret the policy as it saw fit, with little oversight from the GHSA or the medical community.

GHSA changed the policy prior to the 2012 pre-season, which resulted in a more uniform and clear policy from a health and heat standpoint. Further, to ensure that coaches and players adhered to this change, the new GHSA policy instituted a fine for violators. Currently, Georgia is the only state enforcing financial penalties for coaches and school not abiding by the heat safety policy (Yeargin et al. 2016). The new policy implemented a higher standard for all high school athletic teams to abide by during times of physical outdoor exertion (Table 4). The new policy sets guidelines for longer acclimatization, activity modification based on WBGT, required WBGT monitoring, and that each school much have an emergency action plan in place. Although having a more defined policy in place is important, it is also essential to remember that a key prevention strategy for EHI is education. Parents, coaches, and participants need to be aware of the signs and symptoms of heat-related illness and the proper ways to mitigate them after strenuous activity (Binkley et al. 2002).

The new GHSA practice policy for heat and humidity was implemented in 2012 and regulated practices for all high schools across Georgia. However, the climate of Georgia is diverse with hotter temperatures in the southern part of the state across the Coastal plains than in the norther part of the state in the piedmont and mountains. Indeed, many other states like North Carolina are beginning to wrestle with the best approach to developing heat safety guidelines across areas with diverse climates and if different guidelines are needed for climatologically different parts of the state.

The GHSA study provides a unique dataset to examine if there are regional differences in EHIs and if region-specific heat safety guidelines are warranted. This dataset includes EHI data for 30 high schools along with WBGTs during practice sessions. Such information can help to assess if there are regional differences in acclimatization and if regional heat safety policies are needed. Furthermore, this dataset allows evaluation of how effectively the policy change was at mitigating EHI regionally compared to the pre-policy period. Developing a better understanding of EHIs across Georgia will not only help improve player safety in Georgia but may also aid other states as they develop heat safety policies.

2.2 Methodology

2.2.1 EHI Dataset

This study uses a multiyear dataset (2009-2014) of heat-related injuries among football players from 30 high schools across the state of Georgia who employed full-time certified athletic trainers (AT). On average, 20 schools participated per year and 12 schools participated all six years. The high schools were selected from five different geographical regions within the state of Georgia as defined by the GHSA (North, Metro-Atlanta, Central, Southwest and Southeast) to ensure equal representation across the state (Figure 1). The dataset is divided into PRE- (2009-2011) and POST- (2012-2014) heat safety rule changes used by the GHSA. Data collection for each school began at the first official practice session and ended on September 30th each year of the study.

The study collected information on the weather conditions, injuries, intensity, and length of practices. Heat-related injuries were recorded by the AT following definitions used by the NATA position statement (Casa et al. 2015) and included EAMC, heat syncope, heat exhaustion, and heat stroke (Table 1). Environmental information was collected on WBGT using a QuesTemp°34 Thermal Environment Monitor (Quest Technologies, a 3M Company, Oconomowoc, WI). The AT was instructed to put the QuesTemp°34 in a sunny central area of the practice field, away from all structures that could obstruct proper readings. Data were collected every 15 minutes and internally stored. Each week, the data were uploaded to a central database. In the analysis, the WBGT observations were averaged over the length of each practice session. WBGTs in this study will be reported in the Fahrenheit scale to conform to how the data were collected and to correspond to the activity modification guidelines developed by the GHSA.

Geographically, schools in the study were partitioned into southern and northern regions for analysis. Smaller regions were considered but resulted in small samples sizes which made assessing statistical significance difficult. Aggregation of GHSA regions were done based on climatological and geographical similarities. The fall line, which marks the separation between the coastal plain and piedmont, was used to divide the state into the Northern and Southern regions. The North region consists of North and Metro-Atlanta GHSA divisions and consists of the Appalachian Plateau, the Valley and Ridge, the Blue Ridge and the Piedmont of Georgia (Duncan 2016). The South region is made up of Central, Southwest and Southeast GHSA divisions, which consist of the Upper Coastal Plain and Lower Coastal Plain (Figure 2). It is important to note that we recognize the limitation of creating a broad division of the regions. It is possible that different division of the state could have resulted in different results.

In comparing the climate between the two regions, using the climate division for the state of Georgia as a guide (Figure 3), it was apparent that the schools in the North region were mainly located in the northernmost climate divisions (northeast, north central, and northwest). All but four of the schools in the study were in these divisions. However, the four that were outside the northern climate divisions were all located in counties that bordered the northern climate divisions (Figure 3). For the South region, all but two schools were located in the southernmost climate divisions (Figure 3; southwest, south central, and southeast). Of the two schools not located in these divisions, one is located in a county that is adjacent to the Southeastern climate division.

An analysis of the climate in the northern climate divisions during the six-year study showed a consistently cooler average temperature for months of August and September compared to the southern region. Over the six year period the North had an average temperature of about 74°F temperature, while the South had an average temperature of 79°F. Throughout the study period, the temperature difference between regions ranged from 3.5°F to almost 6°F showing a clear climatological temperature divide between the regions (Figure 4).

2.3 Statistical Analysis

Exertional heat injuries are aggregated for the Northern and Southern regions. There were 206,634 exposures and 492 heat injuries in the Northern region and 109,279 exposures and 409 injuries in the Southern region. For the purpose of this study, EAMCs were not considered a significant heat injury, as they are often regarded as minor illness (Kark et al. 1996 and Martin, 1996) and were not reflected in the final results. Also, no cases of heat stroke were recorded in the study. Due to the low number of heat syncope (HS) and heat exhaustion (HE) cases, these two injury classes were combined to form a significant injury group (HS/HE), as determined by

Cooper et al. 2006, and were used to calculate injury rate, risk ratio, and 90% confidence interval. This resulted in 135 significant injuries in the North and 63 in the South.

Basic descriptive statistics (i.e. mean and standard deviation) were used to describe patterns and trends between regions with regard to EHI types, pre-post policy changes, and WBGT exposures. Differences in WBGT exposure by region were calculated by totaling the number of practices in each region using the GHSA WBGT categories (i.e. <82°F, 82.1-86.9°F, 87-89.9°F, 90-92°F, and >92.1°F; Table 4) and dividing them by the total number of practices. The results are depicted visually in a bar chart (Figures 5 and 6). Injury rates were assessed by GHSA WBGT categories to control for the magnitude of heat exposure.

Exertional heat illness rates were calculated regionally (North and South) for pre-policy, and post-policy change (Figures 7 and 8). Equation 1 expresses the injury rate (IR) per 1000 AEs by dividing the total number of HS/HE cases by the number of AE in each GHSA WBGT category:

$$\textit{Injury Rate (IR)} = \frac{sum\ of\ HS/HE's}{Sum\ of\ AE's}\ X\ 1000\ \textit{(eq. 1)}$$

An assessment of difference in injury rates by WBGT category in the North vs. South was performed in the post policy period. This was done to control for acclimatization because the POST policy period required an acclimatization period. A test of proportion with a p value of 0.05 were done at each WBGT category.

