Faculty of Pre-hospital Care: Consensus Statement on the Pre-Hospital Management of Exertional Heat Illness

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Abstract

Exertional heat illness (EHI) is an increasing cause of morbidity and mortality where physical activity is conducted, particularly in hot conditions. Prompt recognition and treatment of EHI has the potential to significantly alter the patient's outcome, and so adequate pre-hospital management is vital. This consensus statement provides evidence-based guidance and expert recommendations on the recognition, diagnosis, and immediate management of EHI in the pre-hospital environment.

Main Text

INTRODUCTION

Heat Illness can be subdivided into two related, but distinct, conditions: Exertional Heat Illness (EHI) and non-EHI (N-EHI), or 'classic' heat illness as it is commonly known.
EHI describes a syndrome related to a rise in core body temperature (Tc) and disordered thermoregulation during, or immediately after, exercise or physical activity and can range in severity from mild to severe.

Climate change is increasing the frequency, severity, and duration of extreme heat events globally. The incidence of heat illness is therefore likely to increase.
This consensus statement provides evidence-based guidance and expert recommendations on the recognition, diagnosis, and immediate management of EHI in the pre-hospital environment.

This guidance supports all levels of competency within pre-hospital emergency care providers, from first aiders to specialist pre-hospital emergency medicine (PHEM) practitioners and critical care teams. It is also intended to provide guidance to organisations including (but not limited to) the NHS, Fire and Rescue Service, mass participation event organisers, elite and community sports organisations and associations, voluntary aid charities and Government departments including the Ministry of Defence (MOD).

BACKGROUND

EHI can occur during exercise or physical activity when an individual's heat production exceeds their ability to dissipate heat, leading to a rise in core body temperature and thermoregulation becomes overwhelmed. EHI describes a syndrome with a spectrum of conditions ranging from mild to severe. The most severe manifestation of EHI is often referred to as Exertional Heat Stroke[1].

Core body temperature in EHI may range from 38.5°C to over 40°C and is influenced by a variety of factors including aerobic fitness, acclimatisation status, body mass, and body composition[2–4].

Although more common in warm and humid environments, EHI also occurs in temperate climates such as the UK[5]. Severe EHI is a leading cause of critical illness and death in those undertaking prolonged exertion and is particularly common in endurance sporting events and arduous military training [6–8].

Acute complications of severe EHI may include rhabdomyolysis, acute neurological impairment, acute kidney injury, and acute liver failure. These acute complications may progress to fulminant multiorgan failure and death [9,10].

REQUIREMENT FOR FUTURE RESEARCH

The consensus process is detailed in appendix A. We identified a significant lack of high-quality level evidence within the literature for EHI.

Further studies are required to address this issue, including those incorporating prospective research and registry data and detailed retrospective case record review.

Tools and methods to define EHI severity more accurately and quickly must be developed. Improved understanding of the pathophysiology of EHI, at every level of severity, is required to define new targets for therapeutic intervention and assist the stratification of casualties into optimal pathways of care and safe return to physical activity.

There is a lack of valid studies investigating the comparative performance and tolerability of cooling modalities of EHI patients within the clinical environment. The interpretation of data from published case series is hampered by selection and information bias. This may result in misclassification of heat illness casualties in the literature, according to severity and outcomes. This could conceivably lead to erroneous conclusions being drawn as to minimum standards of care in the pre- hospital environment, and definitive care.

CONSENSUS RECOMMENDATIONS

Evidence was graded according to appendix B for the consensus recommendations.

DEFINING EXERTIONAL HEAT ILLNESS

1. Exertional heat illness is a syndrome associated with a raised core temperature and disordered thermoregulation which occurs on a spectrum of severity, ranging from mild to life threatening during or immediately after physical activity.

Hyperthermia may be caused by many different aetiologies, including fever, neuroleptic malignant syndrome and sympathomimetic toxicity. It may also occur as a normal physiological response to intense exercise or physical activity [11].

It is not uncommon to observe core temperatures approaching and occasionally above 40°C during intense or prolonged physical activity, particularly in warm conditions or whilst wearing restrictive clothing and equipment. In the absence of signs or symptoms of heat illness, this raised temperature alone does not necessarily reflect a pathophysiological process [12,13].

Conversely, signs or symptoms of heat illness in the presence of a raised core body temperature during or immediately after physical activity suggests disordered thermoregulation and is described as Exertional Heat Illness (EHI).

EHI occurs on a spectrum of severity from mild to severe which can be life- threatening.

Mild EHI is defined as: *"a core body temperature typically ranging from 38.5°C to 40°C associated with signs or symptoms of heat illness other than CNS (central nervous system) dysfunction during or immediately after physical activity"*.

Patients with mild EHI usually recover rapidly and are unlikely to experience long-lasting effects [14].

There continues to be discussion on the definition of moderate EHI, variously describing it with or without relatively mild CNS dysfunction and evidence of persistent systemic upset despite appropriate initial management. A recent expert consensus statement suggested that the diagnosis of moderate EHI may be made retrospectively, when post- incident blood tests provide biochemical evidence of end organ damage such as acute kidney injury (AKI) or raised serum liver transaminases [14].

After careful consideration, and to avoid confusion, we recommend that in the pre-hospital environment, patients should either be considered as severe EHI if they have signs of CNS dysfunction and a proven or suspected raised Tc . If not, they may be treated as mild EHI and further classification may be undertaken in hospital.

