Maximizing Athletic Performance in the Heat

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Abstract:

Athletes train and perform at optimal levels in cool environments; however, many individuals do not alter their training in hot environments. The purpose of this review is to explore existing research related to enhancing performance in the heat by modifying the following practices: (a) hydration, (b) body cooling, (c) heat acclimatization, (d) clothing and protective equipment, (e) nutrition and supplementation, (f) sleep, and (g) technology. This review explores practical ways athletes can change their exercise habits with the goal of increasing performance in hot environments.

Keywords: hydration | body cooling | heat acclimation | equipment | nutrition | sleep

Article:

INTRODUCTION

Many athletes compete and practice in warm environmental conditions around the world, which can alter heat balance of the body. Heat balance occurs when heat produced by the body or acquired from the environment equals heat dissipated from the body. However, when exercising in hot environments, heat cannot always be dissipated at the rate it is being produced. This results in heat storage, leading to increased internal body temperatures throughout exercise, uncompensable heat stress (UHS), which can decrease athletic performance.

Exercising in warm environments can decrease performance for a variety of reasons including dehydration, increase in internal body temperature, and increased cardiovascular strain. To attenuate the detrimental effects warm environments have on exercise and performance, athletes can adjust their behaviors before, during, and after exercise with a variety of modalities. This review will discuss the physiological factors and practical applications to enhance performance in the heat. These topics include hydration, body cooling, heat acclimatization, clothing and protective equipment, nutrition and supplemental aids, sleep, and technology.

HYDRATION

SCIENCE AND EVIDENCE

Hydration is an important intrinsic factor that can impact athletic performance. Because an individual exercises in the heat, the body relies heavily on the evaporation of sweat for cooling to attenuate changes in body temperature. Because fluid is lost through sweating, blood volume and stroke volume are attenuated, plasma osmolality is increased, and fluids are needed to replace the water losses contributing to these outcomes. If fluids are not replaced during exercise, the body becomes hypohydrated ([2]). This state causes a cascade of physiological effects including increased heart rate, which negatively impact sport performance.

The body uses sweating as the main heat dissipation technique during exercise. Although sweating is vital to thermoregulation, it deprives the body of fluids necessary to maintain cardiovascular efficiency, therefore decreasing maximal intensity of exercise. Hypohydration, or sustained dehydration, lowers the sweat rate. An approximate 29 $g \cdot m^{-1} \cdot h^{-1}$ reduction in sweat volume for each 1% body mass loss at the commencement of exercise has been reported ([60]). Both mechanisms increase heat gain and can lead to performance decrements.

Increased body temperature is one of the most established responses to dehydration during exercise. Increased sweat rates because of exercise-heat stress not only allows for greater heat dissipation but also leads to greater total body water loss. If sweat loss is not adequately replaced, dehydration-induced rises in core temperature likely ensue. Research has documented an average increase of 0.21°C in body temperature for every percent body mass lost during exercise in warm environmental conditions (Table) ([16,24,30,39,60]). For example, a body mass loss of 1.5%, which is common for football players wearing protective equipment exercising in a hot environment ([23]), equates to an increase of 0.32°C in internal body temperature.

Table. Changes in physiological variables for every 1% body mass loss

	Lopez et al.(39)	**Casa et al.(16)**	**Gonzalez-Alonzo et al.(24)**	**Montain and Coyle(43)**	**Sawka et al.(60)**
Body temperature increase (°C)	0.17	0.22	0.21	0.25	0.15
Heart rate increase (bpm)	—	6	4	7	4
Performance decrements	1.2% overall finish time	2% overall finish time	4.8% SV	—	—

SV = stroke volume. Absolute changes (not adjusted per 1% body mass loss).

Heart rate response to dehydration is also very well established, with a 4–6 bpm increase for every additional 1% body mass lost ([16,43,60]). This occurs to maintain blood pressure, ensure delivery of blood to working muscles, and skin blood flow to maintain heat dissipation, despite a decreased stroke volume because of decreased plasma volume. The magnitude of cardiac drift is associated with the degree of dehydration and heart rate response ([43]). Cardiac drift is an increase in heart rate causing a decrease in stroke volume ([18]), a common occurrence in hot environments. Performance decrements such as a 28–37% reduction in time to exhaustion and a 12–17%

reduction in peak power capability can occur because of cardiac drift and increased cardiovascular strain ([73]).