Risk ratios (RR) were calculated to assess the effectiveness of the uniform heat safety policy on injury rates in the PRE verses the POST policy change in the North and the South at each GHSA WBGT category. RR were used to identify a change in injury rate based on an association with one condition relative to another condition (Dick et al. 2007). To effetely asses the regionally differences in response to the GHSA policy change in each region, the incidence of injury rate in the POST policy change was considered the control group and the incidence of injury in the PRE period was the non-controlled group. The RR were calculated by dividing IR of the POST period by the IR of the PRE period of the South by GHSA WBGT categories (<82°F, 82-86.9°F, 87-89.9°F, 90-92°F and >92°F) for the North and the South regions. Ninety percent confidence intervals (90% CI) and standard errors were calculated for all RR's according to Altman, 1991 & 1998, where in this study *n* is the number of non-injured (athletic exposures) in selected group and x is the number of injuries.

$$\ln(RR) \pm 1.645\sqrt{\frac{(\mathrm{n}_1 - x_1)}{n_1}} + \sqrt{\frac{(\mathrm{n}_2 - x_2)}{n_2}} \text{ (eq.2)}$$

Visual representation of RR and the upper and lower 90% CI's were completed using Forest Plots (Figures 9 and 10).

2.4 Results

2.4.1 Regional Exposures

The regional differences in heat exposure between the North and South regions can be examined by looking at the practice days that occur under different WBGT categories (Figures 5 and 6). In North, a majority of the practices are held with WBGTs below 82°F in both the PRE and POST periods at 66% and 77% respectively. Smaller percentage of practice days were held with WBGTs 82-86.9°F at 24% during the PRE period and 21% during the POST period. Practices in the 87-89.9°F and >90°F WBGT categories were infrequent. In the North region there were no HS/HE injuries above the WBGT >92°F during the total six-year study. The absence of heat injuries above 90°F may be a result of only less than 1.5% of practice days in the north were held during conditions with WBGT ≥90°F.

Compared with the North, practices more frequently occurred under higher WBGTs in the South (Figures 5 and 6). In the South, 54% of practices occurred WBGT above 82°F PRE policy change and 38% in the POST. Compared to only 33% and 23% respectively in the North. Unlike the North region, the South region had heat injuries above 90°F. In the PRE period 8% of practices were held during WBGT above 90°F and after the policy change the percent of practices decreased to only 2% of the total practices being held WBGT above 90°F.

The differences in practice days at different WBGTs between regions PRE/POST could have been influenced not only by year to year differences in weather conditions but also by coaches shifting practices to cooler times of the day when there were less practice restrictions. For example, a coach could take the WBGT measurement at 2 p.m. in the afternoon and get a reading above 90°F, and realize that that practice would be restricted to only one hour with minimal equipment. Thus, it is possible the coach decided to move the practice to later in the evening when WBGTs were lower.

2.4.2 Comparison of Regional Injury Rates in the POST policy Period

Injury rates by GHSA activity modification categories were assessed by region in the POST policy period to control for acclimatization, which was now required. There was a statistically significant ($p < 0.05$) difference in regional HS/HE IR per 1000 AE at all WBGT categories below 90°F (Figure 8). The North had higher injury rates, then the south in all categories when practice activities were not prohibited (Figure 8). The largest difference in IR between regions occurred in the WBGT category 87-89.9°F. Here, the North had an IR of 3.07 HS/HE IR per

1000 AE compared to the South's IR of 0.88 in HS/HE IR per 1000 AE (Figure 8). The absence of injuries WBGT above 90°F in the North could be a result of less than 1.5% on practices occurring during times of elevated WBGT (Figure 6). Furthermore, the South had injuries occurring with WBGTs > 92°F, which should not have occurred according to the policy change regulations which prohibited practice activities at this level.

These results suggest that acclimatization played a role in the amount of injuries occurring during periods with elevated WBGTs in the North. Athletes in the cooler Northern region may not have been exposed to higher WBGTs to properly acclimatize, resulting in the greater heat injury rates compared to athletes in the South.

2.4.3 Effectiveness of Policy Changes in Injury Rates by Region

Risk ratios were calculated to understand the effectiveness of the uniform heat safety policy on IR in the PRE verses POST policy periods in the North and the South. Significance was assessed using 90% confidence intervals (Figures 9 and 10). RR were computed for each region by GHSA WBGT category. Because there were no injuries above 90°F WBGT in the POST policy change period in the North, risk ratios were unable to be computed for the two highest WBGT categories (Figure 9). The South had injuries occur at all WBGT categories during the entire study period (Figure 10).

An analysis of the risk ratios for the Northern region suggests that the change in policy produced no change in injury rate. The risk ratios for all WBGT categories were near 1, indicating that injury rates during the PRE and POST periods were similar and that policy change did not result in a decrease in injury rates. For example, the WBGT category 87-89.9°F had a RR of 1.06 (90% CI=0.57-0.1.96), indicating that between the PRE and POST period there was almost no change in the risk of injuries (Figure 9).

The South region had a reduction in risk for a HS/HE injury for all categories, except for the >92°F WBGT category, at which no practices should have been occurring. Athletes practicing at the lowest WBGT category <82°F had a statistically significant reduction in risk of HS/HE of 63% with a RR of 0.36 (90% CI=0.06-1.65) and the 82-86.9°F range had the largest decrease in risk of 70% with a RR of 0.29 (90% CI=0.09-0.77) (Figure 10). These two categories are noteworthy due to the fact that a majority of practices over the six-year study period were held during these WBGT values. Additionally, the upper WBGT categories which practices can still occur saw similar changes in reduction of risk of injury rates. The WBGT range of 87-89.9°F had the smallest reduction in injury rate of all the categories at 50% (RR=0.5; 90% CI=0.22-0.25). Overall, these results suggest that the change in heat safety policy greatly reduced the amount of HS/HE injuries occurring compared to the PRE policy change.

CHAPTER 3

DISCUSSION AND CONCLUSION

3.1 Discussion and Conclusions

The data collected in this study offered a unique opportunity to assess the impact of a heat safety policy change on Georgia high school football players at a regional level. This study is the first to assess geographical differences in acclimatization in two regions (North and South) of Georgia. The study also assessed the impact of the revised heat safety policy, which was uniformly applied across the state, on injury rates in the North and South portions of the state.

Results showed statistically significant differences in acclimatization between the North and the South. Northern football players experienced greater injury rates in all WBGT categories compared to athletes in the South. In the 87-89.9°F category there was a substantial difference in injury rates. Here, the North had an HS/HE injury rate of 3.07 per 1000 athletic exposures, while the South only had a rate of 0.88.

The new policy resulted in a statistically significant decrease in injury rates in the South but not the North. The results of the analysis suggest that there was an impact on EHIs in the South with a 50-70% decrease in injury rates at all WBGT categories. The difference in injury rates between the two regions could be explained by different practice heat exposures. A majority of practice days (94%) in the North were during WBGT values below 86.9°F, yet the largest occurrence of injury rates were in the WBGT range of 87-89.0°F. In comparison, the South had over three times the athlete exposures in this WBGT range, possibly conferring a greater degree of acclimatization. This suggests that practice days above 87°F WBGT are important in assessing the relative risk for high school football players in North Georgia and that the new policy activity modification guidelines may not be sufficiently restrictive.

The South had consistent RRs below 1, which meant that there was a decrease in injury rates post policy change for all categories (Figure 10). The only exception was for the WBGT above 92.1°F, that had a RR close to 1. This result is not considered in assess the policy because no school should have been holding practice during WBGTs is GHSA category.

