THE THERMAL OUTDOOR ENVIRONMENT IN TRACK AND FIELD—BEST PRACTICES RECOMMENDATIONS FOR MINIMIZING RISKS

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INTRODUCTION

Track and field in the United States is a spring sport, which usually means athletes experience the associated late-spring heat temperatures. The 2019 National Collegiate Athletic Association (NCAA) Outdoor Track and Field Championship was held at Mike A. Myers Stadium in Austin, TX, from June 5 – June 8, 2019 (Figures 1 – 3). This track meet ran from 8 am – 10 pm for each of the four days of competition. Track and field officials, volunteers, parents, and athletes were exposed to high thermal conditions during the days of competition, especially during the middle part of the day. Austin averages 111 days a year when the temperature ranges between 95 – 104 degrees Fahrenheit, with 16 of those days above 100 degrees Fahrenheit (24,25). The humidity in Austin during the month of June peaks at 80 percent in the morning and drops to 50 percent by mid-afternoon (24,25). When temperatures get close to and exceed 80 degrees Fahrenheit, especially if the relative humidity is greater than or equal to 50 percent humidity, it can hinder the aerobic and sprint performance of these athletes (1,3,4,5,7,14). There is very little research on the environment in which track meets occur during the spring and summer months. In the summer, the artificial track surface can reach temperatures as high as 147 degrees Fahrenheit. The temperature of the track surface may not seem like a significant problem for a sprinter running the 100-m race, but it becomes significant for those running for longer periods, such as the 5,000-m or 10,000-m races.

The International Association of Athletics Federations (IAAF) World Championships in Doha, Qatar, hosted a marathon that had to start at midnight because the daily temperatures were around 100 degrees Fahrenheit (9,17). The Women's World Cup in 2019 saw temperatures over 100 degrees Fahrenheit in France (17). The 2016 Olympic Marathon Trials saw runners struggling with the heat (17). The 2020 Olympics in Tokyo was predicted to be one of the hottest on record (6,17,21). The purpose of this article is to help disseminate information on the thermal environment during track meets, risk management, and thermal reducing approaches coaches, athletes, and sports medicine personnel can employ for improved athletic performance in a hot environment. The term "thermal" will be defined as caused by outside environmental temperature.

RISK MANAGEMENT GUIDELINES FOR OUTDOOR TRACK AND FIELD MEETS

Wet bulb globe temperature (WBGT) is an instrument used to estimate the effects of hot temperatures in direct sunlight by measuring these factors: temperature, humidity, wind speed, and visible and infrared radiation (8,22,23,29). Figure 4 illustrates a heat stress monitor, a portable device that measures WBGT. It is used internationally by sporting events, athletes, military, and industrial hygienists to determine appropriate levels to elevated temperatures on individuals (13,18,19,21).

There are four risk categories when reading a WBGT. These temperatures vary from low risk, moderate risk, high risk, and extreme risk. Table 1 outlines the four risk categories and recommendations (15). These categories have different temperature readings and humidity that can affect the heat stress formula (15). The categories of various alert levels with WBGT readings are as follows:

- **Low Risk**: WBGT index reads less than 64 degrees Fahrenheit; collapse can still occur (6).
- **Moderate Risk**: WBGT index reads between 84 – 87 degrees Fahrenheit; hydrating throughout activity is necessary (6).
- **High Risk**: WBGT index reads between 88 – 89 degrees Fahrenheit; cool areas and hydration need to take place (6).
- **Extreme Risk**: WBGT index reads more than 89 degrees Fahrenheit; athletes can develop heat illnesses (6).

In 1974, the Men's NCAA Championship Division I for distance competitors developed two sets of heat stress guidelines (19). The first guideline was to minimize the chance of heat injury during competitions. The second guideline was established to present heat stress predictions within related performance decrements (19). The establishment for these guidelines were for athletes to avoid extremely hot, humid, and cold months, or other unaccustomed weather. In 1984, the American College of Sports Medicine (ACSM) warned competitors by guiding them into understanding the risks of hazardous heat within the WBGT guidelines (1).

