Exploring Environmental Heat Injuries in the Pediatric Population

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EXPLORING ENVIRONMENTAL HEAT INJURIES IN THE PEDIATRIC POPULATION

by

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Abstract

Children are considered a vulnerable population in society. While thermoregulation in children is similar to that of an adult, children are vulnerable to heat-related illness. Student athletes have been found to be particularly vulnerable to heat-related illness for numerous reasons, including intense outdoor play. Football players are perhaps the most at-risk population of student athletes due to the intense physical requirements, outdoor practice during the hottest months of the year, and the extensive protective equipment required. By conducting a literature review on the subject of pediatric heat illness, the purpose of this thesis is to explore evidenced based research and guidelines regarding heat-related illness prevention. This review of literature was conducted through the utilization of the University of Central Florida's online databases using the EBSCOhost platform of: CINAHL Plus with Full Text, Cochrane Database of Systematic Reviews, ERIC, Health Source: Nursing/Academic Edition, MEDLINE, PsycINFO and SPORTDiscus. This thesis is unique because it does not focus on an individual sport; rather, it focuses on pediatric athletes from various disciplines. The prevalence, pathophysiology, prevention, and treatment of heat-related injuries are complex phenomena requiring the attention of law makers, athletic associations, school officials, coaches, athletic trainers, parents, and students.

Keywords: Pediatric heat injury/illness; exertional heat injuries; heat stroke; heat exhaustion; athletes

Dedication

For my children; your safety and well-being are my inspiration in writing this thesis. Raising, protecting, and guiding the two of you throughout your lives is the most challenging, yet rewarding and formidable feat I will ever entail.

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Introduction

Society's most valuable, precious and most vulnerable assets are children. "The elderly, children (<18) … [and] athletes… are among those at risk for developing heat illness" (Raukar, Lemieux, Finn, Stearns, & Casa, 2015, p.1). The hottest months of the year are May to August in the continental United States. Based on these facts, youth participating in summer and early fall sports programs are at an increased risk for heat-related injuries. By exploring the prevalence, pathophysiology, and prevention of pediatric heat injuries, children will be better protected from these preventable phenomena.

Significance and Background

Heat-related injuries during athletic practices are one of the leading causes of death in high school students and are entirely preventable (Yard et al., 2010). A study of emergency departments in the United States showed that adolescents under the age of 19, during the period of 1997-2006, were the highest portion of patients being treated for heat-related illnesses (Somboonwong, Sanguanrungsirikul & Pitayanon, 2012). According to an article by Kerr, Casa, Marshall and Comstock (2019), “In Summer 2011, six high school football players died due to high temperatures and lack of rehydration” (p.8). Additionally, children under the age of five show an increased risk of emergency department visits in relation to hot weather conditions (Sheffield, Merrera, Kinnee, & Clougherty, 2018). The rates of the incidence of heat-related injuries are far too high for being an entirely preventable illness.

Unfortunately, regulating agencies for school related activities lack appropriate safety codes for conduct regarding exercise and the heat during children’s play. By implementing policies regarding a cut off point for play when environmental temperatures rise to extremes, regulations of heat acclimatization, exercise duration, intensity, rest periods, and adequate hydration, heat injuries may be avoided (Yeargin et al., 2010). Change is needed and is essential because education of the prevalence, pathology, and prevention of heat-related injuries is lacking for students, parents, activity coordinators, and coaches alike.

Purpose Statement

The purpose of this research is to explore the prevalence of heat-related injuries in relation to age groups and activities in the pediatric population, briefly detail the pathophysiology of heat injuries, and offer prevention strategies. This thesis will include a review of literature as well as explore policies with a special focus on heat safety in Brevard County, Florida. This research paper could be also used to create educational materials regarding heat injuries for parents, schools, and activity directors. By exploring prevalence, pathology, and prevention of heat-related injuries and illness, this research aims to provide evidence-based education of heat-related injuries in pediatric populations for all stake holders.

Methods

A review of literature on the subject of pediatric heat injury was conducted by utilizing a search of various databases through EBSCOhost via the University of Central Florida's online library tools. Databases included CINAHL Plus with Full Text, Cochrane Database of Systematic Reviews, ERIC, Health Source: Nursing/Academic Edition, MEDLINE, PsycINFO and SPORTDiscus. Keywords included: Heat Exhaustion, Heat Stress, Heat Adverse Effects, Heat N3 exhaustion, heat injurN*, heat stroke*, (MH "Heat Stress Disorders"), (MH "Heat Stroke"), Heat Illness*, and child*, toddler*, youth*, adolescen*, perdiatric, paediatric, elementary, player and daycare, childcare, school*, team*, football, soccer*, sport* or athlet* . This search resulted in approximately 227 results. Search results were then limited to scholarly, peer-reviewed journals published in the English language and available in full text; which limited results to 101. The researcher then meticulously read through all abstracts to determine the applicability of the articles to the objectives. Thirty-six articles were kept to include in this literature review. Further sources were added based on the citations and references of the chosen journal articles. Finally, additional needed information was found through the utilization of a brief internet search.

Objectives

This thesis is a literature review that explored both qualitative and quantitative research available regarding pediatric heat-related illness. The aim of this project was to explore as many aspects of pediatric heat illness as possible. These aspects include the pathophysiology, clinical signs and symptoms, contributing factors, risk factors, and current policies regarding heat injuries and the pediatric population. Additionally, an easily understood handout based on synthesized research findings was created for possible distribution to community organizations with members who are at risk for heat injury. Specific objectives are as follows:

1. Complete a literature review of the prevalence of heat injuries in the pediatric population and evidenced-based recommendations for safe practice regarding pediatric heat injuries.
2. Document pathophysiologies of the vast spectrum of heat injuries in pediatrics including signs and symptoms of the clinical manifestations of which peers, parents, and coaches should be aware.
3. Review current safety protocols regarding heat injuries in varying governing agencies including those specific to Brevard County, Florida.
4. Create a simple informational pamphlet as an exemplar of how the information might be distributed to community organizations.

Review of Literature

Heat Illness Occurs on a Spectrum

According to Pryor, Casa, Holschen, O'Connor and Vandermark (2013), exertional heat illnesses are conditions that occur in a variety of settings in which the risk increases as the ambient temperature increases. These injuries range from heat cramps, heat syncope and heat exhaustion, to exertional heat stroke. The less severe symptoms can be remedied on the site of physical activity without a medical professional. But the most severe condition, heat stroke, must be treated as an emergency illness by appropriately trained and equipped healthcare professionals. The same article goes on to explain that there are internal and external risk factor for heat injuries. Some examples of risk factors are: obesity, lack of heat acclimatization, race, gender, hypohydration prior to and during exercise, wet-bulb globe temperature (which uses environmental measurements to compose a temperature more accurate than ambient temperature alone) greater than 82°F and poor medical supervision (Pryor et al., 2013).

Another journal article regarding heat-related illness by Somboonwong, Sanguanrungsirikil and Pitayanon (2012) details the pathophysiology of heat illness and entails a spectrum as well. Injuries from heat illness result from a rise in core body temperature as a reaction to metabolic demands not being met in conjunction with environmental temperature and include, "…heat edema, heat rash, heat syncope, heat cramps, heat exhaustion, and heat stoke" (Somboonwong et al., 2012, p. 2). This article also explains how heat exhaustion occurs when the core body temperature reaches 38-40 degrees Celsius (°C) or 100.4-104 degrees Fahrenheit (°F) and heat stroke occurs when the body temperature is above 40°C (104 °F). The risk of heat-related injuries to children is further explained by their social or behavioral differences regarding re-hydration, a knowledge deficit about hydration, and their overall time spent outside when compared to adults (Somboonwong et al., 2012).

The Influence of Environment and Geographical Location

Meteorological conditions are a consistent factor in heat related injuries, especially for outdoor sports like football. However, Grundstein, Williams, Phan, and Cooper (2015) report that within the continental United States, states with lower average temperatures and humidity like Nebraska and Iowa have comparable rates of heat-related injuries in comparison to southern states like Georgia and North Carolina, where the heat and humidity are much higher. Additionally, Grundstein et al., (2012) conducted an analysis of the total number of fatalities during football that were documented with hyperthermia being the cause of death. The researchers found that most of the deaths occurred during days considered high or extreme heat based on the wet bulb globe temperature (WBGT), and over half of these deaths happened during unusually hot days in the month of August (Grundstein et al., 2012). These facts lead to the conclusion that heat acclimatization is a crucial component in heat-related fatalities. Geographic location comes into factor because of the average wet bulb globe temperatures during the same times of year can vary drastically. Therefore, athletes should follow different guidelines regarding heat acclimatization based on the geographical location in which they are practicing (Grundstein et al., 2015).

The National Athletic Trainer's Association has an updated position statement regarding exertional heat illness (Casa et al., 2015). In this article, heat acclimatization in athletes is presented as an important component in preventing heat-related injury. Heat acclimatization should follow specific guidelines based on the type of activity in addition to the wet bulb globe temperature (WBGT) which takes into consideration hot and humid weather conditions. Generally, the first two to three weeks of practice should be shortened, delayed, or rescheduled if there are particularly high WBGT days (Casa et al., 2015). Geographic locations must be considered for the previously mentioned factors.

Geographic locations have varying average WBGT readings. For example, according to the Monthly Weather Summary from the National Weather Service Forecast Office of Grand Junction, Colorado, in July of 2018 Aspen, Colorado had an average maximum temperate of 86.4°F, the mean temperature was 68.6°F and the average relative humidity average was 40% (National Oceanic and Atmospheric Administration [NOAA], 2018a). The National Weather Service Forecast Office of Melbourne, Florida's Monthly Weather Summary lists the average maximum temperature as 92.1°F, the mean temperature of 84.2°F, and the average relative humidity as 72% (NOAA, 2018b). Using a table from the Korey Stringer Institute (n.d.) that calculates WBGT from humidity and temperature alone, the mean temperature in July with the average relative humidity for Aspen, Colorado and Melbourne, Florida respectively were approximately 66.2 °F and 87.8 °F. If a student athlete is acclimated to the mean WBGT of 66.2°F in Aspen, Colorado experiences the WBGT average maximum temperature in Melbourne, Florida of 96.8 °F or 36°C, the athlete would be at a much higher risk for heat-related injury based on heat acclimatization of geographical location alone than the athlete from Florida who hypothetically was acclimated to the mean WBGT of 87.8 °F.

Grundstein, Williams, Phan and Cooper (2015) recognize the impact geographical location has on heat acclimatization. Accordingly, these authors developed three specific categories within the continental United States based on the WBGT. According to Table 2 from

Grundstein et al. (2015), an athlete participating in an outdoor sport in Colorado with a WBGT of 80.6°F (27°C) should carefully limit the intensity of exercise and amount of daily exposure. Whereas the safety guideline from the same source recommends that the acclimated athlete in Florida playing at the same WBGT can participate in normal activity while monitoring hydration. Because regional differences impact the average WBGT readings, the athletes have varying tolerances to the thresholds of weather extremes.