Although many effects of hypohydration are widely known from an aerobic standpoint, such as decreased pacing ability ([64]), research also demonstrates its effects on anaerobic performance. Body mass loss of 3–4% reduces muscular strength by approximately 2%, muscular power by approximately 3%, and high intensity endurance by approximately 10% ([33]). The influence of hypohydration on anaerobic work is not presently known; however, proposed mechanisms include changes in cardiovascular functioning (decreased cardiac output, decreased muscle blood flow because of water loss, reduced oxygen and nutrient delivery) and metabolic and neuromuscular mechanisms ([33]).

PRACTICAL APPLICATION/STEPS TO SUCCESS

Because of the impact hydration has on performance, it is important that athletes know how to precisely and deliberately consume the appropriate amount of fluids during performance to avoid dehydration. Individual sweat rate varies across athletes based on many variables (e.g., age, exercise and heat acclimatization status, sex, fitness status) emphasizing the importance of replacing fluids based on individual sweat rates ([2]). Current recommendations state that an athlete should replace 80–100% of fluid lost through sweat, which will keep the athlete under 2% dehydration for a majority of athletic events ([2]). Below is a summary of practical steps to ensure euhydration during exercise.

- Calculate the sweat rate within a few weeks of the event to determine fluid need and practice the hydration plan to ensure <2% body mass loss.
    - The athlete should exercise 45–60 minutes at a similar intensity and in a similar environment that is expected on the day of competition.
    - Body mass measurements before and after provide an accurate estimate of sweat loss (given no food or fluids are excreted or consumed). This number should be used to calculate the sweat rate, that is, pre-exercise body mass (kg) − postexercise body mass (kg)time of exercise (hours).
    - If food or drink is consumed, weigh the food and drink before and after the exercise bout and add the difference to the estimated sweat loss.
- Re-evaluate sweat rate whenever there is a major change in one of the influential variables (e.g., fitness status, environmental conditions, or intensity of exercise bout).
- Assess urine color to determine hydration status. A hydrated athlete will have urine that is light in color, approximating more of a “lemonade” color, as opposed to a dehydrated athlete whose urine is darker, approximating an “apple juice” color ([2]). Clear urine may indicate over hydration. A urine color chart can be used to make this assessment easier (http://hydrationcheck.com).
- Drink water in small boluses throughout exercise as to not cause gastrointestinal upset.

BODY COOLING

SCIENCE AND EVIDENCE

Precooling an athlete creates a lower internal body temperature at the beginning of exercise, which would theoretically allow a longer duration of exercise because of increased heat storage capacity before reaching a critical limiting temperature ([25]) or a temperature at which the athlete would need to slow down. This notion also holds true for athletes undergoing body cooling between multiple exercise bouts ([76]). The athlete can return to the succeeding exercise bout with a reduced internal body temperature and a lower heart rate ([21]). A recent systematic review demonstrated that the attenuation of internal body temperature improves aerobic performance by an estimated 4.25% and anaerobic exercise by an estimated 0.66% ([55]). As an example, this improvement in the 2008 men's Olympic 5-km run would have meant the difference between first and 11th place.

A recent area of interest among exercise physiologists and clinical medical professionals is investigating different methods of body cooling to enhance athletic performance ([55]). Body cooling can be integrated before an event, during athletic participation, between multiple bouts of exercise (such as during a halftime break of a game or in between two-a-day practice sessions), or for recovery after exercise (Figure). Cooling during any of these times can decrease body temperature and physiological strain.

