Heat Stress During American Football

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Abstract:

American football is a team sport involving cycles of short duration, high-intensity bouts of exercise followed by a brief period of recovery. With the competitive season starting in August in the Northern hemisphere, athletes are subjected to potential extreme environmental conditions, which may have detrimental effects on athlete safety and performance. The purpose of this chapter is to discuss the physical characteristics of American football followed by the various strategies that can be utilized to maximize performance and enhance safety during exercise in hot environmental conditions.

Keywords: Hyperthermia | Heat acclimatization | Body cooling | Hydration | Environmental conditions | Activity modification guidelines | Safety | Performance

Article:

1 Introduction

American football is the most popular televised sport in the USA. Teams of 11 players perform sets of intermittent activity, called "downs," attempting to advance the football down of a 100-yard (91.44 m) field. Each down is culminated by either a team scoring, an incomplete pass to a receiver, or a runner with the ball being tackled to the ground. Most downs are completed within a matter of 4–6 s, resulting in a high velocity game [1]. The construct of gameplay varies depending on the level of competition and consists of four quarters that are 12–15 min in length with a 12–20 min half-time rest period separating quarters two and three.

American children begin playing the sport as early as 5 years old and can advance all the way to professional American football in the National Football League. Most American secondary schools and colleges also field interscholastic teams. Being a Northern hemisphere fall sport, most teams begin training during the warmer summer months. Many teams have historically utilized this time of year to conduct the hardest training sessions and to practice multiple times in 1 day [2].

The combination of athletes of large body mass, warm environmental conditions, heavy protective equipment, and intense exercise has created situations where heat illnesses are a serious concern for medical staffs and coaches. The danger of these combined circumstances can be highlighted by the high-profile death of National Football League player Korey Stringer [3]. Similarly, athletes at both the secondary school and collegiate levels of American football die every year from exertional heat stroke, typically during summer pre-season training [4]. Epidemiological data shows that 54 American football players (42 secondary school, nine collegiate, two professional, and one sandlot) have died from EHS between the years of 1995–2014 [5]. Since nearly all heat related problems that American Football players experience occur during training, activity modifications and other preventative manners can greatly decrease risk if they are understood and implemented by coaching, training, and medical staffs.

Given the unique characteristics of American football (i.e., physical characteristics of these athletes, timing of their competitive season, and physiological demands of the sport), environmental heat stress can have detrimental effects on both athlete safety and performance. Acknowledging the factors that predispose these athletes to heat stress is essential for mitigating risk and optimizing performance in the heat. This chapter will focus on the physical characteristics of the American football athlete and discuss the influence that environmental-based activity modifications, heat acclimatization, hydration, body cooling, sleep, and protective equipment have on safety and performance during participation in the heat. At the conclusion of this chapter, the authors will also discuss some strategies that can be utilized in American football to keep athletes safe and performing at an optimal level (Fig. 1).

