MONITORING ENVIRONMENTAL CONDITIONS

AT FIVE SOUTHEASTERN UNIVERSITIES

by

EARL R. COOPER, JR.

(Under the Direction of Michael Ferrara)

ABSTRACT

Athletic trainers must consider environmental conditions when making decisions concerning football practices. Those working in southern settings are faced with stressful environmental conditions often associated with the late summer and early fall. Strategies to minimize heat stress include proper acclimatization, hydration, conditioning, heat illness recognition, and weather monitoring. The purpose of this study was to evaluate the rate of exertional heat illness (EHI) in athletes during a three month period (August-October) at five southeastern universities. The Heat Stroke Checker (KEM Kyoto Electronics Manufacturing Ltd; Japan) was used to measure environmental conditions three times a day at each location. The American College of Sports Medicine (ACSM) and Department of Defense (DOD) Wet Bulb Globe Temperature (WBGT) Heat Stress Index Charts were used to identify the levels of heat illness risk. Heat cramps, heat syncope, heat exhaustion, heat stroke, and hyponatremia were evaluated based on the NATA Exertional Heat Illness position statement. A reportable injury was any athlete who incurred a heat related illness evaluated by the medical staff. A total of 139 heat-illnesses were reported with an EHI rate of 4.19/1000 athlete-exposures (AE) during the three-month period. No cases of heat stroke or hyponatremia were reported. Evaluating each month individually, the greatest number of EHI's occurred during August (88%) with an EHI rate of 8.95/1000 AE. During August, the EHI rate was 6.31/1000 AE for heat cramps, 2.06/1000 AE for heat exhaustion and 0.58/1000 AE for heat syncope. Pearson correlations between the ACSM and DOD Heat Stress Index Charts and specific heat illnesses were not statistically significant relationships ($p>.05$). In our study we found a higher heat exhaustion injury rate compared to the NCAA surveillance data possibly due to differences in EHI definitions and reporting mechanisms. The incidence of heat illness in the months of September and October decreased dramatically, suggesting football athletes are at greatest risk of heat illness during August. Our data suggests that during the late summer, previously reported guidelines may overstate the risk of heat illness in highly trained football athletes practicing with the southeastern United States. The development of regionally specific heat index guidelines is recommended.

INDEX WORDS: Environmental Exposure, Environmental Heat Stress, Exertional Heat Illness, Heat Injuries, Heat Stress, Heat Stress Characteristics, Heat Stress Index, WBGT, WBGT Risk Index

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DEDICATION

This work is dedicated in the memory of my father, Earl R. Cooper, who instilled in me the dedication and discipline to chase my dreams and realize that all is within reach if you keep focused on your goals.

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CHAPTER 1

INTRODUCTION

Sporting events and recreational activities all have a common factor – individuals participating in physical activity. These activities take place during every season of the year, and there are a number of factors that have a direct effect on performance. These factors include both intrinsic and extrinsic variables. Examples of intrinsic variables include acclimatization status, fitness status, percent body fat, and age. Extrinsic variables can include exercise intensity and duration, extreme environmental conditions, equipment/clothing used, and frequency and length of rest intervals between bouts of activity. While many of these factors can be controlled, environmental factors remain a variable that is not controllable. Environmental conditions vary as to the time of the year and location and therefore can place additional stress on the individual if these conditions become extreme. These stressful environmental conditions can present numerous problems for the participant. Exertional heat illness (EHI) is one such problem that is associated with physical activity in a hot and humid environmental condition, and the incidence of heat illnesses is correlated with the rise in ambient air temperature and humidity.

From 1979 through 1999, 8,015 deaths were attributed to heat-related illnesses as a result of exposure to excessive heat in the United States (1). In addition, the recent and untimely deaths of several football players due to heat stroke have generated national attention on the topic of exertional heat stress injuries among athletes. Many professional organizations have published position stands (2-10) regarding the appropriate means to recognize, treat, and prevent these injuries. Environmental heat stress places a significant tax on the body's ability to perform while enduring many varying responses by various internal organs (11). These responses include mobilizing nutrients and electrolytes, and maintaining an appropriate equilibrium of body fluids, body temperature, pH, and blood pressure. Exposure to environmental heat stress can place high demands on an athlete's bodily systems and, if appropriate measures are not taken, can place the athlete in a potentially catastrophic condition. The safety of athletes who perform in these hazardous environmental conditions depends on adhering to specific participation guidelines, proper conditioning regimes, and monitoring of environmental conditions.

The American College of Sports Medicine (ACSM) and the federal government's Department of Defense (DOD) military branches have studied the effects of heat stress and made specific recommendations regarding the participation of individuals in athletic activities/competitions. These recommendations consist of participation guidelines (Wet Bulb Globe Temperature Heat Stress Index) relating to heat stress. The severity level of heat stress, recommendations are made regarding the type, duration, and frequency of exercise regimes for that particular day, the frequency of hydration and rest breaks, whether or not specific types of clothing/equipment should be worn, and finally whether or not the activity should be moved to a different time of day or cancelled altogether. The WBGT Index is a single number derived mathematically from three independent environmental readings: dry bulb temperature (ambient air temperature), wet bulb temperature (humidity), and black globe temperature (radiant heat). These numbers are inserted into a mathematical equation to determine the WBGT Index score. Once the WBGT Index score is calculated, a decision can be made regarding the intensity, length, time of day, and required rest periods to be implemented for the exercise session via the recommendations of the Risk Chart.

The ACSM Heat Stress Index recommendations were derived for all geographical areas of the United States (US) and do not take into account the various environmental conditions specific to the different regions of the country, nor do they take into account the different environmental conditions each region presents or the level of conditioning/fitness of the athlete(8). A review of the literature indicates there is minimal regional data supporting this risk chart. The DOD recommendations, which risk categories are less conservative than the ACSM, are based on data gathered in the southeastern region of the US and may not be appropriate for regions where the environmental temperature does not reach those seen in the Southeast. Individuals who have acclimatized to the hot and humid regions of the Southeast will respond differently to environmental stress than those of other regions whose environments are less stressful. The question remains, which environmental risk chart is appropriate for participants in the different regions of the country?

Purpose

Currently, most athletic organizations follow the WBGT Index Risk Chart developed by the ACSM rather than the risk chart developed by the DOD. In a comparison of risk charts, the ACSM scale is the more conservative of the two and is recommended for all regions of the country. Developed with data collected from the Midwest, there is little supporting or refuting evidence in the literature to substantiate the development of the ACSM Risk Chart. Given the stressful conditions typically seen in the summer months in the Southeast, adherence to the ACSM guidelines would curtail or prevent much of the athletic activities during the hot and humid months of the summer season. The DOD chart, however, is based on data gathered in the southeastern US and has higher WBGT values, thereby allowing for activity participation under the unique environmental conditions seen in the South. The purpose of this study was to evaluate the incidence of EHI's during football practice sessions at five Division I Universities during the months of August through October, as it relates to the WBGT readings on a daily basis. Utilizing this data, an assessment can be made to determine the incidence of EHI's among individuals who participate in physical activities under stressful environmental conditions in the Southeast.

Hypothesis

The following hypotheses were investigated in this study:

1. There is no difference in EHI rates by ACSM WBGT Heat Stress Index categories.
2. There is no difference in EHI rates by DOD WBGT Heat Stress Index categories.
3. The WBGT readings by the 103F Heat Stroke Checker are moderately reliable.