Prevalence of Heat-Related Injuries in Youth Activities

"The 5-year period of 2005-2009 saw more exertional heat stroke-related deaths in organized sports than any 5-year period in the past 35 years" (Kerr, Marshall, Comstock & Casa, 2014, p.1). Preseason football practices have the highest rates of heat stroke (Kerr et al., 2014). Raukar, Lemieux, Finn, Stearns, and Casa (2015), report that each year there are approximately 9,000 high school athletes treated for heat-related injuries. Shockingly, this number is projected to rise. Additionally, this article discusses how athletes in general are at a higher risk of heat-related illnesses from physical exertion, in addition to water loss from the body during physical exertion. For each hour of exercise, approximately one liter of water is lost from the body as a cooling mechanism (Raukar et al., 2015). These authors continue to state that during high intensity exercise or in extreme environmental conditions, an athlete can lose up to 2.5 liters of water per hour. In such situations, dehydration can occur if re-hydration is not prioritized, thus; increasing the risk for a rise in core body temperature.

Heat-related injuries are most likely to occur during practice in football, but also have been found to occur in wrestling and track (Kerr, Casa, Marshall, & Comstock, 2013). Heat injuries are also more likely to occur during August, when the autumn sports season is beginning, the temperature and humidity are the highest, and athletes have not yet become acclimated to the outdoor ambient temperatures (Kerr et al., 2013). According to their study titled, "Epidemiology of Exertional Heat Illness Among U.S. High School Athletes," most heat-related injuries occurred during boys' football activities (Kerr et al., 2013). The same study also found that the highest incidence of heat-related injuries during football happened in Florida, Alabama, Arizona and Kentucky. Additionally, it found other sports with reported heat injuries include volleyball, and soccer. Overall, it is "estimated 51,943 EHI [Exertional Heat Illness] events occurred nationally in the nine original sports [in the study]" (p. 10). This study also states that 66.4% of the exertional heat illnesses in the study had a medical professional on site when the injury occurred. When a medical professional was on site, 95% of the time it was an athletic trainer (Kerr et al., 2013). Considering these facts, it is important to analyze the amount of education and training athletic trainers receive regarding prevention, identification, and effective treatment of heat-related illness.

To continue forward, it is important to draw attention to the fact the hydration status prior to, during, and after exercise are all important in the pathology of heat-related injury. The body's ability to regulate temperature is likely impacted by large sweat losses and insufficient fluid intake (Bergeron et al., 2005). Any resulting fluid deficits in the body put athletes at risk for hyperthermia and poor performance. Therefore, any sports where athletes are inadequately hydrated potentially put the adolescent athlete at risk for heat-related injury.

A case report by Kurowski, Lin, Mohammad, Krug, and Alonso (2016) found that indoor wrestling can also be a risk for pediatric heat-related injuries. This individual case report explored how a child who was participating in an indoor wrestling training event during the winter had experienced heat-stroke followed by acute liver failure. As it turns out, the child was attempting to lose a few pounds to meet a lower weight class; he used baby oil on his body and wore an athletic training sweat suit. The athletic trainer on site suspected the child was experiencing heat illness at the time of the injury, and appropriately submersed him in an ice bath in an attempt to cool the child's core body temperature. Emergency medical services were contacted, and the child was taken to the hospital. After experiencing and being treated for cerebral edema as a result of hyperthermia, his blood laboratory values suggested acute liver failure in addition to alterations in the patient's coagulation functioning. The child survived after appropriate medical intervention.

While the case above is extremely unusual and rare, it demonstrates how wrestling in pediatrics can pose a threat (Kurowski et al., 2016). This child must have felt an extreme amount of pressure to succeed in wrestling. By attempting to lose enough weight to be in a lower weight class, he would have been one of the heaviest wrestlers in the lower weight class, thus giving him an upper hand against opponents. The psychological impact of this stress and the child's developmental emotional and psychological states led to a poor decision that ultimately resulted in exertional heat illness despite a lack of environmental heat factors. This case report summarizes that heat-related injuries should be recognized and treated appropriately and early in all athletic situations, even when the circumstances have low risk for heat-related injuries (Kurowski et al., 2016).

Other athletic events in which athletes may feel pressured to meet weight classes are in the martial arts. A study by Rivera-Brown and De Félix-Dávila (2012) found that adolescents participating in Judo (a combat type sport similar to jujitsu) are prone to dehydration. This event has competitions like wrestling, where athletes compete one on one in combat based on weight categories. These athletes often seek to make weight for the lower categories for the reasons mentioned previously. The preferred method this is done by is in this days or hours before competition by increasing their sweating and restricting their fluids (Rivera-Brown & De Félix-Dávila, 2012). The same study describes how the official judo rules state that weigh in is the day of competition and is usually done three to six hours before the actual competitions. Most of the athletes use this time to rehydrate after their weigh-in, since they had been restricting their fluids for so long. Additional risk factors for heat-related injuries in judo athletes are their uniforms, training in hot or humid environments, the intensity of the training, and persistent dehydration states (Rivera-Brown & De Félix-Dávila, 2012).

This study utilized various measurements before, during, and after judo training of 24 adolescent participants (Rivera-Brown & De Félix-Dávila, 2012). These measurements included: weights, urine specific gravity and color, as well as absorbent patches placed on the forehead of participants to measure the sodium concentration of the sweat loss, environmental temperature measurements during training, typical hydration patterns, and a subjective assessment of symptoms of dehydration such as "thirst, fatigue, dizziness, nausea, cramps, headaches, irritability or chills" (Rivera-Brown & De Félix-Dávila, 2012, p.3). The results of this study showed that 90% of the students began their practice dehydrated, fluid intake was inadequate during training, and most of the participants reported symptoms of dehydration. The researchers conducting the study determined that the athletes should have consumed 625-1500 milliliters of fluids after their exercises with a 50-100 millimoles per Liter (mmol/L) concentration of sodium to replace the water and sodium lost during exercise (Rivera-Brown & De Félix-Dávila, 2012, p.7).

The results of the study by Rivera-Brown & De Félix-Dávila (2012) are significant because the particular athletes in this study were predisposed to heat-related injury. These factors were the training environment (a tropical climate indoors only cooled by fans), the thick judo uniform, the physical demand of judo, and the poor hydration status of the adolescents (Rivera-Brown & De Félix-Dávila, 2012). Interestingly, core temperatures were not included in this study; something which should have been measured if only for safety due to the risk factors and physical symptoms reported of heat-related illness.

Another sport in which children participate in strenuous physical exertion outdoors is tennis. A study by Bergeron, McLeod and Coyle (2007), examined the hydration status of adolescent tennis players in a hot climate. The findings indicate that there is a strong relationship between pre-game hydration status and end of game body temperatures (Bergeron et al., 2007). These researchers essentially found that when children begin their exercise poorly hydrated, their bodies are not maintaining thermoregulation as efficiently as children who begin play with good hydration. Measurements included urine specific gravity, heights, weights, and body temperatures before and after tennis matches. The authors concluded, "junior tennis players who begin a match not well hydrated could have progressively increasing thermal strain and a greater risk for exertional heat illness as the match advances" (Bergeron et al., 2007, p. 4). The conclusion of this study supports the statement that hydration status is an important factor in preventing heat-related injuries.

One overlooked activity among high schoolers is marching band. These students are athletes too, who practice outdoors and are also prone to dehydration and heat-related illnesses (Vepraskas, 2002). Highschool marching band practices often entail creating formations with a large group of students who are all playing heavy instruments while marching in unison. During performances and events, marching band students may be required to wear thick uniforms which are not suited for hot weather. Breaking formation for water breaks every fifteen minutes during practices or performance would be very challenging for a music director to coordinate (Vepraskas, 2002). Additionally, the staff member supervising high school marching bands is often a music teacher, who may lack medical knowledge of heat illness symptoms (Vepraskas, 2002). Because of the lack of medical knowledge on the importance of simply requiring adequate hydration by the music teacher, many marching band students may begin to complain of symptoms like headaches, nausea, and muscle cramps, all of which should be recognized as symptoms of heat-related illness (Vepraskas, 2002).

Finally, a study by Sheffield, Herrera, Kinnee and Clougherty (2018), explores the vulnerability of the pediatric population ages zero to four. While this population does not participate in athletic activities like high school athletes do, the study notes increased incidence of emergency department visits during days that had high maximum daily temperatures in New York City (Sheffield et al., 2018). The study used a case-cross-over design (an effective heat illness research tool) in addition to daily temperature data from varying locations. While this study has several limitations, it did find statistical significance that increased heat does have health effects on the pediatric population; thus, further research is warranted regarding heat and this age range of pediatrics. Based on the findings of this study, the authors recommend caretakers, including daycares that service children aged zero to four, should have customized approaches regarding environmental heat safety (Sheffield et al., 2018).

Foreign Prevalence of Heat Injuries

The United States of America is not the only country to recognize the dangers of heat-related injury. In fact, several other studies have been conducted in developed countries such as the United Kingdom, Canada, France and Australia. A syndromic study of emergency department visits during the summer of 2013 during an unusual heatwave in England showed results that infer pediatrics are a vulnerable population regarding heat-related injuries (Smith et al., 2016). Smith et al. report that children are particularly vulnerable to dehydration, therefore heat injury, due to their bodies' relative volume of water. This balance of body mass to water volume is involved in thermoregulatory mechanisms. Syndromic surveillance, used by Smith et al. (2016), is a method of near real time evaluation of data. As deadly heatwaves began occurring more frequently across Europe, the United Kingdom began to use more early warning systems and found that syndromic surveillance is beneficial in evaluating public safety during heat waves (Smith et al., 2016). This specific study evaluated one heat wave in which 1,166 persons were treated for heat illness. The highest rates were of school children and elderly people. Based on the results found in this study, the authors concluded that system wide monitoring of heat-related injuries in children could provide better early warning systems and situational awareness, ultimately providing for better safety services for children, based on the vulnerability of this population (Smith et al., 2016).

Additionally, the first Australian multicity study based on heatwave mortality by Tong, Wang, Yu, Chen, and Wang (2014) showed interesting results. The authors' findings are based on their study of mortality rates in three large cities in Australia from 1988 to 2009 (Tong et al., 2014). Demographic groups were only divided by city, gender, and age ranges of 0-75 or 75+. The limited demographic separation was mainly due to privacy concerns. The study compared mean air temperature rates of heatwaves to mortality rates. Overall, the study found that there is a statistically significant relationship between heatwaves and increased mortality rates in the cities included in the study (Tong et al., 2014). Of all the demographics included, elderly females were the most vulnerable population. This is interesting because it is a well-known fact that elderly and pediatrics are the two most vulnerable populations. Perhaps, if the study would have included a third age range of 0-19, pediatrics would have been shown to be vulnerable to the negative effects of heat waves as well.

Next, a study by Lowe, Ebi, and Forsberg (2011) presented how climate change has increased heatwave prevalence and severity, and examined heatwave early warning systems as well as action plans across Europe. This study also mentions that mortality rates associated with heatwaves are often much different than reported, due to deaths being recorded as cardiovascular or respiratory related events. Additionally, this article reports that The World Health Organization has recognized and prioritized preventing increased mortality rates during heatwaves (Lowe et al., 2011).

