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Original Research Article

Heat-Related Health Risks: Revisiting a Persistent Global Concern

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Abstract:

The global rise in temperatures due to climate change has led to record-breaking heat events, with 2024 identified as the hottest year globally by the World Meteorological Organization. For the first time, the global average temperature surpassed 1.5°C above pre-industrial levels. Extreme temperature events are associated with a rise in mortality, particularly from cardiovascular and respiratory conditions, although heat-related deaths are often underreported due to challenges in establishing direct causality. Vulnerable groups including infants, the elderly, and individuals with chronic illnesses are disproportionately affected. This narrative review compiles current epidemiological findings and health impact assessments to provide a comprehensive understanding of how heat affects public health and to inform strategies for effective intervention and risk reduction.

Keywords: Climate Change, Global Warming, Heat Stroke, Heat Stress, Heat-Related Mortality.

Introduction

Our world is experiencing rise in temperature due to climate change. The year 2024 has been recorded as the warmest year by the World Meteorological Organization and it was the first time that the global average temperature rose above 1.5°C compared to pre-industrial times (a limit highlighted in the Paris Agreement to help minimize the dangers and effects of climate change).[1] As per the Indian Meteorological Department, the average annual land surface air temperature across India in 2024 was 0.65°C higher than the long-term average for the period 1991–2020. This made 2024 the hottest year since national records began in 1901, exceeding the previous record set in 2016, which had a temperature anomaly of +0.54°C. [2]

The Indian Meteorological Department (IMD) has provided criteria for Heat Waves. Temperature rise of 5°C to 6°C in areas with maximum normal temperature of 40°C indicates moderate heat wave, whereas an increase of 7°C or more indicates severe heat wave. Temperature rise in areas with normal maximum temperatures exceeding 40°C, an increase of 3°C–4°C and ≥ 5°C indicates a severe heat wave respectively. If the maximum temperature of a region exceeds 45°C for two consecutive days it is also declared as heat wave. [3]

Temperatures above normal averages and heat waves are reported to be linked with high mortality.[4] It is difficult to establish the etiological link between heat exposure and mortality, and therefore heat related deaths are underestimated. [5,6] Heat exposure can aggravate medical conditions other than heat-stroke and hyperthermia. Heat waves are commonly documented as a contributing factor to deaths caused by cardiovascular and respiratory conditions.[7]

Though regarded as the dangerous natural hazard, mortality due to heatwaves are not immediately known. (Heatwaves, WHO). Children under one year of age, elderly population (>65 years of age) year and people with cardiopulmonary and other chronic diseases are reported to be more vulnerable to the effects of heat, irrespective of socio-economic status and geographical locations. [8-12]

Understanding the effects of hot weather on health, as well as the strategies available to mitigate these effects, is essential for planning and implementing effective public health interventions. This narrative

review aims to synthesize evidence from epidemiological research and health impact assessments to present a comprehensive overview of effects of heat on public health.

Thermoregulation: Human body maintains temperature through behavioral and autonomic mechanisms, which includes vasodilation and sweating. The central nervous system's primary temperature sensor is the preoptic nucleus of the anterior hypothalamus. By responding to hypo- or hyperthermic situations by delivering excitatory and inhibitory signals to various brain regions, the anterior hypothalamic preoptic nucleus maintains the core body temperature at 37°C. [13]

Heat generation due to endogenous metabolic activity and from environment (exogenous) contributes to the total heat load that needs to be managed. Greater levels of humidity worsen the difficulties in heat dissipation. If human body's thermoregulatory system overloaded by high heat levels by external heat, endogenous heat, or both, a range of heat-related disorders can arise. These ailments vary from mild non-life threatening (heat exhaustion, heat syncope, heat edema, heat cramps, and heat rash) to fatal heat strokes.[14] The range of 41.6°C to 42.0°C has been documented as the maximum core body temperature that human can tolerat. [15]