Delimitations

This study was delimited to

1. Data collected from college football participants at Auburn University, University of Florida, Florida State University, University of Georgia, and University of South Carolina from August 1, 2003 to October 31, 2003.
2. Use of the WBGT – 103F Heat Stroke Checker (KEM Kyoto Electronics Manufacturing, Ltd., Japan).

Limitations

The findings of this study were limited by

1. Correct usage/interpretation of the EHI definitions.
2. Participant's ability to accurately report EHI's to the medical staff.
3. Proper mechanical functioning of the environmental monitoring equipment.

Definition of Terms

For the purpose and scope of this study, specific EHI definitions developed by the National Athletic Trainers Association (3) were utilized for the identification of heat cramps, heat syncope, heat exhaustion, exertional heat stroke, and exertional hyponatremia.

Heat Cramps – Intense pain and prolonged involuntary contractions of working muscles during an intense or prolonged bout of exercise often brought on by excessive water and electrolyte losses, neuromuscular fatigue, or any such combination of these factors

Heat Syncope – Brought on by peripheral vasodilation, decreased venous return, pooling of blood in the lower extremities during prolonged standing, reduced cardiac output, and dehydration. Brief loss of consciousness or orthostatic dizziness may also be present.

Heat Exhaustion – An inability to continue physical activity due to any of the following factors: profuse sweating, excessive water and/or sodium loss, and muscular fatigue. This condition is often brought on by the cardiac system's inability to deliver sufficient blood volume to the peripheral tissues in order to maximize cooling and allow for continued work.

Exertional Heat Stroke – An elevated core temperature of $>40^0$C (104^0F) due to the failure of the thermoregulatory system to control body temperature. Signs/symptoms usually include cessation of internal organ system functions and changes in the central nervous system (altered consciousness, coma, convulsions, disorientation and irrational behavior).

Exertional Hyponatremia – The dilution of sodium levels in the bloodstream due to excessive fluid intake, usually brought on by excessive sweating during exertional activities in a warm/hot climate. Signs/symptoms include blood-sodium levels below 130 mml/L, low sodium intake, excessive fluid intake (particularly water), altered mental status, disorientation, headache, nausea/vomiting, and pulmonary and/or cerebral edema.

CHAPTER 2

MONITORING ENVIRONMENTAL CONDITIONS AT FIVE SOUTHEASTERN UNIVERSITIES

Understanding Physiological Stress

Stress research on individuals is not new to the scientific field. One of the pioneers in stress research was Hans Selye. Selye's research examined an individual's response to prolonged exercise, extended exposure to hot and cold environments, and other variables that were identified as "damaging stimuli or stressors". It was Selye's conclusion that the damaging stimuli caused specific physiological responses by the individual(12). Stress can be defined as any influence that disrupts the homeostatic balance of the body and thereby causes a physiological response or adaptation(13). These stressors are further categorized as either intrinsic or extrinsic factors. Possible intrinsic stressor includes hunger, thirst, fear, anxiety, or muscle tension. Extrinsic stimuli could entail such factors as heat and cold (environmental), hypoxia, trauma or injury, and illness. Physiological changes that minimize the amount of strain to the body, or "adaptations," are the body's attempts to combat or reduce the stressor and return itself to the desired homeostasis. These adaptations can be categorized as either short-term, intermediate, or long-term duration. Adaptations of short-term duration are the immediate physiological changes in the degree of sensitivity of a cellular response or "accommodation" in the external environment. Intermediate duration adaptations are either adaptive responses to an artificial environment (acclimation) or to exposure to natural environments (acclimatization). Genetic adaptation would be the long-term adaptations that are referred to as those physiological changes that occur over many generations where a particular species has a higher survival rate in a particular environment(14).

When an athlete is exposed to stress in a hot environment (heat stress), there are many physiological responses that occur to maintain the individual's ability to perform adequately. Both cardiovascular and neurological systems become taxed, as do the organ systems of the body. These physiological responses will be stimulated through hormonal and nervous intervention. When the athlete combines two significant stressors - exercise and high environmental temperatures, the strain on the body's physiological systems to respond to these stimuli increases significantly. The combination of both exercise and high environmental temperatures not only challenges the physiological control systems of the body, but can produce a potentially life-threatening scenario as well.

Defining Exertional Heat Stress

Determining the exact rate of occurrence for exertional heat illness is a difficult task as not all agencies use a common operational definition for exertional heat illnesses. However, utilizing a standardized nomenclature for heat disorders will enable the researcher to clarify the rate of incidence. The International Classification of Diseases (ICD) by the World Health Organization has standardized the nomenclature for these heat illnesses. The ICD has established ten categories of heat disorders and the associated etiologies and are presented in Table 1(15). While the ICD has established these definitional categories, for the scope of this study the following exertional heat illnesses will be investigated: heat cramps, heat syncope, heat exhaustion, exertional heat stroke, and hyponatremia.

Table 1 - International Classification of Heat Disorders

ICD Category	Etiology
Heatstroke	Thermoregulatory system dysfunction
Heat Syncope	Decreased venous return
Heat Cramps	Excessive water & electrolyte loss
Anhidrotic heat exhaustion	Excessive water & electrolyte loss
Salt deficiency heat exhaustion	Excessive water & electrolyte loss
Water deficiency heat exhaustion	Dehydration; hypohydration
Unspecified heat exhaustion	Excessive physical exertion
Transient heat fatigue	Physiological exhaustion due to water/electrolyte loss
Heat edema	Excessive water & electrolyte loss
Unspecified heat effects	Sodium and water deficiency
Hyponatremia	Excessive sodium loss
Water intoxication	Excessive consumption of water
Miliaria rubra	Clogging of sweat glands
Sunburn	Ultraviolet radiation burn of the skin
Tropical anhidrotic asthenia	Neurotic illness

(15)

Heat Cramps

Exercise-associated muscle or heat cramps is a condition that can occur at anytime during physical activity and the etiology is a difficult condition to describe. Involuntary muscle cramping or heat cramps may be brought on by physical activity and can be due to muscle fatigue, decreased levels of sodium and/or electrolytes, dehydration, or any combination of these factors. This cramping can be experienced in either hot or cold climates, but is more prevalent in the hot and humid environment. This cramping or muscle spasticity has been shown to increase in frequency when a body's dehydrated fluid levels are replenished by means of water only rather than through the use of sports drinks containing the additional electrolytes and sodium often lost through this excessive sweating. The frequency of this exertional heat illness may also be more common with the unfit athlete or the individual who is not acclimated to the environmental conditions (16). Dehydration induced by exercise as well as muscular fatigue has been shown to affect performance (17-21) levels of athletes. Martin(22;23) examined the effects of heat stress on performance at the Atlanta 1996 Olympic Games and the Sacramento 2000 Trials and concluded that proper planning and scheduling of event times as well as regional location of race events will have a significant effect on the athlete's ability to perform at his best, allowing for the least amount of heat stress to play a role in performance levels.