Competing on a hot, humid day can present athletes with challenging heat risks. Coaches, athletic trainers, or athletic directors in charge of organizing a track and field competition, should consider all risks involved by closely monitoring extreme weather information that can lead to illness or injury. To prepare for a competition, the following are essential: medical coverage, medical professionals, a medical tent, and fluid stations during competitions (3). Additional supplies, such as medical kits, intravenous (IV) bags, IV apparatuses, blankets, towels, rehydration fluids, and blood pressure cuffs, are standard equipment of the sports medicine team (3).

Thermal imaging on the various areas within a track and field meet, such as field events areas, the track, pole vaulting area and runway, and staging areas, would be an effective way of surveilling the outdoor environmental temperatures, especially those track meets in the southern United States. Improved pre-cooling strategies for athletes, such as a cooling vest and access to small cold towels before specific events, may also aid in battling the heat (12,16,27,31).

An often overlooked environmental condition, the ultraviolet (UV) index, occurs during the highest peak of the day, which typically ranges from 11 am – 4:00 pm. The UV index dramatically starts

FIGURE 1. 2019 NCAA DIVISION I OUTDOOR TRACK AND FIELD CHAMPIONSHIP

FIGURE 2. 2019 NCAA DIVISION I OUTDOOR TRACK AND FIELD CHAMPIONSHIP

FIGURE 3. 2019 NCAA DIVISION I OUTDOOR TRACK AND FIELD CHAMPIONSHIP

FIGURE 4. EXAMPLE OF A HEAT STRESS MONITOR

FIGURE 5. EXAMPLE OF DIGITAL UV RADIOMETER

FIGURE 6. EXAMPLE OF HANDHELD THERMAL IMAGING CAMERA - FRONT

FIGURE 7. EXAMPLE OF HANDHELD THERMAL IMAGING CAMERA - SIDE

TABLE 1. WET BULB GLOBE TEMPERATURE ALERTS

ALERT LEVEL	EVENT CONDITIONS	RECOMMENDED ACTIONS
Extreme **Black WBGT index; more than 89° F**	Event cancelled due to dangerous conditions	Athletic events should be postponed or cancelled and/or athletes withdrawing from competition.
High **Red WBGT index; between 88 – 89° F**	Potentially dangerous conditions	Rest in cool areas is recommended along with hydration.
Moderate **Yellow WBGT index; between 84 – 87° F**	Less than ideal conditions	Slow down but be prepared to stop if conditions worsen. Hydration during exercise is recommended.
Low **Green WBGT index; less than 64° F**	Good conditions	Enjoy the event but still be alert.

to decline after 4:00 pm. Athletes should use the appropriate sunscreen protection to avoid any harmful damage to their skin during peak hours of the day (30,36,38). Having an emergency action plan and environmental guidelines for heat can help minimize the risks for athletes during or after competition. Coaches should educate their athletes about the importance of extreme temperatures, humidity, wind speed, cloud cover, and other environmental factors that may present during competition (3).

RISK IDENTIFICATION

When extreme body temperatures occur, emergency medical attention and immediate care is warranted to minimize or prevent any of the following heat illnesses: heat edema, heat rash, heat cramps, and heat syncope, among others (6,11,15). These heat illnesses provide an opportunity for a collaboration between the medical community and athletic personnel, such as coaches, athletic directors, and athletic trainers to provide education that can help minimize or prevent these heat-related conditions during a competition in extreme environmental conditions (11). Early recognition, along with proper treatment and care, are critical to the prevention of heat illnesses.

RISK ANALYSIS

Heat illness occurs when heat production is greater than diffusion, known as hyperthermia (1,2,3). In other words, the rate at which the body is producing heat is greater than the speed of cooling. The body starts to sweat heavily to restore balance, but heavy sweating causes the body to lose water and salt, leading to dehydration (1,30). The lack of fluid in the body results in decreased blood flow, allowing for heat to accumulate (1,30). The accumulation of heat causes the body temperature to rise, and with no way for that heat to escape the body, heat illness can occur (1). Heat illness progresses from mild to severe disease to a life-threatening condition if not treated (15). Mild heat illnesses include heat edema, heat rash, and heat syncope (15). Heat exhaustion is a severe heat illness, but can easily transform into a life-threatening condition such as heat stroke, if not treated properly (2,15). The longer the athlete has a high body temperature, the higher the chances of the situation being fatal. Therefore, athletes, coaches and the sports medicine team should pay particular attention to those factors affecting athletic performance in a hot environment. Table 2 provides a brief description of the different heat illnesses, their signs and symptoms, and possible treatment.

