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IOC consensus statement on recommendations and regulations for sport events in the heat

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ABSTRACT

This document presents the recommendations developed by the IOC Medical and Scientific Commission and several international federations (IF) on the protection of athletes competing in the heat. It is based on a working group, meetings, field experience and a Delphi process. The first section presents recommendations for event organisers to monitor environmental conditions before and during an event; to provide sufficient ice, shading and cooling; and to work with the IF to remove regulatory and logistical limitations. The second section summarises recommendations that are directly associated with athletes' behaviours, which include the role and methods for heat acclimation; the management of hydration; and adaptation to the warm-up and clothing. The third section explains the specific medical management of exertional heat stroke (EHS) from the field of play triage to the prehospital management in a dedicated heat deck, complementing the usual medical services. The fourth section provides an example for developing an environmental heat risk analysis for sport competitions across all IFs. In summary, while EHS is one of the leading life-threatening conditions for athletes, it is preventable and treatable with the proper risk mitigation and medical response. The protection of athletes competing in the heat involves the close cooperation of the local organising committee, the national and international federations, the athletes and their entourages and the medical team.

Key points

- ⇒ Protecting the athlete's health and safety during sport events in the heat requires involvement and collaboration among the local organising committee, the national and international federations, the athletes and their entourages and the medical team.
- ⇒ The local organiser should monitor and communicate the environmental conditions before and throughout the event, provide sufficient ice and hydration and propose adequate heat stress mitigation facilities (eg, shade and recovery areas).
- ⇒ The athlete should specifically prepare for the expected environmental conditions (ie, heat acclimation), manage their health status before the event and plan their hydration, cooling, warm-up and clothing according to the risks associated with the forecasted environmental conditions.
- ⇒ Medical providers should receive specific training on exertional heat stroke management including early recognition (eg, field of play supervision and finish line triage) and diagnosis (including rectal temperature assessment) as well as in the use of rapid on-site whole-body cooling (ie, cool first, transport second).
- ⇒ International federations are encouraged to develop specific environmental heat policies with a clear communication pathway on the level of risk and the associated countermeasures (eg, using a colour-coded 1–5 heat stress scale).

INTRODUCTION

Major international sporting events, such as the Olympic Games, face numerous challenges in providing optimum healthcare for athletes. As the Summer Olympic Games and most summer sport international federation (IF) events are often held during the hottest months of the year, one important athlete health challenge includes the prevention and treatment of heat-related illnesses.[1 2]

Irrespective of the environment, muscle contractions during physical activity produce vast quantities of heat,[3] which lead to an elevated core temperature after only a few minutes of exercise.[4] If the environment allows for skin surface heat dissipation (eg, via convection, radiation and sweat evaporation) to counterbalance the rate at which metabolic heat is produced, then core temperature will reach a plateau (often ~38.5–39°C, depending on the intensity of exercise). However, if the heat dissipation capacity of the athlete is limited due to hot and/or humid ambient conditions, and/or clothing and protective equipment worn, then the resultant thermal strain will induce additional cardiovascular strain leading to a decrease in self-selected absolute exercise intensity.[5 6] The levels of performance impairment and health risk for a given environment are specific to the heat production of the sport and its heat dissipation capacity (eg, clothing), along with the characteristics of the athlete (eg, body size

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and heat acclimation status).[7] Although numerous well-trained athletes will transiently achieve core temperatures in excess of 40°C (and even 41°C) when competing intensely in hot ambient conditions, most will remain healthy and asymptomatic.[8 9]

Nevertheless, heat is responsible for more deaths than all other natural disasters combined,[10] and severe exercise-induced heat illness (ie, exertional heat stroke (EHS)) is one of the two main causes of death in athletes.[11 12] Unfortunately, the level of environmental heat stress experienced by elite athletes will continue to rise in the coming years due to a combination of the increased prevalence, intensity and duration of bouts of extremely hot weather (ie, heat waves) that are occurring due to climate change and sport globalisation leading to more competitions being organised in extremely hot climates. While there is a multitude of mitigation strategies that can effectively reduce the risk of one's vulnerability to exercise heat stress (eg, acclimation), implementation of these strategies remains insufficient in sport settings.[13] In addition, as sport events continue to be held in extreme heat, we must ensure that evidence-based treatment of EHS is implemented to maximise survival from this potentially lethal medical condition.[14]

This document presents the consensus recommendations from the panel of experts and stakeholders convened by the IOC Medical and Scientific Commission to protect athletes competing in the heat. These recommendations were established following the Delphi method, including contributions from several IF along with clinical and academic experts. The recommendations are also informed from the experience gained during the recent 2020 Summer Olympic Games in Tokyo. Although some of these recommendations may require logistics only available at international/elite events, all athletes and organisers are advised to apply as many as they can.

METHODS

Panel selection

The IOC created the 'IOC Adverse Weather Impact Expert Working Group for the Olympic Games Tokyo 2020' in August 2018 (including 11 members). This group worked for 3 years ahead of the Games to develop heat mitigation related recommendations, and this document is the legacy of its work. The group also identified the discrepancies in the indices and policies used by different IFs as a challenge leading up to the Games. This was discussed during a meeting of the Association of the Summer Olympic IF in 2019, and seven IFs were invited to the final IOC consensus meeting held in September 2021. Academic experts, with experience in establishing heat policies for international competitions, were also invited to this meeting. Of note, six members of the panel were also part of the IOC Medical and Scientific Commission Games Group and three were working for the Tokyo Organising Committee of the Olympic and Paralympic Games (see author contribution).

Evidence review

The previous IOC consensus statement on thermoregulatory challenges for high-level athletes included four modifiable factors: hydration, acclimatisation, warm-up and precooling, and clothing.[15] Similarly, another consensus recommendations on training and competing in the heat included four sections: acclimation, hydration, cooling and recommendations for event organisers,[7] and the most recent review on exercise under heat stress also covered three mitigation strategies: acclimation, cooling and hydration.[6] In addition to the aforementioned topics, risk mitigation strategies concerning event operation based on the IFs' experiences and the recent 2019 World Athletics Championships and 2020 Summer Olympic Games were incorporated in the current review. These points have been grouped under the following three categories by the target population for implementation: (1) event organisers, (2) the athlete and their entourage and (3) the medical services. The purpose of this document is not to recreate existing reviews on this topic but rather to provide actionable recommendations for future events. Thus, only a brief narrative review is included before each recommendation to refer the reader to existing studies and reviews.

Consensus process

As per the Delphi method, the exploration phase was followed by an anonymous evaluation phase. Each recommendation was first reviewed by at least two members of the group and then assessed online (Qualtrics) by every member of the group for validity, feasibility and clarity using a 1–9 Likert scale. A higher score indicated a recommendation being more valid, feasible or clear. Recommendations with an average score <4 were discarded, recommendations with a score ≥7 were retained and recommendations with a score in-between were revised before entering the second round of scoring. In addition, the online assessment offered participants the opportunity to provide open comments about each recommendation, which were taken into account during the revision process. Following the first round of scoring, 12 recommendations received a score between 5.9 and 7 in at least one of the assessment categories. Those recommendations were amended, and eight scored higher than 7 in all categories, while four scored 6.8 or 6.9 in one category. Those recommendations were further amended and validated by the two leading authors. Lastly, one recommendation was added after the Delphi process to fill a gap that was identified during the manuscript writing process. This revision was approved by coauthors. Of note, most of the agenda for the in-person meeting (September 2021) discussed the areas without consensus, such as the exploration of developing standardised heat policies across IFs. An agreement was reached on the third day of discussion and a method for heat policy development is proposed below (section 4). This specific section is expert informed rather than literature based.