These results are consistent with other study of heat acclimatization and EHSs, such as the strong geographic pattern related to environmental conditions and heat-related injuries that were observed by Carter et al. (2005). These results are also observed in the football heat-related deaths in Grundstein et al. *In Press* that EHSs tended to occur at lower WBGT values in the northern states verses deaths in the southern states which occurred at normal to below normal WBGT (Grundstein et al. *In Press*.) These results suggest that a uniform heat safety policy may not effectively protect athletes in cooler regions and that regionally specific guidelines are needed (Grundstein et al. 2014).

3.2. Recommendations

The higher rate of injury in the North region compared to the South region may be attributed to athletes in the North being unable to acclimatize during times of elevated WBGT. During the POST period, the North had almost 98% of their practice session in the WBGT range of <82-86.9°F and only had about two percent of practice days at the critical injury rate WBGT category of 87-89.9°F. The lack of practice days at the 87-89.9°F could result in a deficiency in acclimatization. Therefore, when practice days at this WBGT occurred, athletes may have had increased risk of EHI occurrence.

These results suggest the potential need to reevaluate the GHSA position on WBGT thresholds and actively levels in the North. These findings would suggest that there is support for shifting in activity and risk guidelines for the WBGT readings of 90-92°F to be the guidelines for the lower range of 87-89.9°F for North region of Georgia and similar regions within other states (Table 5). In other words, during environmental conditions with WBGT values of 87-89.9°F, practices would need to be limited to a maximum of one hour with a mandatory 20-minute rest break during practice time, no protective equipment may be worn and there may be no conditioning activities. This change in activity modification by WBGT values is also supported by similar ACSM recommendation, which states, at WBGT 86.1- 90.0 °F, acclimatized and low risk induvial, "Limit intense exercise and total daily exposure to heat and humidity…" (Armstron et al. 2007). This change in policy would have impacted 4% of the practice days at this WBGT range during the months of August and September in six-year study in the North. This shift would also affect practices at all other WBGT values. Practices above 90°F would be prevented until cooler WBGT were reached, which would have affected only 1.3% of all practices in the North.

Moving forward, other states such as North Carolina, which has a similar regional and climatological difference comparable to Georgia, may want to take into account similar policy consideration when developing their heaty safety policy. The state of North Carolina can be divided into three regions, mountains, piedmont, and coastal plains. These regions vary geographically, but also climatologically. During the critical months of high school football athletics, August and September there is over a 7°F difference in average temperature between the mountain and coastal plain regions.

Tables and Figures

Table 1 – American College of Sports Medicine definitions for exertional heat illnesses (Armstrong et al., 2007).

EHI Condition	**Definition**
Exercise-Associate Muscle (Heat) Cramps	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. 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.
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. 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 (97°F) and 40°C (104°F)
Exertional Heat Stroke	Exertional heat stroke is an elevated core temperature (usually >40°C [104°F]) 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.

Table 2: Practice data the Athletic trainer was instructed to keep track of each session.

Data collected at each practice session by the Athletic Trainer	
Date, Start and End-time of Session	Number of Participants
Session Number (if there were multiple sessions in a single day)	Number of Team Rest/Water Breaks
Team Level (Freshman, Junior Varsity, Varsity)	Intensity of Session
Equipment Worn (Full Pads, Shells, Helmet only, Shorts and T-shirt)	Whether or not an EHI occurred
Session type (Conditioning Split, Practice, Regular Practice Scrimmage, or Game)	Environment Data-Wet Bulb Globe Temperature

Table 3: Session data the Athletic trainer was instructed to keep track of each session IF an EHI occurred

Data collected if an EHI occurred during the Session	
Player ID	Return during same Practice or Game
Team Level (Freshman, Junior Varsity, Varsity)	Period of EHI
Session Type (Conditioning Split, Practice, Regular Practice Scrimmage, or Game)	EHI Type
Session Number	If EHI was Evaluated by a Physician
Date and Time of Injury	Evaluation by a Physician
Data and Time of Return	Treatment Administered

Table 4: GHSA standard for WBGT that must be conducted by a scientifically approved instrument that measures Wet Bulb Globe Temperature readings and must be utilized at each practice to ensure that the written policy is being followed properly.

WBGT	ACTIVITY GUIDELINES AND REST BREAK GUIDELINES
Under 82.0	Normal Activities - Provide at least three separate rest breaks each hour with a minimum duration of 3 minutes each during the workout.
82.0 - 86.9	Use discretion for intense or prolonged exercise; watch at-risk players carefully. Provide at least three separate rest breaks each hour with a minimum duration of 4 minutes each.
87.0 - 89.9	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. *If the WBGT rises to this level* ***during*** *practice, players may continue to work out wearing football pants without changing to shorts.* For All Sports: Provide at least four separate rest breaks each hour with a minimum duration of 4 minutes each.
90.0 - 92.0	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.
Over 92.1	No outdoor workouts. Delay practice until a cooler WBGT level is reached.

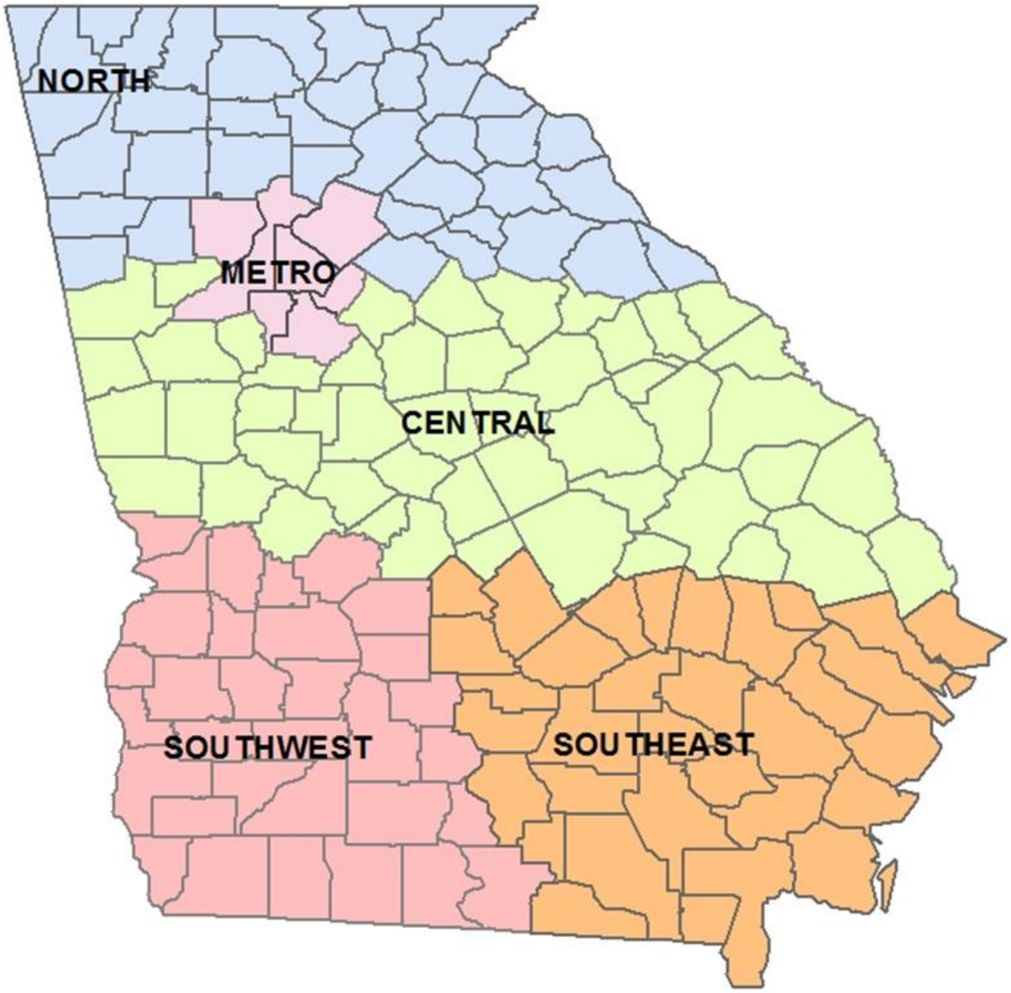

Figure 1. Georgia High School Association regional divisions.