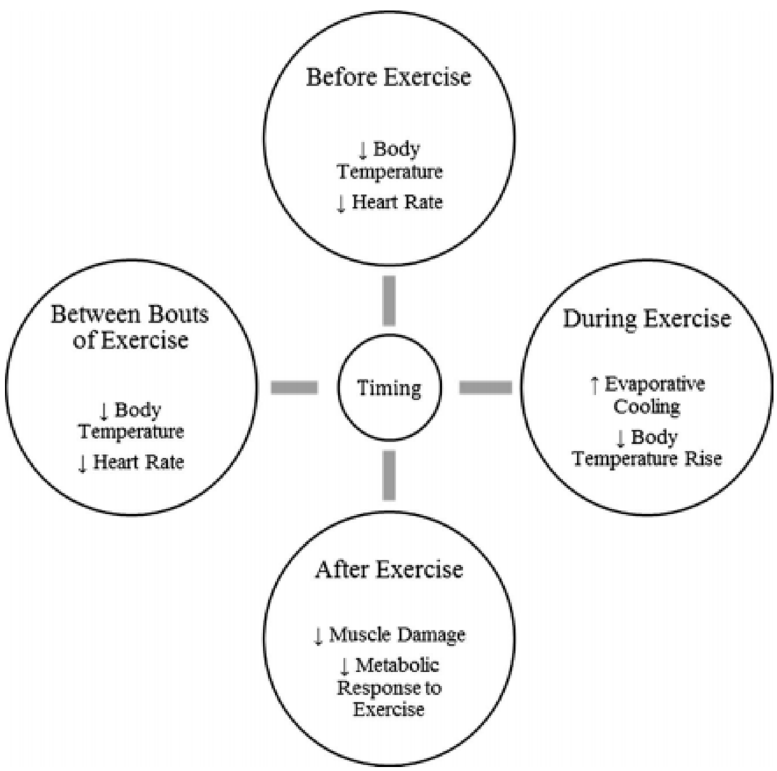

Figure. Timing and benefits of body cooling to enhance performance.

Body cooling has shown clear performance benefits. Arngrïmsson et al. ([7]) demonstrated an increase in running performance during a 5-km run after precooling with a cooling vest in a heated chamber (32°C, 50% relative humidity). This modality is practical to most athletes and is relatively inexpensive. More recently, studies evaluating the benefits from ingesting ice slurry have shown promise not only in lowering pre-exercise internal body temperature ([61]) but also in enhancing submaximal endurance performance in the heat ([61,62]).

Increased performance because of body cooling can result from decreasing internal body temperature and enhancing central blood volume return, therefore restoring cardiovascular function. An example of a cooling modality that can accomplish both of these responses is the cold water immersion because of low water temperature and the hydrostatic effects of immersion([69]). The temperature gradient between the cooling modality and the skin will largely determine the cooling rate; therefore, colder modalities promote faster cooling. For example, it has been shown that immersion in 2°C water had a cooling rate twice as fast as cooling times in 8°C, 14°C, and 20°C baths ([53]).

Theories have been proposed as possible explanations of how hyperthermia negatively impacts exercise performance. One theory involves reaching a critical limiting temperature during exercise, approximately 40°C, at which an athlete becomes fatigued and unable to continue exercise ([41]). A second theory proposes that an exercising individual will alter the exercise intensity to avoid reaching the critical limiting temperature, thus allowing the athlete to continue exercising but at a slower pace ([67]). Initiating body cooling with an athlete who has been or who will be exercising in the heat incorporates both theories.

PRACTICAL APPLICATION/STEPS TO SUCCESS

When considering clinical applications of body cooling in athletes, it is important to consider modalities that not only promote beneficial physiological responses but also those that are practically applicable. The following list describes 5 key items to keep in mind when choosing a cooling modality.

- Timing of cooling
    - If limited in time such as cooling during breaks from exercise, choose a modality that is not labor intensive (e.g., misting fans setup on the sideline and ice water towels in a cooler on the sideline).
- Cooling rates
    - Modalities with the fastest cooling rates are the most effective and practical when there is a restricted amount of time in which cooling can occur.
    - Cold water immersion provides the fastest cooling rates; however, if immersion is not feasible, ice towels are a good alternative.
- Uniforms or equipment
    - If it is not feasible to take equipment off when cooling, such as during a half-time period, choose a modality that will not interfere with the equipment (e.g., ice water buckets in which the athlete can immerse his or her forearms, ice slurry ingestion and ice water towels).
- Amount of skin that is covered by clothing/equipment
    - Maximizing skin exposure enhances the cooling surface area for evaporation.
    - Cold water immersion directly cools almost all of the body surface area, whereas misting fans are optimal to enhance evaporative cooling in hot dry conditions.
- Cooling location

- Cooling modalities exposed to high temperatures and/or direct sunlight have diminished optimal cooling ability.
- Set up cooling tubs inside a locker room or in the shade outside. If outside, only fill the tub with water initially as ice can be added when needed.