SECTION 1: RECOMMENDATIONS FOR RISK MITIGATION BY THE ORGANISERS

Environmental monitoring

For the IFs or IOC to accept a bid for an international event, and for the athletes and their entourage to prepare appropriately for a given sport event, they should have access to the historical weather information for the location of the event. The environmental parameters should also be recorded throughout the event to allow the IFs to adapt the implementation of their heat policy accordingly (see further). In addition, the different competition surfaces and the environment surrounding the fields of play (FoP) induce diverse microclimatic environments[16 17] that may differ from established weather stations.[18] Thus, the measures should be representative of the FoP,[19] at approximately 1.2–1.5 m above the surface (or at a depth of 40 cm for water temperature) to represent the conditions experienced by the athlete (figure 1),[20] and should include all the parameters required by the IF to implement their heat policy. The instruments should be in a fixed position such as on a tripod (and not handheld) and use well-established sensor technology[21] that provides accurate and stable measurements with sufficient resolution to meet decision-making thresholds. Measurement variability due

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Figure 1 Environmental condition monitoring and reporting. Panels A and B: devices specifically developed for World Athletics and for the Australian Open Tennis tournament, respectively. These are the recommended solutions. Panels C and D: commercially available units used on the field of play. It is not recommended to use a hand-held device (panel C) when the device was stored in the shade between measurements as it led to a 2°C error compared with the stationary device. The device should be fixed on a tripod prior to the event to allow for some time to equilibrate to the environment for accurate measures (panel D). Panel E: the display of wet bulb globe temperature (WBGT) monitor and risk category prepared by the Tokyo Organising Committee of the Olympic and Paralympic Games. This display may confuse the athletes as most do not know the WBGT and may misinterpret it as air temperature. Furthermore, the colour coding was different from what has been implemented by various international federations. Panel F: colour-coded 1–5 Heat stress scale developed for the Australian Open Tennis tournament by the University of Sydney. It provides the actual index (value) and the corresponding recommendation. This feedback method provides a clear message for athletes and is recommended.

to independent factors, such a fluctuation in an air temperature measurement due to intermittent wind, should be avoided. Data should be sampled in real-time and time-averaged appropriately for each individual variable (eg, longer for black globe temperature than ambient air temperature). Sensors should also be maintained and calibrated according to manufacturer specifications and regularly inspected. In the case of the wet bulb globe temperature (WBGT), there are many commercially available options, but most do not respect the original standards. For example, WBGT requires a true measure of natural wet bulb temperature, a dry-bulb thermometer shaded by a structure eliminating effects of thermal radiation and with mechanically aspirated ambient air and a black globe with a diameter of 15 cm. Although most portable devices do not match those specifications (eg, no aspirated ambient air temperature, smaller black globe), it is recommended to use a device classified under category 1 (have black globe and natural wet bulb temperature sensors) or category 2 (have a black globe and humidity sensor) by the Japanese National Institute of Occupational Safety and Health, with an accuracy within of±2°C (online supplemental appendix 1).[22 23] The provision how the environmental measurements are taken (including sampling rate and average span) and who records the measurements should be clear, as well as the mode of communication and the recipient of this information. An example of the standard operating procedures drafted for the 2020 Summer Olympic Games is included in online supplemental appendix 1. Of note, while IFs are encouraged to develop their own risk analyses due to the WBGT limitations (see below), WBGT is currently used by several IFs to guide their heat safety guidelines and recommendations[7] and was measured by several IFs during the 2020 Summer Olympic Games (including tennis, triathlon and athletics). Among IFs, there is no common WBGT-based limit/regulation. Human heat balance studies show that even under the same environmental conditions (eg, identical WBGT or temperature/relative humidity), factors like metabolic heat production (eg, marathon vs archery), clothing/equipment worn and air movement (natural or self-generated wind speed; eg, running vs cycling) that vary among sports can affect heat stress.[24–28] Studies have shown the effectiveness of using WBGT-based event modification decisions to reduce the risk of exertional heat illness[29] and to identify resources (eg, volunteers, equipment and consumables) required at athlete medical stations.[30]

Recommendations

- The historical weather data (at least temperature and humidity) of the city/area should be provided at the time of the bid for at least the 10 years preceding. Those data are commonly available from airport weather stations or public databases and allow an overall estimate of potential extreme heat risk.
- If the range of the historical data suggests any risk of extreme heat, the environmental parameters relevant to those used by the IFs (eg, WBGT) should be continuously monitored on the FoP (eg, one value at least every hour) every year for the period of the competition from the time that the bid becomes successful until and throughout the competition. As the feasibility of this recommendation depends on numerous factors, it can be adapted while maintaining its essence. For example, if the FoP has not been built yet, the recordings could be done in proximity or similar surroundings.

Ice supply

Ice is used at different time points (eg, pre-event, during and postevent), in a different format (eg, cold water immersion (CWI), ice-towels, ice-socks, crushed ice and ice cubes) and by different stakeholders (eg, sports teams, athletes, officials and medical personnel). It is therefore important to plan for the provision of a sufficient quantity of medical ice. For example, a single medical ice bath requires 30–35 kg of ice at first plus continuous renewal to maintain the ice bath temperature between 5°C and 15°C.

During the 2020 Summer Olympic Games, the quantity of ice was determined based on: (i) venue setting, (2) competition schedule, (3) the number of athletes, (4) the number of medical ice baths and recovery ice baths, (5) the number of FoP medical tents and (6) empirical analysis of the amount of ice used in pre-Olympic events. Figure 2 summarises the ice provision by sport during the 2020 Summer Olympic Games. These numbers would need to be adapted to the event configuration and environmental conditions. It is the Local Organising Committee's (LOC) responsibility to have a contingency plan to supply additional ice in times of urgent need, as was the case for the race-walk competitions at the 2020 Summer Olympic Games. In addition to the total of >22 tons of ice used at the competition venues during the 2020 Summer Olympic Games, ice consumption reached as much as 2200 kg per day for the Athlete Village Polyclinic. Moreover, there were three ice machines located in the polyclinic in the Olympic Village, and the athlete residences were also provided with at least one ice machine; each machine producing 1200 kg of cubed ice per 24 hours. Moreover, at the opening of the Olympic Village, 42 tons of cubed

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Figure 2 Ice provision per sport during the 2020 Tokyo Summer Olympic Games. Panel A: values in kilogram per venue. It does not account for the ice provided at the polyclinic and the Olympic Village. Panel B: example of ice storage facilities during the event.

ice were delivered and stored in the large ice containers in the residences of each building. Some teams stationed outside the Olympic Village also secured their own ice-making machines in their camps.

Recommendations

- Although its benefits for non-heat-related issues is equivocal, ice is commonly required by all stakeholders (eg, IFs, National Federations, sports, officials, medical, media, etc). These requirements should be recognised and accounted for to avoid shortage in case of heat-related issues.
- A vendor, method of transport (ie, cold chain in good sanitary conditions) and considerations for mobilising existing resources (ie, moving ice from one venue to another) should be preplanned in case of shortage for treating heat-related issues. The venue coordinator needs to be empowered (including financial and security clearance) to activate this plan on request of the venue medical officer.

Removing regulatory and technical limitations for in-competition hydration and cooling

In-competition hydration is limited by various constraints, including access to fluids. Therefore, several IFs have implemented changes to their rules, often known as a heat policy, which allows the official in charge to alter the competition format to facilitate athlete hydration and cooling. For example, FIFA rules allow a hydration and cooling break after 30 min of play in each half of a football (soccer) match; the International Tennis Federation rules allow an additional 30 s for each change over in a tennis match as well as a 10 min break after the second set; the Union Cycliste Internationale rules allow one car-feeding during a cycling time trial; the World Athletics rules allow for the installation of a refreshment table on the track for 5000 m and 10 000 m races; and World Triathlon improved the number of aid/drink stations numbers during the run course with a maximum distance of 1.25 km between aid stations. Some adaptations, however, require advanced planning by the LOC, such as enlarging a road section along a cycling road race course to accommodate a feeding station.

Of note, while one could argue that there is no need for an athlete to have access to more fluids than 1 L/hour due to the limited gastric emptying rate (see below '*Fluid intake in competition*'),[31] the provision of in-competition feeding/refreshment stations also supports the midevent athlete cooling strategies. Indeed, a study conducted during the 2019 Athletics World Championships showed that most athletes (93%) had a midcooling strategy, consisting mainly of head/face water dousing (65%) and cold-water ingestion (52%).[32] The LOC is also an important stakeholder in assisting athletes in their planned precooling methods. For example, athletes often use ice vests[32] for precooling, a technology requiring a phase change material to be maintained in a frozen state before use. However, security measures may impede a team from installing a freezer in the secure competition zone after the security sweep. It is therefore paramount for national teams and IFs to agree ahead of time with the LOC if any structural changes are required (eg, providing power for the cooling devices) and how to accommodate the security provisions. However, personal preferences (eg, specific hydration and cooling products) are not an LOC responsibility.

Recommendations

- Plan for the necessary space, power supply, ice supply and security authorisation for the installation of cooling devices (eg, freezer, ice slushy machine).
- Although not possible in all sports, consider if the FoP and/or the competition rules of the event could be adapted to allow in-competition access to fluid.
- Although not possible in all sports, consider if the FoP and/or the competition rules of the event could be adapted to accommodate in-competition access to cooling interventions such as additional break time in team/racket sports and shade in waiting and warm-up areas.

Adapting competition distances and durations

A common belief is that shortening an event may minimise the risk associated with heat stress in athletes. Though it is true that short-duration events such as sprinting are not negatively impacted by heat stress,[33] this does not apply within prolonged events of different durations. For example, the organiser of the Tel Aviv marathon cancelled the full marathon in 2013 due to a heat wave but authorised the half-marathon resulting in one death and 20 hospitalisations.[34] Indeed, the main determinant of heat strain level in athletes is the exercise intensity, and it has been shown that elite cyclists actually reached higher core temperature during a 40–45 min time trial than during a road race of several hours.[9] As such, the Falmouth Road Race, a running event of only 7 miles (11 km), is notorious for its very high rate of EHS.[35] Moreover, while shortening an event is technically possible in some sports (eg, the running of the women's triathlon Olympic test event was shortened from 10 km to 5 km in 2019), this may not be feasible in other sports (eg, a cycling finish line requires time to be designed, secured and installed).