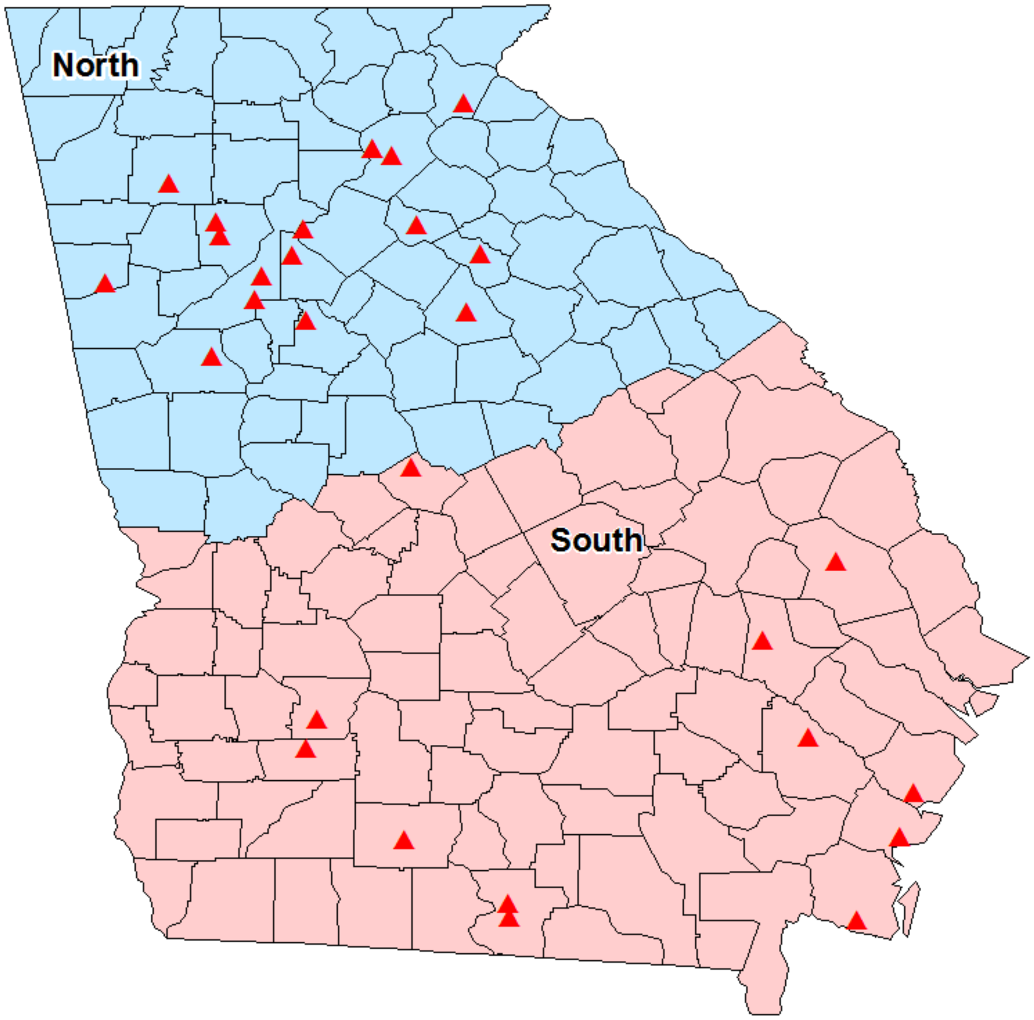

Figure 2. Regional division of Georgia study area with participating high school (triangles).

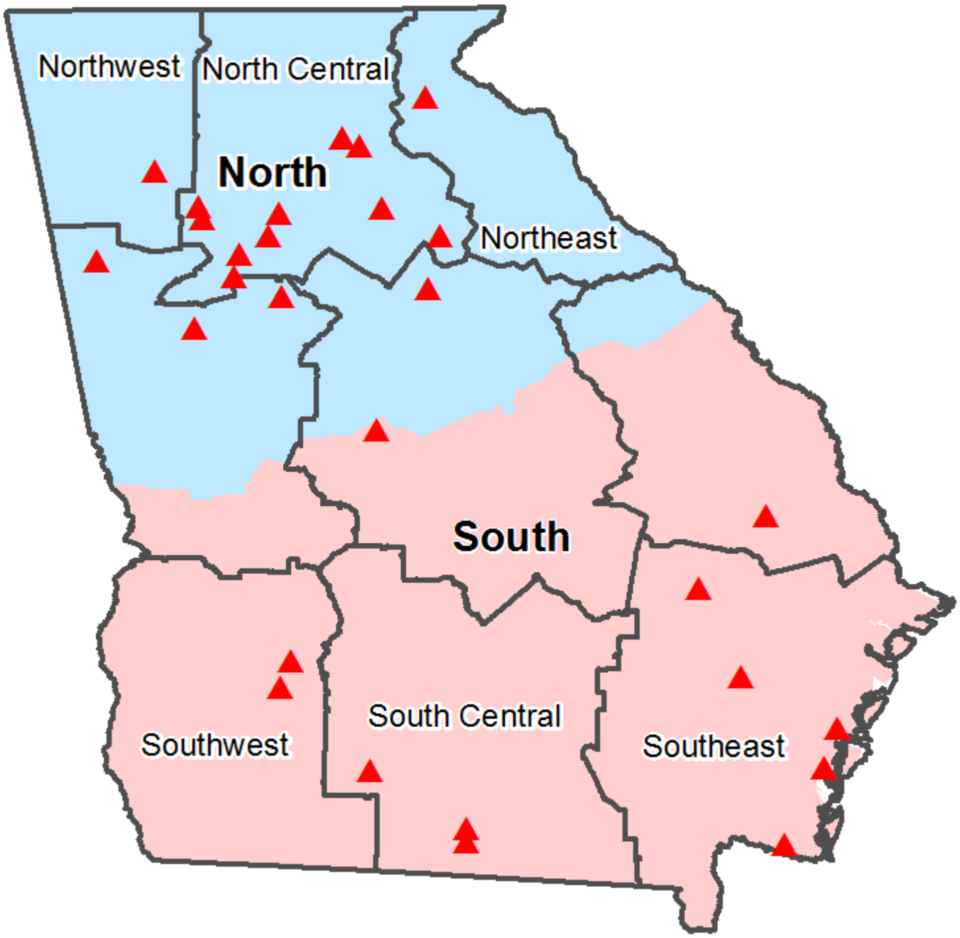

Figure 3: Regional division of Georgia study area with participating high school (triangles). The North region consists of the Northeast, North Central, and Northwest climate divisions. The South region is made up of the Southwest, South Central and Southeast climate divisions.