HEAT ACCLIMATIZATION

SCIENCE AND EVIDENCE

Heat acclimatization involves a series of adaptations that reduce physiological strain in a hot environment by improving heat dissipation ([6]). For athletics, the goal of acclimatization is to reduce thermoregulatory and cardiovascular strain to enhance performance. This process takes approximately 10–14 days for changes to fully occur in all body systems, but individual differences in fitness level and geographic location can alter this timeframe ([6]).

Physiological changes, all of which benefit performance, occur at different points throughout the heat acclimatization process. Plasma volume expansion begins at day 3 and continues through day 6 during which time interstitial fluid and plasma volumes can expand 3–27% ([4,6,40]). This adaptation decreases cardiovascular strain by increasing stroke volume and decreasing heart rate 15–25%, the combination of which enhances cardiovascular efficiency ([40]). The summative result of these changes promotes increased blood flow to the skin to dissipate heat and maintain a lower internal body temperature. The mitigation of internal body temperature rise during exercise and decreased resting internal temperature by approximately 0.5°C occurs by day 5 of heat acclimatization ([40,77]).

Sweat rate and sweat sensitivity increase after heat acclimatization because of improved vascular response and sweat gland adaptation ([40,77]). These adaptations can occur in both hot humid conditions and a hot dry environment ([6,45]). Athletes sweat sooner and with greater volume during exercise, which enhances evaporative heat dissipation, lessening the chance of UHS.

Hormonal changes because of heat acclimatization are responsible for changes in sodium and water balance. During the heat acclimatization process, enhanced vasopressin bioavailability results in a reduction in urinary water loss, conserving body fluid. Furthermore, aldosterone concentration increases during exercise minimizing sweat sodium loss ([35]). With sweat and urine sodium concentration preserved, plasma and interstitial fluid volumes are optimally preserved([6]). The combination of these hormonal adaptations expands plasma volume, enhancing cardiovascular and thermoregulatory efficiencies.

Anaerobic metabolism is also enhanced with heat acclimatization. Reduced blood and muscle lactate at a given power output was observed, which may allow athletes to maintain higher absolute workloads, reduce relative intensity, and improve time trial performances ([40]). This is postulated to be because of increased maximal cardiac output from plasma volume expansion and increased ventricular compliance. Reduced lactate may be because of decreased glycogenolysis and enhanced lactate removal with increased plasma volume and blood flow to the muscle ([40,77]). Overall, these beneficial changes because of heat acclimatization can increase performance and delay muscular fatigue during exercise in the heat.

If the exercise stimulus in the heat is not maintained, the benefits of acclimatization can begin to diminish by day 6 ([10]). Cardiovascular adaptations such as decreased heart rate and plasma volume expansion are the first to decay ([6]). While the adaptation can be regained with further heat acclimatization, the process starts over and an additional 10–14 days of exercise in the heat is needed to become re-acclimatized.

PRACTICAL APPLICATION/STEPS TO SUCCESS

Heat acclimatization protocols should be followed for a minimum of 10–14 days to adapt to the heat, although maximal acclimatization may take up to 2–3 months ([10]). This process can take place in a hot outdoor environment or heated room/gymnasium.

- Throughout all heat acclimatization programs, internal body temperature (gastrointestinal) and hydration status should be measured to ensure athletes are within safe limits (≤39°C) to avoid heat illnesses ([6]).
- For individuals, in a heated room, exercise for 1–2 hours at an intensity great enough to increase internal body temperature above 1–2°C baseline (approximately 50% V[Combining Dot Above]O_2max workload) ([6,50]).
- Integrating sport-specific drills, such as shuttle runs, agility drills, and short sprints at a high intensity, is an effective way to acclimatize aerobic and anaerobic sport teams to the heat. Four 30- to 45-minute sessions of this high intensity activity (approximately 75% V[Combining Dot Above]O_2max) over the course of 10–14 days in hot conditions are sufficient to see improvements ([29,65]).
- Sports requiring protective equipment such as football, lacrosse, and field hockey goalies should avoid wearing protective equipment for the first 5 days of practice in a hot environment and then gradually add equipment to subsequent practices. Introduce these athletes and nonacclimatized or aerobically unfit athletes to single practice sessions for the first 5 days with succeeding practices altering between single and double practice days ([15]).