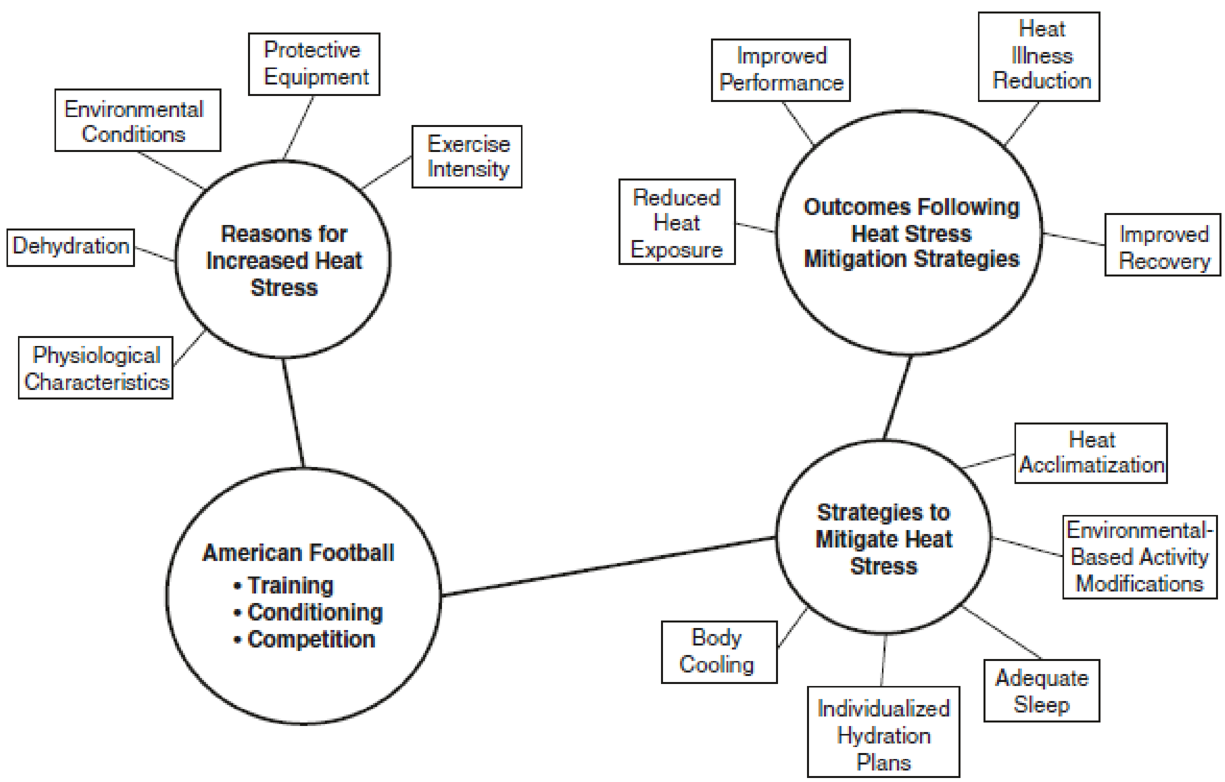

Figure 1. Factors responsible for increased heat stress and subsequent strategies to mitigate associated risk factors in American football