FACTORS AFFECTING ATHLETIC PERFORMANCE IN A HOT ENVIRONMENT

Environmental heat conditions that can affect athletic performance include hydration, acclimation, acclimatization, core cooling, and cutaneous cooling.

HYDRATION

When an athlete is hydrated, that means they have consumed enough water to allow for their body to properly function. Hydration is the process of replacing lost fluids with water. Water is a crucial element in minimizing heat illnesses such as heat stroke and heat stress. Most importantly, water reduces the chances that an athlete becomes dehydrated. A common mistake in athletes is to only drink water right before the competition. Consuming only water at this time is not an acceptable way for them to hydrate and can often lead to being overhydrated. Usually, when an athlete is overly hydrated during the competition, they become vulnerable to vomiting or throwing up. Different temperatures of water can also help with cooling. When athletes consume hot water at 136.4 degrees Fahrenheit, greater sweating will occur due to the elevated temperature affecting the body core (23). When consuming water at a temperature of 60.8 degrees Fahrenheit, there is less sweating (23). Athletes in hot environments can drink cooler drinks to minimize sweating, which would help prevent them from becoming dehydrated in the hot climate. If the athlete is already dehydrated, the consumption of the colder water will again lead to less sweating, allowing the body to retain as much water and moisture as possible so rehydration can occur. After the competition, athletes should consume about 1.2 liters of water to replace the fluids lost in the form of sweat (20). Athletes should consistently stay hydrated for them to see the best enhancements in training and performance.

TABLE 2. RANGE OF HEAT ILLNESSES

SEVERITY	HEAT ILLNESS	SIGNS AND SYMPTOMS	TREATMENT
Severe	Heat stroke	Core temperature higher than 104 degrees Fahrenheit, disorientation, confusion, dizziness, irrational or unusual behavior, inappropriate comments, irritability, headaches, inability to walk, and loss of balance and muscle function. Can result in collapse, fatigue, hyperventilation, vomiting, diarrhea, delirium, seizures, coma, and hot sweaty or non-sweaty skin.	• Relocate to a cooler setting • Cold/ice water immersion • Administration of IV fluids • Admission to the hospital
	Heat exhaustion	Core temperature between 98.6 – 104 degrees Fahrenheit, dizziness, muscle cramps, malaise, fatigue, nausea, vomiting, and headaches.	Mild symptoms and stable vitals: • Relocate to cooler area • Elevate legs • Consume cold salted drinks Severe symptoms and abnormal vitals: • Application of ice bags to axilla and groin area to lower body temperature • Administration of IV fluids • Take to hospital if symptoms do not improve
Moderate	Heat syncope	Muscle weakness, dizziness, and loss of consciousness after exercises has been stopped.	• Relocate to a cooler area • Position athlete on their back • Elevate legs to allow blood flow to the brain
	Heat cramp	Excruciating muscle contractions resulting from the combination of extreme temperatures, dehydration, and depletion of minerals.	• Relocate to a cooler setting • Cool affected area • Stretch and massage cramped muscle
	Heat rash	Itchiness and appearance of lesions on the skin.	• Remove clothing and cool affected area • Application of anti-inflammatory lotion to rapidly improve condition
Mild	Heat edema	Extreme swelling of soft tissues such as hands and feet.	• Relocate to a cooler setting • Elevate the affected area • Consume appropriate amounts of water and salt

When athletes exercise, they typically sweat as the body's natural response to cool itself. When an athlete sweats, they excrete sodium in the sweat. The athlete should consume 500 milliliters of fluids 1 – 2 hr before the competition to prevent heat illness from occurring (20). Due to sodium lost through sweat, the athlete needs to replenish it post exercise by consuming a drink that is high in sodium (5). Athletes also lose electrolytes during physical activity. The best way to replenish electrolytes during and after physical activity is through sports drinks that are high in electrolytes.