2. Severe exertional heat illness is 'a life-threatening condition of disordered thermoregulation with central nervous system dysfunction, associated with a core body temperature above 40°C during or immediately after physical activity'.
Severe EHI is commonly referred to as Exertional Heat Stroke (EHS), but the term is slightly misleading as the associated CNS dysfunction observed in EHS is more encephalopathic in nature. However, EHS is the current recognised term for severe EHI in academic and clinical medicine internationally.

The precise Tc at which severe EHI occurs is a matter of debate. Several organisations define the threshold for severe EHI as a Tc >40.5˚C[15,16]. However, a lower threshold of 40˚C is also commonly reported [17] and there is a risk of significant harm if the diagnosis of severe EHI is overlooked when Tc is below 40.5˚C [15].

As the threshold for developing symptoms is likely to differ between individuals, the key diagnostic criterion for severe EHI is the presence of CNS dysfunction[6].

3. Exertional heat illness can present with a range of signs and symptoms ranging from mild and transient, to life-threatening. (Grade: D)
EHI may present with a variety of signs and symptoms, as described in Tables 1 and 2 [18,19]. Detailed assessment is required to differentiate between mild and severe EHI.

Signs and Symptoms of Mild Exertional Heat Illness		
Feeling uncomfortably hot	Dizziness	Nausea
Headache	Excessive fatigue	Profuse sweating
Tunnel vision	Tachypnoea & tachycardia	Unable to continue exercise
Able to stand unaided	Generalised weakness	Core temperature usually 38.5 - 40˚C

Table 1: Signs and Symptoms of Mild Exertional Heat Illness

Signs and Symptoms of Severe Exertional Heat Illness (NB: Patients may also have concurrent mild EHI signs and symptoms)			
Core temperature usually >40˚C and Central nervous system dysfunction - less than "Alert" on (Alert/Confused/Voice/ Pain/Unconscious) scale			
Confusion	Agitation, or aggression	Behavioural changes	Seizures
Stumbling gait (Ataxia)	Vomiting	Loss of consciousness & coma	Urinary or faecal Incontinence
Flushed or pale skin	Collapse	Hypotension	Cardiac arrhythmias

Table 2: Signs and Symptoms of Severe Exertional Heat Illness

EHI is a syndrome which can present with a wide spectrum of conditions and therefore patients with severe EHI may present with concurrent signs and symptoms of mild EHI.

CNS dysfunction is the key feature differentiating severe EHI from mild EHI[6]. CNS dysfunction may initially manifest with relatively mild symptoms, such as confusion or subtle behavioural changes therefore a careful cognitive assessment is essential to ensure these signs and symptoms are not missed.

Patients with severe EHI may be pale and appear to be shivering or occasionally not sweating, however the presence of CNS dysfunction during or after physical activity should suggest the possibility of EHI despite these paradoxical signs [18,19].

Patients with severe EHI can rapidly develop multiorgan dysfunction, including metabolic dysfunction, distributive shock, cardiac arrhythmias, seizures, coma and cardiac arrest [20].

ASSESSING EXERTIONAL HEAT ILLNESS

4. Exertional heat illness should be considered in all individuals who become unwell during or immediately after physical activity. (Grade: D)

EHI must be considered in individuals who become acutely unwell during or shortly after exercise or other strenuous activity. This also includes occupational activity, especially whilst wearing restrictive clothing or personal protective equipment (PPE), as seen in construction, mining, manual labour, the fire and rescue service and military.

It is important to note that EHI can occur in relatively cool temperate climates including the UK throughout the year and is not restricted to warm and humid environments [5,21].

5. Core body temperature assessment should not be delayed during the initial primary survey if exertional heat illness is suspected. (Grade: D)

Core Temperature (Tc) measurement is essential to confirm a diagnosis of EHI[22], and hence early assessment will support early commencement of appropriate treatment.

Once severe EHI is suspected, active treatment should occur in parallel with the primary survey and resuscitation.

6. Rectal temperature is the preferred method of assessing temperature in suspected exertional heat illness patients. (Grade: B)

Rectal temperature assessment provides a more accurate measurement of Tc than peripheral temperature assessments [23–26] and is easily measured via a flexible probe in the rectum [27].

Rigid anal and rectal thermometers have the potential to cause local tissue damage, and their use is therefore not routinely recommended.

Rectal temperature monitoring is relatively simple and should be performed with the insertion of a flexible thermistor probe to a depth of 15cm [26]. Insertion to a depth less than 15cm may lead to an inaccurate Tc measurement [28].

In patients who have been intubated, oesophageal temperature measurement may be appropriate and has been shown to provide Tc measurements with a similar accuracy to rectal temperature measurements [26].

7. Tympanic, oral and non-contact infrared skin thermometers are not recommended for assessing temperature in patients with suspected exertional heat illness. (Grade B)

Treating Exertional Heat Illness

Tympanic thermometers are commonly used in clinical practice but are inaccurate in measuring Tc in patients with EHI [29].

Oral and infrared non-contact thermometers demonstrate poor sensitivity for temperatures above 38.0°C [30–33] and demonstrate variable results in differing ambient temperatures as well as in direct sunlight. This further limit their utility in a pre-hospital setting. [34] In line with agreed national guidelines in the US, we do not recommend their use to assess temperature in EHI patients.