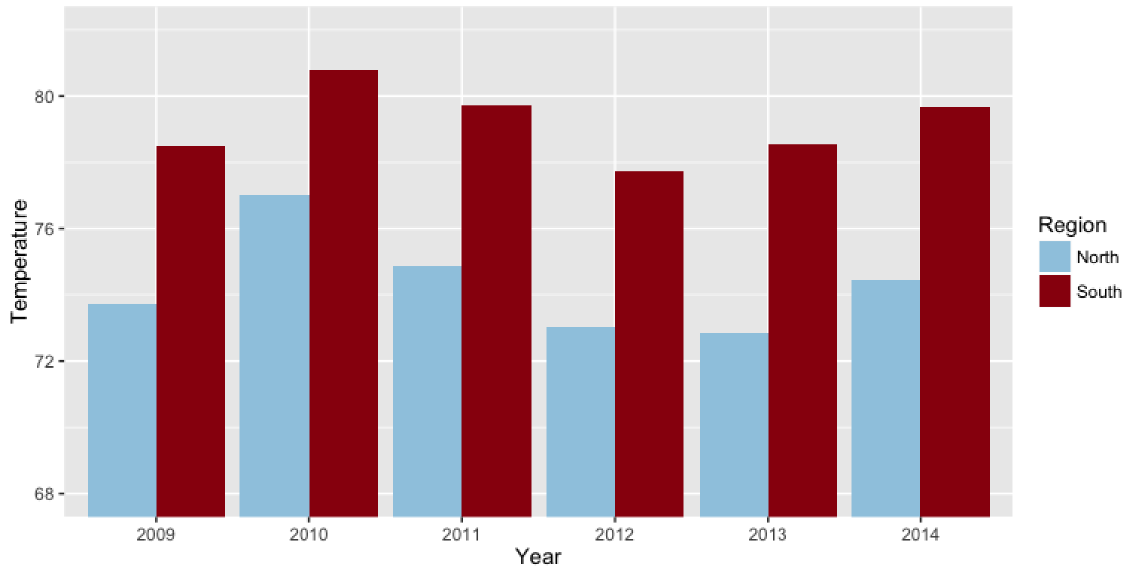

Figure 4: August and September average temperatures during the six-year study period for the North and South region based on climate division data. The North region consists of the Northwest, North Central, and Northeast climate division data. The South region consists of the Southwest, South Central, and Southeast climate division data.

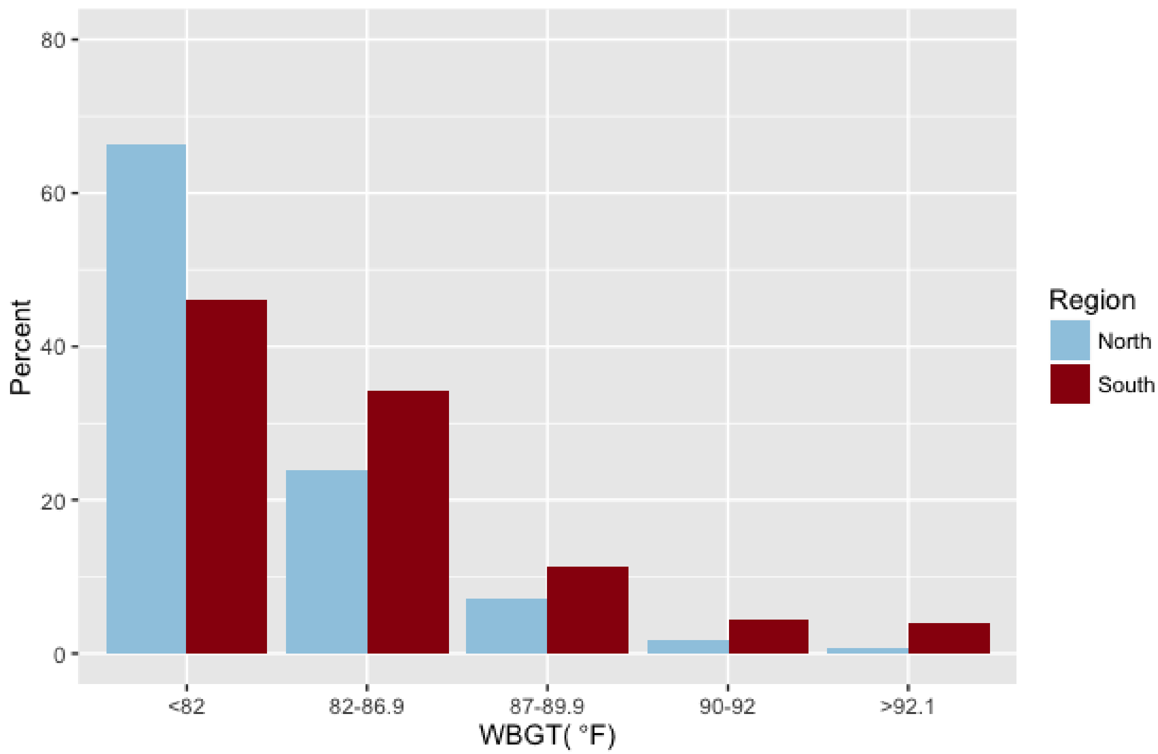

Figure 5: Percent of practice day PRE policy change (2009-2011) by GHSA heat and safety WBGT categories

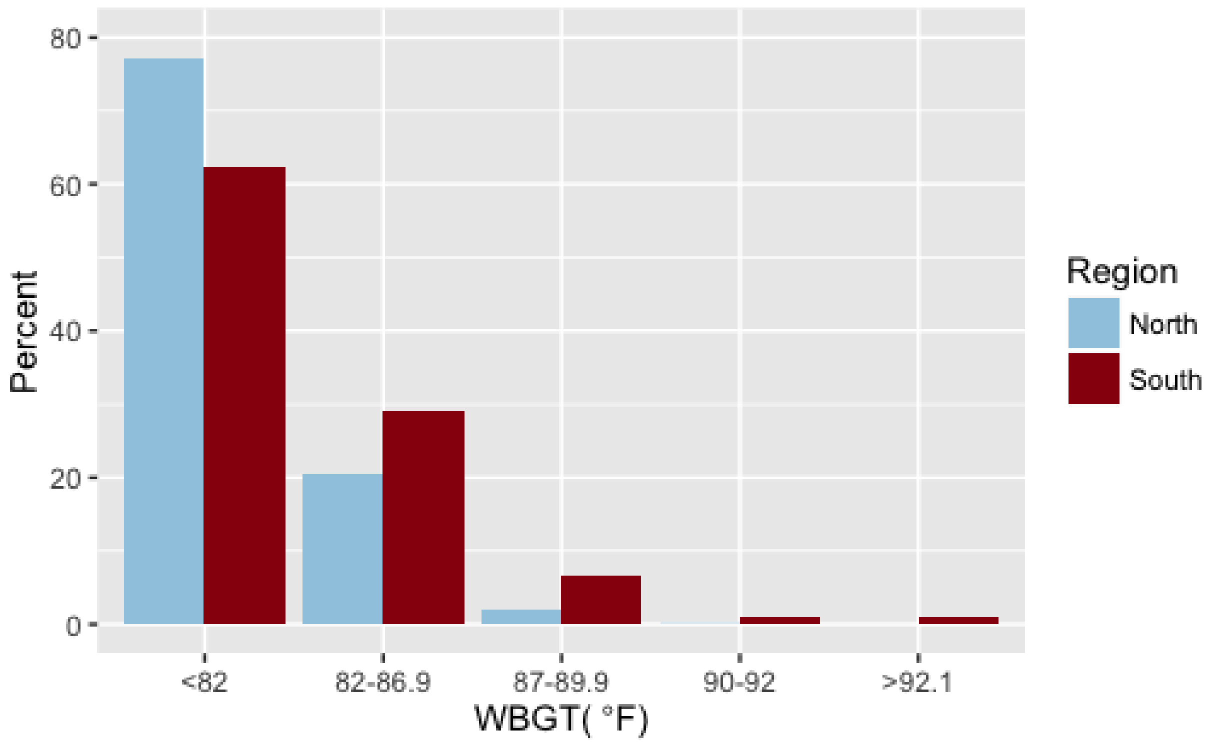

Figure 6: Percent of practice day POST policy change (2012-2014) by GHSA heat and safety WBGT categories