Lowe et al. (2011) included a scoping review of the heatwave early warning systems across Europe. This research explored thresholds, components of action plans, warning message contents and delivery, to guide the creation of new plans for countries that do not have any or adequate heatwave early warning systems. The study found 33 countries which used similar warning systems but only 12 that included action plans. Typically, the plans utilize a trigger point measured by meteorological services and with alerts coordinated through the appropriate governing agency. Thresholds include environmental readings like temperature and humidity. A few countries even used real time temperature mortality relationships to measure how effectively heatwave effects are being controlled in the general population. Additionally, a few countries included measurements of air pollution due to its effect on the ozone and public health.

Overall this article (Lowe et al., 2011) found that the specificity of the thresholds, how much time in advance of heat waves that alert messages were sent, and the delivery to vulnerable populations were all crucial to the success of the programs. Interestingly, the researchers found that France had multiple tailored informational brochures regarding heat safety for vulnerable populations: for athletes delivered via sport groups and centers, child caretakers delivered via schools, daycares, and parents, as well as via caretakers of the elderly. The authors conclude that by examining how these action plans have been developed, utilized, and their effectiveness on reducing the increased rates of mortality during heatwaves, knowledge can be shared instead of having to be relearned by different countries.

Another article discovered during the literature review process is by Perry, Korenberg, Hall, and Moore (2011). The purpose of this report is to compare syndromic surveillance versus predictive weather warnings in preventing or reducing heat-related mortality increases during heatwaves in Canada. The authors present the idea that real-time surveillance of heat-related injury can provide more beneficial information regarding public health, because alerts can be made immediately in response to inclement weather rather than retrospectively by analyzing mortality data during heatwaves a year or two after the event (Perry et al., 2011). However, the authors note that both forms of heat surveillance have their drawbacks, so a combination of both may be most effective in designing a heat warning system. Interestingly, by examining heat-related illness events in hospitals on days with higher temperature readings, they found that there is an early heat effect confirming that heat acclimatization plays an important role in heat illness.

The prevalence of heat warning systems in foreign countries demonstrates how impacting heat is on public safety. Because society's most valuable and precious assets are children, this population needs special protections. The finding that tailored information is most effective proves that heat regulation should be specialized for children and children athletes (Lowe et al., 2011). While progress is being made, there is still much to be done to protect children from heat-related injuries. By studying and examining the benefits of real time monitoring of heat related injuries and early weather monitoring systems (Perry et al., 2011), perhaps warning systems can be developed specific to geographic locations on a county by county basis in regards to specific thresholds to trigger monitoring systems to alert school systems or regulatory agencies that are responsible for the safety of youth participating in athletic activities in the United States of America thus preventing heat-related injuries, and shared internationally.

Pathophysiology of Heat Injuries

Athletic activities in children are without a doubt beneficial for numerous reasons. Sport participation is beneficial to the child's health for promoting exercise in addition to their social and academic success (Falk & Dotan, 2011). However, heat-related injury is a known risk in many athletic activities especially in the pediatric population. In general, children are as physiologically capable to adapt to environmental changes as adults (Falk & Dotan, 2011). There are differences in the anatomy of children in comparison to adults that may have an impact on their susceptibility to heat-related injuries.

To begin, "children have greater surface-area-to-mass ratio, lower sweating rate, higher peripheral blood flow in the heat, and a greater extent of vasoconstriction in the cold" (Falk & Dotan, 2011, p.1). A child's surface area to body mass ratio plays a role in fluid balance in the body; this leaves them more susceptible to dehydration. Additionally, this ratio increases the absorption of heat during strenuous exercise (Gomes, Carneiro-Junior, & Marins, 2013); raising the body temperature further. The added peripheral blood flow in children means that more blood can reach the surface of the body. In cooler conditions, this means the blood can be cooled to effectively lower the core body temperature. When the environmental temperatures are near body temperature, this mechanism is useless (Falk & Dotan, 2011). The child's decreased sweat rate due to physical sweat pore size means that sweating as a thermoregulatory mechanism is less effective when compared to an adult's ability to thermoregulate via sweating (Falk & Dotan, 2011). Additionally, differences in cognitive functioning and decision making may impede the child athlete's ability to appropriately recognize their body's needs like drinking more water, taking a break, or getting out of the direct sun (Falk & Dotan, 2011). Falk and Dotan (2011) also report that children's core body temperature is faster to rise in response to environmental heat, contributing to the incidence of heat-related injury. These anatomical factors in addition to lack of development of cognitive critical thinking may contribute to the pediatric population's increased risk for heat-related injury.

Morrison and Sims (2014), describe thermoregulation in children. Heat in general is lost in the body through radiation, convection, or evaporation. Factors affecting these mechanisms include "…metabolic rate, their external work rate, convective, radiative, evaporative and conductive heat exchange, which can also depend on one's cardiovascular and sweating response…" (Morrison & Sims, 2014, p. 4). This article also lists heat-related injuries in children like heat rashes or cramps to heat exhaustion or heat stroke. Interestingly, this article details how the cardiovascular system is affected by the stress of exercise and temperature extremes. Exercise increases the heart rate and decreases stroke volume. After around 10 minutes of strenuous exercise, blood flow near the skin is increased to lower the core body temperature. Additionally, dehydration commonly experienced by the adolescent athletes further raises the heart rate and lowers stroke volume due to hypovolemia. Between the blood flow shifting and dehydration leading to less circulatory volume, the cardiovascular system and organs begin to compete for blood, which is carrying essential nutrients and oxygen to vital organs (Morrison & Sims, 2014).

Epstein and Roberts (2011) detail the pathophysiology of heat stroke. Heat stroke is marked by an internal core body temperature above 40.5°C or 104.9°F and encephalopathy. There are many modulators that factor into exertional heat stroke: "genetics, fitness, acclimatization, illness, medications, and sleep quality… exercise intensity and duration, clothing and equipment, ambient air temperature, relative humidity, and solar radiation…" (Epstein & Roberts, 2011, p.1). In response to rising body temperature, a cascade of regulatory responses occurs in the body that become overwhelming and ultimately can result in organ failure if the body fails to reach a normal core temperature (Epstein & Roberts, 2011). Hypothalamic neurons in the brain receive signals from afferent thermoreceptors from the skin and the spinal core and work to select appropriate thermoregulatory mechanisms. This monitoring system aims to rid the body of its heat load at the same rate heat is produced or gained in order to maintain an optimum body temperature of 97.7-99.5°F (36.5-37.5°C) (Robertson & Hill, 2019). Initially, cardiovascular activity changes and blood flow to the skin is increased in order to transfer heat out of the body through evaporation and radiation (Epstein & Roberts, 2011). Cardiac output is increased, and blood is shunted from central circulation to the periphery. If the body temperature is still not within acceptable bounds, sweating will ensue. This phase of thermoregulation is considered the compensatory phase, meaning the body is relatively unharmed in this process. Figure 1 depicts an easy to read pathology flow; the compensable phase of thermoregulation is pictured above the dashed red line. Throughout the thermoregulatory response, there is a cascade at a cellular level which can ultimately bridge the compensable phase to the un-compensable phase of heat stress (Epstein & Roberts, 2011).

Epstein and Roberts (2011) continue to detail the body's thermoregulatory response at the cellular level. Cellular stress proteins are released in response to the stress of heat called heat shock proteins (Epstein & Roberts, 2011). Essentially, these proteins are meant to protect cells from injury, ischemia, hypoxia, oxidative stress and heat (Epstein & Roberts, 2011). Levels of these proteins have been found to be reduced in patients with severe heat stroke (Wang et al., 2001). Cellular metabolism also changes from hyperthermia in the body increasing total energy requirements and involves the sodium potassium pump, acidosis, and the calcium ion gradient. These changes are harmful to the cell and lead to cellular necrosis.

Physiologically, heat stroke leads to multiorgan dysfunction syndrome (Epstein & Roberts, 2011). Fluid losses from hypohydration and sweating in conjunction with circulatory changes during strenuous exercise in the heat can lead to cardiovascular collapse. Ultimately, dehydration results in a cessation of sweating, which is a cooling mechanism for the body, leading to heightened hyperthermia (Epstein & Roberts, 2011). As the degree of heat-related injury worsens, the un-compensable phase of heat-related injury ensues (pictured in figure 1 below the dashed red line). With blood flow being impaired to organs such as the mesentery, spleen, liver and kidneys during circulatory changes, further injury occurs. Central venous pressure decreases, which slows the blood flow to the skin, again adding to heightened hyperthermia in attempt to re-vitalize organs. Examples of complications of these mechanisms include systemic acidosis, endotoxin-mediated shock syndrome, and intestinal and liver hypoxia (Epstein & Roberts, 2011). The endotoxins which are released due to injury to the intestinal tissue are unable to be filtered by the spleen and liver (due to hypoxia and damage to these organs) and initiates a lethal inflammatory cascade. Additionally, blood flow through the hepatic portal vein is severely decreased and hepatocyte functioning is altered from thermal insult. The liver loses all ability to filter the endotoxins from the intestinal wall, and endotoxemia shortly follows. In response, the body releases inflammatory cytokines which triggers endothelial vasoactive factors ultimately leading to circulatory collapse and neuronal injury. Additionally, the blood brain barrier is weakened from ischemia to the brain and endogenous pyrogens. The inflammatory cytokines and other harmful chemicals that would otherwise be kept out of the brain, leak in causing severe damage. The damage to the brain further worsens hyperthermia because the thermoregulatory centers in the brain become dysfunctional. This cascade triggers encephalopathy due to high intracranial pressure, low cerebral blood flow, vasogenic edema, and cellular injury causing severe neuronal injury (Epstein & Roberts, 2011).