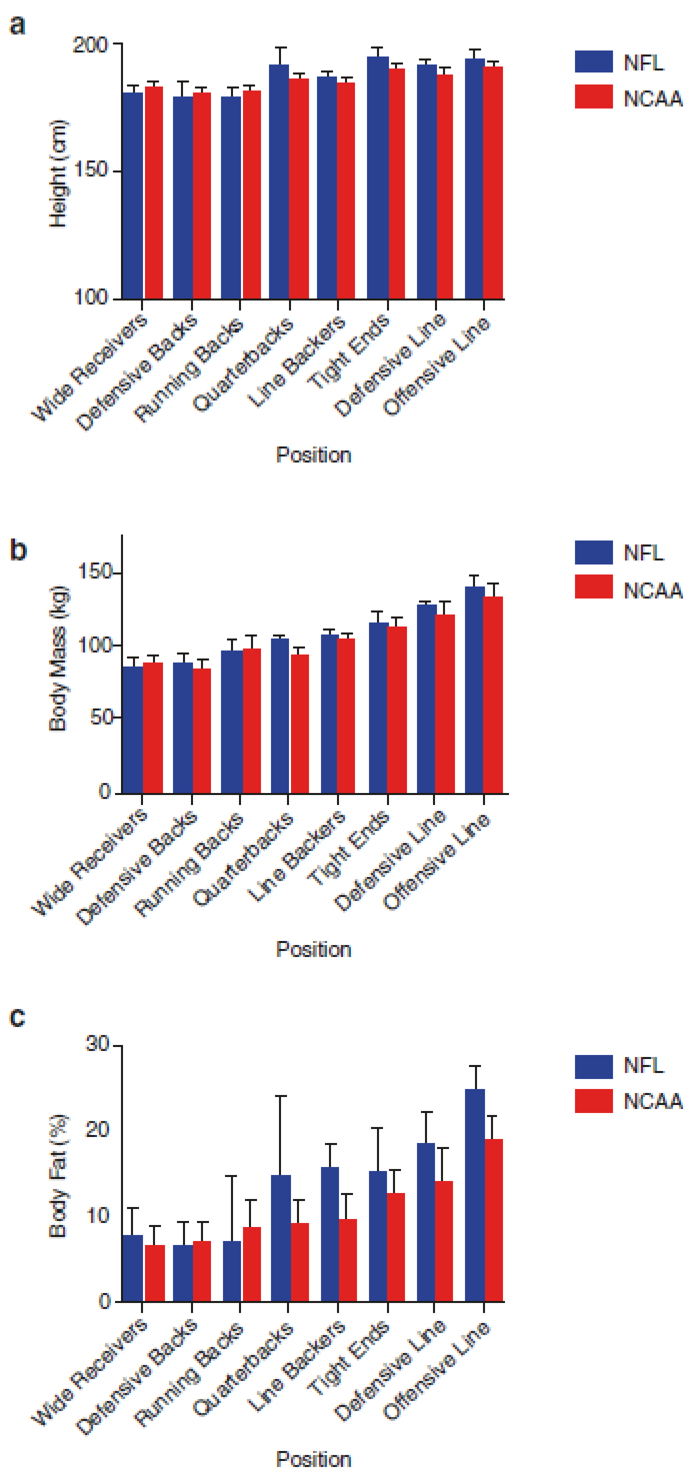

Figure 2. Average (**a**) height, (**b**) body mass, and (**c**) body fat percentage among professional and collegiate American football athletes by position. *NFL*, National Football League; *NCAA*, National Collegiate Athletics Association

2 Physical Characteristics of Football Athletes

American football athlete's anthropometrics vary based upon the positions they play, with most American football players playing only one position. Example anthropometrics by position are presented in Fig. 2. Skilled position players like the quarterback, kicker, and punter are typically leaner as their positions require more technique. Wide receivers and the defensive backs who try to prevent them from catching the ball are typically the tallest and fastest players on the field [6]. Running backs and line backers typically have stockier builds but remain highly athletic [6]. Finally, offensive and defensive linemen are the largest players on the field, relying on strength, power and technique more than pure athleticism.

While all American football athletes face the challenges of training in warm environmental conditions, linemen face a unique challenge as a result of their size. American football lineman have been observed to have a high internal body temperature during exercise [7] and are at an increased risk of exertional heat illness [4], which can be attributed to several factors. Linemen in comparison to other players possess increased body fat, lower surface area to body mass ratio, and lower aerobic capacities [8]. This increases the metabolic demands of a given activity while concomitantly decreasing the ability to dissipate heat. Furthermore, since they do not move as quickly as skilled positions, a lower convective airflow leads to lower heat loss potential despite an increased sweat production and skin wettedness [9, 10]. The anthropometric features of linemen can also affect hydration. Linemen have been found to have higher sweat rates independent of metabolic heat production [10]. Interestingly this still typically only yields mild dehydration with the frequency of water breaks that has become commonplace during practices [8].

3 Environmental Considerations and Activity Modifications

Meteorological conditions are an extrinsic factor that can affect an athlete's thermal environment and thermal response. There are multiple approaches for measuring environmental heat stress but the wet bulb globe temperature (WBGT) is the most widely endorsed for use in an athletics setting, including American football [11, 12]. This index integrates the influences of key weather variables affecting the human heat balance including ambient air temperature, humidity, radiant heating, and wind speed via a weighted average of the wet bulb temperature (WB), globe temperature (GT), and the dry bulb temperature (DB) in the following equation:

$$WBGT = 0.7\,WB + 0.2GT + 0.1DB$$

The WBGT is often coupled with guidelines that adjust other factors such as length/intensity of physical activity, modification of work-to-rest ratios, and alteration of clothing/protective equipment worn during activity. Activity modification guidelines developed by the American College of Sports Medicine (ACSM) are frequently used to guide heat safety policies for many sports in the USA [11]. American football specific heat safety guidelines have also been developed by the Georgia High School Athletic Association (GHSA) that incorporate activity modification and equipment adjustments with changes in WBGT [13] (Table 1).

