International Journal of Clinical Frontiers

Article

Heat Stroke in the Era of Global Warming: Assessing the Emerging Threats to Human Health

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Received: Feburary 20, 2025; Accepted: March 30, 2025; Published: June 25, 2025.

Abstract: The most difficult and persistent natural disaster that is causing a rise in the frequency of extreme heat waves and heat events is global climate change. The world temperature is expected to climb by 1.5°C until 2050, according to the Economic Survey of Asia, but it is now growing at a pace of 2°C per century. In addition to posing major health risks including heat exhaustion and heat stroke, this year's most frequent weather-related deaths are brought on by the constant rise in temperature and intense heat. Heat stroke is a non-contagious type of hyperthermia marked by a core body temperature as high as 40°C. This is caused by a breakdown in thermoregulation, which results in neurological dysfunction ranging from mild cognitive impairment to coma. The current study determines and summarizes what is currently known about heatstroke. A summary of heat stroke cases from various regions of Europe and Asia was compiled. The main causes of heat stroke have been determined to include tall buildings, deforestation, pollution, greenhouse gasses, loss of thermoregulation, and destruction of the green belt. Patients can be quickly cooled with cold packs, immersion in cold water, prompt removal from heat sources, and hydration. Because of the severity of the situation, governments must act quickly and decisively to alleviate the threat that global warming poses to public health, including heat stroke. Raising public awareness could be helpful in this context.

Keywords: Hyperthermia; Heat Stroke; Rhabdomyolysis; Global Warming; GHG

1. Introduction

Global warming is a phenomenon that causes Earth's temperature to steadily rise every day. As a result, it is the primary cause of many heat-related ailments. The combustion of fossil fuels releases greenhouse gases into the atmosphere, which increases global warming and raises the earth's average temperature. Only CO_2 and H_2O were recognized as greenhouse gases (GHGs) until the 1950s; however, as of 1971, CH_4, N_2O, and CFCs are also included in the list. According to scientific studies, the rate of global warming is rising at a rate of 2°C every century. Heatstroke, which can result in multiple organ failure, is a notable aspect of global warming. Due to the greater effects of heatwaves and the urban heat island effect, major cities like Lahore, Faisalabad, Rawalpindi, Multan, Gujranwala, Sargodha, and Sialkot have higher population densities and are hotter than rural areas. There is a correlation between the growing population in Asia, and other parts of world with the frequency of heatwave events. Heatwave incidents are predicted to rise in Asia, while the Bangladesh plains are predicted to see the most notable increase.

Exertional and non-exertional heat strokes are the two main categories of heat strokes. A detailed Table 1 illustrates the various parameters that may vary between heatstroke that is not exertional and that is. While non-exertional heatstroke is brought on by heat created by muscular activity during intense exercise or prolonged work on hot days, exertional heat stroke is caused by extremely high temperatures and heatwaves [1].

The earth's average temperature has increased since the turn of the 20th century, and it has done so especially quickly over the past 50 years. The number of deaths caused by high temperatures in various parts of the world from 2003 to 2015 is shown in Figure 1 [2,3].

Table 1. Factors that can differentiate exertional and non-exertional heatstroke

Factors	Non Exertional heat illness	Exertional heat illness
Age group	Mostly in very young or elderly people	Young people mostly sports man and military personnel
Heat factor	External heat mostly due to heat waves	Intrinsic heat due to muscular activity
Cause	Inefficient thermoregulatory mechanism	Inability to dissipate excess heat production
Time of occurrence	Mostly in summer season due to extremely hot environment	In any time of year

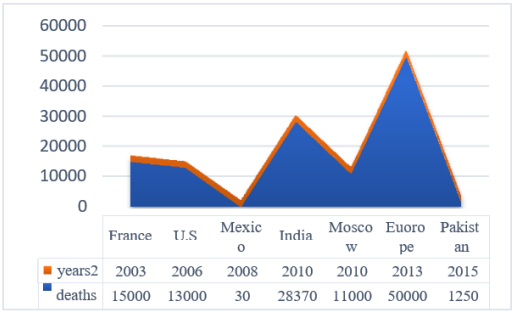

Figure 1. An area graph that is showing no. of deaths in different countries at different times

It is anticipated that the number of heatwave events in Asia will increase to around 75 by the end of the twenty-first century, with an increase of three incidents per year [4].

June 2017 was an extraordinarily hot month in Western Europe. This weather returned to Spain in July, resulting in a catastrophic forest fire. These heat waves persisted throughout August and affected a large portion of southern Europe. Table 2 displays many parameters in varying years, including age, sex, deaths, and symptoms associated with high temperatures [5].