Heat strokes usually results from abnormal physiological processes like inability to release excessive body heat, which encompasses a reduction in central venous pressure, the emergence of cellular and organ malfunction, damage to the gastrointestinal tract and subsequent endotoxemia, activation of a systemic inflammatory response, and increase in the core body temperature.[16] Study reports have documented that high temperature aggravates conditions like ischemic heart disease, cardiac dysrhythmias, ischemic stroke, asthma and chronic obstructive pulmonary disease, respiratory tract infections, hyperglycemia, kidney failure, neuropsychiatric disorders (e.g., psychosis, suicides, homicides, anxiety, and depression), and adverse birth outcomes, such as preterm delivery and small-for-gestational-age infants. [17-20]

Spectrum of Heat-Related Illness

Mild Illness

Heat syncope: Vasodilation and blood pooling in the limbs as a result of the body's physiological reaction to heat exposure cause a brief loss of consciousness. The first attempt to dissipate heat in a hot environment is peripheral dilatation, which increases blood flow to the skin and can lower blood pressure and, consequently, brain perfusion. Heat syncope can result from dehydration and a low blood flow to the brain.[21]

Heat edema: Swelling of limbs due to interstitial pooling and peripheral vasodilation as a result of the body's compensatory reaction to heat exposure. After removing patients from heat, elevation of affected limbs will reduce swelling. [6,22]

Heat cramps: Excessive salt loss from perspiration from physical effort frequently results in painful muscular spasms in the arms, legs, or abdomen during or after activities in the hot environment. Tachycardia and a raised body temperature usually accompany heat cramps. Patient treated with oral electrolytes, and fluid replacement after removing them from the heat.[23]

Heat rash: Sweat gland obstruction causes an inflammatory condition of the epidermis, which may be followed by a bacterial soft-tissue infection. Application of glucocorticoids and antibacterial creams on the affected part. Patients should be advised to wear loose clothing and to stay away from hot areas. [24-26]

Moderate Illness:

Heat exhaustion: Heat exhaustion is the commonest type of HRI, presenting with extreme fatigue, weakness, nausea, headache, or dizziness resulting from reduction in blood volume or body water content as a result of heat exposure-induced salt or water depletion. Elevation in core body temperature (38°C to 40°C) may be present in heat exhaustion.[22] Treatment includes, moving the patient from hot to cooler area, intravenous or oral rehydration and maintaining electrolyte balance.[27]

Severe Illness:

Heat stroke: Acute heat stroke is a potentially fatal condition marked by central nervous system dysfunction and a core body temperature increase of more than 40°C.[28] Given the pathophysiology of thermoregulation, heat stroke is typified by hyperthermia, which triggers a series of inflammatory modulators that result in encephalopathy and multiorgan failure.[29] Heat stroke is differentiated into classic and exertional. Classic heat stroke mainly occurs due to extrinsic factors and common among older persons and young children with impaired behavioral and physiological compensatory reactions to heat exposure.[30] The most common cause of exertional heat stroke in healthy individuals is excessive metabolic heat generation brought on by intense physical activity, which frequently but not always happens in conjunction with concurrent exposure to ambient heat.[31] After on-site cooling is completed, move the patient to a cool location, control breathing, circulation, and airway; provide rapid cooling using cold water; give intravenous rehydration; and transport to the emergency room[Table-1].[24-26]

Table 1: Heat related illnesses and their management approaches [14].

Heat Related Illness	Description	Management
Heat Syncope	Heat-induced vasodilation and blood pooling in the limbs can cause temporary loss of consciousness	The first attempt to dissipate heat in a hot environment is peripheral dilatation, which increases blood flow to the skin and can lower blood pressure and, consequently, brain perfusion.
Heat edema	Swelling of limbs due to interstitial pooling and peripheral vasodilation as a result of the body's compensatory reaction to heat exposure	After removing patients from heat, elevation of affected limbs will reduce swelling. Diuretic agents are not indicated.
Heat cramps	Excessive salt loss from perspiration from physical effort frequently results in painful muscular spasms in the arms, legs, or abdomen during or after activities in the hot environment. Tachycardia and a raised body temperature usually accompany heat cramps.	Remove patient from heat, treat with rest, oral electrolytes, and fluid repletion.
Heat rash	Sweat gland obstruction causes an inflammatory condition of the epidermis, which may be followed by a bacterial soft-tissue infection.	Application of glucocorticoids and antibacterial creams on the affected part. Patients should be advised to wear loose clothing and to stay away from hot areas.
Heat exhaustion	Extreme fatigue, weakness, nausea, headache, or dizziness resulting from reduction in blood volume or body water content as a result of heat exposure-induced salt or water depletion. Elevation in core body temperature (38°C to 40°C) may be present in heat exhaustion.	Treatment includes, moving the patient from hot to cooler area, intravenous or oral rehydration and maintaining electrolyte balance.
Heat stroke	Fatal condition marked by CNS dysfunction and a core body temperature increase of more than 40°C. Classic heat stroke mainly occurs due to extrinsic factors and common among older persons and young children with impaired behavioral and physiological compensatory reactions to heat exposure. Exertional heat stroke occurs in healthy individuals due to excessive metabolic heat generation brought on by intense physical activity, which frequently but not always happens in conjunction with concurrent exposure to ambient heat.	After on-site cooling is completed, move the patient to a cool location, control breathing, circulation, and airway; provide rapid cooling using cold water; give intravenous rehydration; and transport to the emergency room.