ACCLIMATION AND ACCLIMATIZATION

Acclimation and acclimatization are ways for athletes to become used to a hot or cold environment. Acclimation, in terms of athletic training, is when there is a manipulation of the indoor environment the athlete trains to become accustomed to specific conditions, such as heat and humidity. During acclimation training, one can do two things: active or passive training. Active strategies for acclimation training would be the athlete performing some type of ergometry training. Because the focus is on track athletes, they would typically perform running ergometry. As for passive

strategies, athletes are typically hot and sweaty after exercise, so placing them in these warm environments will allow for the body temperature to stay elevated, and they will adapt to the hot climate. They can utilize saunas, soak in hot water baths, or even sit in an environmental chamber (14). Both active and passive strategies are ways for an athlete that trains in a cool or cold environment to acclimate to a hot competitive environment.

Acclimatization refers to training in a natural environment, typically outdoors, that allows athletes to adapt to the climate. Acclimatization is dependent on these four factors: intensity, duration, frequency, and number of heat exposures (28). Given these four factors, athletes should train at the same intensity they will be performing in competition, while having training sessions for more extended periods during the mesocycle leading up to the competition. Lastly, athletes should take note of the number of heat exposures, making sure they have adequate rest from these exposures and ensuring that not all training takes place in the heat to prevent over fatiguing. Therefore, exercising during the same time when the competition is going to occur is beneficial and can enhance performance in an outdoor hot environment. As the competition gets closer, typically there is an itinerary of when the events will occur. Knowing the timing of the event is beneficial to the athlete because they can start training at the specific time their event is supposed to take place to become more acclimated to the heat and humidity at that particular time of day. Also, it will help the athlete's body to get into a routine, so the athlete becomes even more adapted to the specific timing of the performance. Acclimatization is a great way for athletes to adapt to thermal environments.

CORE COOLING: COOLING VEST

The core of the body is where most of the internal heat is stored because most of the body processes occur there. When in a hot environment, if the core of the body is cooled, it is easier to perform physical activity. Sport companies manufacture a core cooling vest, which was proven to be beneficial in lowering the core temperature of athletes prior to competition and after (16). When using a core cooling vest before a race, runners will experience a slower increase in their core body temperature during the competition (16). Pre-cooling via core cooling vests before track meets have shown significant improvements in intermittent sprinting and endurance running performance (7). The vest also allows for greater blood flow, which supplies the muscles with more oxygen and less thermal strain (16). Athletes that have used these vests before competitions have experienced reduced sweat rates and lower heart rates (16). These benefits could lead to enhanced competition performance in a hot outdoor environment. The core cooling vest is an option for coaches to help their athletes in a hot climate.

CUTANEOUS COOLING

Cutaneous cooling is when the athlete takes measures to cool their skin. This can be done in a number of ways, such as homeostatic measures like vasodilation. Vasodilation allows for heat to escape the body through the surface of the skin. In return, the body produces sweat to cool off the surface where the heat is passing through. To aid the body in this, athletes can use different techniques to cool the surface of the skin. Different types of cooling items that an athlete can use are cooling towels, ice packs, or even misting fans. The addition of water to the surface of the skin will ultimately lead to heat loss due to a portion of the water being evaporated off the skin, thus allowing the body to retain its moisture, preventing dehydration (23). Some people suggest placing cutaneous cooling devices near major arteries because that is the site of heat exchange between the body and the environment (20,31). All of these are effective ways to help provide relief from the hot environment.