We acknowledge that many pre-hospital care providers do not have the ability to measure Tc. However, it is important to emphasise that peripheral temperature measurements are unreliable indicators of Tc [33] and risk providing inaccurate readings and false reassurance in EHI.

8. Cooling must not be delayed in a patient with a suspected exertional heat illness if a core temperature is not available. (Grade: C)

If EHI is suspected and Tc is not available, active cooling and supportive treatment should commence until clinical improvement and preferably confirmation of a normal Tc .

TREATING EXERTIONAL HEAT ILLNESS

9. Severe exertional heat illness is a time critical illness and the priority is rapid and effective cooling prior to transfer (grade D).

The consequences of EHI are greatly worsened by the amount of time the patient is hyperthermic. EHI is therefore one of the few conditions where transport to hospital should be delayed to prioritise rapid on-site cooling. Early recognition and diagnosis of EHI in the pre-hospital environment is critical and will allow initiation of rapid on-site cooling.

Rapidly reducing the patient's Tc is vital to minimise tissue and organ damage and will substantially reduce the risk of morbidity and mortality [35–37]. In contrast, delayed cooling is a common risk factor in many cases of fatal EHI [10,38,39].

Data from animal models show that survival outcomes from EHI are inversely proportional to cumulative time spent with an elevated Tc. [40].

Although the optimal cooling rate in humans has not yet been established, animal studies have shown limited evidence that a cooling rate of >0.15°C per minute is associated with less morbidity and mortality in severe EHI [38].

Rapid and effective cooling is difficult to perform during transport and hence should be performed on site and not be delayed by patient transfer.

10. Cold water immersion is the preferred and recommended method of cooling patients with severe exertional heat illness. (Grade: C)

Cold Water Immersion (CWI) is recognised internationally as the most effective and hence preferred cooling modality for treating severe EHI [14,41,42], demonstrating consistently good outcomes for patients [43,44].

CWI should be conducted with patients immersed up to the neck where possible.

Continuous Tc monitoring should be used when CWI is performed.

There is little robust evidence around contraindications to CWI in Severe EHI. There is theoretical evidence, extrapolated from non-EHI cases, that in patients with cardiac arrhythmia or cardiogenic shock there is a risk of haemodynamic instability [45]. We suggest these should be considered as relative contraindications until further evidence is forthcoming.

Shade, strip, spray and fan (S3F) is recommended in severe EHI patients where CWI is contraindicated or not possible [46], and this should be delivered with continuous core temperature monitoring if available.

We note other cooling methods suggested in the literature such as application of ice sheets / towels which are rotated from a tub of ice slurry every 30-180 seconds. However, they are not as effective as CWI [38,47] and hence not routinely recommended in patients with severe EHI.

11. Active cooling via cold water immersion should cease when core body temperature reaches 38.5-39°C. (Grade: C)

In general, the literature supports stopping CWI at least one degree above normothermia to reduce the likelihood of developing overshoot hypothermia[48–50]. Therefore, in line with other consensus statement recommendations [14–16,51] a target Tc of 38.5-39°C balances the aim of minimising organ damage from EHI with the risk of hypothermia related to the treatment of EHI.

The Tc of patients who have received CWI should be continuously monitored for at least 30 mins following termination of CWI due to the risk of rebound hyperthermia or overshoot hypothermia [52–54].

Early recognition of rebound hyperthermia can usually be managed via “shade, strip, spray, fan” (S3F) approach, however recommencing CWI should be considered for refractory hyperthermia.

Following CWI, a further reduction in Tc can be reduced by removing wet clothing, drying thoroughly, and wrapping the patient in blankets.

In line with other consensus statement recommendations, [14–16,51] gentle re-warming using active external warming devices to achieve normothermia may be required after CWI but should be used with caution and requires continuous Tc monitoring.

12. Patients with severe exertional heat illness should be transferred to hospital for further assessment after cooling. (Grade: D)

Immediate cooling is critical to remove the underlying pathological process in severe EHI. However, it is recognised that some end organ damage may occur prior to the onset of symptoms and before active cooling has commenced [55]. Post EHI monitoring to assess for biochemical evidence of end organ damage [56] through sequential blood tests is important. Patients who exhibit persistent CNS dysfunction or abnormal clinical observations, despite effective cooling and treatment, should be transferred directly to hospital for further assessment and management.

Patients with mild EHI and complete resolution of symptoms after initial treatment may be considered for discharge from scene. However, all patients must be provided with robust safety-netting advice and recommended appropriate medical follow-up.

13. In mild exertional heat illness, a "shade, strip, spray and fan" (S3F) method of cooling is recommended. (Grade: D)

In patients with mild EHI, cooling via a S3F method is recommended.

S3F is logistically simple and can be performed easily with minimal resources and training to enable effective cooling in EHI patients.

Spraying or dousing the entire exposed body surface with water is essential and therefore recommended.

Fanning must be continual, rigorous and may be performed by several people simultaneously. Fanning may utilise rigid or semi-rigid hand-held items or powered electric fans. Small hand-held fans, and clothing do not produce sufficient air flow for effective cooling.

Although preferred, continuous Tc monitoring is not essential during S3F.