In sports structured to permit extended or additional pauses (eg, tennis, soccer and sailing), introducing more structured breaks and/or longer breaks is a relatively common feature of

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extreme heat policies in these sports. However, relatively few physiological studies have assessed optimal break frequency and duration across different sports. Nevertheless, it has been shown that while short (90–180 s) breaks alone provide a limited cooling effect if athletes cannot be relocated to a cooler environment,[36] such breaks enable the application of active cooling strategies such as ice towels and additional opportunities for rehydration with cool water.[37 38] In the context of football (3 min breaks after 30 min play in each half) and tennis (standard 90 s breaks after every odd numbered game, and a 120 s break after each set), cooling strategies during these breaks have successfully attenuated the rise in core temperature.[37–39] Extending half-time breaks in soccer by 5 min[38] and in rugby by 8 min[36] have also been shown to permit greater reductions in core temperature relative to regular half-time durations.

Recommendation

- A hasty relocation of the finish line may alter the quality of the medical services on arrival and is not recommended except if this scenario has been integrated into the planning of the event, trialled (eg, during a test event) and approved by the chief medical officer, the organising committee and the IF.
- Reducing competition duration could however be considered if this allows to substantially reduce the risks associated with heat without increasing the risk associated with exercise intensity or altering the level of care at the event (eg, reducing the running part of an Olympic triathlon from 10 km to 5 km by performing one lap instead of two).
- In sports structured to permit extended or additional pauses in play (eg, tennis, football/soccer), breaks can be used to apply active cooling strategies such as ice towels, which can reduce the physiological heat strain of the athlete.

Mist

Spray mist cooling using misting fans is a cooling strategy that involves vaporising droplets of water into the air. These droplets evaporate and cool the air by removing heat via the phase change of liquid water to water vapour.[1] Studies have shown that spray mist cooling can reduce ambient air temperatures from 1°C to 12°C, depending on the mister design, environmental conditions such as humidity and air movement and proximity to the mister.[40] Strong air movement can reduce the effectiveness of spray mist cooling by dispersing the droplets and cooling tends to be larger in drier environments, although it has also been effectively used in humid climates.[40] Thus, optimal cooling seems to be obtained when operating misting fans at an ambient air temperature >30°C, relative humidity <70% and wind speed <3 m/s.[40] The use of misting in poorly ventilated enclosed spaces may increase ambient humidity, which in turn could attenuate evaporative cooling from the skin and paradoxically worsen heat strain. While most of these studies have been conducted in urban environment designs, misting fans have also been reported to be a very efficient half-time cooling strategy in rugby league.[36]

Spray misting can be used to reduce heat stress in mass gatherings.[41 42] For someone exercising, misting fans could also enhance evaporative heat loss from the skin without additional perspiration[1] and have been reported to improve thermal comfort in sport and leisure settings.[36 40] As such, misting was implemented in some warm-up areas during the 2020 Summer Olympic Games (eg, rowing; figure 3). It has also been reported that some racewalkers may choose to use a misting shower.[43] However, misting showers are generally not implemented in-competition as: (i) their cooling effect may be limited in athletes who have already reached full skin sweat coverage; (2) the exposure time would be very limited; and (3) they pose a variety of concerns including water-soaked shoes and socks, an increased risk of accidents during sports such as in cycling due to a slippery road surface and the interference of vision for athletes wearing glasses.

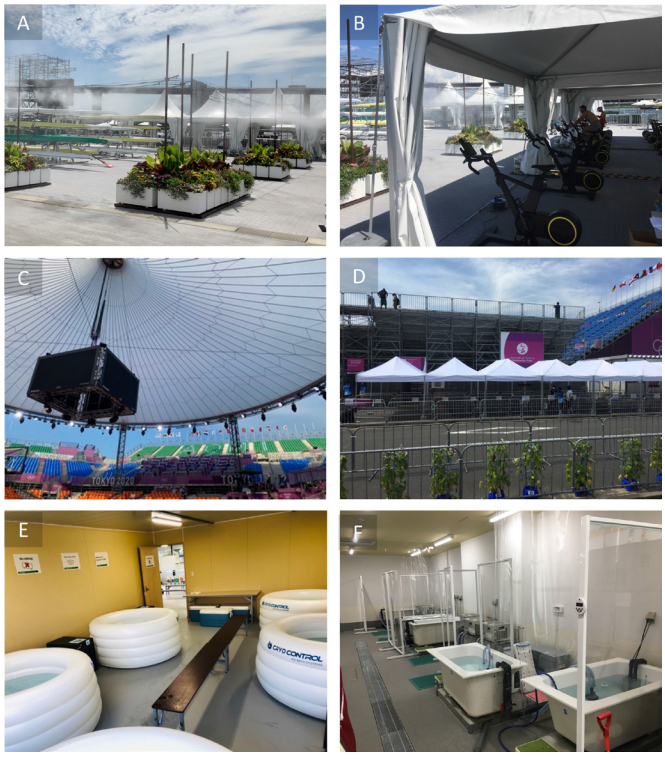

Figure 3 Example of heat mitigation strategies by the Tokyo Organising Committee of the Olympic and Paralympic Games. Panel A: misting of the boat preparation area. Panel B: shading of the warm-up area. Panel C: shading of the field of play. Panel D: shading of the mixed-zone. Panel E–F: cold bath for recovery at a sport venue and at the polyclinic, respectively.

Recommendations

- While their effectiveness depends on set-up and environmental conditions, misting fans can be appropriate for providing a cooling effect for mass gatherings and spectators, especially at high temperature with low humidity and air movement (eg, queuing lines).
- Misting fans may be appropriate for providing a cooling effect in the warm-up area, or in-game break areas for racket or team sports but should be placed in a way that athletes can choose to use them or not.

Surface colour and material

Mega-events are organised in large cities where ambient air and surface temperatures are several degrees higher than in surrounding rural areas; a phenomenon called an 'urban heat island'.[44] While the built environment (eg, tall building) can shade the direct short-wave radiation from the sun, open spaces are also required to dissipate the heat trapped between buildings.[45] Similarly, while the use of high albedo/reflection materials has been promoted to decrease the surface temperature, the reduction in air temperature may not offset the increased radiant load, manifested as a greater mean radiant temperature, that reflective surfaces induce.[46 47] For exercising athletes, it is

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important also to consider the potential effects of lower wind velocity due to the surrounding buildings[48] and spectator stands on their potential for heat dissipation.

Recommendation

- To date, most studies that investigated the use of high albedo/reflective surface materials have focused on thermal comfort and heat load in pedestrians, and the effectiveness of such measures for exercising athletes is inconclusive.

Shading

Direct solar radiation has a profound influence on the level of prevailing heat stress in an outdoor environment. Black globe temperature, which is used to help determine the mean radiant temperature—one of the four fundamental environmental parameters that define a thermal environment—is often 10 to 15°C higher than the ambient (shaded) temperature in the middle of a clear summer day. The subsequent radiant heat load can exacerbate physiological heat strain and be detrimental to exercise performance.[49 50] Moreover, as for heat stress,[51–54] high levels of solar radiation, especially when directed towards the head, may also affect complex motor–cognitive tasks.[55 56]

Shading, provided by lightweight utility canopies/awning or customised sails, is a simple and effective intervention that mitigates the negative effects of the additional heat load from thermal radiation.[57] While for most sports shading cannot be applied on the FoP, it serves as a key heat stress mitigation measure for athletes during mandated rest breaks in play and/or for athlete warm-up and cool-down areas (figure 3). Shading coverage should be sufficient to accommodate the number of players on the FoP for the given sport, permit natural ventilation from prevailing winds from any direction to maximise convection and preferably constructed of material with reflective properties.[1] Shading is also important for officials, staff and volunteers exposed to the sun on the FoP. When shading is limited, a rotation in work shifts should be planned to allow adequate relief time from the heat for these personnel.

Recommendations

- While shading may not be possible on the FoP, the preparation (eg, rigging area in sailing), recovery (eg, in-between or after events) and postevent (eg, mixed zone) areas should provide shade for the athletes.
- Shading should also be provided to all officials, staff and volunteers on the FoP. If not possible, a rotation in work shifts should be organised.

Recovery and postcooling

Athletes commonly use CWI for recovery, and their use post-competition is common, especially following heat stress.[58] However, their benefits during training have been challenged due to a potential delay in muscle recovery and training adaptation.[59 60] Recent observation from the 2019 Athletics World Championships showed that more than half of the endurance athletes planned CWI postrace (unpublished). CWI for recovery is an essential complement to the medical CWI for EHS but has a different rationale. Appropriate triage will direct all athletes with minor heat exhaustion to the recovery ice bath, allowing to spare the medical ice bath within the heat deck for the EHS.[61]

For example, while the recovery area is under the Sport Department, which is independent from the Medical Department within the Olympic Games operational structure, it appears important for the efforts to be coordinated between the two departments to avoid ice shortage (see previous) and assure that the recovery area may support the clinical needs. It is necessary to supervise (and reassess) the athletes using CWI themselves to recover from heat exhaustion as their status may change to EHS. Thus, a clinician (eg, physiotherapist and athletic trainer) should be supervising the recovery CWI area and have a radio to call the medical station in case of an athlete who was initially triaged as minor heat exhaustion deteriorates and requires transfer to the medical station. In the event of an athlete suffering EHS in a sporting venue without a heat deck, the medical team may also choose to annex the recovery area for emergency cooling (figure 3).