Heat Syncope

Heat Syncope or fainting is brought on by the pooling of blood in the lower extremity, peripheral vasodilation, decreased venous return, and dehydration. This condition can be brought about by exposing the unacclimated individual to exertional activity in a hot environment and usually occurs within the first week of acclimatization. Heat syncope is often seen in individuals who have participated in strenuous activities followed by periods of standing or where there is a rapid change in posture - from seated/supine to standing. Vasodilation of the blood vessels in the legs in combination with vagal inhibition of the heart rate brings about inadequate vascular return. This decrease in vascular return has consequential effects on cerebral blood flow and therefore brings about symptoms of weakness, dizziness, and decreased heart rate, and can eventually lead to fainting. This condition is rarely seen in the acclimated or physically fit athlete and is more likely to be experienced among the sedentary or unfit population (3;14;16).

Heat Exhaustion

Heat Exhaustion is typically the most commonly seen exertional heat illness among the athletic population and can be described as an inability to continue exercise in the heat (13). This inability to continue is usually brought on by the depletion of energy stores and body fluids, and a failure of the cardiovascular system to respond to high workloads under high environmental temperatures. While heat exhaustion has no known chronic or harmful effects, if left untreated, can lead to exertional heat stroke. The athlete who collapses and cannot resume exercise and who has a body temperature of <104^{0}F and has no true central nervous system dysfunction may be properly diagnosed as having heat exhaustion. Symptoms may include profuse sweating, headache, nausea, muscle weakness and a rapid breathing pattern (4;10;14;16).

Exertional Heat Stroke

Exertional Heat Stroke is a true medical emergency and is the most dangerous of the exertional heat illnesses. This illness is considered severe and can be characterized by a breakdown of the central nervous system which can result in possible tissue damage due to the high body temperature brought on by intense physical activity and excessive environmental heat stress. Unlike classic heat stroke, which typically is associated with the pediatric and geriatric populations, or the unhealthy/sedentary adult, exertional heat stroke occurs during physical activity (4).

Hyponatremia

Exertional hyponatremia is an obscure medical condition not often documented in the literature. This medical condition is produced when an individual's serum-sodium level falls below 130 mml/L. These low serum levels are generally associated with physical activities of more than four hours of length. Etiology for this illness is the ingestion of large quantities of water or low sodium fluids in excess of sweat loss (sometimes referred to as water intoxication) or when an individual's sodium loss through sweating is not adequately replaced. Symptoms of this illness include disorientation and a confused mental state, headache and nausea with possible vomiting, pulmonary edema, and a lethargic state. If left untreated, exertional hyponatremia can be fatal(15).

Exercise and Heat

When athletes participate in activities in a hot environment, specific bodily responses become taxed. These are seen specifically with the thermoregulatory and cardiovascular responses as well as metabolic changes(24). Issues of concern regarding heat stress occur when the rate of heat production from the surrounding environment outpaces the athlete's internal mechanisms designed to dissipate this heat. When athletes participate in sustained and intense physical activity during harsh environmental conditions, the thermoregulatory systems become significantly taxed. This taxation become significantly more difficult to deal with when any of the following conditions are also present: the wearing of protective clothing or athletic equipment, presence of a fever, a pre-existing dehydrated state, or the ingestion of certain drug compounds(19;25-28).

Environmental heat stress places increased demands on an individual's ability to maintain sufficient sweating as well as the appropriate circulatory responses to dispose of this additional generated heat. As the environmental temperature rises beyond that of normal skin temperature, the exercising athlete gains additional environmental heat and thus increases the work load on the regulatory systems to dissipate not only the effects of environmental heat stress but those generated by muscular activity as well(29). Participation in exercise-related activities bring about an increase in heat production and thereby a response from the thermoregulatory system. This increase in core temperature results where the maximal evaporative capacity in the surrounding environment outpaces the evaporation required by the individual to maintain a constant body temperature. This rise in core temperature triggers heat-loss responses such as sweating; however, this increase in core temperature continues to spiral upward until sufficient heat loss will equal that of heat gain. Thus, heat balance is restored and the core temperature and heat-loss response achieve a new level of steady state(24;30). The core temperature increase experienced during exercise is correlated to the metabolic rate of that individual. Astrand (31) demonstrated that when comparing an individual's response to heat stress, the change in core temperature is similar when the response is expressed as a percent of maximal oxygen uptake (VO_2max). This study is important due to its implication that when two individuals who have differing levels of aerobic fitness are engaging in activities equal in absolute workloads, the individual who has a lower VO_2max will have a greater steady state core temperature. The study demonstrated that individuals who are less fit and working at the same intensity as those who are fit will experience a greater increase in heat storage and therefore a greater rise in core temperature.

The cardiovascular response to exercise is that of shunting blood flow from the core regions to the extremities and peripheral tissues (skin) to effect heat loss through radiation, convection, and evaporation. This response is stimulated via the heat stress response. Blood flow is re-directed to the skin and consequently decreases central blood volume. This action therefore reduces venous return to the heart. By lowering venous return, cardiac filling decreases as does stroke volume. With this decrease in stroke volume and increased demands by the musculature and peripheral tissues, heart rate must conversely increase to match the demands placed on the cardiovascular system. When exercise is performed in combination with a "hot" environment, the muscles as well as the skin compete for increased blood flow to offset the demands of the increase in metabolic rates as well as increases in core temperatures. Peripheral demands are shunted to meet the needs of the musculature, which ultimately results in a rise in core temperature. Eventually, if inadequate blood supply to the central core continues, a heat syncope condition may present itself(24;32).

There is conflicting evidence whether the effects of sub-maximal physical effort elicits a greater metabolic rate when performed in a "hot" environment rather than a moderate environment. This dilemma is evidenced by methodology used by many researchers who only considered the aerobic metabolic rate during the sub-maximal exercise and thereby ignored the contribution of the anaerobic metabolism as it contributes to the total metabolic rate(33).

Dimri et al.(34) compared metabolic rate changes and the percentage of change due to both aerobic and anaerobic work at differing ambient temperatures and concluded that aerobic metabolic rates increased more than the decrease seen in anaerobic metabolic rates. They concluded that the total metabolic rate needed for an individual to perform a given activity at a given power output will increase as the ambient temperature increases. However, when comparing muscle glycogen usage in both hot (105.8^0F) and cold (48.2^0F) environments, glycogen depletion was greater at the higher temperature than at the lower temperature(35). Interestingly, when performing exercise to an exhaustive state in a hot environment, muscle glycogen levels are not depleted, as they were when performed at a cooler temperature, even though the glycogen utilization has been documented to be a greater amount during exercise under heat stress(36).

<u>Dehydration and Its Effect on Athletic Performance</u>

The effect of dehydration on muscle performance has been well documented in the literature. Studies dating back to the 1940's(37;38) investigated the negative effects of dehydration on performance; unfortunately, during much of the next twenty years a mind-set was created where athletes who ingested fluids during practice and/or games were viewed as being weak of character and stamina. At the beginning this new century, the mind-set regarding fluid ingestion during activity has significantly changed for the better. But what are the effects of a dehydrated state as it relates to cardiovascular function, neuromuscular function and more specifically, performance? First one must determine the causative factors that lead to the dehydrated state. Exercise-induced dehydration and hypohydration seem to be the two distinct areas of concern for the athlete. Barr(19) examined numerous studies which investigated many of these factors regarding the effects of dehydration, hyperthermia, and hypohydration on exercise performance. The conclusion by the author is that based on all of the relevant work done throughout the last 100 years, exercise-induced dehydration has a negative impact on endurance performance, and this condition is exacerbated by environmental heat stress. Further more, when all variables are held equal, the degree to which performance is negatively impaired is correlated to the degree of exercise-induced dehydration. In regard to hypohydration, when this condition is induced prior to athletic activity, there is a negative impact as well on aerobic endurance, but there is a more substantial negative effect when considering the performance levels of those competing in muscle strength and endurance events. It is only when the athlete is given the opportunity to fully recover from the effects of a prior heat exposure that little or no ill effects are seen from hypohydration.