Due to the low risk of overshoot hypothermia, S3F should be terminated at a Tc of 37.5°C or following resolution of symptoms.

It is recommended that patients with mild EHI who have been cooled with S3F should be monitored for at least 30 mins following cessation of cooling, prior to a decision whether discharge from scene is appropriate.

14. In the pre-hospital environment, anti-pyretics, dantrolene, steroids, antibiotics and depolarising neuromuscular blocking drugs are not recommended in the management of exertional heat illness. (Grade: D)

Anti-pyretic use in EHI has not been investigated and the pathophysiology of EHI means that there is no plausible mechanism for their benefit. There is potential that anti-pyretic drugs such as paracetamol and non-steroidal anti- inflammatory drugs may contribute to EHI-related end organ damage [57,58].

Some studies have reported improved cooling rates with dantrolene, but none identified a clear benefit in morbidity or mortality in EHI [59].

There is limited animal study evidence that may indicate some benefit from the administration of antibiotics and steroids in heat illness [60,61]. However, a lack of evidence specific to EHI means these medications are not recommended at present.

Core temperatures may be elevated in anaesthetised patients who have received suxamethonium [62] and its use is therefore not recommended.

15. Cold IV fluids are not recommended as an initial method of cooling in the pre-hospital environment. (Grade D)

Current evidence does not support the routine use of IV fluids, cold or otherwise, to reduce Tc in EHI patients in a pre-hospital setting [63].

We recommend that securing venous access to commence IV fluid administration during initial resuscitation of severe EHI should not be a priority unless clinically indicated, as this risks delaying initiation of effective cooling.

In the pre-hospital setting where exercise associated hyponatraemia may not be easily excluded, IV fluids should be administered with extreme caution[64–66].

PREPARING TO MANAGE EXERTIONAL HEAT ILLNESS

16. Pre-hospital healthcare organisations should ensure staff are provided with the training and equipment to diagnose and treat exertional heat illness. (Grade: D)

Due to the significant morbidity and mortality associated in EHI, organisations responsible for pre-hospital care provision must ensure clinical staff are able to recognise and effectively manage patients who present with EHI [15].

Where there is a recognised risk of patients presenting with severe EHI, pre- hospital healthcare organisations and medical service providers should provide:

- Education and training in the recognition, diagnosis, and safe and effective management of EHI.
- Equipment to effectively and safely diagnose and monitor patients with EHI[67].
- A capability for rapid and effective cooling at the scene[41,46,68].

17. Event Organisers of mass participation sporting events should ensure on-site treatment is available for exertional heat illness. (Grade: D)

We note there is the potential for significant numbers of EHI cases at mass participation sporting events [36].

Communication before and during the event should aim to educate participants on measures to reduce the risks of EHI [67].

Event organisers and medical directors should implement strategies for risk mitigation and management of EHI cases within their pre-event risk assessment and medical plans [41]. Resources for transfer to definitive care needs to be available [15].

If the pre-event or dynamic risk assessment identifies a risk of severe EHI amongst event participants, the medical plan should the capability to provide safe and effective on-site cooling. This should include the provision of equipment, resources and trained medical personnel with the competency to manage severe EHI, including effective delivery of CWI (6,41).

CONCLUSION

EHI is an increasingly common and dangerous syndrome seen in a wide variety of environmental conditions, sporting events, and occupational groups in the UK.

Early recognition of EHI through increased education and the capability to measure core temperature, provides an opportunity to initiate immediate pre-hospital treatment.

The consequences of EHI are greatly worsened by the amount of time the patient is hyperthermic. EHI is therefore one of the few conditions where transport to hospital should be delayed to prioritise rapid on-site cooling.

'Shade Strip, Spray and Fan' (S3F) is effective for the treatment of mild EHI and when cold water immersion is not available for severe EHI. However, rapid cooling with cold water immersion is the preferred and most effective method of cooling in severe EHI. This should be considered in the same way as other immediate lifesaving medical interventions such as early defibrillation in cardiac arrest.

Those responsible for the provision of medical services at events where EHI is a potential risk, should include provision for management of EHI in their medical plans during the pre-event risk assessment process. Provision of appropriate resources, equipment, logistical support and trained personnel to ensure a rapid and effective treatment capability for EHI casualties must be included.

Statements

Authorship and acknowledgements

RH and FS contributed equally to this paper as joint first authors. RH, FS and TL drafted the initial consensus statement, with further editing by RH and FS. RH prepared the final statement and is guarantor of the work. RH, FS, TL, DF, GJ, FW, AB, JMA, AT, MB, AH, EW, HP, CK and MS all contributed to the consensus process and reviewed the manuscript prior to publication.