Factors Affecting Morbidity and Mortality of Heat Related Illness:

Age and Gender: The elderly are more vulnerable to the effects of heat because aging has been linked to negative changes in the thermoregulatory system. An increase in cardiac output is necessary for heat

dissipation from the body surface in a hot environment, but aging has been linked to a decrease in cardiac output.[32] Similarly, children are more vulnerable to heat related illness due to limited thermoregulation.[33] Age affects how the thermoregulatory system develops.[14,34] Extreme heat is linked to increased infant mortality, especially among newborns.[8] Infants, especially newborns, experience higher death rates during periods of extreme heat. This increased vulnerability is linked to the ongoing maturation of their thermoregulatory systems. Their physical characteristics, including higher body surface area-to-volume ratio results in increased body heat loss to the environment than children and adults, make them more susceptible to heat stress and hyperthermia. [35-37]

Both males and females are susceptible to heat-related illness, and various physiological factors like differences in sweat rates and body composition between sexes influences the susceptibility. [14,38]. Age and occupational exposures further contribute to vulnerability, with older women and those in certain work environments, especially outdoor or climate-sensitive jobs facing heightened risk. [39,40] Study reports from the United Kingdom suggests that high temperatures and heat waves pose an elevated mortality risk, particularly for older women. [33,39, 41,42]

Physiological factors: Controlling the rise in core temperature requires physiological heat stress responses, which can vary from person to person. People with pre-existing health issues have adverse consequences than healthy individual.

Cardiovascular disease: Cutaneous vasodilation causes blood to be redistributed and flow more freely to the skin, which raises cardiac demand and lowers filling pressure of heart. These reactions make heart to pump more intensely thereby raising the oxygen requirements of coronary tissue. [43,44]. In individuals with existing heart conditions, this reaction may cause an imbalance between the heart's elevated need for oxygen and its reduced ability to supply it. A prolonged imbalance can result in cardiac ischemia, heart attack, and eventually, cardiovascular failure.[45]

The increased cardiovascular strain caused by heat stress is a major health risk during extreme heat, as more elderly individuals die from heart-related events than from almost all other heat-related causes combined.[46] Moreover, excessive sweating can cause dehydration if lost fluids aren't properly replaced. This reduction in body water lowers blood volume, intensifying cardiovascular strain [47] and potentially leading to acute kidney injury or failure. [48,49]

Long-term dehydration may result in kidney fibrosis and chronic kidney disease, posing a serious risk for outdoor workers in areas like India, and similar regions.[50] This condition can aggravate existing cardiovascular disease [50] and is more frequently observed during or after periods of extreme heat.[51]

Respiratory diseases: Lung damage caused by heat, such as pulmonary edema and acute respiratory distress syndrome (ARDS) along with a high prevalence of pre-existing respiratory conditions [52], increased breathing strain from heat-induced hyperventilation [53], and higher air pollution levels during heatwaves [54], collectively account for the second leading cause of illness and death during heat waves, following cardiovascular disease.