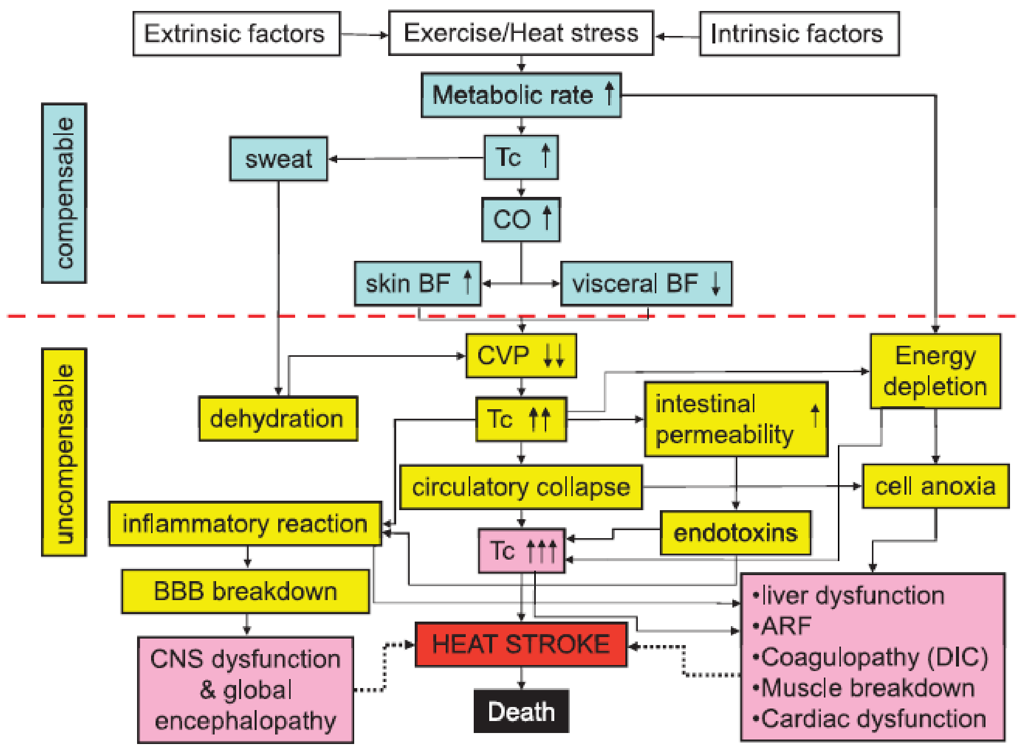

Figure 1: Pathophysiology Flow Chart of Heat Injury
From [Figure 1] "The Pathopysiology of Heat Stroke: An Integrative View of the Final Common Pathway," by Y. Epstein and W.O. Roberts, 2011, *Scandinavian Journal of Medicine & Science in Sports, 21,* p. 7. Copyright 2011 by John Wiley and Sons. Reprinted with permission.

Hassanein, Razack, Gavaler and Van Thiel (1992) write that for patients who have had a heat stroke, and who have survived the initial neurological insult, liver failure can cause death a week or more after injury. This article describes epidemiology of heat stroke as “hyperpyrexia…, anhidrosis, and a pan-tissue injury that present initially as a major neurologic problem” (Hassanein et al., 1992, p.1). Heat stroke has a varying mortality rate, but an average it is about 25%, with prompt rapid cooling being the most effective aspect in complete recovery (Hassanein et al., 1992). The most common initial insults that result in death from hyperthermia are neurologic injury, hypotension, and circulatory collapse. Patients who present with prolonged unconsciousness are likely to pass away within the first few days due to neurologic insult or coagulopathies. Those who survive past three days are at risk for kidney and liver failure. Acute renal failure was recorded to occur in 25% of patients suffering exertional heat stroke (Hassanein et al., 1992). Both liver and renal failure can be a cause of death, unless the patient receives a transplant. Pathologically, changes in the hepatocytes and endotoxemia ultimately lead to centrolobular necrosis in liver failure. Ultimately, the epidemiological flow of injury to the body in heat stroke is vast and requires prompt professional medical treatment including on-site core body temperature monitoring and immediate cooling of the body through ice water immersion (Pryor, Huggins & Casa, 2014).

Signs and Symptoms of Heat Injury

The Centers for Disease Control and Prevention (CDC) has an informative web page posted that lists signs and symptoms of heat-related injury (Centers for Disease Control and Prevention, 2017b). At the lowest end of the spectrum is heat rash. This is described by the CDC as red clusters that look like pimples. After that is sunburn and then heat cramps described as red, painful, blistered skin and muscle pain or spasms during intense activity, respectively. Heat exhaustion is finally followed by heat stroke. Heat exhaustion includes cool clammy skin, tachycardia with a weak pulse, dizziness, nausea, vomiting, headache, and even fainting. Heat stroke is described by the CDC as hyperpyrexia of a body temperature greater than 103°F, headache, dizziness, nausea, confusion and loss of consciousness. This information is presented in a format which could be easily distributed to any person responsible for adolescents at risk for heat-related injuries.

An article by Pryor, Casa, Holschen, O'Connor, and Vandermark (2013) also include details of spectrum of heat-related injuries. This source includes heat cramps, heat syncope, heat exhaustion, and exertional heat stroke as the four most major types of heat-related injury. Heat cramps are defined as painful muscle spasms. Heat syncope is dizziness followed by collapse due to blood pooling in the legs. Heat exhaustion is defined as the body temperature being less than 104.9°F (40.5 °C) and an inability to continue exercise due to cardiovascular instability. When the body temperature is greater than 104.9°F (40.5°C) coupled with neurologic impairment such as agitation, aggression, confusion, or loss of consciousness, the patient likely is experiencing exertional heat stroke (Pryor et al., 2013).

Ultimately, most academic resources describe the varying components of the heat illness spectrum in similar fashions. Slight difference may exist, but all professionals agree that heat stroke is the most severe and deadliest form of heat-related injury. This condition is entirely preventable with adequate prevention, early recognition, and immediate cooling techniques (Pryor et al., 2013).

Associated Factors of Heat-Related Injuries

There are additional risk factors that put an athlete in danger of heat-related illness: temperature and humidity, heat safety ranges, hydration, acclimatization, uniform, duration and intensity of play, health of the child, and the sports medicine staff size.

Temperature and Humidity

To begin, outdoor air temperature is quite possibly the largest attributing factor to most cases of heat-related injuries. Hassanein, Razack, Gavaler and Van Thiel (1992) write that when the ambient air temperature reaches 95 °F, sweating is the body's primary cooling mechanism. However, when the humidity reaches higher than 75%, sweating becomes insufficient. Because sweating essentially cools the body through evaporation, high humidity impedes this effect (Hassanein et al., 1992). Therefore, both ambient air temperature and humidity are crucial in the body's ability to thermoregulate.

Heat Safety Ranges

Most commonly, people think of outdoor weather as temperature alone. However, several other environmental factors should also be considered, especially regarding heat-related injuries. According to the Korey Stringer Institute, these include direct sunlight, wind speed, and relative humidity (n.d.). One method of measuring these conditions espoused by the institute is the wet bulb globe temperature (WBGT) measurement tool. The Korey Stringer Institute, in affiliation to the University of Connecticut, is an organization created to prevent exertional heat stroke. Their website details this measurement tool. The WBGT device was originally invented in the 1950s in response to the number of heat-related casualties of United States armed forces service men. The military used this measurement system to make modifications to their training sessions, especially when weather became extreme. There is also a table based on the work of Grundstein, Williams, Phan and Cooper (2015) displayed on the Korey Stringer Institute's website which provides guidelines for physical activity depending on geographical location (Table 2).

After the death of a professional football player, Korey Stringer, who played for the Minnesota Vikings and died in 2001 during a training camp, exertional heat illness awareness and policies have increased substantially at the professional, collegiate, and interscholastic levels (Grunstein, Vanos, Knox, Cooper, & Casa, 2017). The Korey Stringer Institute was developed with affiliation to the University of Connecticut in his honor to continue to raise awareness of heat-related injuries. An individual case study was published in 2017 evaluating exactly what led to this tragic event (Grundstein et al., 2017). As reported in the case study, both the day of and the day before this untimely death, the athlete was showing signs of heat exhaustion including vomiting and struggling to practice. On arrival to the emergency department after collapsing on field, the athlete's core body temperature was 108.8 °F (42.67°C). No prior attempts to cool the athlete had been made on field or in transit to the emergency department. Multiple risk factors for heat-related illness were present in this case including high body mass index, lack of heat-acclimatization, dehydration from the repeated vomiting, an unusually hot and humid day, full uniform and gear, and high intensity exercise (Grundstein et al., 2017). Between the multiple risk factors for heat-related injury and lack of appropriate monitoring and intervention for increasing core body temperatures, a series of preventable events led to the tragic loss of Korey Stringer.

The Korey Stringer Institute believes that all athletic programs, including those taking place in schools, should use the WBGT as a guideline, and provide specific policies on when and how it is safe for youth to participate in outdoor activities. For example, the United States military found it necessary to use the WBGT measurement parameters to modify basic training during extreme temperatures (Korey Stringer Institute, n.d.). In addition, the Korey Stringer Institute uses the Georgia High School Association as an example of a school system that has used WBGT successfully to mandate all its high schools make practice and game modifications based on the readings (Korey Stringer Institute, n.d.). The WBGT measurement system can and should be used as an objective measurement to help prevent heat-related illness and injuries among youth participating in athletic activities.

Hydration

Bar-Or, Dotan, Inbar, Rotshtein, and Zonder (1980) write that during heat waves, children and infants have been found to be particularly at risk for heat illness, especially if they are dehydrated. The same authors conducted a study to explore if children who were partially acclimated to the environment have the tendency to voluntarily dehydrate (when fluid is consumed voluntarily) and if it impacts thermoregulation. The study compared the hydration status of the children who participated in the study in a controlled environment at 39°C (102.2°F) and 45% humidity when they drank fluid voluntarily versus drinking a prescribed amount of fluid during exercise. This study found that the children who drank fluid during exercise at will, consistently (9 out of 11 children) were mildly dehydrated. Interestingly, this study also found that for each 1% of body weight loss experienced during exercise in these children, there was a 0.28°C rise in body temperature (Bar-Or et al., 1980) whereas a study of young men (Greenleaf & Castle, 1971) found that for each 1% of weight loss, there was only a 0.1°C rise in body temperature. While these two studies show marked differences, this suggests that children's core body temperature raises at a higher rate than adult men in response to the percentage of body weight loss (fluids) during exercise. The findings here simply put mean that adequate hydration is imperative in preventing heat-related injury. An article published on the National Alliance for Youth Sports' web page states, "To prevent dehydration, child athletes should consume six milliliters (ml) per pound of body weight per hour …2-3 hours before and during exercise" (Castle, 2014, p. 1).

Bergeron et al., (2005) report that most football players begin activities dehydrated. The added metabolic demands in high heat and humidity, plus intense physical activities place added strain on the hydration status of athletes. Teenage athletes tend to experience mild to severe hypohydration (Yeargin et al., 2010). The same source reports that most athletes are under hydrated before they begin and maintain the same hypohydration during practice. Yeargin and associates (2010) also conducted a survey of high school football players regarding hydration. They found that the participants overestimated their hydration practices compared to how much water was lost during exercise, failed to recognize hydration's relation to heat-related injuries, and generally reported the need to rehydrate was based on symptoms of dehydration like thirst and headache. All team activities should have cooled water available for participants at all times and encourage participants to take water breaks regularly. Additionally, athletes should be encouraged by parents, coaches, peers, and athletic trainers to hydrate not only during practice, but in-between and prior to practices to enhance their overall hydration status.

A study of female volleyball players who were playing in a warm and humid environment regarding hydration was recently conducted (Cleary et al., 2012). The problem that initiated this study was that athletes typically do not rehydrate adequately to prevent dehydration when allowed to rehydrate voluntarily. These researchers sought to find out if hydration education coupled with a prescribed hydration regimen was enough to prevent dehydration in this population. Interestingly, these researchers report that during practices in this study, the average sweat rate was 0.6 liters per hour (L/hr). However, McDermott and associates (2012) reported that during games, athletes lost an overage of 1.3L/hr during games. This may be due to added physical stress on the body during games, lack of emphasis on proper hydration, and less rest periods (McDermott et al., 2012). Fluid intake after exercise should exceed sweat loss by 25% in 4 to 6 hours (Yeargin et al., 2010). Based on the above findings of sweat loss, fluid intake should range from 0.15-0.33L/hr in addition to water consumed during practice. Sweat loss rates are dependent on the heat and humidity, intensity of exercise, and uniform worn; therefore, rehydration practices should depend on the same variables.