CLOTHING AND PROTECTIVE EQUIPMENT

SCIENCE AND EVIDENCE

American football, lacrosse, and field hockey (goalies only) require athletes to wear protective equipment in addition to a uniform, covering up to 70% of the body ([5]). During participation, the microenvironment between the body and equipment traps heat and decreases air flow to the skin causing decreased heat dissipation through evaporation, convection, and radiation ([51,52]). Additionally, the weight of protective equipment increases metabolic rate during exercise, thus increasing the amount of heat produced ([9,17]). UHS causes greater heat gain than dissipation. When this occurs, internal body temperature continues to rise until exercise is ceased or intensity is decreased ([17]).

Research indicates that thermal protective barriers as seen in the military, occupational, and athletic settings produce cardiovascular and thermal strain, decreasing performance. Soldiers and first responders experience an increased ending heart rate and increased ending rectal temperature when exercising in protective clothing in the heat versus light clothing ([13,47]). Wearing a full football uniform in a hot environment increases the rate of rectal temperature rise, exercising heart rate, and ratings of perceived exertion as compared with partial and no pad conditions ([5,32]). The combination of these physiological perturbations has been shown to increase fatigue as shown by time to exhaustion ([5,32]).

To mitigate UHS, clothing plays a large role in maximizing heat loss from the body during exercise ([42]). Thin, loose-fitting, cotton clothing increases evaporative and convective heat loss by increasing sweat evaporation rate and airflow to the skin ([26]). Tight moisture-wicking fabric made from a synthetic smooth yarn inhibits heat from being trapped within the clothing versus a wool or cotton material that stores heat ([66]). This fabric can also decrease skin temperature and improve thermal comfort ([68]). In addition, wearing light colored clothing has been shown to decrease the radiant load of heat in exercising individuals versus those exercising in seminude or dark colored clothing ([26,46]). Overall, wearing these types of clothing may decrease heat gain, which helps maintain exercise intensity and mitigate fatigue.

PRACTICAL APPLICATION/STEPS TO SUCCESS

Clothing and protective equipment can lead to performance decrements in athletes exercising in a hot environment, therefore, steps should be taken to ameliorate heat gain caused by attire.

- Wear loose fitting, cotton, and light colored clothing to increase air flow to the skin and help reduce the amount of heat storage in the body during exercise, especially in hot and humid conditions ([51]). Additionally, wearing tight-fitting wicking material can improve heat dissipation.
- Wear as little clothing as required during exercise. Remove helmets during times of instruction and water breaks.
- An appropriate heat acclimatization protocol at the start of the sport season helps attenuate increased physiological strain when protective equipment is worn and will allow for a safe transition into full geared high intensity practice ([26]).

NUTRITION AND SUPPLEMENTAL AIDS

SCIENCE AND EVIDENCE

The use of nutraceuticals (i.e. food or supplements that benefit health) and ergogenic aids are commonplace in athletics. New substances and strategies specifically targeted to enhance performance have been identified, some of which are beneficial to exercise performance in the heat. Traditionally, nutraceuticals, food, and supplements work by preserving plasma volume and replacing fluid electrolytes. Although many supplements are purported to increase athletic performance in the heat, few provide a benefit to exercising individuals.

Exercise in hot conditions increases carbohydrate utilization and glycogenolysis compared with exercise in a cooler environment at the same intensity ([12]). This shift in metabolic fuel preference can prematurely deplete carbohydrate stores within the body and lead to performance decrements when participating in long endurance events. One of the most popular supplements to combat this depletion of carbohydrate stores and maintain hydration status during exercise is the carbohydrate-electrolyte drink. Although complete restoration of electrolytes lost in sweat is unachievable with standard concentrations of carbohydrate-electrolyte drink, some of the lost electrolytes in sweat can be replaced and the added carbohydrate improves cycling cadence and time to exhaustion when consumed before and during exercise compared with water alone ([14,20]).