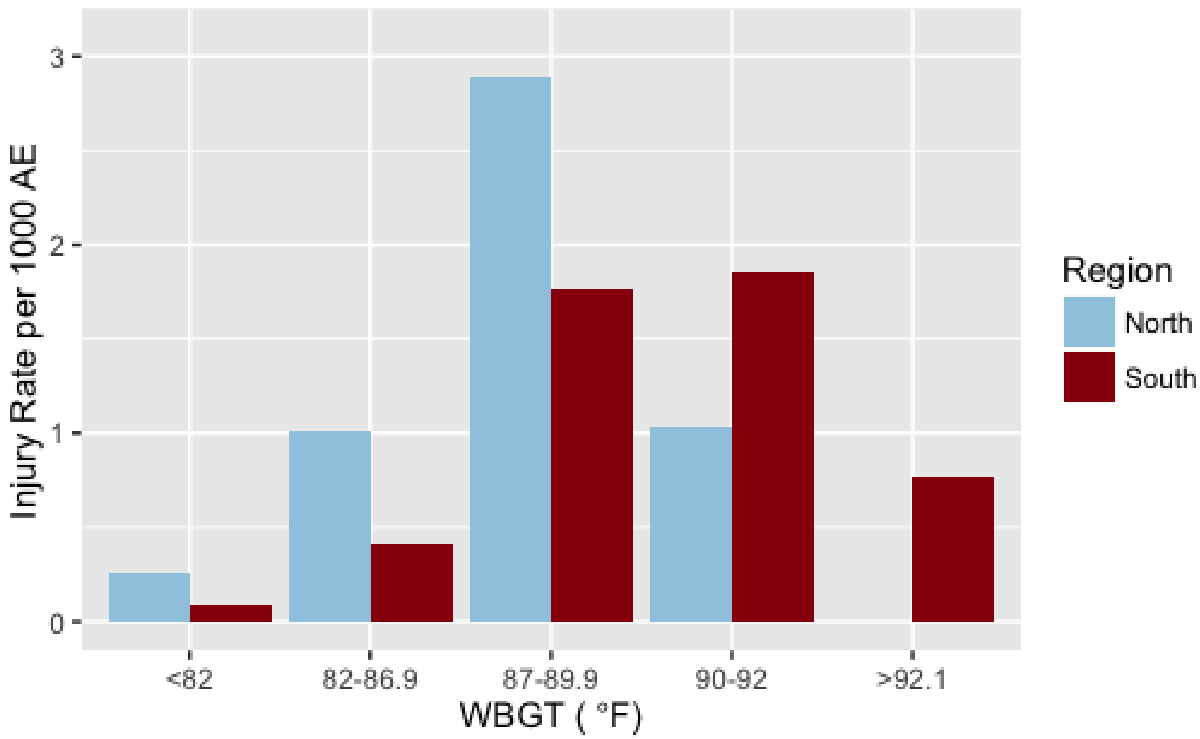

Figure 7: Regional heat syncope and exhaustion injury rate per 1000 athletic exposures PRE GHSA policy change (2009-2011).

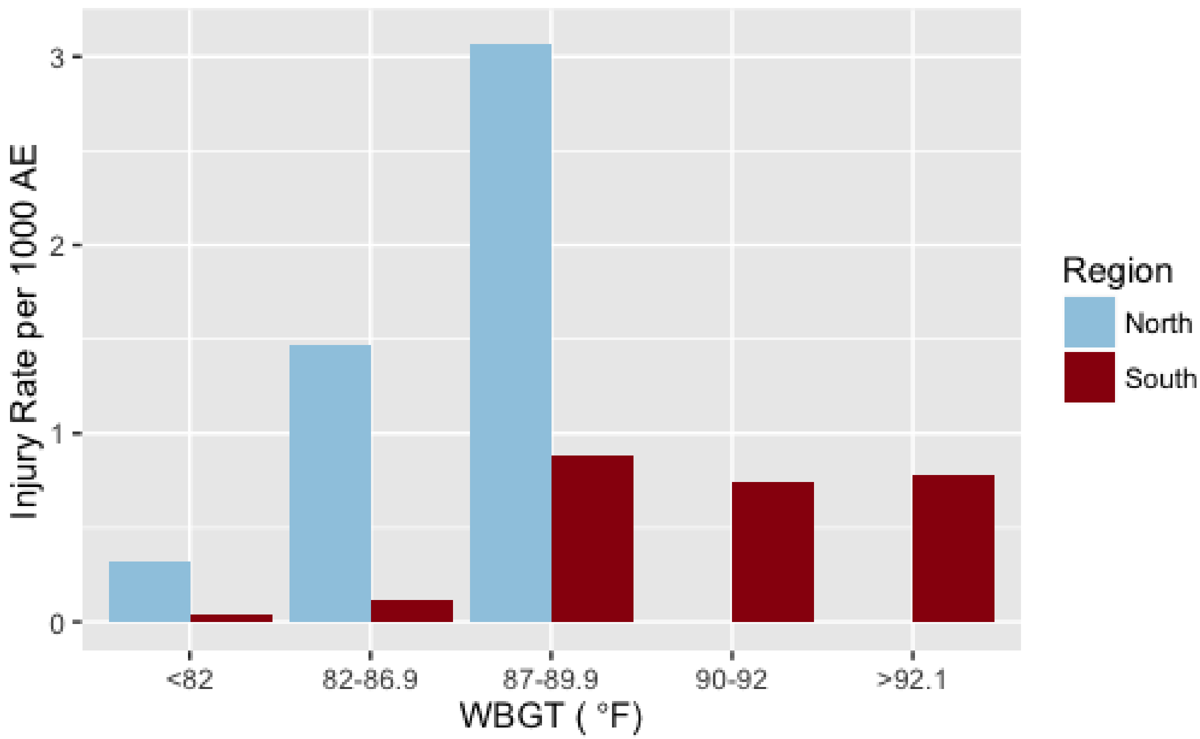

Figure 8: Regional heat syncope and exhaustion injury rate per 1000 athletic exposures POST GHSA policy change (2012-2014).