Several epidemiological case studies of American football players show strong associations between WBGT and variations in heat injury occurrence and provide support for the use of

WBGT as a useful heat exposure metric. The most extensive research has examined exertional heat injuries (EHIs) among collegiate-level American football players. A study of five Division I universities in the Southeastern United States during the late summer and early autumn 2003 collected data on 128 EHIs (e.g., exercise-associated muscle cramps, heat syncope, and heat exhaustion; no exertional heat strokes) from 26,993 athlete exposures with associated WBGT measurements [14]. Incidence rates per 1000 athlete exposures (AEs) increased markedly from approximately 1 in the "moderate" (18–23 °C) to near or over 6 for "high" (23–28 °C) or "extreme" (>28 °C) risk categories. Further, all of the heat exhaustion and heat syncope incidents occurred in the "high" or "extreme" WBGT categories. Building upon this work, Cooper et al. developed a more expansive 4-year study of 60 US colleges and universities (553 EHIs over 365,810 athlete exposures) spread across five geographic regions [14]. They observed that injury rates for the more serious heat illnesses (i.e., heat syncope and heat exhaustion) increased with higher WBGT risk category. EHI rates per 1000 AEs were 0.23 for WBGTs <27.8 °C, 1.34 for WBGTs between 27.9–30.0 °C and 30.1–32.2 °C, and over 4 for WBGTs ≥32.3 °C [14].

Table 1. Environmental-based activity modification policy developed by the Georgia High School Association (GHSA) with American football specific guidelines [12]

WBGT (°C)	Activity guidelines and rest break guidelines
<27.78	Normal activities—Provide at least three separate rest breaks each hour with a minimum duration of 3 min each during the workout
27.78–30.50	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
30.50–32.17	Maximum practice time is 2 h. *For football:* players are restricted to helmet, shoulder pads, and shorts during practice and all protective equipment must be removed during conditioning activities. If the WBGT rises to this level during practice, players may continue to work out wearing football pants without changing of shorts. *For all sports:* Provide at least four separate rest breaks each hour with a minimum duration of 4 min each
32.17–33.33	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
>33.33	No outdoor workouts. Delay practices until a cooler WBGT level is reached

WBGT wet bulb globe temperature

There is more limited research on environmental conditions and heat injuries among secondary school and youth athletes. A 3-year study (2009–2011) investigated EHIs among secondary school football players in the state of Georgia, USA, found that EHI rates increased for WBGTs over 27.8 °C with a peak in the 30.1–32.2 °C range; EHI rates, however, decreased for WBGTs ≥32.3 °C as many schools limited or cancelled practice activities under these conditions [15]. Furthermore, in a 3-month study of American football players at 12 Florida high schools, Tripp et al. found that almost three-quarters of EHSs (73.7%) occurred with WBGTs considered "high" (23–28 °C) or "extreme" (>28 °C) risk [16]. There are no similar studies of youth football players but Yeargin et al. noted that almost half of youth football events occurred under conditions that would warrant an EHI concern based on ACSM WBGT activity modification criteria [17].

Finally, Grundstein et al. performed a retrospective analysis of 58 fatal exertional heat stroke (EHS) cases of American football players, including youth, collegiate, and professional levels. Median exposure WBGTs were high during these incidents at 27.7 °C for morning practices and 30.2 °C for afternoon practices [4]. In a follow-up study, Grundstein et al. found that relative environmental conditions were also important, reflecting the role of local acclimatization. In mild climates (e.g., Northern portions of the USA), 80% of fatal EHSs had above average WBGTs and 50% had WBGTs that were one standard deviation from the local long-term mean. In comparison, half of the incidents in hotter climates (e.g., Southern United States) occurred with WBGTs that were near or below normal, as even typical conditions in these areas are sufficiently hot and humid to cause heat stress [18]. Given this evidence, proper policies should be adopted and implemented across all levels of American football that utilizes region specific environmental conditions to establish graded levels of activity modifications to enhance athlete safety and performance in hot conditions.

4 Heat Acclimatization

Heat acclimatization describes the process of obtaining physiological adaptations to heat stress that results in decreased exercising heart rate and internal body temperature, increased plasma volume, increased sweat efficiency, and increased work capacity [19, 20]. Induction of heat acclimatization requires one to exercise for approximately 7–14 consecutive days in a hot environment and under a moderate to vigorous intensity training load that would induce an elevation of internal body temperature (≈38.5–39.5 °C), skin temperature, and sweat rate for ≥60 min [19, 20]. Superior outcomes in protocols longer than 14 days have been reported, which is required to achieve 95% of the physiological adaptations [19, 20].