Because heat-related injuries stem from multiple sources, they can remain dangerous even after the body is cooled back to normal temperatures. [14,55] Likewise, while most heat-related hospitalizations happen within the first 24 hours of exposure, cognitive [56] and organ impairments can last for years, leaving affected individuals with a two to three times higher risk of death for decades after the initial injury.[57]

Medications: Anticholinergic medications can limit the body's ability to sweat, increasing the risk of overheating during exercise or in hot environments. Antipsychotics like phenothiazines influence the central nervous system in multiple ways, including impairing temperature regulation and mimicking anticholinergic effects. Drugs such as thioxanthenes can disrupt thermoregulation by blocking dopamine receptors, which may elevate the thermoregulatory center’s temperature set point and reduce the body’s ability to manage heat effectively. During heatwaves, individuals with psychotic disorders or those using antipsychotic medications are especially vulnerable to heat-related illnesses, similar to the risks faced by children and the elderly. This heightened risk is due to both the pharmacological effects on temperature control and potential behavioral factors.[58]

Socio-economic status: Studies from United Kingdom has not shown any association between socio-economic status and greater vulnerability to heat or heatwaves, [39,59] whereas study reports from North America have documented association with socio-economic status. [60,61] Socioeconomic factors also influence housing quality and access to air conditioning.

Occupation: A review report on the occupational health effects of heat exposure, which incorporated data from various countries, revealed that manual laborers working in extremely hot conditions particularly in tropical low- and middle-income nations face a heightened risk.[62] Occupations considered to be at risk included farming, construction, firefighting, manufacturing jobs involving heat exposure, and military service.[63] A review report from United States documented that,

between, between 2000 and 2010, 359 work-related deaths caused by heat exposure, resulting in an average annual death rate of 0.22 per million workers. The individuals at highest risk were men and those employed in agriculture and construction.[64] (Gubernot et al., 2015).

Limited control over their surroundings and tasks makes it challenging for outdoor workers to manage heat stress effectively.[65]. As per the data from the Center for Disease Control and Prevention, crop workers are nearly 20 times more prone to heat stroke related death than general U.S. civilian workers. Most fatalities fall in the age group of 30 to 50 years.[66] Several factors increase the risk of heat-related illness among outdoor workers, including direct heat exposure, intense physical labor, insulating protective gear, and concerns over job security.[67]

Constructed Environment: The term constructed environment or built environment describes the physical elements of our living and working spaces, such as buildings, roads, public urban areas, and infrastructure. Urbanisation changes the local microclimate by influencing how heat, moisture, radiation, and air flow interact, ultimately affecting the urban areas where people reside and carry out their activities. [37,68] Urban growth leads to a phenomenon called urban heat islands, causing cities to generally experience higher temperatures than surrounding rural regions. This phenomenon is especially noticeable at night due to the release of heat accumulated during the day and becomes more severe as cities expand and population density rises.[68]

Urban temperatures are elevated due to human-generated heat from sources such as vehicle traffic, energy waste from buildings, and to a lesser extent, body heat from people. Anthropogenic heat flux is typically estimated using city energy consumption patterns, calculated by multiplying average per capita energy use by the urban population density. Greater use of air conditioning increases the release of human-generated heat into the urban environment, creating a self-reinforcing cycle that further raises city temperatures. [37,69]

Preventive Measures: Approaches to preventing heat-related illness are primarily based on clinical practice and observational evidence. This evidence highlights the value of risk screening and behavioral interventions, especially when directed toward vulnerable individuals, their caretakers and outdoor workers.[14]

Experts advise that clinicians should identify patients vulnerable to heat before the onset of the warm season and inform them and their support networks about the possible risk and harmful effects of extreme hot conditions. They should also provide guidance on how to recognize hazardous heat conditions and the symptoms of heat-related illnesses, along with clear advice on how to minimize risks and when to seek medical help. [14,70,71]

To lower the heat related health risk, it's recommended to keep living areas cool using fans or air conditioning, find cool locations, avoid strenuous activity, stay well-hydrated, wear light clothing, cool off with showers or self-dousing, and watch for symptoms, along with regular check-ins from caregivers.[72]

Strategies like Heat Health Warning System (HHWS) can be used to alert the public and authorities of upcoming heat events, enabling timely protection of at-risk populations. HHWS relies on weather forecasts to trigger preventive actions aimed at minimizing the health effects of extreme heat.[73] Interventions such as setting up air-conditioned shelters, conducting public education campaigns, reaching out to at-risk individuals through calls and home visits, and posting updates on official websites, have been shown to have positive effects on mortality due to heat related illness.[74]