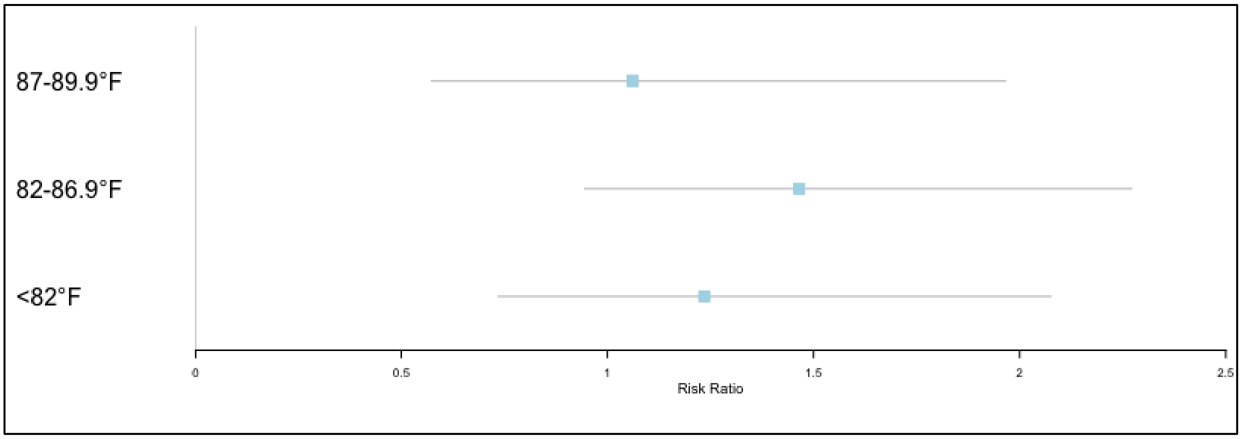

Figure 9: Forest Plot Risk Ratios of HS/HE in the North region of the POST policy change compared to the PRE policy change based on athletic exposures in GHSA WBGT restrictions.

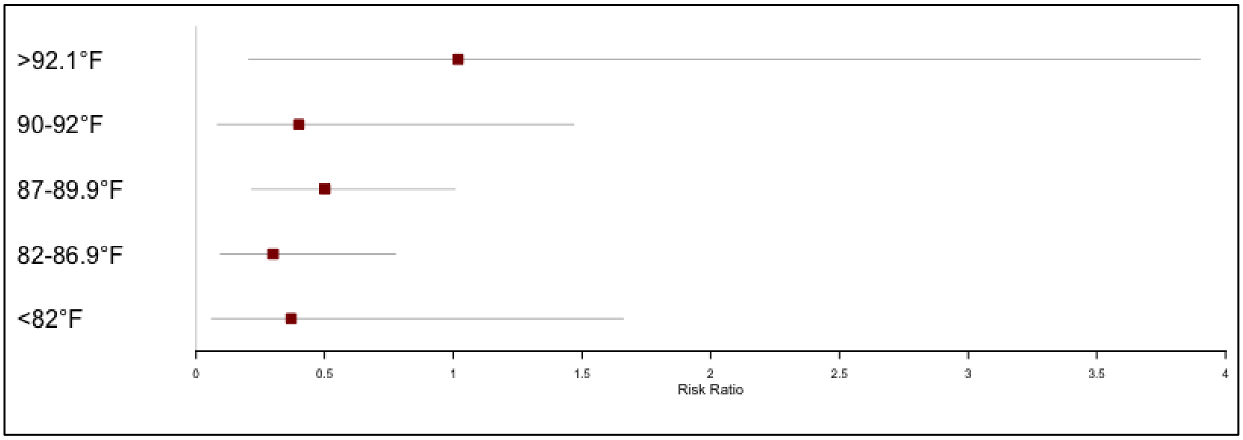

Figure 10: Forest Plot Risk Ratios of HS/HE in the South region of the POST policy change compared to the PRE policy change based on athletic exposures in GHSA WBGT restrictions.

Table 5: Proposed Heat and Safety Policy guideline for the North region of Georgia for activity modification based on WBGT values.

WBGT	ACTIVITY GUIDELINES AND REST BREAK GUIDELINES
Under 82.0	Use discretion for intense or prolonged exercise; watch at-risk players carefully. Provide at least three separate rest breaks each hour with a minimum duration of 4 minutes each.
82.0 - 86.9	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. If the WBGT rises to this level during practice, players may continue to work out wearing football pants without changing to shorts. For All Sports: Provide at least four separate rest breaks each hour with a minimum duration of 4 minutes each.
87.0 - 89.9	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.
Over 90.0	No outdoor workouts. Delay practice until a cooler WBGT level is reached.

REFERECES

American Academy of Pediatrics. (2000) Climatic heat stress and the exercising child and adolescent. Pediatrics 106(1):158 –9.

Adams, W. M., Hosokawa, Y., Casa, D. J. (2015). The timing of exertional heat stroke survival starts prior to collapse. Med Sci Sports Exerc. 14(4):273–274.

Armstrong, L. E., Johnson, E. C., Casa, D. J., Ganio, M. S., McDermott, B. P., Yamamoto, L. M., et al. (2010). The American football uniform: uncompensable heat stress and hyperthermic exhaustion. Journal of Athletic Training, 45, 117e127.

Armstrong, L. E., Casa, D. J., Millard-Stafford, M., Moran, D. S., Pyne, S. W., and Roberts, W. O. (2007). American College of Sports Medicine position stand: exertional heat illness during training and competition. Medicine and Science in Sports and Exercise, 39(3), 556e557.

Binkley, H. M., Beckett, J., Casa, D. J., Kleiner, D. M., and Plummer, P. E. (2002). National Athletic Trainers' Association position statement: exertional heat illnesses. Journal of Athletic Training, 37, 329e343.

Blackwell C (2002). Division I off-season football plan makes athlete safety first and goal. NCAA News Archive.

Boden, B. P., Breit, I., Beachler, J. A., Williams, A., and Mueller, F. O. (2013). Fatalities in high school and college football players. The American Journal of Sports Medicine, 41(5), 1108e1116.

Brothers, R. M., Mitchell, J. B., and Smith, M. L. (2004). Wearing a football helmet exacerbates thermal load during exercise in hyperthermic conditions. Medicine and Science in Sports and Exercise, 36, S48.

Bergeron, M. F., McKeag, D. B., Casa, D. J., et al. (2005). Youth football: heat stress and injury risk. Med Sci Sports Exerc. 37(8):1421–1430.

Carter, R., Cheuvront, S. N., Williams, J. O., Kolka, M. A., Stephenson, I. A., Sawka, M. N., et al. (2005). Epidemiology of hospitalizations and deaths from heat illness in soldiers. Medicine and Science in Sports and Exercise, 37(8), 1338e1344.

Casa, D. J., DeMartini, J. K., Bergeron, M. F., Csillan, D., Eichner, E. R., Lopez, R. M., and. Yeargin, S. W. (2015). National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses. Journal Of Athletic Training (Allen Press), 50(9), 986-1000.

Casa, D. J., Anderson, S. A., Baker, L., et al. (2012). The Inter-Association Task Force for Preventing Sudden Death in Collegiate Conditioning Sessions: best practices recommendations. J Athl Train. 47(4):477–480.

Casa, D. J., and Csillan, D. (2009). Preseason heat-acclimatization guidelines for secondary school athletics. Journal of Athletic Training, 44(3), 332e333.

Casa, D. J., Almquist. J., Anderson, S. A., et al. (2013). The Inter-Association Task Force for Preventing Sudden Death in Secondary School Athletics Programs: best-practices recommendations. J Athl Train. 48(4):546–553.

Casa, D. J., Stearns, R. L., Lopez, R. M., et al. (2010). Influence of hydration on physiological function and performance during trail running in the heat. J Athl Train. 45(2):147–156.