Recommendation

- Sporting events in hot ambient conditions should plan a shaded or indoor recovery area with CWI, with (para-) medical supervision. This recovery CWI area can accommodate the minor heat exhaustions to spare the medical CWI area within the heat deck for the management of EHS.

SECTION 2: RECOMMENDATIONS FOR RISK MITIGATION BY THE ATHLETES

Of the cohort of athletes exposed to similar hot conditions during a given event, only a minority will require medical support.[13] While there is interindividual variability in both the acute responses to heat and heat acclimation kinetics, all athletes can and should adapt and prepare for the heat.[62–64] There is also a growing evidence showing that the recent health status of the athlete (especially if the athlete is experiencing diarrhoea) is a major risk factor for an adverse medical outcome when competing in the heat.[13 65]

Acclimation

Hot ambient conditions limit an athlete's capacity to dissipate the heat produced by the contracting muscles in the environment, therefore imposing thermal and cardiovascular stress limiting exercise capacity.[6 66] Fortunately, repeated exposures to heat allow for specific physiological adaptations allowing to minimise this thermal and cardiovascular stress via an enhanced sweat response, a lower decrease in plasma volume, electrolyte conservation and a range of other adaptations described previously.[67 68] This process, to train in the heat, is referred to as heat acclimation when using simulated environments such as hot rooms, saunas or baths and heat acclimatisation when exposed to naturally hot areas/environments.[69] The term 'acclimation' is used throughout this document as a generic nomenclature for both. Generally speaking, a 'heat acclimation session' is when an individual exercises in the heat with a core body temperature between 38.5°C and 39.8°C for at least 60 min,[70] along with elevated skin temperatures, sweating and skin blood flow.[7] Heat acclimation is considered one of the primary countermeasures to protect the athletes' health and performance in hot environments.[7] Research studies have consistently reported that performance in the heat increases after days/weeks of training in the heat,[71] or that athletes are less likely to suffer a heat-related medical event when they are acclimated to hot ambient conditions when required to do intense exercise.[65 72] The physiological and performance benefits of heat acclimation have been extensively covered in numerous recent narrative reviews,[67 73] meta-analyses,[68] consensus statements,[7 15] Delphi consensus[74] and practical recommendations.[70]

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Recommendations

- Athletes should heat-acclimate before competing in hot ambient conditions.
- The preferred method of heat acclimation is to train in a similar hot environment to the competition; however, if athletes cannot, other methods (eg, overdressed training, passive heat exposure) that increase the core and skin temperature, stimulate profuse sweating and increase skin blood flow can be used as an alternative.
- The optimal duration of heat training/exposure to acclimate is 60–90 min per day for at least 2 weeks but shorter/other duration can still invoke powerful positive heat acclimation changes and should not be discarded under the premise that they are not optimal.
- The recommended frequency for heat-acclimation session is of at least four sessions per week to induce heat acclimation and two sessions per week to maintain it.[70 75]

Tapering and maintaining acclimation

While the principles of heat acclimation are relatively well understood, and it has clearly been shown that performance is increased after 1 or 2 weeks of training in the heat,[71] several athletes are still reluctant to modify their usual precompetition training plan (eg, altitude camp, taper period and travel arrangements) to accommodate heat acclimation just before a competition. Given that the decay of acclimation appears to be slower than its induction,[76] those athletes could acclimate up to 1 month in advance and then briefly reacclimate for a few days before competing.[77 78] Indeed, a subsequent acclimation stimulus within a month of a first stimulus induces faster and greater adaptations.[76 79] It is also possible to minimise the decay in the acclimation phenotype between the heat-acclimation period and the competition by maintaining regular active (or even passive) heat exposures.[75 78]

Recommendations

- If athletes cannot heat-acclimate in the 2 weeks preceding a competition, they can schedule their heat-acclimation period ~1 month earlier to accommodate their final preparation (eg, taper, travel requirement) and then reacclimate a few days before the event (while minimising the decay of adaptation in-between using biweekly heat exposures).

Hydration principles

Healthy humans are generally well hydrated[80] with a day-to-day variation in total body water of 0.2%–0.7% of body mass.[81 82] However, the rise in sweat rate when exercising in the heat can dramatically change this fluid balance. A reduction in total body water is associated with a decrease in plasma volume and an increase in plasma osmolality[83] that will increase the core temperature threshold for vasodilation and sweating,[84 85] reduces the sweat rate for any given core temperature[86] and decreases cardiac filling and challenges blood pressure regulation.[87–89] Dehydration will therefore exacerbate the rate of heat storage and cardiovascular strain imposed by exercising in the heat, thus reducing exercise heat tolerance.[90–92] Given the potential limit in accessing and ingesting fluid during the competition (see further), the general principle of hydration should be to avoid hypohydration (less than 2% body mass) during the periods of training in the heat, especially immediately before and during intense training and competition exercise in the heat. Any increase in fluid consumption should be progressive and not limited to competition day as an acute increase in fluid absorption may first increase the urine production.[93] The fluid needs for an athlete training in the heat are highly individual but consistent within the individual when influencing variables are consistent. Fluid needs should be adapted based on changes in body mass and/or plasma osmolality and/or urine specific gravity. Hydration measures should be obtained in the morning to avoid confounding effects of recent diet and exercise.[94] The following examples can also be used as a general guide at first before individualised data are ascertained: 6 mL of fluid per kg of body mass every 2–3 hour,[7] or 2 L per day plus 1–2 L per hour of exercise plus 1 L for each 5°C increase in ambient temperature above 21.5°C.[95]

Recommendations

- Hydration capacity during exercise itself is limited; therefore, athletes should ascertain sufficient fluid intake "out of exercise", from the days before and throughout the period of training/competing in the heat.
- A simple way to monitor hydration status during a period of training/competing in the heat is to follow the weight–urine–thirst principle with daily monitoring of body mass (changes should remain <1–2%), urine specific gravity (should remain <1.020) or colour and thirst. If available to the team, plasma osmolality (<290 mmol/kg) can be included in cases of suspected chronic dehydration.

Fluid intake in competition

Sweat rate and body mass changes are highly variable between athletes participating in a given sport[32 96 97] making any recommendation on an absolute fluid quantity complex.[7 98] Sweat rates will also change for a given individual depending on the environmental conditions (ie, temperature, humidity, wind and sun exposure), metabolic rate, clothing worn and heat-acclimation status.[63 99] While some athletes may sweat ~1 L/hour, others may sweat >3 L/hour,[96 97 100–103] an amount likely higher than what athletes can absorb during exercise. Indeed, fluid consumption has been estimated at ~0.5–0.7 L/hour for the elite marathoner and ~1.1 L/h for the elite race walk (20 km).[32 104] Even if athletes, such as tennis players (ie, frequent breaks) or cyclists (ie, carrying their water bottle), have more opportunity for hydration, there is also a limit in gastric emptying rate.[31] While emptying rate may be higher in some large athletes, values of ~1 L/hour have been reported while exercising in the heat.[105] Therefore, hydration should not aim to fully compensate for the sweat loss during competition but rather to limit the level of dehydration.[7 98] To do so, while there is a debate regarding the need to follow a hydration plan versus drinking to thirst,[106–108] the vast majority of elite athletes have a hydration strategy based on personal experience.[32] Body mass changes are however highly variable, even between athletes of the same level of participation in the same competition.[32] Lastly, hydration does not have to be linear through time. For example, a cyclist may focus on early hydration to account for the delay in absorption, allowing him or her to limit fluid intake during the final climb for body weight advantage. Personalising in-competition hydration strategies, however, require accounting for the rules of the sport, fluid storage and transportation logistics. Furthermore, beverage temperature becomes an important factor since cool beverages (10°C–15°C) are reported to increase the volume of fluid consumed over a given period of time and improve performance.[109]

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Recommendations

- Given the limit in fluid consumption and absorption in competition, the primary focus is to avoid beginning a prolonged exercise bout in a hypohydrated state.
- During intense prolonged exercise in the heat, body water mass losses are normal. Hydration should aim at only minimising these losses (especially at the beginning of the event) but without increasing body weight during the event (ie, overhydration).
- Irrespective of being thirst driven or preplanned, any hydration strategy needs to be practised at training during similar intensity and environmental conditions and using similar beverages before being implemented in competition.