Treatment Measures: Heat-related illnesses can vary from mild issues like heat edema to severe, life-threatening conditions such as heat stroke, treatment options are decided based on the severity of the illness. In mild cases, where individuals have an elevated core temperature and dehydration but no systemic involvement like nervous system dysfunction, treatment involves cooling the person in a cold environment and administering oral fluids. In cases of severe heat-related illness, prompt cooling of the core body temperature and supportive management are essential. Treatment typically initiated with an empiric approach, focusing on airway, breathing, and circulation.[6]

In cases of exertional heat stroke, full-body immersion in cold water up to the neck is considered the most effective cooling method. However, its effectiveness in treating classical heat stroke has not been clearly established. If cold water immersion is not feasible due to patient intolerance, symptoms like vomiting and diarrhea, or comorbidities such as cardiovascular disease, cooling is achieved by spraying tepid water on the body.[75]

The body's ability to regulate blood pressure is significantly impaired when core temperature rises, primarily because of cutaneous vasodilation. This causes a drop in cardiac output and redirects blood flow toward the skin, leading to reduced central venous pressure (CVP). However, the severity of heat stress does not directly correspond to the degree of CVP reduction, and individual responses vary considerably. [76]

Management of heat-induced cardiomyopathies often involves the use of vasoactive medications that

enhance cardiac output by stimulating calcium channels. However, since calcium transport also plays a role in muscle contractions, which can further elevate body temperature and this aspect must also be considered. [77,78]

To develop appropriate treatment guidelines, clinical research is needed to assess how inotropic agents influence heat production from muscle activity, as well as how muscle relaxants like dantrolene affect cardiac output in heat stroke patients, particularly during the critical early phase of emergency care.

Conclusion:

As climate change progresses, heat-related illness and death are expected to rise. Strong evidence linking hot weather to illness and death is now being supported by growing research on its impacts in other areas, such as among occupational workers. This is especially concerning in tropical regions, where rising temperatures may increasingly push people to their physiological limits in the coming decades. Rising average temperatures and more extreme heat events will result in future summers with increased illness and mortality, along with significant restrictions and shifts in activities currently seen as routine. Besides public health initiatives to minimize risks, steps to reduce greenhouse gas emissions are essential to prevent further increase in illness and death caused by heat exposure.

References:

1. World Meteorological Organization. 2025. January 2025 sees record global temperatures despite La Niña. https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level.