Exercise-Induced Dehydration

Exercise-induced dehydration refers to a dehydrated state that develops during a bout of exercise. This condition can be exacerbated by environmental conditions that have an increased effect on fluid loss (increased ambient temperatures, humidity, or lack of wind), by the restriction of fluid ingestion during the activity, and by increasing the intensity of the activity which would place greater demands on the body to dissipate the additional metabolic heat generated(19). Studies(27;28) have indicated the derogatory effects of dehydration on physical performance as well as the negative effects of fluid restriction on performance. When athletes exercise in a hot environment, the cardiovascular system is stressed at a higher level and in order to perform adequately and avoid an exertional heat stress injury, maintaining cardiac output, blood pressure, and organ function is vital. J. Rico-Sanz et al.(39) investigated the effects of hyperhydration on total body water, temperature regulation and performance of elite young soccer players in a warm climate during environmental conditions graded as “high” (WBGT Index of 23.5 ± 0.5^0 C) on the ACSM Risk Chart. Two groups of acclimated and conditioned soccer athletes (one group voluntarily hydrated and one group was hyperhydrated) were assessed for performance levels as well as body temperature regulation during a soccer match after a two-hydration period. While sweat losses and core temperature increases were similar for both groups, the hyperhydration group displayed improved temperature regulation during play. Given this improvement in core temperature increases, an individual is better able to withstand the stresses of climatic heat stress when competing or practicing. Bearing this conclusion, it has been the practice of coaches and sports medicine personnel to allow for voluntary hydration among athletes and to encourage hyperhydration to stave off any derogatory core temperature increases.

Incidence Rates of Heat Illness

Incidence can be defined as the frequency of occurrence of a specific incidence over a certain time frame as it relates to a specific population where the incidence occurs(15). Incidence rates are calculated by correlating the number of athlete exposures (1000 participants per practice session divided by day, month, or year) in a given time frame. As each type of exertional heat injuries is studied, it is seen that the incidence rates are influenced by a number of factors. Participation rates, the demographics of the population, what environmental stresses are present, and the etiological factors imposed by the specific event will undoubtedly have an effect on the outcome. Prediction of exertional heat injuries is difficult given the variance of incidence as reported by previous studies. Data on heat stroke varies from 0.1/1000 participants/3months (40) and 0.4/1000 participants/3 months(41) to 26.2/1000 participants/day(42). Heat exhaustion has slightly less variance of incidence reported in the literature with reported incidence rates of <0.1/1000 participants/day (43) and at 1.4/1000 participants/day(44). Armstrong(15) reviewed numerous studies on exertional heat injury rates and concluded that there is a wide discrepancy among researchers regarding the rates of incidence as it relates to different settings and therefore presents a difficult dilemma for prognosticating the number of injuries from one event to another.

As reported by the Center for Disease Control(1), 8,015 excessive heat exposure deaths occurred from 1979 – 1999, documenting the greatest number of heat related deaths in the United States to date. This number accounts for more deaths than those attributed to hurricanes, tornadoes, floods, and earthquakes combined. Exertional heat illness has also been an area of concern with military operations and training regimes dating back to the biblical times and has been mentioned in many accounts of ancient military confrontations. An epidemiological review of medical reports by Gardner and Kark(45) indicated that World War I exhibited an abnormally high number (>600) of heat related deaths among British troops stationed in Mesopotamia. Documentation of medical treatment reveals ice administration, increased fluid intake, and the relieving of personnel between the hours of 10 AM and 4 PM to help reduce these drastic rates. During World War II, the troops experienced many of the same pitfalls, especially those from Britain who served duty in the Middle East. Exertional heat illnesses did not escape the American troops, however, during this current wartime campaign. There were approximately 250 deaths attributable to heatstroke, primarily at training centers in the southeastern region of the US alone. The Marine Corps Training Center at Parris Island, South Carolina has been reporting data on their military personnel training regimes and the effects of the environment and its impact on the incidence rates of exertional heat illnesses. Most recent data, covering a time period of 1982 through 1991, has indicated an average incidence rate of EHI's of recruits at 0.7% during the 12-week basic training period, with this incidence rate increasing to 2% during the summer months. Further investigation revealed that incidence rates were the greatest during the summer months, and of these cases, most occurred during the exercise session held between 7 AM and 9 AM. When these exertional heat illnesses were plotted against WBGT readings, there was a positive correlation when the WBGT readings were above 18^0C(17;45).

The National Center for Catastrophic Sport Injury Research has been collecting data since 1965 and can reference data dating back to 1931 when the American Football Coaches Association initiated the First Annual Survey of Football Fatalities. Catastrophic fatalities have been on the decline since the 1960's, and in 1990 for the first time there were no fatalities directly related to football. College football has approximately 75,000 participants per year with another 1.5 million high school and junior high participants. The twenty-year rate for direct injuries per 100,000 AE for high school and junior high school participants in football was 0.31 while the rate for collegiate participants is less than one per 100,000 AE during the same reporting period. The figures for non-fatal injuries and serious injuries were 0.72 and 0.76 for the high school/junior high group and 1.79 and 5.24 for the collegiate group respectively(46). However, a major concern regarding these football fatalities over the past eight years has been the number of indirect deaths that have occurred as a result of heat stroke. Data(46) indicates that there have been 22 deaths during this eight-year period attributed to heat stroke during the football season. This number is high, when considering that heat stroke deaths are preventable when the proper prevention mechanisms are adhered. Since 1974, there has been a dramatic reduction in heat stroke deaths with the exception of 1978, 1995, 1998 when four deaths were reported for each of these years, and the year 2000 when 5 deaths were reported. Extraordinarily, the years 1993, 1994, and 2002 did not have any reported heat stroke deaths(46;47).

Support for a Heat Stress Index

An individual's ability to work efficiently while under varying environmental conditions can be correlated to the environmental stress level. In the case of environmental heat stress, as the heat stress increases, the risk of exertional heat illness becomes greater. The safety of the individual who participates in rigorous physical activities in a hot environment must be considered along with exposure time and the intensity level of the activity. The environmental heat stress experienced during activity by the individual must be matched with the individual's ability to dissipate the increase in heat to survive the activity and continue to perform at an acceptable level. The environmental heat stress and activity create a "thermal load" for the individual which can be complicated by variables such as intensity of exercise, duration of exercise, the type/amount of clothing worn during exercise, equipment used/worn during exercise in addition to the actual environmental heat stress(11;16;48;49). Heat stress placed upon the individual must be measured in order to accurately predict this thermal load. Environmental heat stress can be determined by measuring environmental variables such as ambient air temperature, the relative humidity, air movement, and solar radiation. Environmental measurement techniques have been documented as far back as the beginning of the twentieth century. Haldane(50) examined the similarities of wet-bulb thermometer and a man drenched with sweat; this association was then used to develop a measurement technique utilizing wet bulb temperature readings to measure severe and hot conditions of tin mining operations. While this approach addressed some of the issues, it did not account for conditions of high humidity or the dry, arid climates. In the 1920's, Houghten and Yaglou established the *Effective Temperature Index* to define thermal comfort levels. This index was calculated through the measurement of the ambient air temperature, wet-bulb temperature and wind velocity to create an *equivalent thermal sensation.* This approach was limited as well, since it did not address radiant heat(48). Not until 1957 was an accurate measuring equation developed to assess environmental stress. Yagloo and Minard(51) suggested an equation to measure heat stress using the Wet Bulb Globe Temperature (WBGT) Index. This equation includes measures of ambient temperature (Ta), wet bulb temperature (Tw), and black globe temperature (Tg), and weights each measurement independently. This equation was further defined for indoor measurements and outdoor measurements:

