Hyperthermic-related challenges in aquatics, athletics, football, tennis and triathlon

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Accepted 26 June 2012

ABSTRACT

Although many elite sporting events occur in climate-controlled venues, some athletes train and compete in environments that can potentially pose a risk to the athlete's health. In particular, athletes in aquatics, track and field, tennis, football and triathlon can be exposed to extreme heat during competition or while training. The International Federations responsible for these sports are aware of these health risks and have implemented measures to help protect the health of their athletes. This review paper outlines the sport-specific environmental health risks and the safety standards implemented to safeguard athlete health.

INTRODUCTION

'In each sports discipline, minimal safety requirements should be defined and applied with a view to protecting the health of the participants and the public during training and competition. Depending on the sport and the level of competition, specific rules should be adopted regarding sports venues, safe environmental conditions, sports equipment authorised or prohibited, and the training and competition programmes'.[1]

According to the Olympic Movement Medical Code, sports organisations are encouraged to ensure athlete health and safety through the provision of rules, regulations, and standards to minimise injury risk, including protecting athletes from environmental challenges and threats. With this responsibility in mind, International Sports Federations are tasked to evaluate competition venues and climates in which their athletes train and compete, and subsequently develop guidelines to safeguard athlete health by minimising the risk arising from potentially dangerous environmental conditions. Regularly monitoring the climatic conditions and adjusting preparation, oversight and activities accordingly are essential. It is also imperative to systematically observe the clinical signs and symptoms of the athletes and ensure the capacity of healthcare staff to rapidly and appropriately respond to exertional illnesses and injuries related to the climate.

Certain sport-specific and event-specific physiological demands and expected athlete responses can be anticipated. However, individual variability makes it difficult to develop and implement universal safety standards and guidelines to account for all possible physiological responses and potential environmental scenarios. This review outlines the hyperthermic environmental safety realities and challenges facing five large International Sports Federations: aquatics (Fédération Internationale de Natation, FINA), athletics (International Association of Athletics Federations, IAAF), football (Fédération Internationale de Football Association, FIFA), tennis (International Tennis Federation, ITF) and triathlon (International Triathlon Union, ITU). Underscoring these potential barriers to and providing guidelines and research recommendations for enhancing athlete safety can serve as a platform for further critical dialog and developing effective sport-specific solutions.

AQUATICS (FINA)

Swimming in rivers, lakes and oceans has been a recreational sport for centuries; however, open water swimming did not officially become a discipline of FINA until 1992. The 10-km marathon distance became an official event in the Olympic Games in 2008. With the recent inclusion in the Olympic sport programme, open water swimming has enjoyed a rise in popularity with an explosion in global participation and the number of competitive events. The official competitive distances at the FINA World Championships are 5, 10 and 25 km. The FINA Marathon circuit is comprised of 10 km races held around the world; while the swimming distances for the FINA Grand Prix circuit range from 15 to 88 km. The open water events attract athletes that are not only proficient, top-level swimmers, but also adventuresome athletes who enjoy the challenges of prolonged physical exertion mixed with unpredictable environmental obstacles that are not found in the controlled climate of the swimming pool.

Water and other environmental challenges to thermoregulation

The environmental challenges in open water swimming are varied and complex, with diverse concerns depending on the location of the event. Water temperatures at FINA sanctioned events range from a minimum of 16°C up to 31°C. Notably, current FINA rules stipulate a minimum water temperature; but the federation is yet to establish a firm upper limit providing only a recommended limit of 31°C for FINA events. Other contributing factors affecting the athlete's thermal balance are the ambient air temperature, humidity, wind and water currents and athletes level of fitness and heat acclimatisation. In addition, the marathon swimmer also must contend with other environmental hazards such as flora and fauna, algae, water pollution and boat exhaust fumes. FINA rules strictly regulate the textile composition and silhouette of the competitive uniform; and the properties of this clothing readily promote rapid heat transfer. Accordingly, there is little-to-no protection from hypothermia in cold water.[2] Conversely, data

 Br J Sports Med 2012;46:800–804. doi:10.1136/bjsports-2012-091272

published from the 2009 FINA World Aquatic Championships held in Rome, Italy in July revealed that some swimmers were reported to have suffered from exertional heat illness.[3] Moreover, unpublished data derived from medical reports from the FINA Marathon and Grand Prix circuits in open water swimming show that athletes have required treatment for exertional heat illness when competing in warm environments.