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Clearances

CC1 clearance has been obtained and uploaded to ScholarOne

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REFERENCES

1. Périard JD, DeGroot D, Jay O. Exertional heat stroke in sport and the military: epidemiology and mitigation. Exp Physiol [Internet]. 2022 Oct 1 [cited 2024 Mar 27];107(10):1111–21. Available from: https://onlinelibrary.wiley.com/doi/full/10.1113/EP090686
2. Koppe C, Kovats S, Jendritzky G, Menne B. Heat Waves: Risks and Responses. 2004.
3. Dervis S, Coombs GB, Chaseling GK, Filingeri D, Smoljanic J, Jay O. A comparison of thermoregulatory responses to exercise between mass-matched groups with large differences in body fat. J Appl Physiol [Internet]. 2016 Mar 3 [cited 2024 Mar 27];120(6):615. Available from: /pmc/articles/PMC4796181/
4. Garcia CK, Renteria LI, Leite-Santos G, Leon LR, Laitano O. Exertional heat stroke: pathophysiology and risk factors. BMJ Medicine [Internet]. 2022 Oct 1 [cited 2024 Mar 27];1(1):e000239. Available from: https://bmjmedicine.bmj.com/content/1/1/e000239
5. Roberts WO. Exertional heat stroke during a cool weather marathon: A case study. Med Sci Sports Exerc [Internet]. 2006 Jul [cited 2024 Mar 27];38(7):1197–203. Available from: https://journals.lww.com/acsm-msse/fulltext/2006/07000/exertional_heat_stroke_during_a_cool_weather .1.aspx
6. Raukar N, Lemieux R, Casa D. Identification and treatment of exertional heat stroke in the pre-hospital setting. J Emerg Med Svc. 2009;42(5):211–6.
7. Stearns R, Casa D, O'Connor F. Exertional Heat Stroke. In: Casa D, Stearns R, editors. Preventing sudden death in sport and physical activity. Burlington: Jones &Bartlett Learning; 2017. p. 71–96.
8. Yankelson L, Sadeh B, Gershovitz L, Werthein J, Heller K, Halpern P, et al. Life-threatening events during endurance sports: is heat stroke more prevalent than arrhythmic death? J Am Coll Cardiol [Internet]. 2014 Aug 5 [cited 2024 Jan 29];64(5):463–9. Available from: https://pubmed.ncbi.nlm.nih.gov/25082579/
9. Heled Y, Rav-Acha M, Shani Y, Epstein Y, Moran DS. The "golden hour" for heatstroke treatment. Mil Med [Internet]. 2004 [cited 2024 Jan 31];169(3):184–6. Available from: https://pubmed.ncbi.nlm.nih.gov/15080235/
10. Rav-Acha M, Hadad E, Epstein Y, Heled Y, Moran DS. Fatal exertional heat stroke: a case series. Am J Med Sci [Internet]. 2004 [cited 2024 Mar 27];328(2):84–7. Available from: https://pubmed.ncbi.nlm.nih.gov/15311166/
11. Macallan DC. Hyperthermia and pyrexia. In: Webb A, Shapiro M, Singer M, Suter P, editors. Oxford textbook of critical care. Oxford: OUP; 1999. p. 797.
12. Stacey MJ, Leckie T, Fitzpatrick D, Hodgson L, Barden A, Jenkins R, et al. Neurobiomarker and body temperature responses to recreational marathon running. J Sci Med Sport [Internet]. 2023 Nov 1 [cited 2024 Jan 31];26(11):566–73. Available from: https://pubmed.ncbi.nlm.nih.gov/37777396/
13. Racinais S, Moussay S, Nichols D, Travers G, Belfekih T, Schumacher YO, et al. Core temperature up to 41.5oC during the UCI Road Cycling World Championships in the heat. Br J Sports Med [Internet]. 2019 Apr 1 [cited 2024 Feb 6];53(7):426–9. Available from: https://bjsm.bmj.com/content/53/7/426
14. Roberts WO, Armstrong LE, Sawka MN, Yeargin SW, Heled Y, O'Connor FG. ACSM Expert Consensus Statement on Exertional Heat Illness: Recognition, Management, and Return to Activity. Curr Sports Med Rep [Internet]. 2023 Apr [cited 2024 Mar 6];22(4):134-49. Available from: https://journals.lww.com/acsm-