Rehydration for recovery

Rehydration is an important component of recovery, especially after exercising in the heat. When a rapid replenishment is wanted, athletes have been suggested to consume 150% of body mass losses in the hour following exercise cessation.[110 111] However, such rapid rehydration is infrequently necessary and is not always feasible considering gastrointestinal limitations. In most cases, athletes may replace 100%–120% of body mass losses.[7] Postexercise rehydration is achieved through both fluids and foods and should also account for the other losses during exercise such as electrolytes (see next paragraph), carbohydrate[112–114] and amino acids.[115] For example, for lactose tolerant individuals, chocolate milk is an appropriate recovery drink with a carbohydrate-to-protein ratio of 4:1, contains sodium[116] and may also better restore fluid balance after exercise than a standard carbohydrate-electrolyte sport drink.[115 117]

Recommendations

- Rehydrate after exercise-heat stress with an amount slightly above (eg, 100%–120%) the body mass loss.
- Consider that fluid can also be provided by food (eg, cucumbers, tomatoes, watermelons and strawberries) and that rehydration is one aspect of the recovery diet that also includes sodium, carbohydrates and protein.

Electrolytes

Sweat includes electrolytes, mainly sodium[118 119] and therefore sweat loss cannot be compensated by water alone. 'Heavy' and 'salty' sweaters have been recommended to include sodium in their diet before, during and after exercising in the heat (eg, 3.0 g of salt added to 0.5 L of a carbohydrate-electrolyte drink).[7]

The sports drinks provide moderate levels of key electrolytes (eg, sodium) to help replace sweat losses and increase the voluntary intake of fluid. Timing of the use of electrolyte supplements can include pre-exercise hyperhydration, sometimes beneficial before a race in hot conditions.[98] Symptomatic exercise-associated hyponatraemia (blood sodium <125 mEq/L) can occur in endurance events. Contributing factors to exercise-associated hyponatraemia include overdrinking of hypotonic fluids and excessive loss of total sodium before, during and sometimes even after the event.[120]

The Institute of Medicine[80] has recognised that public health recommendations to limit sodium ingestion should not be applied to individuals with elevated sweat loss due to exercising in the heat. While exercise-associated muscle cramps are mainly due to premature muscle fatigue[121] and not salt depletion,[122] exercise in the heat may also promote muscle cramping in some athletes,[13] probably when the sodium deficit reach 20%–30% of the exchangeable sodium pool.[123] Thus, most athletes should include a solution with 0.5–0.7 g/L of sodium in their hydration plan when exercising >1 hour.[111 124 125] Sodium supplementation may be increased to 1.5 g/L for athletes prone to exercise-associated muscle cramping in the heat,[126] or rather 1.5 g/hour as organoleptic properties of beverages are affected if the sodium concentration is >1 g/L. As for postexercise recovery, this can be achieved through a combination of fluids and solid foods. Consuming beverages with sodium and/or a small amount of salted snacks or sodium-containing food at meals will help to stimulate thirst and retain the consumed fluids.[127]

Recommendations

- The public health recommendations to limit salt intake do not apply to athletes who experience profuse sweating during periods of training/competing in the heat.
- For a 'salty sweater', it is also possible to use sodium supplementation for exercise lasting >1 hour.

Carbohydrate

Energy availability may not be the limiting factor when exercising in the heat,[128] as high ambient temperatures reduce the overall capacity to perform a prolonged exercise.[129] Fluid ingestion during exercise in the heat should, therefore, focus on maintaining optimal hydration status rather than on substrate provision. For prolonged exercise >1 hour in hot environmental conditions, consuming fluids containing diluted carbohydrates and electrolytes (<6% carbohydrates and 0.4–0.85 g/L of sodium) may improve overall fluid consumption due to the increased palatability. Carbohydrate supplementation may include 30–60 g/hour of carbohydrates for exercise >1 hour,[125] and up to 90 g/hour for events >2.5 hours.[130]

Recommendation

- The ingestion of a diluted glucose and electrolyte drink (approximately 20–40 g/L carbohydrate) can improve performance during exercise (>1 hour) in a hot (30°C) environment.[129]

Warm-up and precooling

Athletes undertake preconditioning exercises to 'warm-up' before competing or even before an intense bout of training. While this activity may increase core temperature and therefore exacerbate the thermal and cardiovascular stress during prolonged exercise, an increase in muscle temperature may conversely benefit muscle contractility.[66] Importantly, the effect of warming-up are both temperature[131 132] and non-temperature[133 134] dependent. Indeed, a preconditioning activity will begin the metabolic and circulatory adjustments[135–138] and may induce a postactivation potentiation[139] along with psychologically preparing for the upcoming task.[140] These various effects have been reviewed with recommendations made elsewhere on the warm-up structure.[66 134]

Recommendation

- Warm-up has both thermal-depedent and non-thermal-dependent effects and should therefore be implemented even in the heat. However, its duration and/or intensity should be lowered in the heat to minimise the increase in core temperature, especially before prolonged events.
- To minimise the increase in body temperatures before competing in the heat, athletes can also use cooling methods (eg, ice vest) while warming-up.

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Clothing

Ultraviolet rays (UVRs) induce a range of skin responses[141] and are the main aetiological agent of skin cancers.[142] UVR exposure can be minimised with appropriate clothing (including head and neck protection).[143] To this end, sun-protective clothing made from lightweight fabrics that absorb or reflect UVR has become a standard in outdoor activities. Garments are designed to cover as much skin as possible (eg, back of the neck) and fit loosely to enable better convective heat exchange with the clothing microenvironment that sits between the skin surface and inner clothing layer. Similar to the sun protection factor (SPF) rating of sunscreen, the ultraviolet protection factor (UPF) indicates how many units of UVR are blocked.[144 145] A UPF of 25 means that only 1/25 (4%) of UVR penetrates the fabric, so the higher the UPF, the greater the protection against UVR. Fabrics with UPF <15 are not considered protective while UPF >50 provides minimal additional protection. However, while protecting from external environmental factors such as UVR, clothing can disrupt heat transfer from the skin surface and thus impose a thermoregulatory burden.[146–148] Therefore, while staff and officials should use clothing for sun protection, this strategy needs to be adapted depending on the metabolic heat production of the athlete. Importantly, the main avenue for heat dissipation during heat exposure and/or exercise is sweat evaporation. It is therefore recommended that clothing should impair sweat evaporation as little as possible, and the exposed skin area available for evaporative heat loss in athletes is maximised.[15 93] For summer sports where the potential for sweat evaporation may be reduced by protective equipment, the heat stress risk of non-heat acclimated athletes can be managed by permitting a progressive period of heat adaptation with minimal equipment coverage over several days before full protective equipment ensembles are worn.[74] The common practice of some sports such as using large 'bibs' (ie, sleeveless shirts with numbers and logos for identifying and commercial purposes) may also have to be adapted to provide the athletes with garments of appropriate fabric, size and fitting so as not to impair sweat evaporation.

Despite our better understanding of sweat physiology[149] and clothing requirements,[150] it remains unclear how different commercially available clothing should be selected depending on the prevailing level of heat stress (eg, tropical vs desert), skin colour, previous exposure/tan and activity.

Recommendations

- Officials and athletes with low metabolic heat production should wear light-coloured, loose-fitting, sun-protective clothing.
- Athletes with a higher metabolic heat production should wear clothing that does not impair direct sweat evaporation from the skin.

Sunscreen

Using sunscreen is one of the main preventive strategies to protect the skin from UVR.[142] Sunscreen application recommendations are to apply ~2 mg per cm^2 of protection to exposed skin,[151] indicating that adult athletes may need ~15–20 mL of sunscreen per application.[152] It has been recommended that athletes use water-based sunscreen (ie, non-greasy) over oil-based sunscreen that may affect sweating.[93] However, there are large differences in the sweating response to different water-based sunscreens.[153] Sunscreen can work as a chemical sun filter or as a physical sunblock. Chemical sunscreen absorbs into the skin and then absorbs UV rays, converts the rays into heat before releasing from the body. The active ingredients in chemical sunscreens include avobenzone, octinoxate and oxybenzone.[145] Physical sunblock sits on top of the skin and reflects the sun's rays. The minerals titanium dioxide and zinc oxide are the main active ingredients in physical blocks. When comparing an organic chemical sun filter (oxybenzone) and an inorganic physical sunblock (titanium dioxide), both water-based with an SPF 50, Aburto-Corona reported that the latter may impair sweating.[153] While the study design was different from real-world utilisation, athletes should be encouraged to use sunscreen when necessary given the importance of sunscreen in preventing skin cancer. Future studies are needed to identify the specific ingredients in sunscreens that interfere with sweating and their interactions with the thermoregulatory response.[143]

Recommendation

- Based on the limited studies in athletes but the well-known health risk associated with UV exposure, athletes are advised to protect the exposed part of their body using sunscreen of SPF ≥25 using a water-based organic chemical sun filter.