Indoor: $WBGT = 0.7\ Tw + 0.3\ Tg$

Outdoor: $WBGT = 0.7\ Tw + 0.2\ Tg + 0.1\ Ta$

The WBGT Index was developed as a heat stress index and yields a single numerical value that can be used to interpret the amount of environmental heat stress present at a given time. Currently, the WBGT Index is the most widely accepted measure of environmental conditions and is used as a monitoring guideline for activities in both athletics and industry. The development of the WBGT equations is well supported by the research of Yaglou and Minard and is referenced by many agencies and governing bodies(3;10;52).

In 1975, the American College of Sports Medicine published a "Position Stand on Prevention of Heat Injury During Distance Running" to address the issues of heat injuries associated with distance running. This position stand was replaced in 1987 with the "Position Stand on Prevention of Thermal Injuries During Distance Running" which included thermal injuries affecting not only distance runners, but also the general community. In 1996, the ACSM issued the "Position Stand on Heat and Cold Illnesses During Distance Running" to replace the 1987 position stand, addressing both the recreational jogging community and the elite distance runner(8;10). This guideline includes a WBGT Index Risk Chart that delineates temperature ranges and descriptive terminology for potential environmental heat stress. The directive of the Position Stand was to advise race sponsors and participants of the dangers associated with athletic activity during specific environmental heat stress and that the monitoring of environmental conditions is vital to the health and well being of all participants. By monitoring environmental conditions and implementing specific preventative measures, the potential for reduction in both frequency and severity of thermal injuries may occur. It is the opinion of the ACSM that while adherence to these guidelines may reduce the risk of exertional heat illness, it is not a fail-safe approach and will not eliminate the possibility of EHI.

Research conducted by Yaglou and Minard(51) at the Parris Island Marine Corps Training Compound evaluated the incidence of EHI's to the personnel participating in military training drills. This location was chosen due to the hot and humid climatic conditions present during much of the training periods that could be seen in other countries. The WBGT Index was used to evaluate environmental conditions and provide valuable information as to what factors contributed to the incidence of exertional heat illnesses to the recruits. These studies indicated that the incidence rates for exertional heat illnesses rose dramatically when the WBGT was >27^{0}C. Upon the recommendations of the researchers, specific guidelines were developed for participation levels in various heat stress conditions. A simple heat index was devised to direct training personnel in the appropriate methods to monitor environmental conditions and what steps should be taken to reduce the heat stress illness risk. Guidelines were established and subsequently updated in 1980, stipulating temperature ranges and descriptive terminology, and outlined what type of training programs could be implemented as well as the potential implications on the unacclimated recruit. Colored flags were used to alert the training commanders as to the environmental risk level present at a given time of the day. These colored flags would be posted at all training locations. Training programs, therefore, were to be planned according to the measured heat index for that day(41;51;53).   The ACSM and the DOD WBGT Index Risk Chart are presented in Table 2.

Table 2 – WBGT Heat Stress Indices

American College of Sports Medicine WBGT Heat Stress Index(10)

WBGT	FLAG	RISK	COMMENTS
<18^{0}C	Green	Low	risk is present on basis of risk factors
18 - 23^{0}C	Yellow	Mod	risk inc. as event progresses through day
23 - 28^{0}C	Red	High	aware of injury potential; at risk individuals should not compete
>28^{0}C	Black	Extreme	consider rescheduling or delay event, if continuing be on high alert

Department of Defense WBGT Heat Stress Index(54)

WBGT	FLAG	RISK	COMMENTS
<26.7 - 29.4^{0}C	Green	Low	Exercise with caution
29.5 - 31^{0}C	Yellow	Mod	Strenuous exercise suspended for 1st phase recruits
31.1 – 32.2^{0}C	Red	High	Strenuous activities suspended for all recruits
>32.2^{0}C	Black	Extreme	All activities suspended

CHAPTER 3

METHODOLOGY

The individuals used for this study consisted of varsity athletes who participated in football practice/games at five Division I universities in the Southeastern Conference. The five universities consisted of Auburn University, Florida State University, University of Florida, University of Georgia, and the University of South Carolina. The data collection period was August 1 – October 31, 2003. Environmental readings were recorded, the number of athlete participants, and the number of exertional heat injuries during football practice were recorded. A designated recorder (a certified athletic trainer [ATC]) at each institution was responsible for all data collection, equipment setup, and transmitting information to the researchers. Each ATC was given a detailed instruction manual that included equipment setup, definitions of exertional heat injuries, and reporting forms (Appendices A, B). Environmental conditions were monitored weekly on days in which the athletic teams participated in a practice session.

Operational Definitions

Exertional heat injury cases were defined by the National Athletic Trainers Association Position Statement on Exertional Heat Illnesses(3) and were assessed by the medical and athletic training staff at each respective institution. EHI cases were defined as exercise-associated muscle (heat) cramps, heat syncope, exercise (heat) exhaustion, exertional heat stroke, and exertional hyponatremia. Clinical signs and symptoms of exertional heat illnesses were provided for consistency of evaluation and assessment of these illnesses. Consistency of assessments between institutions was attempted by the utilization of these documents. Incidence rates for heat illness cases (per 1000 AE) were calculated and compared to WBGT readings for each month. Exposure information and injury data collection instructions were provided to each institution and respective recorder to standardize the collection of data. For each practice session, the starting time, middle time, and ending time were recorded along with the total number of individuals for that session. Following the EHI definitions, those individuals who suffered a bout of heat illness for that practice session were recorded on the data sheet, noting the type of injury that occurred either during or after practice. The number of EHI's were then tabulated for the week and recorded on the data sheet. The illness incidence data was reported to the researcher on a weekly schedule.

Instrumentation

Environmental weather measurements were made daily at each institution on those days where football practice was held. The WBGT-103F Heat Stroke Checker (KEM Kyoto Electronics Manufacturing Co., LTD., Tokyo, Japan) was used to make these measurements to compute the WBGT Index.

The WBGT-103F Heat Stroke Checker is a portable, hand-held environmental monitor, which monitors and records ambient air temperature, relative humidity, globe temperature, and the WBGT. All environmental conditions were monitored and recorded at regular intervals: 8 AM, 2 PM, 6 PM, and at the start/middle/and end of each practice session. All environmental values were recorded on the data collection form and sent to the researcher on a weekly basis. Each recorder at each institution was given an orientation to the operation of the unit and the recording software prior the start of the collection period.