Maintaining effective thermoregulation in the water environment differs significantly from athletes exercising on land. Conduction and convection are very effective avenues of heat transfer from the body surface to the surrounding water; accordingly, heat loss in water is approximately 2–5 times that in air of the same temperature. However, effective heat loss or retention while swimming is also modulated significantly by the habitus of the athlete—the larger the core-to-skin insulation, the slower the rate of heat transfer. This and other factors involved in the maintenance of safe body core temperature in the open water swimmer are summarised in box 1.

Clinical and research needs

To minimise the risk of over-heating and to preserve the health and safety of the elite open water swimmer, a number of unanswered clinical questions and issues need to be addressed through sport-specific research. This research should include:

1. Validating safe upper-limit water temperatures for training and all FINA competitive distances.
2. Determining the influence and interrelationships of other environmental factors, including high and low ambient air temperature, humidity, wind, waves and currents.
3. Identifying objective signs of developing exertional heat illness in elite aquatic athletes.
4. Determining and quantifying factors affecting athlete adaptation to and heat tolerance in water.
5. Determining optimal strategies to better acclimatise athletes to aquatic environmental challenges.

ATHLETICS (IAAF)

Epidemiology of exertional heat illness in athletics

Environmental challenges in track and field athletics typically arise from training, warming up or performing in hot and/or humid weather conditions. Excessive heat and/or humidity particularly affect athletes during high-intensity or long-duration training sessions or events, as premature fatigue and exertional heat illness often result in withdrawal from or collapse during or soon after activity.[5] Environmental-induced and exercise-induced heat illness were the second or third most common clinical conditions among athletes participating in World Athletics Championships Berlin 2009 and Daegu 2011, most frequently occurring in the race walking event.[6 7]

Box 1 Factors affecting body core temperature in the aquatic athlete[4]

- Water temperature*
- Intensity of swimming*
- Duration of exposure*
- Type of swimming
- Subcutaneous fat thickness
- Ratio of surface area-to-mass

*The primary contributing factors to over-heating in open water swimming.

Other exertional heat-related illnesses evident at major events include exercise-associated muscle cramping, heat exhaustion and exertional heatstroke (EHS). Whereas certain individuals are more prone to collapse from exhaustion in the heat (eg, those not heat acclimatised, using certain medications, significantly dehydrated or recently ill), EHS can affect seemingly healthy athletes, even when the environment is relatively cool.[5]

Minimising exertional heat illness risk in athletics

Although numerous contributing factors to developing exertional heat illness have been identified, the primary underlying determining factor for hyperthermia is an individual's degree of exertion relative to their body's ability to dissipate the heat generated from that activity. Each athlete's specific physiological, perceptual and performance responses to physical exertion in the heat are somewhat different and difficult to precisely predict.[8] Thus, each athlete must be aware of his or her own particular heat-related challenges and risks when training and competing in Athletics. Athletes taking diuretics and/or dopamine-reuptake inhibitors are at an increased risk of exertional heat illness.[9] Concern and attention should be elevated not only for race walking and other long-distance events, but also during any long-duration or repeated training sessions and contests that increase overall exposure to heat, as in field jumping events or in combined events, such as decathlon and heptathlon.[10]

Moreover, caution should be particularly paid to practicing or conditioning for Athletics in stressful environmental conditions where peer, coach and leadership encouragement may lead to an individual overextending themselves. A communicative and effective partnership between coaches, athletes and medical staff is vital to ensure safety. Preparedness by local organising committees, specifically the local medical team, is crucial to minimise the risk of these heat-related challenges turning into medical emergencies or catastrophic events. Beyond preparation strategies of the athletes to safely tolerate the heat, administrative prevention measures should focus on appropriate event scheduling, cooling areas and facilities, readily available fluid access and ongoing monitoring of the athletes.[6 7]

Using the Wet Bulb Globe Temperature (WBGT) index to assess on-site environmental heat stress at regular intervals is an important starting point. Then, it is critical to adjust activities and increase monitoring and medical readiness to the extent possible in certain track and field competitions where there is a high risk of exertional heat illness. Recommended actions can be based, in part, on published evidence-based guidelines for distance running competitions. This can play an important role in preventing or minimising the number and severity of exertional heat illness incidents.[5 11 12]

On-field assessment of WGBT was implemented at the World Athletics Championships since Osaka 2007. Although it has some recognised limitations,[13] WBGT assessments in the warm-up areas and on the competition track, along with appropriate announcements of its readings, were also implemented at the Daegu 2011 World Athletics Championships by the local organisers. This measure, together with the addition of printed and web material in Daegu 2011, resulted in a measurable decrease in the incidence of heat-related illness in comparison with Berlin 2009.[7 10].