One of the most significant elements of an outdoor track meet is the sun. The sun provides not only heat, but also UV radiation waves, or UV rays. On the electromagnetic spectrum, UV rays are in the top three of most harmful waves, with the most harmful being gamma rays. Figure 5 illustrates a digital UV radiometer that can be used to measure the UV index. Prolonged exposure to UV rays can lead to skin cancers, such as basal carcinoma and melanoma, with melanoma being the more serious of the two. Limited sun exposure and sunscreen can minimize the risks of skin cancer. There are fewer extreme risks from sun exposure, for example, sunburn. If the skin gets a sunburn, blood will flow heavily to that area, making the skin feel hot. For athletes, this means that due to the sunburn, the athlete will feel not only uncomfortable from the pain of the sunburn, but also feel the heat coming off the skin, which will lead to even more feelings of discomfort on an outdoor hot competition day. Thus, when athletes are training or even competing, they should wear appropriate amounts of sunscreen. There are many types of sunscreen, including those specifically for sports. Sports sunscreen is traditionally water and sweat resistant, allowing it to remain on the athlete's skin for longer periods than regular sunscreen. Even though it is beneficial to wear sunscreen every time the athlete is in the sun, it is not mandatory. Sunscreen needs to be applied when the UV index is at a level three or above and reapplied every two hours (32). The amount of sweat after the application of sunscreen should be taken into account when deciding to apply sooner than every two hours. The minimum recommended sun protection factor (SPF) in sunscreen is an SPF of 15 (32). Still, higher sun protection factors will lead to more protection and less required amounts of application to decrease the risk of sunburn (32). To keep the athlete from developing harmful skin conditions, they should wear sunscreen when training or competing in the sun.

SPORTS SCIENCE AND MONITORING ATHLETES' HEALTH

The development of technology in sports today has allowed the sports medicine team, coaches, and athletes to monitor athletes' body temperature through technology such as thermal imaging and hydration sensors.

THERMAL IMAGING

Thermal imaging is a non-invasive way to detect the thermal temperatures of the body. Figures 6 and 7 illustrate an example of a handheld thermal imaging camera. This camera is easy to operate and can take a thermal image of the human body in track and field environments. This technique is also beneficial for coaches who are socially distancing from their athletes due to COVID-19. Thermal imaging can identify the core body temperature and the skin surface temperature of the athlete or surface of the environment. This technique can detect the average, minimum, and maximum skin temperature in a specific region of the body (12). Noting this, coaches can use thermal imaging to spot core temperature values in their athletes to ensure that athletes are not reaching these values. The usage of this device will help prevent athletes from becoming sick and allow coaches to recognize when an athlete should stop training and seek cooling down strategies.

HYDRATION SENSORS

An effective way of determining hydration is through hydration sensors. There are many different types of hydration sensors. A popular device is a wristband that uses electrical and optical sensors to detect the hydration status of the athlete (29). The device looks at the hydration levels at a cellular level and lights up distinct colors to alert the athlete of their hydration status (29). If the athlete is thoroughly hydrated, the device will light up green; if the athlete needs to hydrate soon, the device will light up yellow; and if the athlete is dehydrated, the device will light up red (29). This device can be conveniently placed on the athlete's body and is easy to use.

A new hydration sensor technology coming out soon is a device that adheres to the skin of the athlete's left forearm and measures eccrine sweat; capturing sweat and sodium at the local level to measure perspiration rate, fluid loss, and sodium concentration (29). The researchers produced a water-tight, flexible, wireless patch with electrochemical biosensors (10). They also made the device lightweight to not interfere with the athlete's training and to be easily ignored (10). The patch is for physical activity lasting over 40 min. After exercise, the athlete will use their phone to scan the patch so the app can provide an analysis of the training session. Within the app, the athlete can generate a personalized hydration plan based on their physiology and the data collected from the workout. A drawback of this device is that it is not reusable. Although this device will not come out until 2021, it is something that coaches and athletes should investigate due to how easy it will be to track and maintain hydration status.

CONCLUSION

The purpose of this article is to help disseminate information on the hot outdoor environment during track meets, its impact on risk management, and heat reducing approaches coaches, athletes, and sports medicine personnel can employ for improved athletic performance. Whether it is a high school track meet, an NCAA Championship, World Track and Field Championships, or the Olympics, the committees of these sporting events need to take great care and organization to ensure the safety of all those attending an outdoor track meet in a hot environment.