The hottest temperature ever recorded in the southern town of Veraguas on June 28, 2019 was 46°C, surpassing the previous mark of 44.1°C set in 2003. Research indicates that students' health is negatively impacted by excessive heat, which inevitably affects their learning outcomes. Children's heat risk is a pressing concern with such a high-temperature threat. According to previous studies, children are more susceptible and vulnerable to heat-related illnesses since their bodies do not acclimatize to the heat as well as adults do. Extreme event attribution is the method through which the role of climate change in an individual event can be assessed and quantified. Over the past two decades, more than 350 studies have quantified the role of climate change in over 400 extreme events. The consequences of heat on cognitive development are anticipated to be more severe in countries such as India where temperatures and levels of poverty are both high. The World Medical Organization estimates that the study that follows attempts to address the negative consequences of rising temperatures on the body, as well as risk factors, potential treatments, and medications for heat stroke.

2. METHODOLOGY

A thorough internet search was done, encompassing news articles, reviews, weather reports, case studies, and original writings. Publications on heat stress and human health were found by using a variety of search terms and themes. The

Table 2. Different parameters related to extreme temperature

Year	Area	T°	Deaths	Age	Sex	Symptoms
Aug 2003	Europe	>40°	14800	Mostly 40- 65yrs Old	Mostly Males	Dehydration Neurological Abnormalities
July 2012	USA	>40°	23	Average 65	Both Male/ Female	Renal And Hepatic Failure
June 2015	Asia	41.2-44.8°	1200	Median Group	Mostly Males	Abnormal Pulse And Respiratory Rate And Low Blood Pressure
2016	Maricopa	47.8°	130	50-64(41%)	Males (72%)	Increase In Body Temperature And Renal Failure

terms "heatstroke," "stroke heat," "heat hyperpyrexia," and "hyperthermia" were used to gather data. most likely 2019 is expected to be one of the five hottest years on record, and the five hottest years from 2015 to 2019 are the range [5,6].

The climate in Asia has been worse over the past few decades. The worst circumstances were in Karachi, when a water scarcity and intense heat in June 2015 claimed the lives of 1200 people. The maximum temperature that was recorded throughout the period was 44.8°C. 18 individuals died from heat stroke in Mohenjo- Daro in 2010, and the maximum temperature ever recorded there was 53.5°C (Figure 2 shows the highest temperature records in several nations). In 2015, there were 4000 cases of heatstroke reported in Asia, 1400 deaths in India from heatstroke, and the heat index in Iran shattered all previous global records that year [7].

'pyrogenic or non-pyrogenic hyperthermia', alternatively. Table 3 lists the various terms used to describe heat stroke. The documents that were retrieved included all the relevant data, including authors, keywords, titles, abstracts, countries, journals, and cited references, among other details.

3. Causes of heatstroke

3.1. Failure of Thermoregulation

Persistent exposure to sunshine can result in heat stroke when the body's internal temperature rises due to a malfunctioning thermoregulatory mechanism [7]. The primary factors that might raise body temperature inside include outside temperature, humidity, UV radiation, clothing, wind speed, and heat-resistant materials [7,8].

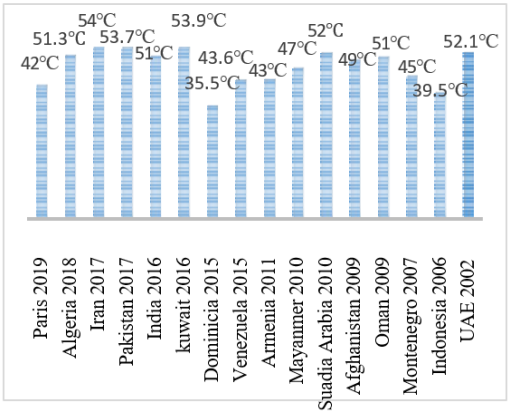

Figure 2. Graph showing highest temperatures recorded in different countries in different years

3.2. Summer season in Asia

Asia had a 3°C temperature increase between 1996 and 2007. As a result, Asia's summer season lengthens and there is a risk of heatstroke. The north half of this heat index is getting more and more spread from the south. The rate of heat-related deaths rises in the summer because of an increase in the heat index [4,7]. Future climate estimates indicate that temperatures over the Indus Delta will rise by at least 5 °C by the end of the 21st century [8].

3.3. Dehydration

Dehydration causes a drop in blood volume, which lowers the blood's ability to carry heat and raises the risk of heat retention, both of which impair thermoregulation and increase the risk of heat disease. Hyperventilation brought on by an increased excretion of salt and water can result in heatstroke [7,8].