Casa, D. J., Armstrong, L. E., Hillman, S. K., et al. (2000). National Athletic Trainers' Association position statement: fluid replacement for athletes. J Athl Train. 35(2):212–224.

Cleary, M. (2007). Predisposing risk factors on susceptibility to exertional heat illness: clinical decision-making considerations. J Sport Rehabil. 16(3):204–214.

Cooper, E. R., Ferrara, M. S., Casa, D. J., Powell, J. W., Broglio, S. P., Resch, J. E., & Courson., R. W. (2016). Exertional Heat Illness in American Football Players: When Is the Risk Greatest?. *Journal Of Athletic Training (Allen Press), 51*(8), 593-600.

Cooper, E. R., Jr., Ferrara, M. S., and Broglio, S. P. (2006). Exertional heat illness and environmental conditions during a single football season in the southeast. Journal of Athletic Training, 41, 332e336.

Carvell, M. "Dad says son who died in practice ‘pushed himself too hard'." The Atlanta Journal-Constitution . August 3, 2011. http://www.ajc.com/sports/high-school/dad-says-son-who-died-practice-pushed-himself-too-hard/odqyJmxc8oU390CqDj8WMP/.

DeMartini, J. K., Casa, D. J., Belval, L., et al. (2014). Environmental conditions and the occurrence of exertional heat illnesses and exertional heat stroke at the Falmouth Road Race. J Athl Train. 49(4):478– 485.

Duncan, M. S. (2016). "Fall Line." New Georgia Encyclopedia. Web. 04 October 2017.

Epstein, Y., and Roberts, W. O. (2011). The pathophysiology of heat stroke: an integrative view of the final common pathway. Scand J Med Sci Sports. 21(6):742–748.

Epstein Y, Moran DS, Shapiro Y, Sohar E, Shemer J. (1999). Exertional heat stroke: a case series. Med Sci Sports Exerc. 31(2):224– 228.

Fox, E. L., Mathews, D. K., Kaufman, W. S., & Bower, R. W. (1966). Effects of football equipment on thermal balance and energy cost during exercise. Research Quarterly, 37, 332e339.

Francis K, Feinstein R, Brasher J. (1991). Heat illness in football players in Alabama. Ala Med 60:10–14

Georgia High School Association. (2016). Practice policy for heat and humidity. http:// www.ghsa.net/sites/default/files/documents/sports-medicine/Risk_ Management_Policies.pdf Accessed 04.06.16.

Godek, S. F., Godek, J. J., Bartolozzi, A. R. (2004).Thermal responses in football and cross-country athletes during their respective practices in a hot environment. J Athl Train 39:235–240.

Grundstein, A., Hosokaw, Y., Casa, D. (*In Press*). Fatal Exertional Heat Stroke and American Football Players: The need for Regional Heat Safety Guidelines.

Grundstein, A., Cooper, E., Ferrara, M., & Knox, J. (2014). The geography of extreme heat hazards for American football players. Applied Geography, 46, 53e60.

Grundstein, A., Ramseyer, C., Zhao, F., Peses, J., Akers, P., Qureshi, A., et al. (2012). A retrospective analysis of American football hyperthermia deaths in the United States. International Journal of Biometeorology, 56(1), 11e20.

Huffman, E. A., Yard, E. E., Fields, S. K., Collins, C. L., Comstock, R. D., (2008). Epidemiology of rare injuries and conditions among United States high school athletes during the 2005–2006 and 2006–2007 school years. J Athl Train. 43(6):624–30

Ingram D, Mount L. (1975). Evaporative Heat Loss. Man and Animals in Hot Environments: Springer; 39-63.

Kerr, Z. Y., Casa, D. J., Marshall, S. W., & Comstock, R. D. (2013). Epidemiology of exertional heat illnesses among U.S. high school athletes. American Journal of Preventive Medicine, 44(1), 8e14.

Kenny, G. P., and Journeay, W. S. (2010). Human thermoregulation: separating thermal and nonthermal effects on heat loss. Front Biosci (Landmark Ed). 15:259–290.

Korey Stringer Institute. (2017). Heat acclimatization guidelines by state. Available athttp://ksi.uconn.edu/news-events/high-school-state-policies/heat-acclimatization-state-policies.

Kulka, T. J., and Kenney, W. L. (2002). Heat balance limits in football uniforms. Physician and Sportsmedicine, 30, 29e39.

Kucera, K. L., Klossner, D., Colgate, B., & Cantu, R. C. (2017). Annual Survey of Football Injury Research, 1931–2016. National Center for Catastrophic Injury Research.

Longhorn, R. (2013). “Where Do College Football Players Come From?” SB Nation Football Study Hall. September 11 https://www.footballstudyhall.com/2013/9/11/4718442/college-football-state-texas-california-florida

Lopez, R. M., Casa, D. J., McDermott, B. P., Stearns, R. L., Armstrong, L. E., Maresh, C. M. (2011a). Exertional heat stroke in the athletic setting: a review of the literature. Athl Train Sports Health Care. 2011a 3(4):189–200.

Lopez, R. M., Casa, D. J., Jensen, K. A., et al. (2011b). Examining the influence of hydration status on physiological responses and running speed during trail running in the heat with controlled exercise intensity. J Strength Cond Res. 25(11):2944–2954.

Mathews, D. K., Fox, E. L., & Tanzi, D. (1969). Physiological responses during exercise and recovery in a football uniform. Journal of Applied Physiology, 26, 611e615

McCullough, E. A., and Kenney, W. L. (2003). Thermal insulation and evaporative resistance of football uniforms. Medicine and Science in Sports and Exercise, 35, 832e837

Nelson, N. G., Collins, C. L., Comstock, R. D., and McKenzie, L. B. (2011). Exertional heat related injuries treated in emergency departments in the U.S., 1997-2006. American journal of preventive medicine, 40(1), 54e60.

Noel, M. B., VanHeest, J. L., Zaneteas, P., Rodgers, C. D. (2003) Body composition in Division I football players. J Strength Cond Res 17:228–237

Roberts, W. O. (2010). Determining a ‘‘do not start’’ temperature for a marathon on the basis of adverse outcomes. Med Sci Sports Exerc. 42(2):226–232.

Rothfusz, L. P. (1990). The heat index “equation” (or more than you ever wanted to know about the heat index). NWS Technical Attachment SR 9023:2.

Sawka, M. N., Leon, L. R., Montain, S.J., Sonna, L. A. (2011). Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. Compr Physiol. 1(4):1883– 1928.

Stearns, R. L., Casa, D. J., Lopez, R. M., et al. (2009). Influence of hydration status on pacing during trail running in the heat. J Strength Cond Res. 23(9):2533–2541.

Stofan, J. R., Zachwieja, J. J., Horswill, C. A., Murray, R., Anderson, S. A., Eichner, E. R. (2005). Sweat and sodium losses in NCAA football players: a precursor to heat cramps? Int J Sport Nutr Exerc Metab. 15(6):641–652.

Thom EC. The discomfort index. (1959). Weatherwise. 12(2):57-61.

Yaglou, C. P., and Minard, D. (1957). Control of heat casualties at military training centers. Archives of Industrial Health, 16, 302e316.

Yard, E. E., Gilchrist, J., Haileyesus, T., Murphy, M., Collins, C., McIlvain, N., et al. (2010). Heat illness among high school athletes United States, 2005-2009. Journal of Safety Research, 41(6), 471.