2. Annual Climate Summary 2024. Indian Meteorological Department. https://internal.imd.gov.in/press_release/20250115_pr_3554.pdf
3. Rajeevan M, Rohini P, Smitha AN. Snehlata T, Tanmoy G, Naresh K. Heat and Cold Waves in India Processes and Predictability. IMD Met. Monograph: MoES/IMD/Synoptic Met/01(2023)/28.
4. Gasparrini A, Guo Y, Hashizume M, Lavigne E, Zanobetti A, Schwartz J, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet. 2015;386(9991):369-375.
5. Shen T, Howe HL, Alo C, Moolenaar RL. Toward a broader definition of heat-related death: comparison of mortality estimates from medical examiners' classification with those from total death differentials during the July 1995 heat wave in Chicago, Illinois. Am J Forensic Med Pathol. 1998; 19:113e18.
6. Khan AA. Heat related illnesses. Review of an ongoing challenge. Saudi Med J. 2019 Dec;40(12):1195-1201.
7. Hajat S, Kosatky T. Heat-related mortality: a review and exploration of heterogeneity. J Epidemiol Community Health. 2010; 64:753-760.
8. Basagaña X, Sartini C, Barrera-Gómez J, Dadvand P, Cunillera J, Ostro B, et al. Heat waves and cause-specific mortality at all ages. Epidemiology. 2011; 22:765–772.
9. Åström DO, Schifano P, Asta F, Lallo A, Michelozzi P, Rocklöv J, et al. The effect of heat waves on mortality in susceptible groups: a cohort study of a mediterranean and a northern European city. Environ Health. 2015; 14:30.
10. Xu Z, FitzGerald G, Guo Y, Jalaludin B, Tong S. Impact of heatwave on mortality under different heatwave definitions: a systematic review and meta-analysis. Environ Int. 2016; 89:193–203.
11. Sheffield PE, Herrera MT, Kinnee EJ, Clougherty JE. Not so little differences: variation in hot weather risk to young children in New York City. Public Health. 2018; 161:119–126.
12. Dang TN, Honda Y, Van Do D, Pham ALT, Chu C, Huang C, et al. Effects of extreme temperatures on mortality and hospitalization in Ho Chi Minh City, Vietnam. Int J Environ Res Public Health. 2019; 16:432.
13. Wingo JE, Low DA, Keller DM, Brothers RM, Shibasaki M, Crandall CG. Skin blood flow and local temperature independently modify sweat rate during passive heat stress in humans. J Appl Physiol. 2010; 109:1301-1306.
14. Sorensen C, Hess J. Treatment and Prevention of Heat-Related Illness. N Engl J Med. 2022;387(15):1404-1413.
15. Bynum GD, Pandolf KB, Schuette WH, Goldman RF, Lees DE, Whang-Peng J, et al. Induced hyperthermia in sedated humans and the concept of critical thermal maximum. Am J Physiol Regul Integr Comp Physiol. 1978;235: R228-R236
16. Epstein Y, Yanovich R. Heatstroke. N Engl J Med. 2019; 380:2449-2459.
17. Basu R, Pearson D, Malig B, Broadwin R, Green R. The effect of high ambient temperature on emergency room visits. Epidemiology. 2012; 23:813-820.
18. Bobb JF, Obermeyer Z, Wang Y, Dominici F. Cause-specific risk of hospital admission related to extreme heat in older adults. JAMA. 2014; 312:2659-67.
19. Gronlund CJ, Zanobetti A, Schwartz JD, Wellenius GA, O'Neill MS. Heat, heat waves, and hospital admissions among the elderly in the United States, 1992–2006. Environ Health Perspect. 2014; 122:1187-1192.