The physiological adaptations observed following induction of heat acclimatization permit performance benefits primarily via cardiovascular and thermoregulatory adaptations. These are characterized by plasma volume expansion, decreased exercising heart rate, the leftward-shift in sweat onset response (i.e. the onset of sweating begins at a lower internal body temperature) and increased sweat rate that will enhance evaporative heat losses, if the extent of dehydration during activity is minimized [20]. These responses also lead to reduced propensity to exertional heat illness by providing cardiovascular and thermoregulatory stability during exercise [20]. For further details regarding heat acclimatization, please refer to Chap. 8 in this text.

In the USA, the governing bodies overseeing American football at the secondary school, collegiate, and the professional levels have implemented heat acclimatization guidelines [21–23]. Although the extent of implementation is currently limited in the secondary school setting, a roughly 50% reduction in overall exertional heat illness incidence was observed in eight states that mandated the guidelines in the secondary school setting [24, 25]. While there are a series of progressive guidelines established at the secondary and collegiate setting (Table 2) to facilitate heat acclimatization, the professional league in the USA (National Football League) only recommends altering the schedule of practices to avoid the hottest times of the day, providing more rest between practices and altering the activities occurring during practice during the first 2–3 days of preseason training.

Table 2. American football heat acclimatization protocols in secondary school and collegiate athletics

	National Collegiate Athletics Association [22, 23]		Secondary school recommendation [21]		
Days	**Practice considerations**	**Equipment considerations**	**Practice considerations**		**Equipment considerations**
1–5	• Single 3-h on-field practice or • One 2-h on-field practice and one 1-h field testing (i.e., speed, conditioning, agility) session • One 1-h walk-through consisting of positional skills • 3-h of continuous rest between practice, testing, walk-through	• Only helmets permitted (Days 1–2) • Only helmets and shoulder pads permitted (Days 3–5)	• No more than 3-h of total practice time and • One 1-h maximum walk-through with at least 3-h recovery period between the practice and the walk-through	• Contact with blocking sleds and tackling dummies	• Only helmets permitted (Days 1–2) • Only helmets and shoulder pads permitted (Days 3–5)
6–14	• No more than one 3-h on-field practice permitted per day • One 1-h walk-through permitted • 3 h of continuous rest between on-field practice and walk-through	• Full pads permitted	• No more than 3-h of total practice time per practice • Two a day practices permitted, however, double-practice days must be followed by a single-practice day • On double-practice days, total practice time (summation of both practice sessions) must not exceed 5 h	• On single-practice days, one 1-h walk-through is permitted, separated from the practice by at least 3 h of continuous rest • Live, full contact drills permitted	• Full pads permitted

Adapted from [26]

5 Hydration

The maintenance of a normal level of hydration is essential for the physiological processes that sustain life. Throughout the day, the regulation of total body water is tightly controlled within the body via neural, hormonal, and osmotic responses, which allows the body to remain in a state of euhydration. However, during exercise, particularly in hot environmental conditions, fluid balance and homeostasis is often disrupted, which can adversely affect athletic performance and safety in exercising individuals. Body water losses during exercise, particularly when losses exceed 2% of body mass, exacerbates cardiovascular and thermoregulatory strain [27–30], impairs musculoskeletal and cognitive performance [31–33], and increases the risk of exertional heat illness [11, 12, 34]. Refer to Chap. 6 for further details on hydration in sport and exercise.

The sport of American Football poses unique challenges surrounding minimizing fluid losses during activity. Factors such as the size of the athlete (i.e., body surface area and overall mass of the athlete), protective equipment worn during participation, the commencement of the competitive season starting in the summer (Northern hemisphere) months which exposes athletes to potentially severe heat stress, and position specific responsibilities of the athletes all contribute to the ability of the athlete to mitigate the dehydration-mediated performance and safety risks [9, 35–38]. Prior literature shows that average sweat rates vary from 1.6 L/h to 2.3 L/h and are dependent upon player position, with linemen exhibiting greater sweat rates than backs [39]. In addition, research examining the hydration practices of secondary school, collegiate, and professional American football players' hydration strategies has found that these athletes are persistently in a state of hypohydration and are unable to replace the fluids necessary to return to baseline hydration levels [37–40]. Due to the propensity of these athletes remaining in a state of hypohydration during and following participation, this evidence suggests that American football athletes may be at greater risk for performance deficits and onset of exertional heat illness.