Heat Acclimatization

Next, heat acclimatization should always be considered in ensuring the safety of outdoor sports participants. "Most of the early-season football heat stroke deaths have occurred in the first 4 d [four days] of practice…" (Bergeron et al., 2005, p. 5). It should always be assumed by supervising staff that the children are not accustomed to the heat or intensity in which play is occurring (Bergeron et al., 2005). Specific recommendations are available from various resources. Bergeron et al. (2005) report that for high school athletes, players should not participate in more than 60 to 90 minutes of total fitness activity per day and players should not practice more than six days in a row. During the first week of practice, there should be no two-a-day trainings, and protective equipment should be added in phases including helmets, pads, and full uniform. During the second week of practice, it may be appropriate to introduce two-a-day practices, but there should be at least a three-hour break in between sessions. Heat acclimatization for high school students should happen over a period of at least two weeks.

Bergeron et al. also report that prepubescent children may take up to five days to reach the same level of acclimatization that high school students reach in two days (2005). Accordingly, heat acclimatization for younger children should take place over three weeks, with no total practices from pre-instruction to post-play cool down being longer than two hours.

Casa et al. (2009) have also published recommendations for heat-acclimatization for school aged athletes. These authors recommend that all preseason heat acclimatization programs be instituted for all athletic programs, whether they be indoors or outdoors. Specific recommendations are available from Casa and associates (2009). The first five days of practice should be no longer than one hour per day, after this time frame activity should not exceed three hours in one day. Additionally, a one hour walk through can be utilized safely to allow athletes to walk through drills without any equipment but a minimum three-hour break should be utilized between this period and any physical practice. On days six to fourteen, two practices a day can begin, as long as there is a minimum of three-hour break period in between practices that cannot last more than three hours. Additionally, days with two practices must be followed by a rest day or a one practice day. Finally, these authors recommend that during the acclimatization period, an athletic trainer who has received training of heat-related injuries be on site due to the high risk of heat-related injuries during this time period (Casa et al., 2009).

The National Athletic Trainers' Association has a position statement regarding exertional heat illness that also includes acclimatization (Casa et al., 2015). Athletes should be acclimatized over one to two weeks. Careful consideration should be taken during this time period to prevent heat-related illnesses. Interestingly, if an athlete does not maintain his or her acclimatization, it will be lost within three weeks. Grundstein, Williams, Phan and Cooper's (2005) journal titled "Regional Heat Safety Thresholds for Athletics in the Contiguous United States" argue that regional location should be considered regarding heat acclimatization. There should be "gradual adjustments in duration and intensity of activity along with amounts of protective equipment…" (Grundstein et al., 2005, p. 5) to prevent heat-related injuries. The same source states that youth athletes should be given at least two weeks to properly acclimatize whereas adults may be able to acclimatize in as little as five days (Grundstein et al., 2005).

Uniform

Unfortunately, research is lacking regarding uniforms and outdoor practice. Football quite possibly has the most intensive uniform due to protective equipment like padding and helmets. Bergeron et al. (2005) write that the football uniform increases metabolic demand and decreases the body's ability to thermoregulate. Other sports to take into consideration are lacrosse, hockey, fencing, marching band, junior reserve officer's training corps (JROTC), jujitsu and taekwondo, just for example. The body primarily thermoregulates through evaporation of sweating and convection through air movement, and radiation from direct physical contact (Robertson & Hill, 2019). When a thick uniform, bulky pads, or most of the body is covered, body fluids cannot be evaporated, therefore heat cannot be expelled adequately. Heat acclimatization programs also take into consideration uniforms. For example, Casa et al. (2009) suggest that during the first two days of practice, a helmet should be the only protective gear worn, days three to five can also include shoulder pads, and by day six the athletes can wear full uniform. This strategy aims to allow the athlete's body time to acclimate to the added protective gear. When youth are participating in outdoor activities, it is important to also protect the skin from the sun to prevent sunburns. One might be compelled to wear long sleeves and pants for this reason. However, it is important to consider that this might ultimately increase the athlete's core body temperature. Further research is indicated regarding fabrics and uniforms that provide necessary physical protection in contact sports and protection from the sun, but still allow the body to thermoregulate efficiently. Duration and Intensity of Play

Besides the heat acclimatization period, precautions should be taken when the WBGT readings reach a certain threshold (or heat and humidity if WBGT devices are not available). Different sources have similar activity modifications. For example, Bergeron et al. (2005) write that in increasing heat and humidity, the body loses its capability to release heat. Additionally reported by Bergeron et al. (2005), is that the uniform and any equipment act as insulators; raising the core body temperature further. Accordingly, activity modifications should be made to include more frequent and longer rest and hydration periods, weather dependent. These authors continue by reporting changes in activity that can prevent heat-related illness. For example, the coach or activity director should respect the hottest parts of the day; between noon and 4:00 p.m. generally (Bergeron et al., 2005). When temperatures become extreme (greater than a WBGT of 91.5°F), coaches should cancel practice, move to an indoor, air-conditioned space, or conduct walk- throughs of an exercise with no protective equipment worn. Pryor, Huggins and Casa (2014) also state that WBGT temperatures should be monitored and activity modifications made to prevent exertional heat illnesses.

Falk and Dotan (2011) point out the cognitive differences in children that may lead to a greater risk of heat injury due to overexertion. Children tend to overexert themselves, partly because they may underestimate how strenuous the intensity of exercise is. A natural competitive drive or pressure from peers, parents, and coaches may add to the risk of overexertion, especially in hot and humid conditions. Additionally, Falk and Dotan (2011) suggest that children lack skills such as pacing, which could also contribute to the likelihood of overexertion. These suggestions ultimately require the attention of coaches and athletic directors to modify and regulate the intensity of exercise, especially in hot and humid conditions.

Several national associations of sports medicine specialists have published valuable information about heat-related injuries; all of which include the importance of activity modifications. The National Athletic Trainers' Association has a position statement regarding exertional heat illness (Casa et al., 2015) that involves activity modifications. The guidelines in this position statement state that when environmental conditions become stressful, activities or drills that are high intensity especially when the participants in full uniform warrant consideration because the added stress to the body.

The American Academy of Pediatrics also has a position statement regarding heat stress and children (Bergeron, Devore, & Rice, 2011). "With appropriate preparation, modifications, and monitoring, exertional heat illness is usually preventable" (Bergeron et al., 2011, p.2). Reaffirmation of the importance of modifying play based on environmental conditions continues in this position statement. WBGT monitoring should be in place (or heat index if WBGT devices are not available). Effective activity modifications include adjusting the intensity of exercise, shortening the duration, and prolonging rest breaks as well as encouraging ample rehydration (Bergeron et al., 2011).

The American College of Sport's Medicine has a policy statement regarding heat-related injuries (Armstrong et al., 2007). This source has an excellent table which includes modifications to exercise based WBGT readings and the acclimatization of the participant (Armstrong et al., 2007, table 2). Activity modifications for the non-acclimatized high-risk participant should begin when the WBGT reading reaches 78.1°F. At a WBGT of 86.1°F or higher, all activity should cease for this population. The acclimatized athlete who is low risk for heat-related injury should ease prolonged or intense activity at 82.1°F, limit intense exercise and total daily duration of exercise as well as be closely monitored for exertional heat illness at a WBGT of 82.1°F, and all exercise should cease at 90.1°F.

Additionally, individual schools have begun implanting policies regarding activity and WBGT readings. For example, the Georgia High School Association (n.d.) has very specific activity modifications for heat and humidity, which are followed for all sports in schools. According to the Georgia High School Association’s policy regarding heat and humidity (n.d.), activity limitations should begin at 82°F. At 87°F, maximum practice time is two hours and to include four separate rest breaks each hour; football players should only wear helmet and shoulder pads for contact practice, and no protective gear during conditioning. At 90-92°F, the maximum time allowed for exercise is one hour with 20 minutes of rest throughout the hour; football players are not allowed to participate in conditioning activities and can not wear protective gear. All play is ended when the WBGT reading reaches more than 92°F.

Geographic location should be considered when monitoring WBGT readings. What is considered extreme heat and humidity in one location, may not be considered extreme in another; as previously explained. The average WBGT readings that children have been acclimatized to are what their bodies can safely thermoregulate in. When WBGT readings become extreme per the geographic location, the child’s body cannot maintain a safe core body temperature as efficiently. Locations with lower WBGT averages require lower heat safety guidelines than warmer climates (Grundstein, Williams, Phan & Cooper, 2015). Therefore, coaches, athletic trainers and parents alike must be knowledgeable about the impact of WBGT readings and be prepared to make activity modifications when the readings become extreme for the specific geographic location (Casa et al., 2013).

Grundstein and his associates (2015), compiled activity guidelines based on geographic location using WBGT readings. They began by separating the continental United States into three distinct categories based on WBGT readings in the 90th percentile of the seasonal daily maximum readings. Category three has the highest WBGT readings of greater than or equal to 90.14°F (32.3°C), category one is the lowest maximums with readings less than 86°F (30°C), and category two is regions with WBGT seasonal 90th percentile daily maxes in between. Using the original guidelines from both the American College of Sports Medicine (Armstrong et al., 2007, table 2) and the Georgia High School Association (n.d., table 3), activity guidelines from WBGT readings were adjusted based on the predetermined categories. The logic behind this is that the athletes are acclimatized to the local weather conditions, so heat tolerance varies based on the local average WBGTs.

Cat 3	Cat 2	Cat 1	Activitiy guidelines
≤10.0	≤8.7	≤6.7	Normal activity
10.1–18.3	8.8–17.0	6.8–15.0	Normal activity
18.4–22.2	17.1–20.9	15.1–18.9	Normal activity
22.3–25.6	21.0–24.3	19.0–22.3	Normal activity, monitor fluids
25.7–27.8	24.4–26.5	22.4–24.5	Normal activity, monitor fluids
27.9–30.0	26.6–28.7	24.6–26.7	Plan intense or prolonged exercise with discretion
30.1–32.2	28.8–30.9	26.8–28.9	Limit intense exercise and total daily exposure to heat and humidity
>32.3	>31.0	>29.0	Cancel exercise

Figure 2: Activity Guidelines Based on Geographic Location and WBGT
From [Table 2] "Regional Heat Safety Thresholds for Athletics in the Contiguous United States," by A. Gundstein, C. Williams, M. Phan, and E. Cooper, 2015, *Applied Geography*, *56*, p. 58. Copyright 2015 by Elsevier. Reprinted with permission.