Sunglasses

UVR (<400 nm wavelength) is not necessary for sight but is a risk factor for cataract and macular degeneration and may damage the retina in children.[154] UVR can be removed by wearing sunglasses (marked UV400) with a wraparound shape to prevent reflective UVR. Short blue visible light (400–440 nm) is not essential for sight but is a risk factor for the adult human retina and should be removed with specific sunglasses for adults >50 years old.[154] Wearing sunglasses when appropriate is recommended on various IOC and IF educational documents.[93] Some contact lenses may also absorb those wavelengths.[154]

Recommendation

- If allowed and safe in their sport, athletes should wear sunglasses with a minimal protection UV400 or grade 3 when exercising in sunny conditions.

SECTION 3: MEDICAL SERVICE AND MANAGEMENT CONSIDERATIONS

The reader is referred to the recently published evidence-based guidelines on EHS management developed for the Olympic[61] and Paralympic[155] Games. This section complements those guidelines by presenting some applied perspectives for their implementation.

FoP supervision

Time to reduce the internal body temperature is the key factor for the success of EHS treatment. Therefore, the FoP medical plan should facilitate the identification of the athletes suffering from heat-related illness and their rapid transfer to a medical station. In the case of endurance sports like race walking, long-distance running, or triathlon, a course that has been planned in laps, may reduce the transfer time to the finish line and/or a medical station. Organisers should however keep in mind that the length of the lap may be influenced by the number of competitors (mass vs elite competitions). For road events spread along a long distance (ie, without lap), positioning medical stations along the route may minimise the transfer time and allow the EHS to be treated immediately (on-site) by trained practitioners as opposed to transferring the patient to the nearest hospital. Thus, the race protocol should supersede the local emergency medical system in case of EHS and should

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be implemented as a common understanding between the FoP medical and local emergency medical services. Assigning spotters at regular intervals on the competition course to inform the triage medical manager of any athlete in distress (as in the 2019 World Athletics Championships) is helpful. For competitions with many participants or competitions where the visibility is not optimal (eg, buildings, tents, turns, etc) spotter towers may be installed to provide a better view of the finishing area. The spotters should be in radio contact with the triage manager and the sweep team, and there should be a well-practised rescue procedure in place for rapid retrieval of collapsed athletes.

Recommendations

- If allowed by the sporting requirements and the number of competitors, organising committees should consider a lap course design to simplify supervision and retrieval of EHS athletes (eg, such as during the marathons of the recent 2019 World Athletics Championships and the 2020 Tokyo Summer Olympic Games).
- Spotters (or video surveillance) should be positioned along the course to identify and report any heat-related event without delay.

Finish area pretriage

Medical personnel should be deployed along the final few hundred metres prior to the finish line. Ideally, the main medical station should be in the immediate vicinity of the finish line, with direct and unhindered access to the finish area. The majority of the event medical staff should be stationed in the medical station with a FoP team directly observing and with direct access to the finish area. Where transfer time from the finish area to the medical station is short, then athlete transfer can be undertaken using wheelchairs. However, where the medical station is not in the immediate vicinity of the finish area, specifically designated transportation methods (eg, golf carts) should be available to transfer athletes from the course to the medical station using predefined routes and FoP points of entry.

A pretriage to discriminate between exhaustion and EHS should be commenced immediately in the finish area. It should be supervised by a medical professional experienced in the recognition and management of exertional heat illness and a knowledge of the sport.

Although athletes may want to rest (often seating or lying) after crossing the finish line, they should be encouraged and helped to walk immediately to avoid congestion of the area as this could jeopardise subsequent triage. It is important that the finish area is kept clear and the pretriage staff should strive to rapidly triage and move competitors away from the finish area. Following a rapid clinical assessment, athletes showing benign signs of exhaustion should be directed to a recovery area, where they can be further observed, rest, rehydrate and cool down. Athletes with more severe symptoms, such as central nervous system dysfunction (including severe difficulty walking and standing), must be transferred immediately to the medical station and to its heat deck (see further) for a complete assessment/triage.

Recommendations

- The medical station should be located in and with direct access to the finish area.
- A medical professional (or several based on the number of participants), with experience of heat-related illness and a knowledge of the sport, should coordinate pretriage in the finish area. Athletes with signs of central nervous system dysfunction should be promptly transported to the medical station for triage and further management (including core temperature measurement, neurological assessment and possible CWI). Those with less severe signs of exhaustion should be directed towards the supervised recovery area so as not to overburden the medical station.

Finish area care

All competitors should be offered water, ice or ice towels at the finish area. Athletes with central nervous system disturbances should be pretriaged and immediately directed towards the medical station. They should not be encouraged to drink until exercise-associated hyponatraemia has been excluded.[61]

Although ice packs and ice towels may provide subjective benefits to the users, their effect on both the core temperature reduction and orthostatic intolerance (postfinish line collapse) is limited for the purpose of EHS treatment. The skin surface exposed to cold is too small to trigger a significant core temperature decrease in a short period of time.[156] For that reason, ice packs and ice towels should be given to competitors at the finish area for immediate relief from heat stress, but they do not replace more aggressive cooling such as CWI (aiming at cooling internal body temperature and enhance central venous return) for athletes suffering EHS.[157]

Athletes sent to the recovery area should be accompanied by their entourage or members of the medical team. Walking (or assisted walking) may support the circulation by activating the lower leg muscle pump, recirculating pooled blood in the lower extremities and reducing the incidence of collapse.

Lastly, the finish line area should be kept in order, with no athletes lingering in the area for longer than necessary. At this time, medical volunteers should actively look for early recognition of EHS, as these athletes need to be immediately transported to a heat deck for prehospital treatment. Transfer from the finish line to the medical station is generally managed by wheelchair with recent data suggesting that endurance event organisers should plan 1 wheelchair per five competitors for elite international athletic events in hot and humid conditions.[13]

Recommendations

- Water, ice bag and ice towels should be available to all athletes at the finish line.
- Depending on the proximity of the medical venue from the finish line and the existence of a pathway to allow the reutilisation of the wheelchairs, a demand of up to 1 wheelchair per five competitors may be considered for elite international athletic events in hot and humid conditions.
- Ensure that the route from the finish area to the medical station is wheelchair accessible. Medical stations must have a ramp for wheelchair accessibility. The wheelchair storage/waiting area should not obstruct the wheelchair route.
- Enough trained volunteers are required to accompany the athletes both to the recovery area and to manage wheelchair transfer to the medical station without depleting the FoP medical staff.
- Unless required to stay by the venue medical officer, the FoP team should immediately return to the FoP after handing

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the patient over to the medical station team for further care. The FoP evacuation, medical station procedures and transfer between these locations must be clearly described and well-practiced before the event.

EHS prehospital management

EHS is characterised by extreme hyperthermia (>40.5°C) that is accompanied by signs of central nervous system dysfunction (eg, irrational behaviour, altered consciousness and loss of consciousness).[158] It is a medical emergency that warrants immediate treatment (ie, whole-body CWI) to ensure survival and minimise the chance of long-lasting sequela.[14 158 159] Therefore, medical volunteers must be proficient in: (1) the transfer of the collapsed athlete from the FoP to heat deck, (2) rectal temperature assessment, (3) the transfer of the collapsed athlete to whole-body CWI bath and (4) determination of whether the collapsed athlete requires advanced care beyond heat deck.[61] The medical team's training should be hands-on and include venue and event specific considerations, such as how the transfer to the heat deck will vary depending on the location and timing of the collapse. A practical guideline is presented in table 1, and a detailed list of equipment needed along treatment procedure has been published in the IOC EHS guidelines.[61]

While not exclusive to EHS, mass participation events should have designated hospitals that will admit collapsed athletes who require advanced medical care (ie, acute cooling of those who are not transported to heat deck, hypothermic overshoot after medical ice bath, follow-up for EHS recovery). Such partnerships will allow the medical organiser to capture the full scope

Table 1 Exertional heat stroke prehospital management on-site preparation and training checklist