Procedures

The Heat Stroke Checker was positioned in a sunny location, as near to the center of the practice field as possible, in a position that ensured that the unit would be in direct sunlight, receiving maximum sun exposure, and not be in shade at any time. Environmental conditions at the specified recording times were then recorded. The Heat Stroke Checker consists of three separate thermometers. Collectively, these thermometers assess all aspects of the environmental atmospheric conditions – heat, humidity, wind, and radiant energy. Each thermometer is connected electronically via circuitry that produces a digital readout of each temperature as well as the calculated WBGT Index (a value representative of all four environmental variables). Data points were collected daily for each individual variable as well as the calculated WBGT Index. The following is a descriptive for the environmental variables regarding the various aspects of climatic heat stress monitoring(10;21):

Dry Bulb Temperature$_{db}$ - Ambient air temperature taken in the shade without the effect of radiant heat. This value is acquired by one thermometer kept under a cover.

Wet Bulb Temperature$_{wb}$ - The influence of wind speed and evaporation on the ambient air temperature. This thermometer is covered by a moistened, white cloth sleeve.

Black Globe Temperature$_{bg}$ - The influence of wind speed and infrared energy from both the sun and the surface of the playing field.

Relative Humidity - A percentage value determined by the difference between the dry bulb and wet bulb temperatures. The greater the difference, the lower will be the percent humidity.

Daily environmental weather conditions were monitored and WBGT values were recorded along with ambient air temperature, dry bulb temperature, black globe temperature, relative humidity, and the dew point by both units. The WBGT Index is calculated by the following formula: $WBGT = 0.7T_{wb} + 0.2T_{bg} + 0.1T_{db}$ and is calculated by each monitoring device, thereby eliminating calculation error by the recorder. This temperature represents the total influence of the environmental conditions. Average WBGT levels were calculated for each practice session, as well as the average WBGT reading for the day. The total number of athletic exposures as well as the exertional heat injury risk rates was then calculated utilizing the data provided by the institution.

Statistical Analysis

Data analyses were performed to determine the mean and standard deviation of the WBGT, air temperature, wet bulb temperature, black globe temperature, relative humidity and dew points for a given day during the stated recording time period. In addition, data analysis was performed to correlate the incidence of exertional heat injuries and the corresponding WBGT Heat Stress risk category. A comparison of the WBGT reading at the time of the exertional heat injury was made to the ACSM WBGT Risk Chart to ascertain at what risk level the injury occurred. Finally, the readings from the Heat Stroke Checker were compared to those of an environmental chamber for reliability and accuracy. Means and standard deviations were calculated for exertional heat injuries and environmental conditions. The rate of exertional heat injuries was computed by dividing the total number of injuries by the total number of AE. This injury rate was calculated for each participating school and by each month the data was collected. A regression analysis was used to compare WBGT risk categories of the ACSM and DOD Heat Indices to the total number of EHI's. The incidence of EHI was analyzed pertaining to the level of WBGT Heat Index scales (ACSM and DOD) readings and then compared to National Collegiate Injury Surveillance data(1;55). All analyses were performed using SPSS® (Chicago, IL, version 11.0). Descriptive statistics were used to determine WBGT readings taken at the stated intervals. A two-way analysis of variance (ANOVA) was performed to examine the incidences of EHI's between each school, between each week in August, between Schools and weeks in August for each specific type of EHI. An alpha level of 0.05 was required to establish statistical significance.

CHAPTER 4

RESULTS

The purpose of this study was to evaluate the incidence of exertional heat illnesses during football practice sessions at five Division I Universities during the months of August through October. Environmental data were evaluated to assess the severity of environmental conditions, as it relates to the WBGT Heat Stress Index scales published by the ACSM and DOD. Environmental conditions were assessed for WBGT readings at three separate times during the day and during all practice sessions.

Analysis of Exertional Heat Illness

Participating institutions reported a total of 139 EHI during the three-month reporting period. The overall illness rate was greatest in August with a sharp decline in the following months (August accounted for 88% of the total EHI's, 12% were recorded in September, and there were not any EHI's reported in October). EHI's were tabulated by the number of illnesses per month, the total athlete exposures, and the illness rate per 1000 athletic exposures as seen in Table 3.

Analysis of the overall EHI cases indicated that heat cramps were the most frequently recorded illness, followed by heat exhaustion, then heat syncope (see Table 4). There were not any reported cases of heat stroke or hyponatremia in the three-month reporting period.

Table 3 - Total Exertional Heat Injuries by month

Month	Number of Injuries	AE	Injury Rate/1000 AE	Percent of Total
August	122	13625	8.95	88%
September	17	10005	1.70	12%
October	0	9566	0.00	0%
Total	139	33196	4.19	100%

Table 4 - Total Exertional Heat Injuries

Injury Type	Number of Injuries	AE	Injury Rate/1000 AE
Heat Cramps	102	33196	3.07
Heat Exhaustion	29	33196	0.87
Heat Syncope	8	33196	0.24
Hyponatremia	0	33196	0.00
Heat Stroke	0	33196	0.00
Total	139	33196	4.19

With August representing the greatest number of recorded EHI's, analysis of recorded EHI's indicates heat cramps had the highest injury rate with lower injury rates found for heat exhaustion and heat syncope (see Table 5).

Table 5- Exertional Heat Injuries for August

Injury Type	Number of Injuries	Total Exposures	Injury Rate/1000 AE
Heat Cramps	86	13625	6.31
Heat Exhaustion	28	13625	2.06
Heat Syncope	8	13625	0.58
Hyponatremia	0	13625	0.00
Heat Stroke	0	13625	0.00
Total	122	13625	8.95

Further analysis of the recorded EHI's during August was assessed on a week-by-week basis. Seventy percent of all reported cases were heat cramps (86 cases), heat exhaustion accounted for 23% (28 cases), and heat syncope had an incidence rate of 7% (8 cases). These values are presented in Table 6.

Table 6 - August Exertional Heat Injury Summary Data by Week

Date	Cramps	Exhaustion	Syncope	Total
8/4 – 8/10	37	7	5	49
8/11 – 8/17	27	8	0	35
8/18 – 8/24	18	11	3	32
8/25 – 8/31	4	2	0	6
TOTAL	86	28	8	122
PERCENT	70%	23%	7%	100%

Weekly injury rates indicated the greatest risk of EHI's to athletes came during weeks one and two of August (Table 7). Sixty percent of the total EHI's reported occurred during this time frame. For the individual month of August, 69% percent of EHI's also occurred during weeks 1 and 2.

Table 7 - Weekly Exertional Heat Illness Rates/1000 AE for August

Date	Number Injuries	Total Exposures	Injury Rate/1000 AE
8/4 – 8/10	49	3205	15.29
8/11 – 8/17	35	4514	7.75
8/18 – 8/24	32	3634	8.81
8/25 – 8/31	6	2272	2.64
TOTAL	122	13625	8.95

Exertional Heat Injury by Heat Stress Index

A two-way ANOVA found no statistical significance between schools ($p > .05$) and between schools by weeks ($p > .05$) for heat cramps, heat syncope and heat exhaustion. There was a statistically significant decrease in heat cramps ($F_{(3, 84)} = 3.250$, $p = .026$) and heat syncope ($F_{(3, 87)} = 3.193$, $p = .028$) between weeks. Using Bonferonni post-hoc analysis, for heat cramps there was a significant decrease in injuries between week 1 (n = 37) and week 4 (n = 4). The relationship was also similar for heat syncope between week 1 (n = 5) to week 4 (n = 0).