20. Sorensen C, Howard C, Prabhakaran P, Horton G, Basu R. Heat illnesses in clinical practice. BMJ. 2022;378: e070762.
21. Coris EE, Ramirez AM, Van Durme DJ. Heat illness in athletes. Sports Med. 2004; 34:9-16.
22. Barrow MW, Clark KA. Heat-related illnesses. Am Fam Physician.1998;58:749-756.
23. Grubenhoff JA, du Ford K, Roosevelt GE. Heat-related illness. Clin Pediatr Emerg Med. 2007; 8:59-64.
24. Heat Illness, In: Marx J, Hockberger R, Walls RM. Rosen's Emergency Medicine: Concepts and Clinical Practice. 8th ed. Philadelphia: Elsevier, 2014: 1896-905.
25. Lipman GS, Gaudio FG, Eifling KP, Ellis MA, Otten EM, Grissom CK. Wilderness Medical Society clinical practice guidelines for the prevention and treatment of heat illness: 2019 update. Wilderness Environ Med. 2019;30(4):S33-S46.
26. Gauer R, Meyers BK. Heat-related illnesses. Am Fam Physician. 2019; 99:482-489.
27. Wexler RK. Evaluation and treatment of heat-related illnesses. Am Fam Physician. 2002; 65:2307-2313.
28. Mahant S. The evaluation and management of heat injuries in an intensive care unit. Indian J Crit Care Med. 2015; 19:479.
29. Bouchama A, Knochel JP. Heat stroke. New Engl J Med. 2002; 346:1978-1988.
30. Glazer JL. Management of heatstroke and heat exhaustion. Am Fam Physician. 2005; 71:2133-2140.
31. Leon LR, Helwig BG. Heat stroke: role of the systemic inflammatory response. J Appl Physiol. 2010; 109:1980-1988.
32. Flynn A, McGreevy C, Mulkerrin E. Why do older patients die in a heatwave? QJM. 2005; 98:227-229.
33. Kovats RS, Hajat S. Heat stress and public health: a critical review. Annu Rev Public Health. 2008; 29:41-55.
34. Tsuzuki-Hayakawa K, Tochihara Y, Ohnaka T. Thermoregulation during heat exposure of young children compared to their mothers. Eur J Appl Physiol Occup Physiol. 1995;72: 12–17.
35. Heim T. Homeothermy and its metabolic cost. In: Scientific Foundations of Pediatrics. Davis JA, Dolbing J. Eds. William Heineman, London, 1981;91–128.
36. Epstein Y, Yanovich R. Heatstroke. N Engl J Med. 2019;380(25):2449-2459.
37. Ebi KL, Capon A, Berry P, Broderick C, de Dear R, Havenith G, et al. Hot weather and heat extremes: health risks. Lancet. 2021;398(10301):698-708.
38. Kenney WL. A review of comparative responses of men and women to heat stress. Environ Res. 1985;37(1):1-11.
39. Hajat S, Kovats RS, Lachowycz K. Heat-related and cold-related deaths in England and Wales: who is at risk? Occup Environ Med. 2007;64(2):93–100.
40. Leach, Olivia K., Cottle, Rachel M., Fisher, Kat G, et al. Sex differences in heat stress vulnerability among middle-aged and older adults (PSU HEAT Project). Am J Physiol Regul Integr Comp Physiol. 2024;327(3):R320-R327.
41. Ellis FP, Prince HP, Lovatt G, Whittington RM. Mortality and morbidity in Birmingham during the 1976 heatwave. Q J Med. 1980;49(193):1–8.
42. Ishigami A, Hajat S, Kovats RS, Bisanti L, Rognoni M, Russo A, et al. An ecological time-series study of heat-related mortality in three European cities. Environ Health. 2008; 7:5.
43. Rowell L. Cardiovascular aspects of human thermoregulation. Circ Res. 1983; 52:367–379.
44. Crandall C, Gonzalez-Alonso J. Cardiovascular function in the heat-stressed human. Acta Physiol (Oxf). 2010; 199:407–423.
45. Boyette LC, Manna B. Physiology, myocardial oxygen demand. StatPearls. Treasure Island, FL: StatPearls Publishing, 2019. https:// www.ncbi.nlm.nih.gov/books/NBK499897/ (accessed Mar 25, 2025).
46. Bunker A, Wildenhain J, Vandenbergh A, Henschke N, Rocklöv J, Hajat S, et al. Effects of air temperature on climate-sensitive mortality and morbidity outcomes in the elderly; a systematic review and meta-analysis of epidemiological evidence. EBioMedicine. 2016; 6:258–268.
47. González-Alonso J, Mora-Rodríguez R, Below P, Coyle E. Dehydration markedly impairs cardiovascular function in hyperthermic endurance athletes during exercise. J Appl Physiol. 1985; 1997; 82:1229–1236.
48. Roncal-Jimenez C, Lanaspa M, Jensen T, Sanchez-Lozada L, Johnson R. Mechanisms by which dehydration may lead to chronic kidney disease. Ann Nutr Metab. 2015;66(3):10-13.
49. Glaser J, Lemery J, Rajagopalan B, Diaz HF, García-Trabanino R, Taduri G, et al. Climate change and the emergent epidemic of CKD from heat stress in rural communities: the case for heat stress nephropathy. Clin J Am Soc Nephrol. 2016; 11:1472–1483.
50. Weiner DE, Tabatabai S, Tighiouart H, Elsayed E, Bansal N, Griffith J, et al. Cardiovascular outcomes and all-cause mortality: exploring the interaction between CKD and cardiovascular disease. Am J Kidney Dis. 2006; 48:392–401.
51. Garcia-Trabanino R, Jarquin E, Wesseling C, Johnson RJ, González-Quiroz M, Weiss I, et al. Heat stress, dehydration, and kidney function in sugarcane cutters in El Salvador-a cross-shift