Cat 3	Cat 2	Cat 1	Activity guidelines
<27.8	<26.5	<24.5	Normal Activities - Provide at least three separate rest breaks each hour with a minimum duration of 3 min each during the workout.
27.9–30.5	26.6–29.2	24.6–27.2	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 min each.
30.6–32.2	29.3–30.9	27.3–28.9	Maximum practice time is 2 h. For Football: players are restricted to helmet, shoulder pads, and shorts during practice. 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 min each.
32.3–33.3	31.0–32.0	29.0–30.0	Maximum practice time is 1 h. For Football: no protective equipment may be worn during practice, and there may be no conditioning activities. For All Sports: There must be 20 min of rest breaks distributed throughout the hour of practice.
≥33.4	≥32.1	≥30.1	No outdoor workouts. Delay practice until a cooler WBGT level is reached.

Figure 3: Detailed Activity Guidelines Based on Geographic Location and WBGT
From [Table 3] "Regional Heat Safety Thresholds for Athletics in the Contiguous United States," by A. Gundstein., C. Williams, M. Phan, and E. Cooper, 2015, *Applied Geography*, *56*, p. 58. Copyright 2015 by Elsevier. Reprinted with permission.

Health of the Child

The American Academy of Pediatrics have a policy statement regarding youth exercise and heat (Bergeron, Devore & Rice, 2011). This report includes information on some of the medical conditions which could ultimately increase the risk of heat-related injuries in youth participating in sports. If an athlete comes down with an acute illness that affects hydration status or the body temperature, he or she should not participate in sports. Examples would be influenza, strep throat, mononucleosis (Epstein-Barr Virus), vomiting, or diarrhea (Bergeron et al., 2011). Any febrile illness is when a child has pyrexia (a fever) greater than 100.4°F (38℃) (Robertson & Hill, 2019). When a child has febrile illness, they should not participate in physical exercise, especially in hot or humid conditions for the increased risk of heat-related injury (Bergeron et al., 2011).

Certain medical conditions require special attention of doctors and athletic trainers regarding participation in sports due to the possibility of decreased heat tolerance. For example, "diabetes insipidus, type 2 diabetes mellitus, obesity, juvenile hyperthyroidism (Grave's disease), [or] cystic fibrosis…" (Bergeron et al., 2011, p.2). Any other disease or condition that may impact electrolyte/hydration balance or thermoregulation should warrant the supervision of a medical provider for athletic participation. Additionally, sickle cell trait can be considered a risk factor for heat-related illness. Athletes who have the sickle cell trait are prone to "vascular dysfunction, exertional rhabdomyolysis, and collapse related to red blood cell sickling in youth during strenuous physical activity in the heat" (Bergeron et al., 2011, p.2).

The National Athletic Trainers' Association states that all children participating in sports programs should have a medical screening by a physician (Binkley, Beckett, Casa, Kleiner and

Plummer, 2002). This screening should include identifying risk factors for heat-related injury including the sickle cell trait. Additionally, history of exertional heat illness should be identified to determine if the athlete has an underlying condition that is predisposing him or her to the injury (Binkley et al., 2002). Additionally, all coaches, athletes, parents, administrators, and athletic trainers should be aware of the extrinsic and intrinsic causes of heat-related injuries. Intrinsic factors of heat-related illness include medical factors such as history of "exertional heat illnesses; insufficient heat acclimatization… substantial dehydration; current or recent fever or gastrointestinal illness; skin conditions…; or certain medications…" (Casa et al., 2013, p.5). Extrinsic factors include WBGT, time spent in strenuous activity, direct sunlight, uniform, hydration, presence of medical staff, and rest breaks (Casa et al., 2015).

Certain medications can also interfere with a child's cardiovascular status and ability to thermoregulate. Bergeron et al. (2015) report that children participating in athletic events should not consume caffeine in high doses such as some supplements and energy drinks contain. Also, ephedrine should, reportedly, be avoided. Additionally, reports that medicines like "antihistamines, diuretics, dopamine-reuptake inhibitors… and dietary supplements (eg, ephedra)" (Casa et al., 2013, p. 5) can be intrinsic causes of heat-related injuries.

Sports Medicine Staff

Reportedly, in 2012, twelve high school students died during athletic events (Pryor, Huggins, & Casa, 2014). Causes of death varied, but included exertional heatstroke, exertional sickling (with Sickle Cell Anemia), and blunt trauma. It is imperative that an athletic trainer with medical knowledge or a health professional be a member of all sports activities faculties and be present for practices and games, especially during the acclimatization period when heat-related injuries are most likely to occur. According to Pryor and associates (2014), this person should be responsible for the medical safety of athletic participants, including ensuring all participants have had appropriate sports physicals, ensuring these physical examinations include screening for risk factors associated with heat-related injuries, acclimatization periods and activities to include specific uniform adjustments, enforcing safety policies regarding WBGT monitoring, as well as modifications and cut-off points for exercise in markedly high WBGT days. This member should also ensure that emergency action plans are in place and that there is always a plan and equipment available for the management of heat-related injuries (Pryor et al., 2014).

A cross-sectional descriptive study was conducted concerning athletic trainers of high schools with football teams regarding exertional heat illness by Pryor, Casa, Yeargin, and Kerr (2018). A survey was used to attain information of the management and prevention of heat-related injuries during the 2011-2012 school year in relation to the number of athletic trainers or physicians on staff. Generally, this study found that schools with more than one athletic trainer on staff had more prevention and management strategies in place than schools with only one athletic trainer (Pryor et al., 2018). This study also indicated that in the rare circumstance a team physician was on staff, that the previously discussed recommendation from Bergeron et al., (2005) of no two-a-day practices during the first five days of heat acclimatization were only followed 24.6% of the time (Pryor et al., 2018). The researchers conclude that presence of a team physician may ultimately result in riskier practices because the availability of a medical professional. It was found that only 32% of the 1,142 of the athletic trainers included in the study reported using WBGT devices (Pryor et al., 2018). Additionally, 61.7% of the athletic trainers in the study reported that athletes were required to wear lightweight clothing. Of the schools studied, only 44.8% had an ice bath filled and accessible prior to practice for the immediate treatment of suspected hyperthermia. The researchers point out that during the time period of this study, only one state had heat safety requirements in place and since this time, seven more states have mandated heat acclimatization guidelines for high schools (Pryor et al., 2018). Overall, best evidence shows that hiring two or more athletic trainers who regulate end enforce heat safety guidelines has an impact on preventing heat-related injuries.

From July 21 to August 15 of 2011, 17 athlete deaths occurred during sports participation; seven of which are speculated to be caused from heat-related causes (Adams, Mazerolle, Casa, Huggins, & Burton, 2014). Athletic trainers receive medical training which should always include information on the signs, prevention, and treatment of heat-related injuries. Coaches on the other hand, do not receive the same medical education. Unfortunately, in 1999 only around 35% of high schools employed an athletic trainer (Lyznicki, Riggs, & Champion, 1999). However, many governing agencies have since pushed for improvements in school regulations including staffing of athletic trainers (Lyznicki et al., 1999). A qualitative studied was recently carried out that examined the relationship between a coach and athletic trainer at secondary schools (Adams et al., 2014). This study found that often, coaches perceived confidence of their ability was much higher than their medical knowledge of emergency care of student athletes. This study also found that coaches hold positive attitudes of the value of athletic trainers especially regarding their role in emergency medical management and injury prevention (Adams et al., 2014).

Various other sources regard a team physician or an athletic trainer as important components in preventing heat-related injuries. Pryor, Casa, Holschen, O'Connor and Vandermark (2013) write that the team physician works as part of a team which also includes athletic trainers, coaches, parents, and the athletic participants. Additionally stated is that the team physician should be at the forefront of preventing heat-related injuries by planning guidelines for the treatment, early recognition, prompt treatment, and emergency action plans based on current evidence regarding heat-related injuries. In the absence of a team physician whether it be for budgeting reasons or not, the athletic trainer and the coach should assume these responsibilities. The American Academy of Pediatrics' policy statement on heat-related injury includes athletic trainers as part of the team who is charged with preventing heat-related injuries in youth (Bergeron, Devore, & Rice, 2011). The athletic trainers, in conjunction with coaches, parents, students, sports governing bodies and agencies should all support "comprehensive awareness, education, and implementation of effective exertional heat-illness risk-reduction strategies" youth (Bergeron et al., 2011, p. 3). Bergeron and associates (2005) report that among other duties, athletic trainers should monitor all participants for signs and symptoms of heat-related injuries. Special attention should be given to football players, especially linemen who had excessive body mass index, unfit players, and those who have not yet become acclimated to the environment in which play is taking place (Bergeron et al., 2005).

Return to Play After Heat-Related Illness

The National Athletic Trainers' Association position statement includes details of return to activity after heat-related illness (Casa et al., 2015). For players who experience muscle cramps or heat syncope, they may simply be monitored by an athletic trainer on field until the player's symptoms have stopped. Heat exhaustion warrants the cessation of activity for the day. The recommendation for players who have experienced heat stroke is dependent on how long player's core body temperature remained at dangerous levels. This is because the degree of neuronal injury and end-organ damage is often dependent on how long the core body temperature was elevated at the time of injury. At the minimum, activity should not resume for three to four weeks and all lab results return to baseline. Return to play after heat stroke should warrant physician approval (Casa et al., 2015). The American Academy of Pediatrics simply states that any children who have experienced heat-related illness of any sort should not resume play for that practice or game (Bergeron, Devore, & Rice, 2011). The American College of Sports Medicine recommends that mild cases of heat exhaustion be followed by a 24-48 hour rest period (Armstrong et al., 2007). Additionally, this source states that no athlete should immediately return to play after experiencing any heat-related injury. While these three sources have slight differences in their recommendations of return to play after heat-related illness, the overall message is clear; return to play after any heat-related injury is risky, so special alterations should be made accordingly.

Studies (and therefore evidenced based practice) are lacking regarding specific safe strategies for return to practice after heat-related injury (Casa et al., 2015). A case study of the functional return to play by a 17-year-old football player was published in 2018 by Lopez, Tanner, Irani, and Mularoni. This child experienced "exertional heat stroke, heat exhaustion, exertional sickling, rhabdomyolysis and cardiac arrhythmia" (Lopez et al., 2018, p.1), after recently moving to a warm climate. This event happened while he was participating in an on-field pre-season football conditioning test in conditions with a WBGT of approximately 94°F. The player collapsed on field, an athletic trainer observed that the boy was conscious but displaying central nervous system dysfunction and was subsequently transported to the emergency department. Unfortunately, the boy did not receive prompt cold-water immersion, the gold standard for heat stroke management, which probably explains why he also developed renal failure and transaminitis (Lopez et al., 2018). This study is unique because the researchers monitored the player's reported exertion and any possible symptoms of heat-related illness, core body temperature by ingestible thermistors, monitored his heart rate through a chest-strap monitor, and hydration was monitored by urine color and weight monitoring before and after exercise over a three week acclimation period. A physician cleared him for return to exercise post heat stroke. The researchers worked closely with the football coaches and athletic trainer to ensure that conditioning exercises were appropriate to adequately prepare the student for his football position. It was found that the mean gastrointestinal temperature during exercise was 101.5°F and his mean heart rate was 139 beats per minute, both in acceptable ranges. After the successful re-acclimatization period, the player was cleared for full football play 60 days after the heat stroke. The researchers of this case conclude that a safe return to play post heat-stroke is possible through appropriate monitoring, progressive return to play, and teamwork of the student's physician, coaches, and athletic trainer (Lopez et al., 2018).