For the August data, EHI's and the HSI (ACSM and DOD) found no statistical significant correlation ($p > .05$). Correlations between EHI's and the ACSM Index for heat cramps (r = .173, η^2 = 0.03) and heat exhaustion (r = .131, η^2 = .019) were low due to the small effect size and were determined to be clinically insignificant. Similar findings were seen between the DOD Index and heat exhaustion (r = .172, η^2 = .031).

Analysis of Environmental Data

Environmental data was collected at specified time periods every day during the reporting period. Readings were obtained at 8 AM, 2 PM and 6 PM and at the beginning, middle and end of each practice session. The 103F Heat Stroke Checker (KEM Kyoto Electronics Manufacturing, Ltd., Japan) was used to record these readings.

A Tenney Environmental Chamber (Lunaire Environmental, Williamsport, PA) was used to determine the reliability of the readings of the Heat Stroke Checker. Agreement between Heat Stroke Checker scores was determined by calculating an intraclass and interclass reliability coefficient – Interclass (r = 0.9930), Intraclass (r = 0.9993) and to that of ambient air temperature readings (r = 0.9132).

WBGT Reading and Risk Relationship

Since August accounted for 88% of the total EHI's, only the environmental data for this month was analyzed. This data was categorized into the various levels of risk for the ACSM and DOD Heat Indices (Table 8). Table 9 describes the maximum WBGT, mean WBGT for Practice 1 and mean WBGT for Practice 2 for each week of the month. In general, the WBGT readings were in the extreme range for the ACSM scale and in the low to moderate range with the DOD scale (Table 10).

Table 8 - Average Maximum WBGT and Average Practice Session WBGT

ACSM Heat Stress Index

WBGT	Risk	Max. Average	Practice 1	Practice 2
< 18^0 C	Low	0	0	0
18 – 23^0 C	Moderate	0	0	0
23 – 28^0 C	High	1	5	12
> 28^0 C	Extreme	27	22	1

DOD Heat Stress Index

WBGT	Risk	Max. Average	Practice 1	Practice 2
26.7 – 29.4^0 C	Low	10	15	12
29.5 – 31^0 C	Moderate	11	6	0
31.1 – 32.2^0 C	High	5	0	0
> 32.2^0 C	Extreme	2	6	1

Table 9 – Average maximum WBGT and average practice WBGT for August by week

Variable	Mean	Standard Deviation
	WEEK 1	
Maximum WBGT	30.50	4.52
Practice 1 WBGT	28.05	5.59
Practice 2 WBGT	26.73	2.21
	WEEK 2	
Maximum WBGT	30.01	3.70
Practice 1 WBGT	29.15	4.17
Practice 2 WBGT	27.10	2.18
	WEEK 3	
Maximum WBGT	29.32	3.68
Practice 1 WBGT	30.13	5.53
Practice 2 WBGT	26.12	1.33
	WEEK 4	
Maximum WBGT	31.41	4.03
Practice 1 WBGT	30.82	5.02
Practice 2 WBGT	n/a	n/a

Table 10 - Average WBGT Readings by Week in August

ACSM Heat Stress Index

Week	8 AM	Risk	2 PM	Risk	6 PM	Risk
1	24.57 (± 2.45)	high	29.97 (± 4.68)	extreme	27.35 (± 1.89)	high
2	25.74 (± 2.26)	high	29.71 (± 3.51)	extreme	27.76 (± 2.05)	high
3	25.38 (± 1.78)	high	30.06 (± 2.48)	extreme	27.31 (± 1.34)	high
4	26.23 (± 1.98)	high	31.75 (± 3.71)	extreme	28.52 (± 4.42)	extreme

DOD Heat Stress Index

Week	8 AM	Risk	2 PM	Risk	6 PM	Risk
1	24.57 (± 2.45)	low	29.97 (± 4.68)	moderate	27.35 (± 1.89)	low
2	25.74 (± 2.26)	low	29.71 (± 3.51)	moderate	27.76 (± 2.05)	low
3	25.38 (± 1.78)	low	30.06 (± 2.48)	moderate	27.31 (± 1.34)	low
4	26.23 (± 1.98)	low	31.75 (± 3.71)	high	28.52 (± 4.42)	low

CHAPTER 5

Summary

The purpose of this study was to evaluate the incidence of exertional heat illnesses during football practice sessions in the Southeast region of the United States during the months of August through October, as it relates to the WBGT readings on a daily basis. Five Division I Universities participated in this study, providing environmental data over a ninety-day period. The majority of EHI's occurred during the first two weeks of August with heat cramps having the greatest injury rate. Heat exhaustion and heat syncope were also noted, but at a much lower injury rate. There were not any reported cases of hyponatremia or heat stroke. WBGT Index readings during all August practice sessions were in the "extreme or high" risk category using the ACSM Risk Index or in the "low or moderate" risk category using the DOD Index Scale. Assessment of WBGT readings during the specified times of this study indicated that the lowest WBGT readings were taken during the 8 AM time frame. Mean practice time WBGT indexes for the month of August were 29.54^0 C (± 1.21) for practice 1 and 26.65^0 C (± .49) for practice 2.

Discussion

Comparison of the data collected with this study to previous studies render varying results. Research conducted by Martin (18;23) during the 1996 Olympic Trials and the 1996 Atlanta Olympics evaluated weather conditions and the number of heat-related medical encounters. This study defined a heat-related medical encounter as falling into one of three categories: heat exhaustion (including dehydration, electrolyte imbalance, dizziness, weakness, fatigue), heat cramps (painful muscle spasms), or heat syncope (fainting). Hyponatremia and heat stroke were not considered in this study. EHI risk rates for the Olympic Trials competition was 2.84/1000 athletes and the 1996 Olympics were 2.93/1000 athletes. EHI related medical encounters were most common among athletes competing in long distance running events or race walking events where these injuries collectively accounted for 53% of the total EHI's at the Olympic Games and 31% at the US Trials. The Heat Stress Index (ACSM Risk Index) for the thirteen men's and women's long distance running/walking events of the 1996 Olympics averaged 22.7^0 C and 24.5^0 C for the Olympic Trials which correlates with the "low risk" category. Average Heat Stress Index values for all of the track and field competitions during the Olympic Trials were 28.8^0 C, which correlates with the "high risk" category (ACSM Risk Index).

Kark et al (41) examined EHI's in Marine Corps recruit training over a ten-year period. Injury rates recorded were defined by 1000 person months. EHI cases were defined as those recruits who visited the base clinic or were admitted to a hospital/emergency room for exercise-induced illnesses: heat exhaustion, heat injury, heat stroke, heat cramps, exertional dehydration, and/or rhabdomyolsis. Injury rates for this 10-year study was 2.24/1000 person months. Finally, the National Collegiate Athletic Association (NCAA) compiled injury surveillance data regarding injuries in football(55). In this study, EHI's are defined as "time-loss" injuries, thereby not including an EHI incidence if the athlete does not miss practice time and included only heat exhaustion and heat stroke as reportable EHI's. The NCAA report a low injury rate (0.18/1000 AE for heat exhaustion and 0.01 for heat stroke); however, considering that these rates represent all of the Division I football programs in the United States, these figures seem to be uncharacteristically low (only 265,841 AE for the reporting year). Comparisons of exposure rates between these studies are seen in Table 11.