FOOTBALL (FIFA)

Epidemiology of exertional heat illness in football

No documented cases of exertional heatstroke or death have been reported among elite football (soccer) players at the international level. Notably, definitive prevalence data of exertional heat illness are available only from the USA among high-school and collegiate athletes.[14 15] Findings reported by the Centers for Disease Control and Prevention indicate that the rate of time-loss heat illnesses among high-school soccer players is 0.3 (boys) and 0.8 (girls) per 100 000 athlete exposures (training and competition); while data from another study reported 0.6 per thousand player hours.[16–18]

Minimising exertional heat illness risk in football

Exertional heat illnesses are preventable as well as treatable conditions. In FIFA competitions, match and training schedules are arranged to avoid the time period of the day of high exertional heat illness risk coincident with the peak afternoon sun (ie, typically 1200–1500 h). FIFA rules allow players to hydrate at the sideline during matches to improve heat tolerance and reduce exertional heat illness risk. In FIFA competitions, all decisions with respect to athlete safety and exertional heat illness risk are based on WBGT. FIFA's professional educational and development programs also help to protect players. The FIFA Medical Committee and FIFA Medical Assessment Research Committee have established guidelines for the safety of players during hot-weather tournaments, which emphasise the introduction of cooling breaks and recommend additional specialised medical support in the event of serious heat-related medical emergencies. For example, in the final football match between Nigeria and Argentina at the Beijing Olympic Games 2008, the game was scheduled in the Olympic programme to be held at noon with a WBGT reading greater than 32°C. Additional cooling breaks were given during the match to protect the player's health. The FIFA Exertional Heat Illness Risk Guidelines are in table 1.

TENNIS (ITF)

Numerous tennis tournaments are played outdoors in warm-to-hot climates, with levels of humidity and solar radiation that often expose players to a significant risk of exertional heat illness. As the individual athleticism, quality and depth of competition continue to improve, matches at all levels of play are often intense, long and physiologically and psychologically demanding, considerably challenging players' fluid-electrolyte and energy balance, thermoregulatory effectiveness and cardiovascular and emotional stability. The consequent effects on a player's health, safety and performance, which can be exacerbated by large heat-retaining stadiums, are well recognised.

Body core temperature

Few studies have examined body core temperature (T_C) responses during sanctioned competition, where the effects of stress and effort on behaviour and physiological responses are likely to be greater than during practice. Players' final T_C at the end of outdoors singles play has been reported from Boy's national competition (38.7 (0.3)°C)[18] and peak T_C from a women's professional tour event 39.1 (0.3)°C,[19] which are broadly consistent with values recorded in men's professional tournament play (hard court: 38.9 (0.3)°C; clay court 38.5 (0.6)°C)[20] or on average in junior elite players during practice.[21] More intense, closely contested or extended 3-set to 5-set matches in more challenging ambient conditions would be expected to lead to measurably greater thermal strain.

Table 1 FIFA: exertional heat illness risk evaluation, based on ambient temperature or WBGT

Ambient dry temperature	Ambient WBGT	Risk of thermal injury
25–31.9°C (77–89.4°F)	24.0–29.3°C (75–85°F)	Moderate
32–38°C (89.6–100°F)	29.4–32.1°C (85–89.9°F)	High
>38°C (>100°F)	32.2°C and above (>90°F)	Extreme

FIFA, Fédération Internationale de Football Association; WBGT, Wet Bulb Globe Temperature.