Betaine, acting as an osmolyte, has been suggested to mitigate the negative side effects of dehydration by preserving intracellular volume thereby preserving cellular function ([19]). Although mechanistic studies are lacking, a fatigue study in the heat revealed that betaine did not improve sprint time to exhaustion. Further, betaine supplementation increased plasma lactate concentration and slightly increased oxygen consumption ([3]). Although others found betaine supplementation improves selected strength and anaerobic power tests in thermoneutral environments ([54]), further evidence is needed to support the efficacy of betaine as an ergogenic aid in thermal environments.

Glycerol has been implicated to allow hyperhydration because of its ability to increase water retention ([27]). This occurs through increased plasma osmolality, which attenuates vasopressin responses, increasing water reabsorption, and plasma volume expansion ([27,34]). Although glycerol supplementation can improve performance by increasing plasma volume, others have found equivocal results ([37]). Glycerol consumption before competition in a hot environment results in a lesser degree of hypohydration ([72]), decreased exercising heart rate ([1]), decreased internal body temperature ([1]), and an increase in endurance performance and work production compared with water alone ([1,27]). Despite the possible benefits, glycerol is banned by the National Collegiate Athletic Association and World Anti-Doping Agency. Glycerol should not be used by these athletes because disqualification may occur.

PRACTICAL APPLICATION/STEPS TO SUCCESS

Performance can be enhanced by consuming certain nutrients and supplements before, during, and after exercise. When considering how to supplement, keep in mind the type, duration and intensity of exercise.

- Electrolyte-supplement beverages and foods may be useful for endurance events and training lasting longer than 75 minutes to replace water and electrolyte losses in sweat.
- The recommended concentration of these supplements varies by individual fluid and electrolyte losses which can be measured individually in a laboratory with the whole body sweat wash-down technique ([31]). Supplementing with 1.0–1.2 g of glycerol per kilogram body weight with 26 mL of fluid per kilogram body weight can maximize fluid retention, which is useful during endurance exercise ([27]).

SLEEP

SCIENCE AND EVIDENCE

Maximizing athletic performance in terms of sleeping behavior is multifactorial. Sleep deprivation affects thermoregulatory variables, mood, fatigue, and alertness ([38,44]). The effect of sleep deprivation on performance in the heat is relevant for athletes with fluctuating travel schedules and laborers (e.g., military personnel, firefighters, and police) who do not have regular sleep patterns. Although physiological changes have been documented because of sleep loss, few studies have isolated the effects of sleep on performance in warm environments.

Sleep-deprived individuals have altered heat loss mechanisms during exercise in warm environments. While internal body temperature did not differ between rested individuals and those who endured 33 hours of continuous wakefulness, sweat rate was 27% lower after sleep deprivation ([58]). Similarly, sweat sensitivity of the chest and thigh was lower after sleep deprivation ([22,58]), possibly because of suppression of peripheral vasodilation during exercise([36]). Overall, this decreased sweat sensitivity could lead to less sweating with similar changes in internal body temperature. Although the mechanisms for altered sweating remain unknown, these results suggest that evaporative heat loss is decreased after extended periods of wakefulness, potentially leading to greater heat gain.

Decreased heat loss because of decreased sweat sensitivity can result in increased heat gain during exercise. Although slight elevation from resting body temperature may enhance performance ([63,75]), extended body temperature elevation without proper heat dissipation can result in UHS ([17]). This in turn can decrease aerobic performance, although this was not directly studied in sleep deprivation studies.

PRACTICAL APPLICATION/STEPS TO SUCCESS

The most effective way to maximize performance by controlling sleep is to ensure quantity and quality, which may only require simple changes in the sleep hygiene of athletes.