csmr/fulltext/2021/09000/acsm_expert_consensus_statement_on_exertiona
l_heat.10. aspx
15. Belval LN, Casa DJ, Adams WM, Chiampas GT, Holschen JC, Hosokawa Y, et al. Consensus Statement- Prehospital Care of Exertional Heat Stroke. Prehospital emergency care [Internet]. 2018 May 4 [cited 2024 Jan 31];22(3):392–7. Available from: https://pubmed.ncbi.nlm.nih.gov/29336710/
16. Hosokawa Y, Racinais S, Akama T, Zideman D, Budgett R, Casa DJ, et al. Prehospital management of exertional heat stroke at sports competitions: International Olympic Committee Adverse Weather Impact Expert Working Group for the Olympic Games Tokyo 2020. Br J Sports Med [Internet]. 2021 [cited 2024 Mar 27];55:1405–10. Available from: http://bjsm.bmj.com/
17. Laitano O, Leon LR, Roberts WO, Sawka MN. Controversies in exertional heat stroke diagnosis, prevention, and treatment. J Appl Physiol (1985) [Internet]. 2019 [cited 2024 Mar 27];127(5):1338–48. Available from: https://pubmed.ncbi.nlm.nih.gov/31545156/
18. Leon L, Kenefick R. Pathophysiology of heat related illnesses. . In: Auerbach's Wilderness Medicine. Philadelphia: Elsevier Health Sciences; 2017. p. 249–67.
19. Sawka M, O'Connor F. Disorders due to heat and cold. In: Goldman-Cecil Medicine. Philadephia: Elsevier/Saunders; 2019. p. 659–63.
20. Pryor RR, Roth RN, Suyama J, Hostler D. Exertional Heat Illness: Emerging Concepts and Advances in Prehospital Care. Prehosp Disaster Med [Internet]. 2015 Feb 27 [cited 2024 Mar 27];30(3):297–305. Available from: https://www.cambridge.org/core/journals/prehospital-and-disaster-medicine/article/abs/exertional-heat-illness-emerging-concepts-and-advanc es-in-prehospital-care/43E289E776989DA149D18AA07A65D631
21. Marchand M, Gin K. The Cardiovascular System in Heat Stroke. CJC Open [Internet]. 2022 Feb 1 [cited 2024 Jan 29];4(2):158. Available from: /pmc/articles/PMC8843991/
22. Hymczak H, Gołąb A, Mendrala K, Plicner D, Darocha T, Podsiadło P, et al. Core Temperature Measurement—Principles of Correct Measurement, Problems, and Complications. Int J Environ Res Public Health [Internet]. 2021 Oct 2 [cited 2024 Oct 31];18(20):10606. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC8535559/
23. Sakwa M, Leon L, Montain S, Sonna L. Integrated Physiological Mechanisms of Exercise Performance, Adaptation, and Maladaptation to Heat Stress. 2019.
24. Ganio MS, Brown CM, Casa DJ, Becker SM, Yeargin SW, McDermott BP, et al. Validity and reliability of devices that assess body temperature during indoor exercise in the heat. J Athl Train. 2009;44(2):124–35.
25. Ronneberg K, Roberts WO, McBean AD, Center BA. Temporal artery temperature measurements do not detect hyperthermic marathon runners. Med Sci Sports Exerc [Internet]. 2008 [cited 2024 Mar 27];40(8):1373–5. Available from: https://pubmed.ncbi.nlm.nih.gov/18614958/
26. Lefrant JY, Muller L, Emmanuel Coussaye J, Benbabaali M, Lebris C, Zeitoun N, et al. Temperature measurement in intensive care patients: comparison of urinary bladder, oesophageal, rectal, axillary, and inguinal methods versus pulmonary artery core method. Intensive Care Med [Internet]. 2003 Mar 1 [cited 2024 Jan 31];29(3):414–8. Available from: https://pubmed.ncbi.nlm.nih.gov/12577157/

27. Tansey EA, Johnson CD. Recent advances in thermoregulation. Adv Physiol Educ [Internet]. 2015 Mar 1 [cited 2024 Jan 31];39(3):139–48. Available from: https://pubmed.ncbi.nlm.nih.gov/26330029/
28. Miller KC, Hughes LE, Long BC, Adams WM, Casa DJ. Validity of Core Temperature Measurements at 3 Rectal Depths During Rest, Exercise, Cold-Water Immersion, and Recovery. J Athl Train [Internet]. 2017 Apr 1 [cited 2024 Feb 6];52(4):332. Available from: /pmc/articles/PMC5402531/
29. Huggins R, Glaviano N, Negishi N, Casa DJ, Hertel J. Comparison of rectal and aural core body temperature thermometry in hyperthermic, exercising individuals: a meta-analysis. J Athl Train [Internet]. 2012 May [cited 2024 Jan 31];47(3):329–38. Available from: https://pubmed.ncbi.nlm.nih.gov/22892415/
30. Mazerolle SM, Ganio MS, Casa DJ, Vingren J, Klau J. Is Oral Temperature an Accurate Measurement of Deep Body Temperature? A Systematic Review. J Athl Train [Internet]. 2011 [cited 2024 Jan 31];46(5):566.
31. Kiekkas P, Aretha D, Tzenalis A, Stefanopoulos N. Diagnostic accuracy of oral thermometry for fever detection in adult patients: literature review and meta-analysis. J Clin Nurs [Internet]. 2022 Mar 1 [cited 2024 Mar 27];31(5–6):520–31. Available from: https://pubmed.ncbi.nlm.nih.gov/34278635/
32. Sullivan SJL, Rinaldi JE, Hariharan P, Casamento JP, Baek S, Seay N, et al. Clinical evaluation of non-contact infrared thermometers. Sci Rep [Internet]. 2021 Dec 1 [cited 2024 Mar 27];11(1). Available from: https://pubmed.ncbi.nlm.nih.gov/34764438/
33. Cutuli SL, See EJ, Osawa EA, Ancona P, Marshall D, Eastwood GM, et al. Accuracy of non-invasive body temperature measurement methods in adult patients admitted to the intensive care unit: a systematic review and meta-analysis. Critical Care and Resuscitation [Internet]. 2021 Dec 1 [cited 2024 Oct 31];23(1):6. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10692504/
34. Chen A, Zhu J, Lin Q, Liu W. A Comparative Study of Forehead Temperature and Core Body Temperature under Varying Ambient Temperature Conditions. Int J Environ Res Public Health [Internet]. 2022 Dec 1 [cited 2024 Mar 27];19(23). Available from: https://pubmed.ncbi.nlm.nih.gov/36497956/
35. Hawes R, McMorran J, Vallis C. Exertional heat illness in half marathon runners: experiences of the Great North Run. Emergency Medicine Journal [Internet]. 2010 Nov 1 [cited 2024 Mar 27];27(11):866–7. Available from: https://emj.bmj.com/content/27/11/866
36. DeMartini JK, Casa DJ, Belval LN, Crago A, Davis RJ, Jardine JJ, et al. Environmental Conditions and the Occurrence of Exertional Heat Illnesses and Exertional Heat Stroke at the Falmouth Road Race. J Athl Train [Internet]. 2014 Jul 1 [cited 2024 Mar 27];49(4):478. Available from: /pmc/articles/PMC4151836/
37. DeGroot DW, O'Connor FG, Roberts WO. Exertional heat stroke: an evidence based approach to clinical assessment and management. Exp Physiol [Internet]. 2022 Oct 1 [cited 2024 Oct 23];107(10):1172–83. Available from: https://onlinelibrary.wiley.com/doi/full/10.1113/EP090488
38. Filep EM, Murata Y, Endres BD, Kim G, Stearns RL, Casa DJ. Exertional Heat Stroke, Modality Cooling Rate, and Survival Outcomes: A Systematic Review. Medicina 2020, Vol 56, Page 589 [Internet]. 2020 Nov 5 [cited 2024 Jan 31];56(11):589. Available from: https://www.mdpi.com/1648-9144/56/11/589/htm