Hydration

Sweat-induced water and electrolyte losses (especially sodium) can be extensive during tennis practice and play in the heat. Depending on player maturation, environmental conditions, and intensity of play, sweating rates can range from less than 1 litre to readily more than 3.5 l/h in certain individuals.[21–25] Importantly, adequate on-court and postplay hydration requires water *and* electrolyte replacement to maintain performance and avert exertional muscle cramping,[26] which is prevalent in tennis players at all levels of competition.[23–25 27] Hydration status directly modulates thermal strain during exercise in the heat; and the strength of its association with prematch urine specific gravity on T_C has been shown to increase as match-play progresses.[22] Accordingly, those players who begin a match not well hydrated, and incur an additional fluid deficit during play, may have a progressively increasing thermal strain and a greater risk for exertional heat illness as the match advances to the later stages of play. This is especially evident with closely scheduled multiple matches on the same day (even doubles), because of insufficient fluid recovery between matches and carry-over effects related to exertion and accumulated heat exposure from previous play.[22 28–30] But, while sufficient fluid intake can minimise on-court thermal strain and is integral to tennis safety, adequate hydration alone does not eliminate exertional heat illness risk or ensure optimal on-court performance.

Players' and governing bodies' responsibilities

Like all athletes who compete outdoors, tennis players have the responsibility to be aerobically fit and acclimatised to the environmental conditions, hydrate adequately before, during and after play/training, and not compete when they are at added risk for overheating due to recent/current illness. Recognising that most professional players meet these standards during tournaments, but that extreme environmental conditions can still give rise to excessive thermal strain and threaten the quality of play and safety of the athletes, the ITF has developed procedures for modification or suspension of play when the WBGT meets or exceeds 30.1°C or 32.2°C, respectively.[31] The 10-min break allowed between the 2nd and 3rd sets in women's professional tennis provides an opportunity for players to implement cooling strategies; although the physiological effectiveness of this intervention has not been clearly demonstrated[19] nor adopted in the men's game. It is imperative for all tennis governing bodies to continue to research the effects of on-court conditions, thermal and cardiovascular strain and modulating factors, and effective and practical prematch and on-court cooling strategies, and provide a format and conditions of play that reasonably assure player safety and encourage optimal performance.

TRIATHLON (ITU)

Exertional heat illness presentations in triathlon

Upper extremes of temperature, humidity, intense solar radiation, rain, wind and surf can profoundly affect the safety and medical outcome of triathlon races. Weather conditions may

 Br J Sports Med 2012;46:800–804. doi:10.1136/bjsports-2012-091272

change unexpectedly, producing dangerous conditions for the athletes, particularly during the longer triathlon contests.[32] Accordingly, exertional muscle cramping, heat exhaustion and EHS are prevalent in many triathlon events. Notably, much of the in-competition prevalence data related to athletes incurring exertional heat illness and injury has been highlighted in Ironman events in which dehydration and exhaustion (58–72% of treated problems) are reportedly much higher than trauma/orthopedic complaints.[33–35] With limited data to confirm this, the prevalence of exertional heat illness may be greater in a standard distance triathlon where elite triathletes run 5–10 km at a high speed of up to 3 min/km. Because these athletes run at up to 90% of their maximum oxygen consumption (VO_2 max), the rate of metabolic heat production is high, thus increasing the exertional heat illness risk. When conditions are hot and especially humid, there is a much greater risk of exertional heat illness and injury in the heavier elite athletes during the run segment of the triathlon.[36] Rate of sweat loss and increasing thermal strain will vary based on a number of factors, including the intensity and duration of the triathlon, the fitness and heat acclimatisation state of the triathlete and the environmental conditions. Whereas exercise-associate collapse is the most common reason that triathletes are treated following a triathlon event, those competitors with excessive hyperthermia should be promptly and aggressively treated to prevent or minimise the duration and consequences of EHS. An afflicted athlete should be cooled until the rectal temperature is just below 39°C or he/she shows clinical improvement.[5 9] Exertional rhabdomyolysis coincident with measurable dehydration and/or EHS, may cause acute renal failure, often requiring treatment with renal dialysis to control hyperkalaemia.[37 38]