Preparation (site visit/ venue assessment)	Training (hands-on training)	During competition
Deciding heat deck location	**Heat deck operation**	**Daily pre-event meeting**
❑ Access to FoP ❑ Access to ambulance ❑ Separated and minimal exposure from mix zone ❑ Within or adjacent to the AMS ❑ Access to water and drainage ❑ Access to electricity ❑ Temperature control (availability of air conditioning) ❑ Location of ice stock (preferably within heat deck, method of ice transfer if outside)	❑ Label ice baths with numbers and identify a heat deck leader that guides medical volunteers to use ❑ Check time to fill (ie, poor water pressure in temporarily structures) and drain ice baths ❑ Check ice quantities in heat deck and who will collect more ice ❑ Instruct on cleaning method **Triage** ❑ Chain of command from FoP triage to heat deck (radio, responsibility, transfer of patient) ❑ Chain of command with AMS and within heat deck ❑ Contingency plan for collapsed athlete far away from AMS and heat deck ❑ Control of wheelchairs, stretchers, and other evacuation devices	❑ Go through the full medical process from FoP triage to EHS management ❑ Identify heat deck leader for the day ❑ Identify who is assessing rectal temperature ❑ Identify who is in charge of continuous monitoring vital signs ❑ Identify who is helping with the transfer (may need assistance from FOP medical volunteer) ❑ Appropriate triage and communication if heat deck separated from AMS ❑ Check communication method with the team medical staff of collapsed athlete ❑ Check on ice storage, provision and how to get more ice
Transfer lines to be tested	**Patient management to know**	**Ice bath management**
❑ From FoP to heat deck (clear, accessible to wheelchair and stretcher) ❑ From heat deck to ambulance (clear, accessible for stretcher transfer) ❑ Within heat deck (spacious enough for medical staff to provide care)	❑ Familiarise with EHS-specific medical chart ❑ Average cooling pattern (know when to doubt incorrect measurements) ❑ Discharge criteria (continuous monitoring heat deck, follow-up care) ❑ Communication with collapsed athlete (reassurance athletes) ❑ Communication with team medical staff (explanation to medical staff)	❑ Water temperature should be kept between 5°C and 15°C
Equipment	**Patient management to practice**	
❑ Purchase equipment needed to operate heat deck (see Hosokawa *et al*. BJSM, 2021.) ❑ Label (number) all rectal thermometers ❑ Rectal thermometer probe≥2 m long (with insertion mark at 10 cm) ❑ Check time and calibration for all monitors (eg, thermometer, point-of-care blood analyser)	❑ Rectal temperature assessment ❑ Handling patient using pole-less mesh stretcher ❑ Transfer of patient to ice bath ❑ Handling of patient while using ice bath ❑ Handling of patient while using ice towels ❑ Taking vitals (eg, blood pressure, heart rate) during EHS management ❑ Blood sodium assessment using equipment provided ❑ Blood glucose assessment using equipment provided ❑ Preparation of intravenous therapy	
Education	**Sport-specific considerations**	
❑ Aetiology of exertional heat stroke ❑ Distribution of medical policies and procedures to key medical stakeholders ❑ Environmental heat policies and how it may influence the event operation and EHS risk	❑ Access to rectal temperature assessment (eg, swimsuit, protective equipment) ❑ Average size of athletes competing in the event ❑ Identify high risk section, event, situation, etc that can be observed in respective sports ❑ Review of games rule to identify who has the right to access athletes first ❑ Extrication of collapsed athlete from unique environment (eg, water, sand and forest)	

AMS, Athlete Medical Station; EHS, exertional heat stroke; FoP, field of play.

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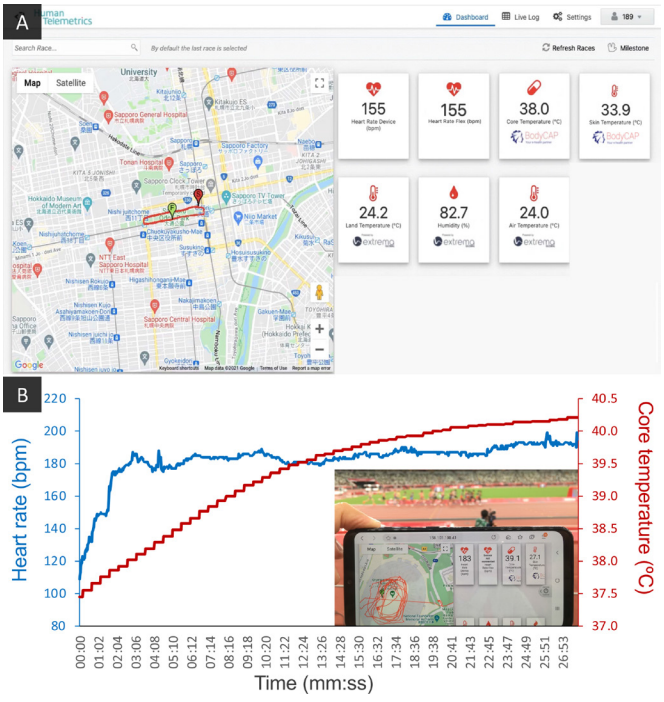

Figure 4 Real-time monitoring of athlete's thermal responses during the 2020 Tokyo Summer Olympic Games. Panel A: dashboard accessible online allowing to follow an athlete during a race walk event (the route consisted of 1 km loops at Odori Park, Sapporo). Panel B: example of data recorded during the male 10 000 m and being visualised in real time (Olympic stadium).

of medical services rendered and medical outcomes from participation in the event.

Recommendations

- A sporting event with a foreseeable risk of EHS should prepare a designated treatment area (eg, heat deck), including appropriately trained personnel, set-up and equipment for rectal temperature assessment and rapid cooling (eg, medical ice baths).
- Medical volunteers must receive a hands-on, pre-event training session on EHS recognition, assessment, treatment and post-treatment management.

Athlete monitoring

As mentioned previously, several IFs have heat policies allowing them to alter an event in case of heat stress. However, the decision is currently informed by environmental parameters. Obtaining real-time athlete data would better inform the decision makers on how the athletes are currently coping with the environmental conditions. The technology in this area is rapidly developing,[160] with several studies having already recorded thermal responses during world championship events.[9 32] The first real-time monitoring occurred during the 2020 Summer Olympic Games (figure 4). Knowing an athlete's physiological status however, raises an ethical dilemma,[161] as there is no ethical or legal grounds for making a decision to withdraw an athlete from a race against his or her will. Real-time physiological monitoring may however inform the LOC and/or IF at the organisational level to determine if an event should be altered when participants appear to have difficulties coping with the extreme conditions.

Recommendation

- While it is too early to take individual decisions regarding a potential risk of EHS based on portable technology alone (eg, core temperature) in individual athletes, and although limited by cost and availability for now, IFs/event organisers may choose to progressively allow or introduce such technology in their event. Whereas this may allow to better characterise the overall risk associated with an event itself, the individual usage has to be regulated (eg, data ownership, the timing of feedback and risk of unfair advantage).

SECTION 4: GUIDELINE FOR RISK ANALYSES AND POLICY DEVELOPMENT BY THE IFS

Most IFs have an extreme weather or heat policy based on the WBGT (eg, football, tennis, triathlon), or simply air (eg, field hockey) or water temperature (eg, swimming, triathlon). There are over 100 existing heat stress indices.[162] Most indices include a temperature and humidity assessment; several also consider radiation, and some integrate human parameters such as heat production (ie, activity) and dissipation (eg, clothing). The WBGT is currently the most widely used for assessing heat stress risk in sport-related settings.[7] Originally developed for managing heat stress risk of USA's military recruits during training activities, advantages of the WBGT method include a single integrated value that fully or partially reflects the environmental parameters that determine human heat stress risk. However, it has been suggested that the WBGT may underestimate the importance of humidity on athletes with elevated metabolic heat production,[7] or that the WBGT may underestimate risk in environments with low air speeds and with high temperatures and low humidity where the limit to human heat dissipation is not determined by the environment but by the ability to secrete sweat.[163] Thus, indices including physiological parameters such as markers of dehydration[164] may be more relevant. Importantly, indices such as the WBGT are often difficult to interpret. Indeed, only 7% of the stadium athletes and 23% of the road race athletes surveyed during the 2019 Athletics World Championships understood the term WBGT. Thus, several IFs have followed the American College of Sports Medicine guidelines in defining categories, habitually represented through a colour-coded flag system.[165] However, while a WBGT of 30.6°C was marked orange by the Tokyo Organising Committee of the Olympic and Paralympic Games (figure 1), it corresponds to a red flag for the World Triathlon and is classified as black by the International Federation of Modern Pentathlon, making the current systems confusing during multisports events such as the Olympic Games. Therefore, experts gathered at the meeting agreed that IFs should henceforth strive to develop sport-specific extreme heat policies that are efficient, understandable and implementable. The section below provides the example of a five-step guideline that summarises key components that should be considered to draft a comprehensive extreme heat policy.

#1: environmental monitoring

Monitoring environmental conditions will allow an IF to estimate the environmental risk for their athletes, similar to the *heat stress monitoring programme* that has been implemented by the International Volleyball Federation (beach) for all international competitions since 2009.[65 166] Monitoring the environmental conditions is also the first step to inform the implementation of a heat stress policy. However, while all components of any indices (eg, natural wet-bulb temperature, black globe temperature and dry-bulb temperature for WBGT) must be physically measured,

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they are often estimated using only temperature and humidity with assumptions on cloud cover and wind speed.[162] All variables required to calculate the chosen heat stress index should be physically measured (using the recommendations provided previously) and not derived or estimated from other measures.

#2: define physiological/physical parameters

Not all sports present the same thermoregulation challenges due to different heat production (ie, intensity and duration) and dissipation (eg, clothing, air velocity). For example, the relatively high velocity in cycling may allow for air movement around the rider and favour the convective heat loss.[71 167] With an ambient temperature of 35°C and relative humidity of 50%, the maximal convective and evaporative cooling capacity of a cyclist at 40 km/hour has been estimated to be 43% higher than a runner at 20 km/hour and 60% higher at 50 km/hour.[168] However, such convective advantage will disappear during up-hill cycling, where the racing speed is lower, or when the air temperature is higher than the skin temperature. Risk thresholds should also be adjusted according to the required clothing and protective equipment by the rule of the sport (and the possibility to adapt them).