Table 3. Different terms related to heat illness

Heatwave	According to the World Meteorological Organization (WMO) heat-wave occurs when the daily maximum temperature of more than five successive days overshoots the maximum temperature by 5°C, from the regular temperature of a particular area.
Heat stress	The discomfort and physical stress of being exposed to a hot environment, especially during physical activity
Heat exhaustion	A condition of dehydration and salt depletion due to high temperature. Tiredness, weakness, headache, nausea, and vomiting are symptoms of heat exhaustion.
Heat syncope	Due to high ambient temperature, a condition of fainting, blood flow reduces to the brain
Heat cramps	A condition of electrolyte deficiency in muscles due to hard exercise
Hyperthermia	Increased body temperature above the hypothalamic set point when heat-dissipating mechanisms become impaired (by drugs or disease) or stunned by external (induced or environmental) or internal (metabolic) heat
Multiorgan-dysfunction syndrome	Continuation of changes in more than one organ system that occur after trauma such as trauma sepsis, or heat stroke

3.4. CO_2 Emission

New findings show that each time the CO_2 emission, heat is produced in the range of 1.9–4.5°C. 5% likelihood of generating heat at 7.1°C for every increment in emission. The release of methane from burning fossil fuels, deforestation, combustion, and wood rot raises CO2 levels and causes global warming. These changes have the potential to impact human health by raising summertime temperatures to extremely high levels and raising the risk of heatstroke [9].

3.5. Symptoms of heatstroke

Heat stroke symptoms can occasionally be mistaken for heart attacks or other illnesses. Common signs of heat stroke include altered physiological response, including neurological dysfunction and hyperthermia. These dysfunctions could include cognitive dysfunctions, nervous excitement, or awareness problems [10].

3.6. Pathophysiology

When heatstroke is severe, multiple organ dysfunction occurs. The efficiency of heat radiation decreases with increasing ambient temperature; in a humid environment, the body's ability to release heat through evaporation is also reduced since perspiration does not evaporate and the surface temperature of the body rises. Multi-organ system effects during heat stroke are depicted in Figure 3.

In one study on heatstroke, 20% of cases showed damage to the central nervous system, 23% showed muscle destruction leading to the release of myoglobin into the bloodstream and risk of renal injury, and 9% showed damage to the hepatocytes, which resulted in hepatitis and the inability for the blood to clot. Damage to the myocardium causes irregular cardiac rhythm, irregular heartbeat, and irregular heart contraction [3,6].

3.7. Effects of heat stroke

Aside from that, the body has a good system in place to compensate for heat injury; nevertheless, as every person has a unique set point, the body may not always be able to compensate for severe heatstroke. The most common organs damaged by heatstroke are the kidney, heart, lungs, central nervous systems, and gastrointestinal tract.

Figure 3. Multi-organ system effects during heat stroke

Heat causes the production of many inflammatory cytokines at a higher rate, which in turn causes neuronal damage, low blood pressure, blood clot formation from an increase in platelet count, damage to endothelial cells, an increase in RBC and neutrophil levels, an increase in blood viscosity, and a greater ability of blood vessel walls to permit the flow of molecules. These events culminate in circulatory collapse and multisystem organ failure. Even during pregnancy, hyperthermia has the potential to result in serious outcomes such as miscarriage, growth retardation, and other developmental abnormalities [3,6,8].

3.8. Central nervous system effects

One of the most frequent effects of hyperthermia is brain injury. Sweating-related activity is seen in the thalamus, cerebellum, premotor and motor areas, ventromedial prefrontal cortex, anterior and posterior cingulate cortices, and visual cortex. Heat loss may be hampered by these controlling centers' malfunction. Heat injury primarily affects cerebellar Purkinje cells [11,12].

Heat stroke can result in tissue damage to the heart, liver, kidney, and blood coagulation system, cellular injury, circulatory abnormalities, Purkinje cell deterioration, and reduction of all cerebral processes. Additionally, it was discovered that aberrant frontal lobe activity brought on by hyperthermia impaired working memory, short-term memory, and the capacity to memorize information [8,9]. Heat stress disrupts the production, release, and activity of cholinergic enzymes, impairing the development of neurons, oligodendrocytes, and CNS tissues [10,11].

3.9. Cellular effects

Apoptosis arises from heat. Cysteine proteases are necessary for the control of apoptosis and other cellular regulatory processes. Denaturing of proteins is thought to be closely associated with cell death. Excessive heat can cause cellular signaling mechanisms to malfunction, ionic transport via transmembrane proteins to be disrupted, electrochemical depolarization to be interrupted, and mitochondrial dysfunction. Heat stress also affects the way neurotransmitters like serotonin and norepinephrine work [5,12].