Minimising exertional heat illness risk in triathlon

There are multiple exertional heat illness prevention strategies that can be implemented in triathlon. Heat acclimatisation, which typically takes 7–10 days, should include a gradual increase in exertion and environmental exposure time. Race starting times should be modified, so the competition begins in the early morning to minimise environmental exposure to the maximum heat at mid-day; while ambient air temperatures over 35°C or a WBGT of 29.1°C should warrant suspension of the event.[39] Adequate competitor education regarding the projected environmental conditions and the provision of sufficient hydration opportunities can also decrease the risk of incurring exertional heat illness.[40] Further study on thermal parameters and the early signs and symptoms of dehydration and/or hyperthermia with the use of a wetsuit in hot ambient temperatures is needed to further ensure triathlete safety.[41]

SUMMARY AND CONCLUSION

Swimming, athletics, football, tennis and triathlon are sports that enjoy worldwide participation with large numbers of athletes training and competing at all levels ranging from recreational to elite. The perspectives from these five large International Sports Federations illustrate the dominant influence of environmental conditions on the health and safety, as well as the athletic performance of the elite athlete. In particular, excessive thermal strain poses significant health risk for athletes, as it can lead to life-threatening EHS. Air temperature, humidity, solar radiation, wind speed, water temperature and water currents greatly affect athlete thermal exposure in these popular sports. Accordingly, modification of activity and event format and increased medical readiness and monitoring are paramount as effective heat stress increases. Moreover, each athlete must be cognisant of and accommodate his or her own personal contributing risk factors to excessive heat strain, including body composition, fitness, heat acclimatisation, sweat and electrolyte loss rates, current and recent health status and clothing/uniform.

As mandated by the Olympic Movement Medical Code, International Sports Federations have an important responsibility to ensure the health and safety of their athletes. In addition, these federations provide important educational support for National Olympic Committees and associated world sport organisations through the provision of factual information on reducing hyperthermic risks for participating athletes, coaches and members of the athlete entourage at all competitive and recreational levels in their respective sports. The International Sports Federations also can play an integral role in promoting and supporting the scientific advancement of knowledge specific to the physiological challenges related to hyperthermia in the elite athlete and the prevention of exertional heat illness and injury. Some of the key research gaps in the field of environmental heat stress in sports relevant to the health and welfare of the elite athlete can be addressed by:

1. Developing effective methods of measuring and determining hyperthermic risk in the field of play on land and in water.
2. Establishing evidence-based sport-specific thresholds beyond which competition should be modified or suspended.
3. Validating the efficacy of specific hydration and heat acclimatisation strategies.
4. Evaluating the effects of competition uniform modifications that could be incorporated into the rules and regulations of international sport to reduce exertional heat illness risk.
5. Evaluating the design of training and competition sport facilities and venues to reduce athlete solar radiation exposure and heat accumulation, and incorporating appropriate climate-control design features to reduce excessive heat exposure and hyperthermic-related clinical risk.
6. Assessing the effects of schedule alteration of training sessions and competitive events (including between-session recovery times) to minimise the risk of accumulated heat exposure and strain.
7. Determining the early signs and symptoms of developing exertional heat illness in the elite athlete to better enable early identification and intervention.
8. Critical analysis of the efficacy of on-site interventions in the medical treatment of exertional heat illness.

What this paper adds

This paper addresses ongoing sport-specific hyperthermic-related challenges in elite athletes from the unique perspectives of five large International Federations.

Acknowledgements The authors would like to acknowledge the International Olympic Committee for their leadership in convening the project on thermoregulatory and altitude challenges in the elite athlete.

Contributors MM is the first author, substantial contributions to conception and design of the paper; drafting the section on FINA, Introduction and Conclusion; revising it critically for important intellectual content; and final approval of the version to be published. J-MA drafted the section on IAAF, revising the paper critically for important intellectual content; and the final approval of the version to be published.

MFB drafted the section on ITF, substantially editing and revising the paper critically for important intellectual content, clarity and flow; English standardisation and final approval of the version to be published. JD drafted the section on FIFA, revising the paper critically for important intellectual content; and final approval of the version to be published. SM drafted the section on ITF; revising the paper critically for important intellectual content; English standardisation and final approval of the version to be published. SM drafted the section on ITU, revising the paper critically for important intellectual content; and final approval of the version to be published. DGS drafted the section on FIFA, revising the paper critically for important intellectual content; and final approval of the version to be published.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

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Br J Sports Med 2012 46: 800-804
doi: 10.1136/bjsports-2012-091272