In addition to the characteristics of the sport (eg, swimming vs cycling vs running vs sailing) and the competition (eg, distance, course), the characteristics of the athletes should also be considered (eg, age and acclimation status). If the chosen heat stress index allows, parameters that broadly define the athlete's thermoregulatory demand should be integrated when interpretating the index. For example, heat acclimation status profoundly alters the boundary between compensable and uncompensable heat stress secondary to modification in maximum skin wettedness.[169] Similarly, injuries such as skin burns, or spinal cord damage, lead to significant physiological impairments to sweating.[170 171] If physical parameters such as the surface area-to-mass ratio are distinctly different along with competitors morphology (eg, children vs adults), parameters should be adjusted accordingly.[172]

#3: define the acceptable level of heat stress risk

The acceptable risk is specific to the population that the policy is designed to protect. Elite-level professional competitors may expect to tolerate (and be appropriately conditioned for) higher levels of heat stress than amateur community-based competitors playing the same sport. Seasonal changes (eg, early summer) or unseasonal weather (eg, heat wave) present additional risks. The readiness of the organising committee and medical services in managing potential cases of exertional heat illness should also be considered (eg, a competition without a proper heat deck[61] cannot afford the same level of risk as a competition where exertional heat illness can be safely managed).

#4: generate a risk assessment format that is easy to understand and implement

Even the most evidence-based heat stress risk assessment will be limited in its effectiveness if the output is not easily comprehended or actionable by stakeholders such as athletes, physicians, coaches and event organisers. For example, raw WBGT values are reported with °C units and can be misleading because they are often lower than air temperature (figure 1). Therefore, outputs from any heat stress index should be scaled appropriately in a format that is accessible and familiar. A traffic light (red, amber and green) system or a 1–5 scale (figure 1) is easily understandable as it is used in many circumstances of everyday life from environmental hazards (eg, fire) to rating systems (eg, ridesharing, movies, hotels etc).

#5: incorporate evidence-based heat stress mitigation strategies that are feasible and implementable

Associated with each risk threshold defined by the scale selected in #4, recommendations can be triggered for implementing a strategy that serves to reduce physiological heat strain (online supplemental appendix 2). These strategies are informed by the scientific evidence and may range from recommendations to the athletes to providing extra services (eg, hydration station and cooling bath), modifying the rules of the sport (eg, additional/longer break) and even postponing the event. Equally important, these strategies must be compatible with the setting, in terms of available resources and opportunities for their use in the context of the standard format of the specific sport without unduly interfering with play.

Other methods and verification

The previous five steps are based on a thermophysiological analysis of the sport. This approach was implemented to develop an extreme heat policy for the Australian Open Grand Slam Tennis tournament as detailed in online supplemental appendix 2. It differs from the common 'sequence of prevention' of sports injuries that aim to establish first the extent of the problem, then the aetiology and mechanism of the injury, then introduce preventive measures before assessing their effectiveness (by repeating the first step).[173] Irrespective of the method employed, it is recommended that IFs work towards developing comprehensive heat stress guidelines that reflect the risks specific to their sports and ensure consistency across competitions within one sport. It is also recommended to assess the effectiveness of the heat policy and to modify it accordingly if required. Lastly, it is recommended to use a 1–5 scale for consistency and clarity in reporting the level of risk and the associated countermeasure (figure 5).

LIMITS, PERSPECTIVES AND CONCLUSION

Limitations

Body temperature has been used as a health indicator for millennia and is still one of the first vital signs measured. The research on the effect of heat on healthy active humans is however much more limited and historically driven by the requirements of the mining industry and the military. While there has been extensive research on exercising in the heat in recent years, most knowledge is derived from laboratory studies using recreational athletes. Therefore, there is a need for research in elite athletes, practising their sports outdoors. This need is further exacerbated by the ethical concerns associated with the technological developments that allow the monitoring of athletes in real time (figure 4).

It was decided for these recommendations to focus on the athlete, their entourage and the event organisers. We have not included spectators in these recommendations, but event organisers are encouraged to seek advice from public health experts and coordinate their effort with the local health services. In some instances, the spectator's protection is also directly related to the event organiser. For example, the IOC working group agreed with the Tokyo Organising Committee of the Olympic and Paralympic Games to allow spectators to bring one plastic bottle filled with water through security (up to 750 mL to accommodate the 21 oz/600 mL sport bottles). Such negotiation involved all concerned stakeholders (eg, security, sponsors) and was carried out 2 years before the event.

Perspectives

The current document covers a range of topics. For some of them (eg, acclimation), there was already extensive referenced

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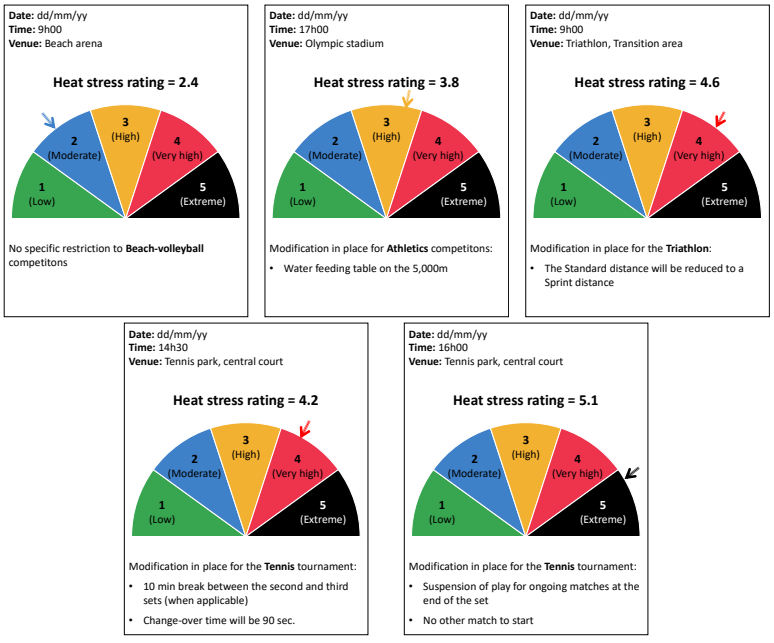

Figure 5 Example of a heat stress scale that could be adapted and used across sports. The scale uses a common 1–5 colour-coded rating with the exact value indicated. The current preventive measures to action are openly listed to inform athletes, organisers, medical services and other stakeholders. The listed modifications are non-contractual examples; each IF is in charge of their heat policies.

literature available. For other topics (eg, mist, shading), more research is required that replicates the conditions athletes experience.

IFs and event organisers are also encouraged to conduct systematic monitoring of the environmental conditions and health hazards during their event to establish an epidemiological database and inform future policies. Along these lines, it is important to understand how widespread heat decks are used, their effectiveness and the problems encountered. With this information, it will be possible to review and modify the heat deck recommendations based on clinical data in the future.

In addition, while research and scientific publications may be considered the two first steps of risk mitigation, it is also necessary to communicate with the different stakeholders using their own language, including video and social media for athletes, policies for IFs and organisers, medical workshops for clinicians, etc. In the case of the Tokyo Summer Olympic Games, the IOC developed educational material based on the previous leaflet from the Union Cycliste Internationale and World Athletics, using athlete role models. For local medical volunteers, the Tokyo Organising Committee of the Olympic and Paralympic Games hosted specific training on exertional heat illness prehospital management.

CONCLUSION

Heat-related issues are one of the main life-threatening events for athletes, commonly summarised as the 3 Cs (cardiac, cerebral/concussion and climate) or the 3 Hs (heart, head and heat). Each of these life-threatenning conditions has their own internationally agreed management protocols that should be integrated into the mandatory training for all FoP medical teams. However, while most team physicians are well aware of the management of cardiac[174] and concussion[175] issues in athletes, several are not familiar with the specific prehospital management of EHS for athletes[61] and para-athletes.[155] Thus, specific training is warranted for medical personnel covering events in hot ambient conditions. The appropriate management of EHS (ie, algorithm and facilities) allow improved recovery and survival.[14]

As for other health concerns, the athlete is the primary actor for their own health. Thus, athletes and their entourage have the responsibility to properly prepare for the competition environmental conditions, including, but not limited to, heat-acclimation, hydration and health status.

Lastly, protecting the athlete's integrity when competing in the heat is also the responsibility of the IF and the event organiser. They need to facilitate both mitigation and treatment measures, as well as adapt the event to the conditions. The governing bodies should make the athlete and their entourage fully aware of the environmental conditions and the counter measures that have been developed in response through, for example, the venue medical plan detailing the different scenarios and a 1–5 colour-coded universal heat stress scale clearly illustrating the current measures in actions (figure 5).

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