- Jet lag and travel fatigue may be avoided by adopting the preflight, inflight, and postflight method ([57]).
    - Ensure athletes get enough sleep preflight and choose an evening flight for travel eastward.
    - Watch times should be adjusted on boarding the plane, and sleeping and eating should occur according to the destination time zone.
    - To adapt to the postflight time zone, napping and caffeine are encouraged when appropriate.
- Because a “rule of thumb” for each time zone crossed, the athlete should plan on 1 day for sleep recovery. For example, if an individual flies across 4 time zones for a competition, it may take 4 days before the athlete feels fully rested ([28]).
- Regulate external stimuli and caffeine intake while maintaining a regular sleep schedule ([38]).

TECHNOLOGY

SCIENCE AND EVIDENCE

To maximize performance in practices and competitions, technology is commonly used to quantify workload, intensity, and cardiovascular variables. Until recent advances in technology, it was difficult to monitor physiological changes outside of a controlled laboratory setting. Technologies such as temperature telemetry units, heart rate watches equipped with global positioning systems (GPS) capability, accelerometers, and wet bulb globe temperature (WBGT) devices are useful to enhance performance.

Moderately increased internal body temperature is known to improve performance, whereas excessive or sustained high temperature is known to inhibit performance ([48]). Pacing strategy, associated with performance, is also related to pre-exercise internal body temperature ([56]). Maintaining a desirable internal body temperature is possible by products such as ingestible thermistors that wirelessly transmit gastrointestinal temperature readings to a receiver as it passes through the digestive tract. During exercise, knowledge of excessively high body temperature aids in modifying training intensity and implementing rest breaks. For example, a reduction in exercise intensity when an endurance athlete becomes excessively hyperthermic reduces metabolic heat production and allows for heat loss mechanisms to dissipate heat and avoid reaching a critical limiting body temperature ([48]). This lower internal body temperature results in decreased muscular fatigue ([25]).

Internal body temperature is directly related to exercise intensity ([59]), among other factors, which can be measured with heart rate systems such as those found on certain watches. Changes in heart rate during exercise in the heat often occur acutely because of cardiac drift ([73]) and changes in hydration status ([43]). As a measure of intensity, heart rate monitoring informs coaches and athletes to adjust exercise intensity based on responses to specific workouts, preventing overtraining boluses and thereby maximizing performance ([11,71]).

GPS also measure exercise intensity and are used in watches and bike computers to quantify performance ([8,74]). These are tremendous assets to training by measuring intensity, pace, and work load ([8,74]). Because pacing ability is diminished with hydration changes that occur in hot environmental conditions ([64]), GPS technology can be implemented to alter running speed. This technology can also be implemented to adjust training load maximally benefiting the training goals of athletes. With certain technologies, GPS monitors can be used along with heart rate monitors by the coaching staff from the sidelines of playing fields to see all real-time data. This allows within-practice adjustments to ensure each athlete exercises within predetermined limits.

Monitoring environmental conditions using WBGT monitors is beneficial to performance and training in the heat. Ozgunen et al. ([49]) found soccer players covered less distance and spent more time walking during games in hot versus moderate environmental conditions. Heart rate was also lower under greater heat stress indicating lower exercise intensity. Monitoring environmental conditions throughout the day can help determine optimal times of day at which athletes can compete and practice without sacrificing intensity because of heat stress. The National Athletic Trainers' Association and American College of Sports Medicine present guidelines for adjusting practices and sports events when WBGT exceeds 24°C ([2,10]).

PRACTICAL APPLICATION/STEPS TO SUCCESS

Incorporating environmental monitors, GPS systems and heart rate monitors to track intensity, and internal body temperature measurements not only help athletes train precisely but also prevent the deleterious effects of overtraining.

- Ingest the temperature pill 8–10 hours before activity to minimize false readings because of fluid ingestion ([70]).
- Set hydration reminders and heart rate zone and pacing alerts on the GPS watch to notify endurance athletes of their cardiovascular responses to exercise.
- Take WBGT readings before, during, and after exercise to determine optimal times of day to exercise at high intensities without sacrificing performance ([74]).

CONCLUSIONS

Exercising in a hot environment induces additional strain to the cardiovascular and thermoregulatory systems of athletes. Using the techniques provided, there are a variety of ways athletes can improve performance and enhance safety. Maintaining hydration levels throughout exercise and progressing through a heat acclimatization protocol are 2 of the best ways to ensure optimal performance and prevent heat illnesses.

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