39. Stearns RL, Casa DJ, O'Connor FG, Lopez RM. A Tale of Two Heat Strokes: A Comparative Case Study. Curr Sports Med Rep [Internet]. 2016 Mar 1 [cited 2024 Mar 27];15(2):94–7. Available from: https://pubmed.ncbi.nlm.nih.gov/26963017/
40. Casa DJ, Kenny GP. Immersion treatment for exertional hyperthermia: cold or temperate water? Med Sci Sports Exerc [Internet]. 2010 Jul [cited 2024 Feb 6];42(7):1246–52. Available from: https://pubmed.ncbi.nlm.nih.gov/20559063/
41. Racinais S, Hosokawa Y, Akama T, Bermon S, Bigard X, Casa DJ, et al. IOC consensus statement on recommendations and regulations for sport events in the heat. Br J Sports Med [Internet]. 2023 Jan 1 [cited 2024 Mar 6];57(1):8–25. Available from: https://bjsm.bmj.com/content/57/1/8
42. Jay O, Broderick C, Smallcombe J. Sports Medicine Australia - Extreme Heat Policy [Internet]. 2021 Feb [cited 2024 May 3]. Available from: https://sma.org.au/wp-content/uploads/2023/03/SMA-Extreme-Heat-Policy-2021-Final-1.pdf
43. Wood F, Roiz-De-Sa D, Pynn H, Smith JE, Bishop J, Hemingway R. Outcomes of UK military personnel treated with ice cold water immersion for exertional heat stroke. BMJ Mil Health [Internet]. 2022 Oct 6 [cited 2024 Jan 22]; Available from: https://militaryhealth.bmj.com/content/early/2022/10/06/military-2022-00213 3
44. De Martini JK, Casa DJ, Stearns R, Belval L, Crago A, Davis R, et al. Effectiveness of cold water immersion in the treatment of exertional heat stroke at the Falmouth Road Race. Med Sci Sports Exerc [Internet]. 2015 Feb 2 [cited 2024 Mar 28];47(2):240–5. Available from: https://pubmed.ncbi.nlm.nih.gov/24983342/
45. Feinstein B, Kelley J, Blackburn P, Connell P. Synchronised cardioversion performed during cold water immersion of a heatstroke patient. Ann Emerg Med. 2023 Jan;81(1):70-72/ Available from: https://pubmed.ncbi.nlm.nih.gov/36334955/
46. Ministry of Defence. Annex A: Commander's Guide to Heat Illness Prevention. 2024 Jun. (JSP 375 Vol 1 Ch 41).
47. Smith JE. Cooling methods used in the treatment of exertional heat illness. Br J Sports Med [Internet]. 2005 Aug [cited 2024 Jan 22];39(8):503–7. Available from: https://pubmed.ncbi.nlm.nih.gov/16046331/
48. Gagnon D, Lemire BB, Casa DJ, Kenny GP. Cold-Water Immersion and the Treatment of Hyperthermia: Using 38.6°C as a Safe Rectal Temperature Cooling Limit. J Athl Train [Internet]. 2010 Sep [cited 2024 Jan 31];45(5):439.
49. Proulx CI, Ducharme MB, Kenny GP. Safe cooling limits from exercise-induced hyperthermia. Eur J Appl Physiol [Internet]. 2006 Mar [cited 2024 Jan 31];96(4):434–45. Available from: https://pubmed.ncbi.nlm.nih.gov/16341523/
50. Douma MJ, Aves T, Allan KS, Bendall JC, Berry DC, Chang WT, et al. First aid cooling techniques for heat stroke and exertional hyperthermia: A systematic review and meta-analysis. Resuscitation [Internet]. 2020 Mar 1 [cited 2024 Jan 31];148:173– 90. Available from: https://pubmed.ncbi.nlm.nih.gov/31981710/
51. Eifling KP, Gaudio FG, Dumke C, Lipman GS, Otten EM, Martin AD, et al. Wilderness Medical Society Clinical Practice Guidelines for the Prevention and Treatment of Heat Illness: 2024 Update. Wilderness Environ Med [Internet]. 2024 Mar 1 [cited 2024 Mar 27];35(1_suppl):112S-127S. Available from: https://pubmed.ncbi.nlm.nih.gov/38425235/
52. Stone GL, Sanchez LD. Hypothermia following cold-water immersion treatment for exertional heat illness. Res Sports Med [Internet]. 2023 [cited 2024 Nov 1];31(3):255–9. Available from: https://pubmed.ncbi.nlm.nih.gov/34383570/