Establishing hydration strategies and guidelines for American football athletes should take an individualistic approach as generalized guidelines [41] are not appropriate and may inadvertently place athletes at risk for other potentially serious medical conditions such as exertional hyponatremia [42]. Calculation of individual sweat rates is an efficient method for determining the volume of fluid that athletes should consume during activity. Coupled with the unlimited access to fluids during activity creates an optimal environment for athletes to optimize both safety and performance while competing in hot environmental conditions.

Current recommendations indicate that athletes should begin activity in a euhydrated state, minimize fluid losses during physical activity to prevent fluid losses that exceed 2% of body mass loss, and replace the remaining losses following activity in preparation of the next bout of exercise [43]. With the variability in sweat rates in American football athletes, it may not be feasible to keep fluid losses under 2% of body mass loss during activity. For example, high sweat rates (i.e., >2–2.5 L/h) that are unmatched to the fluid absorption capacity of the gastrointestinal tract will result in dehydration. In these instances, it is still imperative that athletes minimize fluid losses during exercise to reduce physiological strain during activity and complete activity with a lesser degree of dehydration. Establishing procedures where American football athletes track pre- and post-activity body mass allows for the determination of fluid needs for the subsequent bout of training or competition.

6 Body Cooling

Prior research examining the effect of protective equipment, body mass size, and player position has found that American football athletes exercising in hot and humid environmental conditions with full protective equipment were more likely to experience uncompensable heat stress, an earlier onset of fatigue and exaggerated perception of effort [35, 44]. Furthermore, athletes with a greater body mass, particularly linemen, are at greater risk of exertional heat illness that results from a combination of greater metabolic heat production and reduction of convective heat losses [8, 9]. From this evidence, the utility of body cooling during American football is of particular interest for enhancing safety and optimizing performance. Refer to Chap. 7 for further details on heat stress, exercise, and body cooling.

Body cooling has been extensively studied from both a performance and safety perspective during exercise in hot conditions. The utilization of body cooling prior to and during exercise has relayed convincing evidence supporting its performance enhancing effects [45–47]. Furthermore, from a clinical perspective, the treatment of EHS requires immediate, aggressive, whole-body cooling using a cooling modality with a cooling rate >0.155 °C/min to ensure survivability from this medical emergency [9, 11, 12, 48, 49]. When considering body cooling options for optimizing performance, Adams et al. provide three basic parameters that must be examined: what sport and type of activity (i.e., training or competition) is taking place, when is it most feasible to utilize body cooling (i.e., prior to competition, during competition, or during defined breaks such as half-time in competition), and what is the best cooling modality to use to elicit maximal benefit [50].

Body cooling during training and conditioning sessions (as compared to competitions) is logistically more feasible to manage as body cooling procedures do not have to fall within the confines of game flow logistics, space, and feasibility. The flexibility allotted during training and conditioning allows for a multi-faceted approach for the attenuation of body temperature during activity. Designing training and conditioning sessions to include body cooling breaks in designated shaded body cooling stations, unlimited access to cold fluids for hydration and modification of work-to-rest ratios based on environmental conditions allows an optimal environment focused on athlete safety. Furthermore, inclusion of active cooling modalities such as rotating cold/wet towels, cold water immersion (CWI), immersion of hands/forearms and elbows in ice water, cooling vests and misting fans can supplement the aforementioned strategies to further enhance body cooling capabilities. While CWI should be onsite to treat EHS due to its unparalleled effectiveness [51, 52], the other body cooling options identified above might be more conducive depending on the flow and logistics of the training and conditioning session when cooling is being used for preventative reasons or to enhance performance.