Recommendations for Safe Practice

The American Academy of Pediatrics (Bergeron, Devore, & Rice, 2011), the American College of Sports Medicine (Armstrong et al., 2007), the National Athletic Trainers' Association (Casa et al., 2015; Binkley, Beckett, Casa, Kleiner, & Plummer, 2002), The National Federation of State High School Associations (n.d.) and the Centers for Disease Control (Yard et al., 2010) all have position statements or special reports regarding heat-related injuries. The consensus of these reputable national level organizations is that heat stroke in athletes is a legitimate danger, and is for the most part, entirely preventable. For example, the National Athletic Trainer's Association (Casa et al., 2015) states that prevention begins with educating staff members, parents, and students of the dangers and prevention of heat-related injuries. The same source recommends appropriate heat acclimatization programs. An emergency action plan needs to be in place for every organization that hosts student athletes, to include immediate cooling of an athlete suspected to have heat stroke, and emergency services need to be contacted immediately. Other guidelines should be established for students experiencing the lesser degrees of heat-related injury as well including whether or not the athlete can return to play. Other prevention strategies offered by Casa et al. (2015) include establishing and implementing heat activity guidelines, proper hydration, and to have appropriate medical care available at all times. While the nuances and exact details vary from source to source, the overall consensus of the varying organizations that offer position statements regarding heat-related illness are in unison.

Specific treatment guidelines for the varying degrees of heat-related injuries are available from various sources. For example, the CDC (2017a) lists an easy to read page of first aid for heat illness that could easily be distributed to parents and students. It lists details like slowly rehydrating and resting for heat syncope. For heat exhaustion, this source suggests contacting medical services, remove unnecessary clothing, and cooling with water and cold compresses. The recommended treatment for heat stroke from the CDC (2017a) is to call emergency services immediately, move the victim to a cool location, remove clothing, and immediately begin to cool the person. More in depth management techniques are available from the other listed sources. Armstrong et al. (2007) reports invaluable specific evidenced based recognition, favors, treatment strategies and return to play for heat stroke, heat exhaustion and muscle cramps. Guidelines from reputable sources for the management of heat-related illness are irreplaceable in providing evidenced based care by athletic trainers, coaches, teachers, or anyone else responsible for student athletes.

Heat stroke is the most severe form of heat-related illness and is often times fatal. Many sources have detailed treatment strategies, especially for this phenomenon. Recognition and early treatment of heat stroke is key to a successful outcome in patients. Epstein and Roberts (2011) report that recognizing signs of a rise in core body temperature on the field is the first step in treatment of early heat-related injury. Rectal core body temperatures should be taken. Once hyperthermia is confirmed, rapid cooling is lifesaving. Most ideal is an ice bath, but if not available, rotating wet ice-soaked towels on the body or continuously spraying cold water can be almost as effective. By rapidly cooling the body, end-organ function (brain, liver and kidneys) can be saved (Epstein & Roberts, 2011). Pryor, Casa, Holschen, O'Connor and Vandermark offer emergency treatment strategies of heat stroke both on the field and in the emergency department (2013). For example, on the field, immediate cooling of the body using cold water immersion should be done when heat stroke is suspected before the athlete is transferred to emergency medical services. Casa et al. (2013) also list treatment strategies for heat stroke in secondary school athletic events. Any central nervous system dysfunction should warrant the suspicion of heat stroke during strenuous exercise in the heat. Additionally, this source reports that core body temperature be taken with a rectal thermometer by a medical professional, and if heat stroke is suspected, cold-water immersion or another alternative method to rapidly cool the water immediately. These sources all have the same underlying theme in treating heat stroke; rapid cold-water immersion is key to survivability.

Kerr, Marshall, Comstock, and Casa (2014) carried out a study to determine what interventions were actually in place to manage exertional heat stroke. The schools in the study all had an athletic trainer who was responsible for a football team and was a member of the National Athletic Trainer's Association (NATA). This person was the primary source of gathering information through a questionnaire and data collection process. Strategies reported to prevent heat related illness were to monitor temperature and humidity and to follow acclimatization guidelines from NATA. The top strategies recorded by the athletic trainers in managing heat stroke were to remove the football player's protective equipment, moving the athlete to a shaded area and cooling with wet towels. Shockingly, only 51.6% of the athletic trainers reported that they would take the athletes temperature, and 52% reported that they would immerse the player in ice water. The National Athletic Trainer's 2002 position statement regarding heat stroke clearly recommends that core body temperature be measured to determine the extent of the heat-related illness and that immediate cooling is necessary (Binkley, Beckett, Casa, Kleiner, & Plummer, 2002). The fastest way to lower core body temperature is to immerse the player in cold water (Binkley et al., 2002). Kerr et al. (2014) include the conclusion that a very low percentage of athletic trainers reported following all of the National Athletic Trainer's Associations guidelines of management of heat-related illness. These researchers caution that full responsibility in preventing heat-related illness can not possibly fall on the shoulders of the athletic trainers alone; collaboration of parents, physicians, athletic trainers, coaches, and regulating entities is required to prevent heat-related illness.

Additionally, Lowe, Ebi and Forsberg (2011), bring up that people may be more apt to integrate a health intervention into their life when risk reduction is backed by a proportional statistical date rather that an absolute, yet simple, difference. An example is that a person is more likely to be persuaded to receive an annual flu shot when it is advertised as reducing the chances of getting the flu by 75% rather than saying people who get the flu shot will simply never get the flu. In regard to preventing pediatric heat illness, prevention strategies may be more likely to be integrated as change by being advertised in a similar manner, however, more research would be needed to provide accurate facts.

Current Pediatric Heat Safety Guidelines in Florida and Brevard County

A study focused on exertional heat illness (EHIs) in the state of Florida was recently conducted in order to contribute to the available literature regarding heat-related injuries and evaluate the effect of specific weather conditions during the months of August, September, and October (Tripp, Eberman, & Smith, 2015). The researchers hypothesized that EHIs would occur most at the beginning of the study period and decline thereafter. Twelve high schools were included in this study and the researchers had contact with the athletic trainers to restrict activity based on the WBGT guidelines of the Georgia High School Association (Grundstein, Williams, Phan and Cooper, table 3). The results of the study supported the researcher's hypothesis (Tripp et al., 2015). Of the 29,759 athletic exposures in this study, 57 EHIs were reported. 82.5% of these occurred during the month of August, and all occurred on days of high or extreme WBGT temperatures based on The National Athletic Trainers' Association position statement on exertional heat illness (Binkley, Beckett, Casa, Kleiner, & Plummer, 2002). The researchers also found that 20 practices included in the study during the month of August had extreme WBGT readings, and activity modifications were not followed. Generally, it is the responsibility of the athletic trainer to make modifications or cancellations of exercise in temperature extremes (Tripp et al., 2015). The researchers of this study concluded that the athletic trainers of the schools included in the study had guidelines regarding exercise in extreme temperatures, but they did not follow these guidelines strictly; therefore, legislative backing of geographic specific athletic modifications are needed to protect athletes from heat-related injury. This study indicates that the state of Florida in particular needs mandates regarding pediatric heat-related injuries, especially for student athletes.

An excellent institution that creates policies of pediatric athletic safety is the National Federation of State High School Associations. They have developed rules, guidelines, and even free web-based courses for coaches, athletic trainers, students, and parents regarding heat-related injuries in athletics. Unfortunately, this institution has no governing authority, so policies must be made at the state level (Adams, Scarneo & Casa, 2017). The state of Florida has an institution called the Florida High School Athletic Association. This is a non-profit organization which provides and enforces regulations for athletic programs for its schools that are registered members (Florida High School Athletic Association [FHSAA], n.d.-a). All public schools are eligible for membership to this organization, but private and charter schools must apply for membership (FHSAA, n.d.-b). This institution has a handbook for the 2018-2019 school year that includes regulations regarding heat-related illness (FHSAA, 2018). This handbook states that coaches, athletic trainers, and student athletes are required to participate in the National Federation of State High School Associations ([NFHS], n.d.) web-based education course about heat-related injuries. Additional guidelines regarding the prevention of heat-related injuries from the Florida High School Athletic Association include that all student-athletes have a physical evaluation completed by a physician, an acclimatization period of 14 days, and appropriate rest and hydration breaks. Additionally written is that if a practice is interrupted due to heat restrictions, the practice session is to be divided up into sections, not to exceed 3 hours in total length for the day, although specific heat restrictions were not included. Recommendations (rather than requirements) include that a cooling zone be available at every practice to include cold immersion tubs, ice packs, etcetera, in addition to monitoring the environmental conditions using a WBGT device. Coaches of the athletic programs have sanctions that are listed in this handbook should any of these policies be broken.

Florida State Statute §468.701 (2018) states that the duties of the athletic trainer include prevention, recognition and management of a physically active person who has experienced an injury or illness from physical activity. This would appear to include the recognition and management of heat-related illness. Another Florida Statute, §1006.20 (2018), states that the Florida High School Athletic Association is the "governing nonprofit organization of athletics in Florida public schools" (K-20 Education Code, 2018, para. 1). According to the Florida High School Athletic Association "2018-2019 Handbook" an appropriate health care professional like a physician or athletic trainer is "strongly recommended… [to be] present at all sporting events including practices, where athletes are at risk for concussion…" (Florida High School Athletic Association [FHSAA], 2018, p. 104). While this recommendation is valuable, it is not a requirement, and is not directly targeted to utilize an athletic trainer to prevent and treat heat-related injury. It is not mandated that all athletic programs in public schools in Florida hire an athletic trainer, subsequently, it seems as though heat safety guidelines often are overlooked.

All schools, day care centers, and private organizations who provide care for children in Florida are required to follow guidelines from the Florida Department of Children and Families. Unfortunately, there are no specific guidelines to be found by the researcher set by this entity regarding children and play in high WBGT readings. Additionally, no Florida State Statutes specifically regarding heat-related injury prevention were found. The Florida Department of Health offers "Emergency Guidelines for Schools"; it includes a one-page flow chart of how to respond to heat stroke or heat exhaustion (Florida Department of Health, 2016, p. 46). This source says that when a student appears to be experiencing heat-related symptoms, consciousness should be checked, the initiation of CPR if the student stops breathing, to cool rapidly with "wetting clothing with room temperature water…[and] do not use ice water"

(Florida Department of Health, 2016, p. 46), and finally to then call emergency medical services. It simply offers basic emergency management that is inconsistent with the findings of this thesis and provides in this source.