53. Hutchins KP, Minett GM, Stewart IB. Treating exertional heat stroke: Limited understanding of the female response to cold water immersion. Front Physiol. 2022 Nov 25;13:1055810.
54. Gagnon D, Lemire BB, Casa DJ, Kenny GP. Cold-Water Immersion and the Treatment of Hyperthermia: Using 38.6°C as a Safe Rectal Temperature Cooling Limit. J Athl Train [Internet]. 2010 Sep [cited 2024 Nov 1];45(5):439. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC2938313/
55. Adams WM, Hosokawa Y, Casa DJ. The Timing of Exertional Heat Stroke Survival Starts prior to Collapse. Curr Sports Med Rep [Internet]. 2015 Jul 11 [cited 2024 Mar 27];14(4):273–4. Available from: https://journals.lww.com/acsm-csmr/fulltext/2015/07000/the_timing_of_exertional_heat_stroke_survival.4.a spx
56. Hifumi T, Kondo Y, Shimizu K, Miyake Y. Heat stroke. J Intensive Care [Internet]. 2018;6(1):30. Available from: https://doi.org/10.1186/s40560-018-0298-4
57. Walter EJ, Hanna-Jumma S, Carraretto M, Forni L. The pathophysiological basis and consequences of fever. Crit Care [Internet]. 2016 Jul 14 [cited 2024 Jan 31];20(1). Available from: https://pubmed.ncbi.nlm.nih.gov/27411542/
58. Grogan H, Hopkins PM. Heat stroke: implications for critical care and anaesthesia. Br J Anaesth [Internet]. 2002 [cited 2024 Mar 6];88(5):700–7. Available from: https://pubmed.ncbi.nlm.nih.gov/12067009/
59. Hadad E, Cohen-Sivan Y, Heled Y, Epstein Y. Clinical review: Treatment of heat stroke: should dantrolene be considered? Crit Care [Internet]. 2005 Feb [cited 2024 Mar 6];9(1):86. Available from: /pmc/articles/PMC1065088/
60. Walter E, Gibson O. The efficacy of antibiotics in reducing morbidity and mortality from heatstroke - A systematic review. J Therm Biol [Internet]. 2020 Feb 1 [cited 2024 Jan 31];88. Available from: https://pubmed.ncbi.nlm.nih.gov/32125990/
61. Walter E, Gibson OR. The efficacy of steroids in reducing morbidity and mortality from extreme hyperthermia and heatstroke-A systematic review. Pharmacol Res Perspect [Internet]. 2020 Aug 1 [cited 2024 Jan 31];8(4). Available from: https://pubmed.ncbi.nlm.nih.gov/32666709/
62. Crocker BD, Okumura F, Mccuaig DI, Denborough MA. Temperature monitoring during general anaesthesia. Br J Anaesth [Internet]. 1980 [cited 2024 Jan 29];52(12):1223–9. Available from: https://pubmed.ncbi.nlm.nih.gov/7448100/
63. McDermott BP, Atkins WC. Whole-body cooling effectiveness of cold intravenous saline following exercise hyperthermia: a randomized trial. Am J Emerg Med [Internet]. 2023 Oct 1 [cited 2024 May 3];72:188–92. Available from: https://pubmed.ncbi.nlm.nih.gov/37562177/
64. Mohseni M, Silvers S, Mcneil R, Diehl N, Vadeboncoeur T, Taylor W, et al. Prevalence of hyponatremia, renal dysfunction, and other electrolyte abnormalities among runners before and after completing a marathon or half marathon. Sports Health. 2011 Mar;3(2):145–51.
65. Hew-Butler T, Loi V, Pani A, Rosner MH. Exercise-Associated hyponatremia: 2017 update. Front Med (Lausanne) [Internet]. 2017 Mar 3 [cited 2024 Nov 1];4(MAR):251522. Available from: www.frontiersin.org
66. Nolte HW, Hew-Butler T, Noakes TD, Duvenage CSJ. Exercise-associated hyponatremic encephalopathy and exertional heatstroke in a soldier: High rates of fluid intake during exercise caused rather than prevented a fatal outcome. Physician and Sportsmedicine. 2015 Jan 1;43(1):93–8.

67. Armstrong LE, Casa DJ, Millard-Stafford M, Moran DS, Pyne SW, Roberts WO. Exertional heat illness during training and competition. Med Sci Sports Exerc [Internet]. 2007 Mar [cited 2024 Nov 1];39(3):556–72. Available from: https://journals.lww.com/acsm-msse/fulltext/2007/03000/exertional_heat_illness_during_training_and .20.aspx
68. Hosokawa Y, Racinais S, Akama T, Zideman D, Budgett R, Casa DJ, et al. Prehospital management of exertional heat stroke at sports competitions: International Olympic Committee Adverse Weather Impact Expert Working Group for the Olympic Games Tokyo 2020. Br J Sports Med [Internet]. 2021 Dec 1 [cited 2024 Mar 6];55(24):1405–10. Available from: https://bjsm.bmj.com/content/55/24/1405