Body cooling considerations for American football competition are also very unique. The evidence from Bongers et al. [47, 53] and Wegmann et al. [54] has shown the benefit of pre-cooling, as long as the pre-cooling option is an effective cooling modality (e.g., cold water ingestion, mixed method cooling, cooling vests, etc.) (Fig. 3). Lopez et al. and DeMartini et al. have shown that not all modalities have the same level of cooling potential [55, 56], thus requiring careful consideration as to what cooling modalities are (1) most logistically feasible for use during an American football competition and (2) which cooling modalities are going to offer the best cooling potential. During competition, body cooling can take place prior to the start of the competition, during competition, and during the half-time period of competition. Pre-cooling can occur during warm-ups (e.g., linemen using cooling vests) or during the time period post warm-up when the teams are back in the locker room prior to the start of the competition (e.g., cooling fans, cooling towels, etc.). If a quality warm-up can be performed with minimal influence on the athlete's body temperature, then the body cooling has been effective. Cooling options during the competition will have to be confined to items that can be used on the sideline. Beyond the obvious methods such as removal of equipment (i.e., helmets, gloves, etc.), hydrating with cold beverages, moving to shaded area, prior research has shown the potential benefits for active cooling (e.g., cooling fans, cooling towels) during the flow of the game (i.e., when offense is on the sideline and defense is on the field) (Fig. 3) [47, 53]. The half-time of American football (~12–20 min) offers a unique opportunity for body cooling. Athletes may cool the body by equipment removal, CWI, and other cooling options (e.g., cooling towels) that would be of benefit from the opportunity to having access to a greater body surface area while the athlete is without equipment. Supporting evidence has also shown benefit from an endurance performance perspective when cooling was utilized during designated breaks in activity [57].

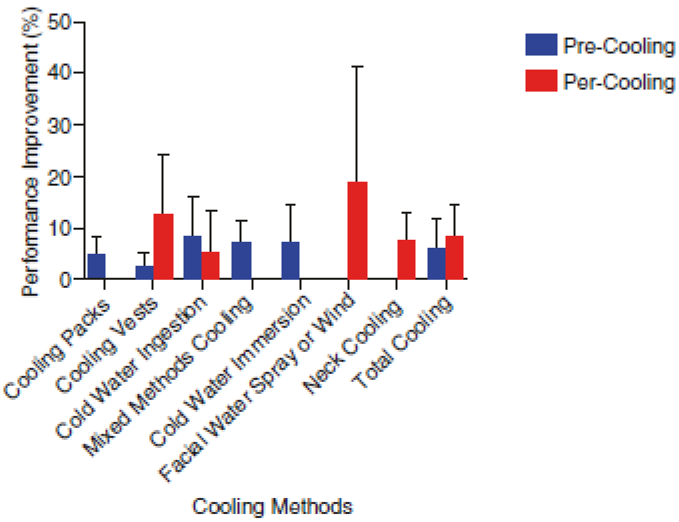

Figure 3. Ergogenic effects of cooling modalities when applied prior to (pre-cooling) or during (per-cooling) exercise in the heat [51, 52, 55]

7 Sleep

Sleep is a primal necessity for life and is responsible for regeneration of energy stores, regulation of stress-based hormones, and improvements in neural plasticity [58–60]. In the context of sport and physical activity, sleep is important for the optimization of performance and safety [61, 62]. Evidence suggests that partial (sleep ≥4 h <8 h) and long-term sleep deprivation (46–72 h) are indicative of motor- and cognitive-related performance deficits [61, 63]. Sleep loss has also been identified as a predisposing factor for exertional heat illness [11, 12], which may be due to the altered thermoregulatory effector responses (i.e., changes in the threshold and sensitivity of local sweating and cutaneous vasodilation) that occur with sleep loss [64–67]. However, it must be noted that the findings on the effects of sleep deprivation on whole-body temperature responses remain equivocal [68, 69]. For American football athletes, it is recommended that 7–9 h of sleep is achieved on a nightly basis to allow for restoration of daily and exercise-related stressors to optimize performance and reduce risk for alteration of body temperature regulation during exercise in the heat.

8 Equipment

Due to the high-speed collisions of the sport, substantial protective equipment is required to minimize the risk of serious injuries. All players wear helmets, shoulder pads, thigh pads, knee pads, and hip pads both during games and most practice sessions. These pads can significantly alter the microenvironment experienced by players and lead to uncompensable heat stress. Typical ensembles cover a majority of the skin surface and decrease convective and evaporative heat loss [70]. Individuals wearing football uniforms and equipment during exercise in the heat had significantly decreased time to exhaustion and increased rates of rise of rectal and skin temperature, even when only wearing a partial ensemble of equipment [35, 44]. A key strategy to decrease the strain of football in the heat is to minimize the amount of equipment required for the given training activity.