This leaves the discretion of continuation of activities in high WBGTs and specific heat injury prevention guidelines up to the individual organizations or schools. Brevard County Public Schools has a High School Curriculum guide regarding physical education, which was last updated in 2014. This handbook offers strategies to prevent heat related illness such as clothing, protection strategies for the skin from sunburns, hydration, avoiding strenuous activity, and frequent breaks. This handbook defines different phases of heat-related injury, referring to heat stroke as the “late stage of a heat-related illness…” (Brevard County Public Schools, 2014, p. 19). Further explained is that this is an emergency, to call for local emergency services, to cool the body, give fluids, and minimize shock. Some ways stated to cool the body are to wrap wet sheets around the body and use a fan, use ice packs at the wrists, ankles, armpits, and neck. Thankfully, Brevard County Public Schools has guidelines regarding heat index. Environmental conditions of temperature and humidity are to be obtained and a heat index should be calculated from a supplied chart. Then activity guidelines should be referenced based on the heat index. Caution with activity is to begin at a heat index of 80°F and all outdoor activity should be stopped at a heat index of 130°F. In schools or private organizations that lack specific guidelines, the ultimate decision if children should be allowed to play or participate in outdoor athletic events in extreme heat situations and for how long may ultimately be left to the decision of an individual care taker, day care provider, teacher, or coach.

Limitations

Overall research is lacking documenting the statistical significance of the prevalence of heat injury at a national level. Technical limitations exist such as lack of realizing heat injury has occurred, lack of reporting because medical codes may be limited regarding the spectrum of heat illnesses, and comorbid illnesses may mask the diagnosis of heat injury. For example, a child athlete may be transported to emergency services for heat exhaustion. While billing codes exist for heat exhaustion, the individual provider must use that diagnosis for injury tracking to be possible. Additionally, the Centers for Disease Control must make heat-related injuries reportable events for accurate data collection to be possible. Also, if a child athlete has any other underlying medical diagnosis such as acute illness, dysrhythmias or sickle-cell disease, any temperature alterations may be attributed to that diagnosis rather than heat exhaustion. Additionally, studies must be able to be repeated and show similar results. With very few studies regarding pediatric heat injury at all, further research is necessary to support or refute accuracy of original studies. Finally, relevant studies may have been omitted or undiscovered unintentionally by this researcher.

Recommendations

Nationally, guidelines that are legislatively backed need to be implemented regarding the safety of the pediatric population in the heat. With no agency able to enforce their policies of prevention and treatment of heat-related illnesses, it is impossible for an entire nation to implement a baseline, bare minimum, protective law for children. Additionally, there should be state or federal requirements to report heat-related injuries in hospitals as opposed to only reporting cardiac events or organ failure when these are aftereffects.

Student athletes are particularly at risk for heat-related illness, so specific attention is needed for this population. School level safety requirements should exist and be more geographically specific than any national policies regarding heat injuries. Schools need to implement mandatory physicals to screen for risk factors of heat-related illness, and policies regarding the prevention and management guidelines for the varying degrees of heat related injuries. All institutions including schools and companies that host students who play outdoors should be required to measure WBGT readings before, during, and after play. It should also be required that each state has geographic specific activity modifications and cut off points for play when WBGT readings become extreme. Subject experts should be consulted regarding the evidence-based practices promoted by any policies which are created and implemented. Additionally, very young children may be even more vulnerable to negative effects of heat. Further research could indicate the need for guidelines directed at institutions such as preschools, day cares, and childcare facilities regarding how long children in age groups under their care can safely play outdoors in varying WBGT environments.

In Florida, heat safety requirements and guidelines regarding the pediatric population are lacking. Those that are available appear to be lacking evidence-based practice, such as the gold standard of confirming a suspected core body temperature on site of practice and immediate cool water immersion (Pryor, Huggins & Casa, 2014). Athletic trainers should be mandated at every school with activity programs; especially if it is ultimately their responsibility to ensure heat safety guidelines are made and followed. State mandates including legislative backing and penalties for not following guidelines are needed regarding heat thresholds and activity guidelines/modifications, acclimatization periods, rest and hydration, and staffing athletic trainers. These mandates need to apply to not only public schools, but every organization or activity in which children participate in outdoor play.

In addition, regional heat safety guidelines should be mandated by state level governing entities. Optimally, temperature levels should be required to be measured using a WBGT device on field before, during, and after all practices, games, or outdoor activities for schools, day cares, and any other facility which cares for children while they play outdoors. The heat thresholds need to have an evidenced based backing and correlate to specific activity guidelines including a cut-off threshold for outdoor play. The recommendations of the Florida High School Athletic Association need to be turned into requirements for all schools. State statutes should be developed and enforced regarding the prevention strategies of heat-related illnesses including the monitoring of WBGTs, cold-water immersion tubs and the staffing of an athletic trainer. If the state is not able to fund such regulations, corporate and private fund-raising efforts must begin immediately. Funding should be specific to supplying schools with WBGT devices, cold-water immersion tubs to immediately treat heat stroke on site and having an athletic trainer on staff and on site of all activities with high risk for heat-related illnesses. Athletic trainers need to be adequately trained and prepared to institute heat-related illness prevention strategies and treatment guidelines.

Future Research

This author found a lack of current literature regarding WBGT measures on outdoor activity for the very young child. Children under the age of six have less thermoregulatory abilities, and heightened risk factors like more frequent acute febrile illnesses and decreased cognitive recognition of feeling too hot or thirsty, as well as a skewed perception of physical exertion based on those sensations. Studies are recommended to record the core body temperature of different age ranges of children in various WBGT conditions, for varying levels of time with different levels of heat acclimatization. Regulations regarding prevention of heat related injury should be developed based on the findings and instituted by regulatory agencies responsible for child welfare.

It is also noted that football is the athletic activity most at risk for its player to experience heat-related illnesses, specifically heat stroke. This sport was found to be the topic of interest in most of the studies found. Additional studies are needed for other sports and activities. There are numerous sports and activities that are popular in the United States. Marching band, baseball, softball, lacrosse, soccer, volleyball, fencing, tennis, and any other sports played either outside or in poorly cooled indoor venues should be studied for prevalence of heat-related illnesses. Other sports that are not played outside should also be studied like wrestling, hockey and gymnastics. There is and will always be settings of practice that lack indoor air conditioning nationally and internationally whether it be due to technical failures, lack of electricity, or lack of finances to afford air-conditioning. Studies should be broad to include these different sports; but specific in recognizing age ranges, gender, race and the spectrum of heat illnesses to determine further risk factors.

Additionally, alternative non-invasive methods to accurately measure core body temperature could be the key in recognizing and promptly treating fatal heat stroke. Parents, students, athletic trainers, and coaches may feel it is intrusive, obscure, and unacceptable to assess core body temperatures rectally. Other temperature measurement devices exist in the hospital setting to measure core body temperatures, but they are highly invasive.

Evidence is also needed to prove the benefits and the success or necessary alterations to existing heat safety guidelines. National level associations have available heat safety guidelines. Differences in activity modifications and WBGT levels as well as acclimatization guidelines exist. Studies are warranted to determine efficacy so that if a specific recommendation is institutionalized and mandated nationally (or even locally by a school or athletic program) safety is ensured.

Practice

All schools, day care centers, sports clubs, community centers and facilities with children should be educated to obtain WBGT devices and at the very least record daily readings to determine safety for play. The same facilities should obtain consent and have medical staff and equipment available to assess core body temperatures. All facilities should be prepared to treat heat-related emergencies including cold-water immersion for heat stroke and policies with specific practices for each variation of heat illness. Schools need to implement specific policies regarding heat-related illnesses. Activity directors, coaches, athletic trainers, teachers, school administrators, and school nurses should all be proactive in protecting students from heat-related illnesses, even if there are no state level or school district level policies on the subject. Education is key in the prevention of heat-related injuries.

Education

Coaches, athletic trainers, physicians and school nurses should have medical knowledge about heat-related illnesses including its prevention and treatment. There are resources available targeted at professionals to prevent and treat heat-related illnesses. Parents and students may not have the same educational opportunities or level. Parents and student athletes should all complete the free educational course (National Federation of State High School Associations, n.d.) regarding heat illnesses from the National Federation of State High School Associations prior to the student participating in any athletic activities. Parents and students should be proactive in prevention strategies and recognizing risk factors like hydration status, medication usage, underlying medical conditions, extreme temperatures, acclimatization, physical fitness, and the level of physical exertion. A simple and easy to read, evidence-based hand out could be used to help fill in any gaps in heat-related illness education. The researcher has created an exemplar in Appendix A by using information from the National Athletic Trainers' Association (Casa et al., 2015).

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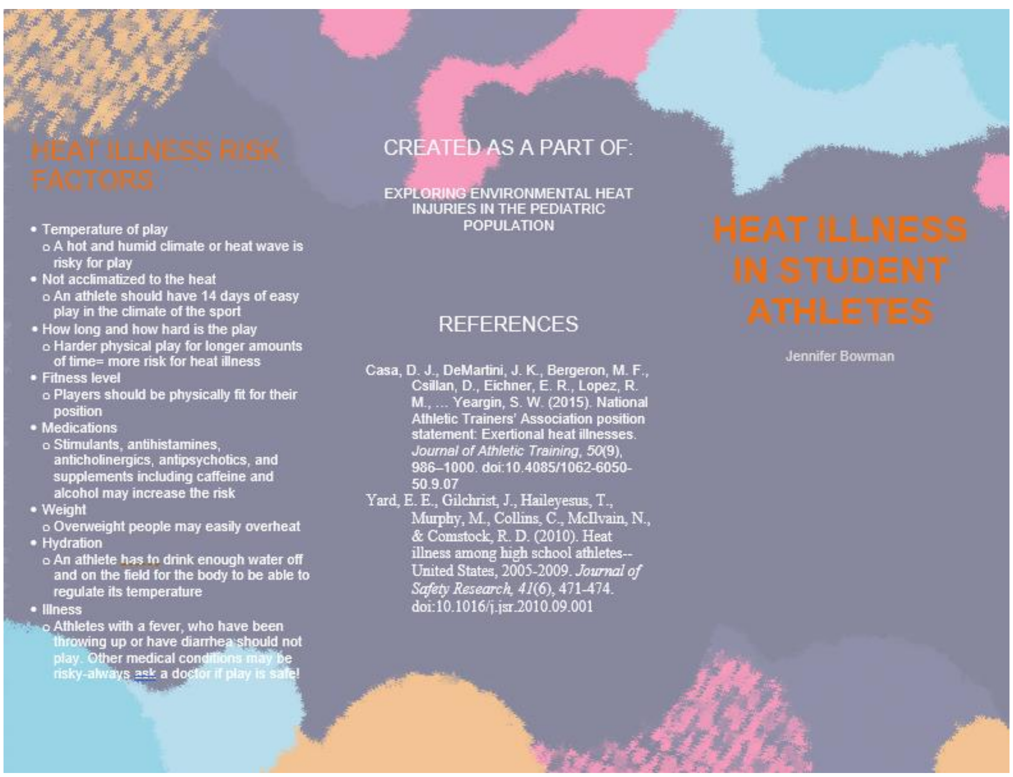
<u>Appendix B: Exemplar of Educational Brochure</u>



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