3.10. Neurological and cognitive effects

Heatstroke is characterized by neurological dysfunction, which is thought to be the initial organ impacted in hypoxia because Purkinje fibers are heat-sensitive. Anxiety, vertigo, coma, impaired blood and oxygen delivery to tissues, cerebral edema, and disordered metabolism are all possible outcomes of neurological injury. Cognitive processes and talents are referred to as The processing of information, memory, and attention can all be negatively impacted by hyperthermia. The pathways and connections involved in cognitive pathways are disrupted by hyperthermia [5,13].

3.11. Gastrointestinal effects

The malfunctioning of multiple organs is associated with the Systemic Inflammatory Response Syndrome (SIRS). SIRS is a reaction to bacterial infection in heat stress that damages the intestines and other organs through protracted

reductions in gastrointestinal blood flow. This blood flow promotes nitrosative and oxidative stress, which results in the "leaky" tight junctions in the gut. Therefore, heat and reduced blood flow impair the GI tract's permeability, which in turn affects the flora of the gut lumen, both Gram-positive and Gram-negative. When these bacteria's toxins pass through the intestinal wall, they enter the portal vein blood flow and travel throughout the body through the liver. In addition, there is a decrease in blood flow to the gastrointestinal tract, protein denaturation, an increase in free radical generation, and a loss of GI barrier integrity [11,13].

3.12. Renal effects

The cause of renal failure in heatstroke was over 30% of the patients' deaths. Heatstroke-related renal damage is complex, with contributory variables including hypovolemia, rhabdomyolysis, and disseminated intravascular coagulation. The clinical results indicate that blood levels of nitrogen compounds rise as a result of insufficient blood supply to each kidney [12,13]. A schematic design that illustrates the steps that lead to heatstroke can be found in Figure 4.

Exertional heatstroke sufferers experience rhabdomyolysis and an increase in myoglobin, which is toxic to the kidney nephrons and causes the body to create a lot of uric acid. Rhabdomyolysis can therefore cause coagulopathy and worsen renal impairment [5,14].

3.13. Hematological effects

Direct tissue damage, protein denaturation, altered membrane fluidity, uncoupled oxidative phosphorylation, elevated blood sugar, and an increase in aldosterone, which decreases potassium levels, are all consequences of heatstroke [15]. Heatstroke also disrupts the synthesis of neurons, oligodendrocyte function, and CNS tissues. Enzyme denaturation begins at the cellular level when the body temperature hits 40°C. When the temperature rises to 41°C, oxidative phosphorylation is disrupted due to a loss in mitochondrial activity, which may result in organ dysfunction [12,16].

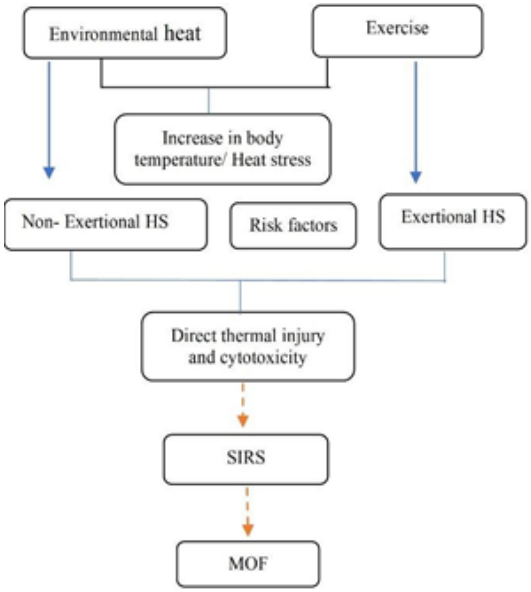

Figure 4. Schematic diagram that shows events that lead to heatstroke. EHS (Exertional heat stroke), NEHS (non-exertional heat stroke), SIRS (Systemic inflammatory response syndrome), MOF (Multi organ failure)

4. Conclusion

Globally, heat stroke is increasingly emerging as a major cause of morbidity and mortality. The earth's temperature is still rising due to global warming. Every year's temperature rise raises the risk of heat-related ailments. Although heat stroke is preventable, persons who spend a lot of time in hot weather-especially the elderly are more likely to experience severe symptoms, and in the worst cases, a delayed diagnosis may be fatal. The development of heat stress into heat stroke is facilitated by impaired regulation of inflammatory and stress responses as well as a failure in thermoregulation, which further exacerbates tissue damage and multi-organ dysfunction. Treatment should be

all-encompassing, supporting respiratory, circulatory, hepatic, and renal functions in addition to controlling body temperature and cooling the body using all possible cooling techniques. Reduce the likelihood of multiple organ damage and heat stroke-related mortality by raising public awareness and providing patients with quick medical attention.

Author Contributions: All authors contributed equally to the writing of this paper. All authors read and approved the final manuscript.

Conflicts of Interest: "The authors declare no conflict of interest."

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