Table 11 - Illness Risk Rates and Associated WBGT Risk Categories

Study	Risk Rate
1996 Olympic Trials	2.84/1000 athletes (Total EHI's)
1996 Olympic Games	2.93/1000 athletes (Total EHI's)
NCAA Football Injuries (2003-04)	0.18/1000 AE (Total EHI's)
Heat Exhaustion	0.18/1000 AE
Heat Stroke	0.01/1000 AE
5 Southeastern Universities	4.19/1000 AE (Total EHI's)
Heat Exhaustion	0.87/1000 AE
Heat Stroke	0.00/1000 AE
Heat Cramps	3.07/1000 AE
Heat Syncope	0.24/1000 AE
Hyponatremia	0.00/1000 AE

Although this study involved a significant number of athlete exposures, when compared with other injury databases, the sample size was still relatively small. In addition, data was only collected from one region - the southeastern United States. Future projects that involved greater numbers of athlete exposures in the Northeast, Northwest and Southwest would be beneficial.

In this study, 5 EHI categories were included in the reporting data. Each reporting institution received a detailed description of the EHI definitions. Heat exhaustion, heat syncope, hyponatremia and heat stroke all are EHI's that require immediate medical attention. Heat cramps, however, are often interpreted as minor injuries and often are unreported. Previous studies (41;55) did not consider "heat cramps" as part of the reported EHI's. The inclusion of heat cramps in this study dramatically increased the injury rate during the three-month reporting period. If heat cramps were not considered, the injury rate of this study was comparable to previous studies.

This study relied on the participating athletes to “self-report” any EHI. It is possible that there cases of EHI (heat cramps) that were not reported, as an athlete may elect to “work through” the heat cramp or ignore the condition altogether. In addition, many times, medical staff is able to resolve the heat cramp condition on site and the athlete is able to return to practice without any time-loss. Comparisons to the NCAA Injury Surveillance Data (55) were difficult due to the NCAA data being based only on “time-loss” injuries.

Second, the equipment used to record the WBGT readings was a hand held device. Each institution had a designated recorder who was instructed on the proper methods of recording the WBGT readings. Specific variables were not considered, however, during the recordings. Height from the playing surface varied as to the height of the recorder, playing surfaces, (natural vs. artificial) was not documented, and current atmospheric conditions were not noted (the presence of rain).

Finally, cause and effect were not considered when analyzing the data. Data was not collected on football participants that may have been the underlying cause for specific EHI’s. Variables such as a pre-dehydrated state prior to the beginning of the recording period, ingestion of medications that would alter the body fluid levels, and previous episodes of EHI were not considered in this study.

Conclusion and Recommendations

Based on the data collected, the results of this study indicate that the majority of EHI's reported were during the first two weeks of practice, with a significant decline in injury rates during the first four weeks. WBGT readings during practice sessions in August were consistently in the "high or extreme" risk category (ACSM Heat Stress Index), for the entire month. There were not any reported cases of hyponatremia or heat stroke during the reporting period. Heat cramps comprised the bulk of the reported EHI's, and they are an EHI most often associated with a lack of acclimatization and/or conditioning. It could be hypothesized that an athlete requires a minimum of 14 days to fully acclimatize to environmental conditions and the specific WBGT Index rating may not play a significant role in the incident rate of this injury(16;30;56;57). While the NCAA has instituted a mandatory five-day acclimatization period, research supports a longer training period. Sufficient time frames that allow acclimatization to hot environments may prove to reduce EHI tendencies. Previous studies indicate that the recommended acclimatization period for athletes is approximately 10 – 14 days (30;45;56;57).

Inconsistencies in EHI definitions and reporting mechanisms also hamper comparative analysis of current literature. Surveillance of EHI's must include not only a tabulation of the incidence rates, but also a monitoring of the severity of the environmental conditions, assessment of the training regimes, and adherence to specific training and medical practices. This study's data suggests that if heat cramps were eliminated from the EHI definitions and not considered as part of the injury risk rate, results would be comparable to previous studies(21-23;55), even while athletes are participating in stressful environmental conditions.

EHI is a representative of specific physical ailments associated with exercise in a warm environment. Symptoms of these ailments include heat cramps, heat syncope, heat exhaustion, hyponatremia, and heat stroke. The influence of extreme environmental conditions present negative effects with regard to the body's ability to ward off fatigue during prolonged activity (28;58) while the effects of heat stress has been seen to also have a negative impact on neuromuscular activity(59;60). Early medical intervention as well as environmental monitoring will allow for a more rapid recovery for the athlete, as well as hopefully reduce the number of EHI's. Attention to hydration levels(19;33), rest, and exercise intensity(56) as it relates to the environmental conditions may prove to be the treatment of choice.

Further research is needed to evaluate the incidence of EHI's in all regions of the United States to determine if the current WBGT Risk Indices should be regionalized to accommodate the athlete who resides in a specific climate of the country and is therefore acclimatized to the environmental hazards of the region. Finally, sports medicine professionals must be mindful of the signs and symptoms of heat illness during these critical times and identify those individuals who are at risk during practice and competition when environmental conditions are stressful, focusing on the necessary hydration and rest intervals needed to stave off the possibility of incurring an EHI.

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APPENDIX A

INSTRUCTION FORM FOR DATA COLLECTION

Data Collection Methods for Heat Stroke Checker

1. Check system to make sure it is operational.
2. Record data at 8 AM, 2 PM and 6 PM on a daily basis. Also, record data at the start of each practice, at the mid-point and at the conclusion of each practice.
3. Record value on the data collection form provided.
4. Send data to UGA every Sunday.
5. For Games, we will <u>not</u> take any measurements with this device.

Exposure Information and Injury Data Collection Instructions

1. For each practice session, record the start time, end time and the total number of participants for that session.
2. For heat related injuries, follow the definitions provided in the consensus statement for exercise associated muscle (heat) cramps, heat syncope, exercise (heat) exhaustion, exertional heat stroke and exertional hyponatremia.
3. For each of the above heat related injures, enter the number of athletes who incurred each type of injury either during or after a practice session.

APPENDIX B

WEEKLY DATA COLLECTION FORM

Week of ___________________________			School ____________________________________					
Instruments	**Variables**	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**
8AM								
Heat Stroke Checker	Air Temp ^{0}C							
	Globe Temp ^{0}C							
	WBGT in ^{0}C							
	RH%							
2PM								
Heat Stroke Checker	Air Temp ^{0}C							
	Globe Temp ^{0}C							
	WBGT in ^{0}C							
	RH%							
6:00 PM								
Heat Stroke Checker	Air Temp ^{0}C							
	Globe Temp ^{0}C							
	WBGT in ^{0}C							
	RH%							
Practice 1 - Start Time ____________	**End Time ____________________**							
Heat Stroke Checker	Air Temp ^{0}C							
	Globe Temp ^{0}C							
	WBGT in ^{0}C							
	RH%							
Heat Stress Injuries								
Total Number of Participants								
Exercise Associated muscle (Heat) Cramps								
Heat Syncope								
Exercise (Heat) Exhaustion								
Exertional Heat Stroke								
Exertional Hyponatremia								
Practice 2 - Start Time ____________	**End Time ____________________**							
Heat Stroke Checker	Air Temp ^{0}C							
	Globe Temp ^{0}C							
	WBGT in ^{0}C							
	RH%							
Heat Stress Injuries								
Total Number of Participants								
Exercise Associated muscle (Heat) Cramps								
Heat Syncope								
Exercise (Heat) Exhaustion								
Exertional Heat Stroke								
Exertional Hyponatremia								