9 Educational/Clinical

Effectiveness of Policy Change Specific to Heat Illness. While it is not possible to prevent 100% cases of exertional heat illness occurring during sport or physical activity, especially in American football, there are a multitude of steps that can be taken to mitigate risk. Developing policies that are grounded in scientific evidence have proven successful in reducing the risk of conditions such as EHS. One such example is the adoption and implementation of heat acclimatization policies for preseason training within American football. Given the start of the season occurring in August in the Northern hemisphere, athletes subjected to potentially extreme heat stress and the benefits allotted from heat acclimatization can be protective for the athlete [71]. Specifically, the implementation of heat acclimatization guidelines at the secondary school level has shown a ~55% reduction in the incidence of EHS [25], which further supports the effectiveness of heat acclimatization and reducing risk.

On-field Heat Illness Prevention Strategies. Prevention of exertional heat illness starts with identification of modifiable risk factors that contribute to increased thermal strain, excess heat gain, impede heat dissipation, or hamper adequate recovery. The following section will list four strategies that American football teams can implement to prevent exertional heat illness and optimize performance in the heat.

1. *Priming physical fitness.* Physical fitness, particularly cardiovascular fitness, contributes greatly to one's thermal-tolerance during exercise [20]. Priming physical fitness well before the warm season has been shown to adequately support the heat acclimatization response in runners, which can also be applied in American football players [72]. As physical characteristics of American football athletes greatly differ by position, special considerations must be placed when forming the training regimen (i.e., linemen should not be expected to complete similar training as wide receivers).

2. *Active body cooling.* Active body cooling is a direct method to attenuate excess heat gain during exercise. The protective equipment required for participation is a unique aspect of American football that warrants special consideration in choosing body cooling modalities [50]. Establishing body cooling procedures for American football athletes should consider the timing of body cooling both training (e.g., having designated cooling breaks during training) and competition (e.g., prior to the start of competition, during half-time and sideline cooling during offensive/defensive sides), and type of cooling modality that is most effective (as determined by the modalities overall cooling rate) for athlete safety and performance optimization [50].

3. *Environmental monitoring.* Avoidance of continuous exercise during extreme heat can be achieved through environmental monitoring. Epidemiological study suggests high correlation between the incidence of exertional heat illness when the WBGT exceeds 28 °C [14]. Measurement of the environmental conditions should be taken at the location of activity since the values collected at the nearest weather station are likely to differ from the microenvironment of the athletic venue [73].

4. *Hydration.* Dehydration directly affects thermal-tolerance by elevating the internal body temperature [74]. Typical sweat rates among American football players have been shown to

be ≈2 L/h, predisposing athletes to a potential to sustain high levels of dehydration if fluid losses are not minimized [7]. Since the intermittent nature of typical American football training and competition offers frequent opportunities to rehydrate, each athlete should monitor the change in body weight before and after practice to recognize the adequate and appropriate amount of fluid needs during and following activity.

The success of aforementioned strategies relies on organizational support. For example, identification of at-risk individual through physical examination and fitness testing (e.g., maximal oxygen consumption test) will help identify individuals with previous history of exertional heat illness and low physical fitness, which is vital information to be shared among the coaching and medical staff to make systematic decisions in providing individualized interventions in the team sport setting to minimize risk. Likewise, predetermined policies and procedures for training during extreme heat regarding heat acclimatization and environmental monitoring will allow safe and efficient scheduling of practices that allows adequate heat exposure to induce heat acclimatization while averting performance decrements from excess heat exposure.

10 Summary

The physical demands, athlete demographics, protective equipment requirements, and the timing of year in which the sport is played elevate the risk profile for American football in terms of susceptibility of heat illness. Implementation of prevention strategies such as heat acclimatization, environmental-based activity modifications, individualized hydration strategies, and body cooling optimizes the health and performance of the athletes competing in this sport.

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