Technology, such as weather apps, can be an effective and inexpensive method for monitoring environmental heat conditions on the field. Thermal imaging technology can also be employed to monitor track environment temperatures to understand the significance of the athlete's exposure to particular temperatures during the actual competition. Athletes can use hydration sensors, but this technology has yet to be proven reliable and consistent. Coaches can try to acclimate their athletes as best as they can for the time of day they will be competing. Athletes coming in from cooler regions must make appropriate plans to condition for the type of heat they will experience and may want to try pre-cooling strategies before events. The 2021 Olympics in Tokyo, Japan are expected to be hot. Track and field athletes and coaches should plan accordingly for the heat and humidity. Elite athletes and coaches will usually anticipate this weather challenge and incorporate heat training into their periodization programs.

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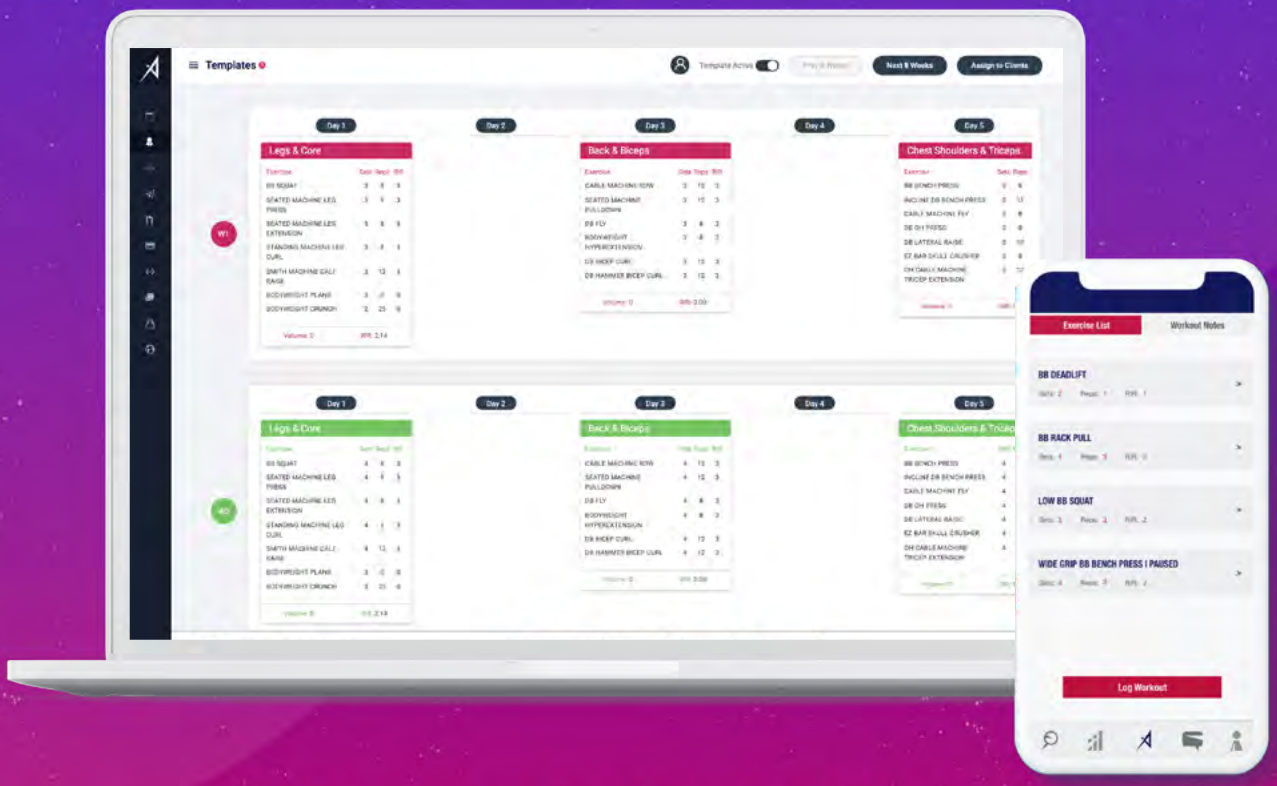

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