study of workers at risk of Mesoamerican nephropathy. Environ Res. 2015;142: 746–755.
52. Zanobetti A, O'Neill MS, Gronlund CJ, Schwartz JD. Summer temperature variability and long-term survival among elderly people with chronic disease. Proc Natl Acad Sci USA. 2012; 109:6608–6613.
53. White MD. Components and mechanisms of thermal hyperpnea. J Appl Physiol. 2006; 101:655–663.
54. Hansel NN, McCormack MC, Kim V. The effects of air pollution and temperature on COPD. COPD. 2016;13: 372–379.
55. Malamud N, Haymaker W, Custer RP. Heat stroke; a clinicopathologic study of 125 fatal cases. Mil Surg 1946; 99:397–449.
56. Dematte JE, O'Mara K, Buescher J, Whitney CG, Forsythe S, McNamee T, et al. Near-fatal heat stroke during the 1995 heat wave in Chicago. Ann Intern Med. 1998; 129:173-181.
57. Wallace RF, Kriebel D, Punnett L, Wegman DH, Amoroso PJ. Prior heat illness hospitalization and risk of early death. Environ Res. 2007; 104:290–295.
58. Kwok JS, Chan TY. Recurrent heat-related illnesses during antipsychotic treatment. Ann Pharmacother. 2005; 39:1940-1942.
59. Bennett JE, Blangiardo M, Fecht D, Elliott P, Ezzati M. Vulnerability to the mortality effects of warm temperature in the districts of England and Wales. Nat Clim Chang. 2014;4(4):269-273.
60. O'Neill MS, Zanobetti A, Schwartz J. Modifiers of the temperature and mortality association in seven US cities. Am J Epidemiol. 2003;157(12):1074–1082.
61. Schwartz J. Who is sensitive to extremes of temperature? a case-only analysis. Epidemiology. 2005;16(1):67–72.
62. Xiang J, Bi P, Pisaniello D, Hansen A. Health impacts of workplace heat exposure: an epidemiological review. Ind Health. 2014;52(2):91–101.
63. Arbuthnott, K.G., Hajat, S. The health effects of hotter summers and heat waves in the population of the United Kingdom: a review of the evidence. Environ Health. 2017;16 (1):119.
64. Gubernot DM, Anderson GB, Hunting KL. Characterizing occupational heat related mortality in the United States, 2000-2010: an analysis using the census of fatal occupational injuries database. Am J Ind Med. 2015;58(2): 203–211.
65. Gubernot DM, Anderson GB, Hunting KL. The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. Int J Biometeorol. 2014; 58:1779-1788.
66. Centers for Disease Control and Prevention (CDC). Heat-related deaths among crop workers-United States, 1992–2006. Morb Mortal Wkly Rep. 2008; 57:649-653.
67. Department of Labor. OSHA technical manual section III: chapter 4. Heat stress. Occupational Health and Safety Administration, 2017 (https://www.osha.gov/otm/section-3-health-hazards/chapter-4.)
68. Arnfield AJ. Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. Int J Climatol. 2003; 23:1–26.
69. Li C, Zhou J, Cao Y, Zhong J. Interaction between urban microclimate and electric air-conditioning energy consumption during high temperature season. Appl Energy. 2014;117: 149–156.
70. Hajat S, O'Connor M, Kosatsky T. Health effects of hot weather: from awareness of risk factors to effective health protection. Lancet. 2010;375: 856-863.
71. Climate Psychiatry Alliance. How to survive extreme heat: posters in English (https://www.climatepsychiatry.org/coping-with-extreme-heat-english)
72. Centers for Disease Control and Prevention. Frequently asked questions about extreme heat. June 1, 2012 (https://www.cdc.gov/disasters/extremeheat/faq.html)
73. Kovats RS, Kristie LE. Heatwaves and public health in Europe. Eur J Public Health. 2006; 16:592-599.
74. Fouillet A, Rey G, Wagner V, Laaidi K, Empereur-Bissonnet P, Le Tertre A, et al. Has the impact of heat waves on mortality changed in France since the European heat wave of summer 2003? A study of the 2006 heat wave. Int J Epidemiol. 2008; 37:309-317.
75. Bouchama A, Dehbi M, Chaves-Carballo E. Cooling and hemodynamic management in heatstroke: practical recommendations. Crit Care. 2007;11: R54.
76. Brothers RM, Keller DM, Wingo JE, Ganio MS, Crandall CG. Heat-stress-induced changes in central venous pressure do not explain inter individual differences in orthostatic tolerance during heat stress. J Appl Physiol. 2011; 110:1283-1289.
77. Periasamy M, Herrera JL, Reis FCG. Skeletal Muscle Thermogenesis and Its Role in Whole Body Energy Metabolism. Diabetes Metab J. 2017;41(5):327-336.
78. Shah K, Seeley S, Schulz C, Fisher J, Gururaja Rao S. Calcium Channels in the Heart: Disease States and Drugs. Cells. 2022;11(6):943.