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Research on the effects of extreme heat exposure on human health

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Abstract. Nowadays, more and more studies indicate that heat exposure negatively affects human health. As climate change and global warming increased, extreme heat exposure became more rigorous and killed mountains of people every year. Extreme heat is not only a threat to physical health but also to mental health. Epidemiological studies have shown that heat waves can increase people's morbidity and mortality. This literature review will discuss in detail the impact of extreme heat on human health, and what measures governments and individuals can take to respond to or prevent the damage of extreme heat. We used extreme heat and human health as keywords to collect the papers in the Embase database and review all the results. After sorting out all the results, the research focuses on the effect of extreme heat exposure on human physical and mental health. It can be found that extreme heat exposure causes heat-related illnesses (HRI) and aggravates chronic diseases, especially cardiovascular and respiratory diseases. And extreme heat can also lead to Preterm birth (PTB) which threatens the lives of pregnant women and infants. Mental health and related deaths are also affected by extreme heat exposure.

Keywords: Extreme Heat, Human health, Heatwave, Mental health, Heat-related illness

1. Introduction

Climate change is one of the most pressing challenges of our time. The rise in temperature as a result of climate change has a negative impact on human health. Extreme heat refers to abnormally high ambient temperatures over a prolonged period. Extreme heat events become more common and more severe. A 2018 study on extreme heat in the Northern Hemisphere indicated that the area of the Northern Hemisphere exposed to warm and hot weather increases by around 16% for every 1°C rise in global temperatures [1].The number of morbidities and mortalities associated with heat exposure is increasing over time. Extreme heat is not only a threat to physical health but also to mental health. The extreme heat event has been associated with a significant loss of life. Around the world, there's plenty of evidence of a dramatic rise in fatalities during heatwaves. 70,000 people died in the August 2003 Western Europe heatwave. A study from the United States shows that the number of deaths caused by extreme heat each year is higher than all other weather-related disasters combined. There is mounting evidence that unexpected heat exposure endangers human health.

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This review searched all the publications in the Emabse database and made a conclusion to improve the understanding of the hazards caused by extreme heat, which can lead in the direction of the latter research.

2. Analysis of the effects of extreme heat exposure on human physiological health

Exposure to extreme temperatures that exceed the body's thermoregulatory capacity can cause physiological damage to the body and the development of heat-related illness (HRI). Part of this is due to heat exposure disrupting the body temperature regulation mechanism, leading to acute fever. The mild disease of acute HRI includes heat cramps, heat edema, heat syncope, and heat tetany [2]. The above mild diseases are the initial mild symptoms of heat injury, and if they further develop, they will become heat exhaustion, the most common type of HRI. When heat exhaustion occurs, the core body temperature of the human body will be between 38.0°C and 40.5°C, manifesting as malaise, anorexia, nausea, vomiting, and other symptoms. There are no major neurological deficits at this stage.

Heat stroke occurs when the thermal damage worsens and the core body temperature exceeds 40.6°C. Heat stroke is an acute syndrome that can be life-threatening. Studies show that the mortality rate of heat stroke patients may reach 10%. When the core temperature is too high and exceeds the heat stroke standard, various tissues and organs will fail, accompanied by neurological dysfunction. Heat stroke is defined as a condition in which body temperature rises to a level that becomes harmful, leading to dysfunction and damage to body tissues and a characteristic multi-organ clinical and pathological syndrome [3]. Heat stroke patients often suffer permanent damage to the central nervous system or other organs even after recovery. HS can be divided into two types, experimental and classic heat stroke. Classic heat stroke occurs when individuals with low immune function, such as the elderly and young children, cannot adapt themselves and are affected by the external environment. Exertional heat stroke usually occurs in athletes and people engaged in specific jobs. Excessive exercise in hot environments causes the body temperature to rise, exceeding the body's heat dissipation capacity. If heat stroke patients cannot receive timely treatment, or if the attack lasts for too long or is severe, it may cause permanent damage or even endanger life.

Heat exposure can not only cause certain diseases directly, but it can also make chronic illnesses worse. The most obvious effect on human health is the aggravation of cardiovascular diseases. Heat waves lead to an increase in heart diseases such as heart failure and myocardial infarction. Heat-related cardiovascular disease not only increases the rate of emergency hospital admissions, but also causes a large proportion of deaths, and the number of out-of-hospital deaths should not be underestimated [4]. According to an analysis of cases from 50 cities in the United States, 42% of deaths during heat waves occurred outside hospitals, and 34% of deaths were caused by cardiovascular disease [5].

In addition to cardiovascular disease, rising temperatures are also closely linked to respiratory health. As the core temperature rises, the body helps to dissipate heat by increasing lung ventilation, including two breathing patterns, thermal tachypnea or thermal hyperpnea [6]. Hyperventilation, when the core temperature is too high, can lead to alveolar hyperventilation, causing respiratory alkalosis, which can lead to tissue damage [7]. As the temperature rises, the movement of particulate matter molecules in the air increases, which has a greater impact on the respiratory system. In addition, climate change and global warming have extended the pollen season, and rising temperatures have increased pollen concentrations, which will also increase the incidence of allergies and thus affect respiratory function [8]. An analysis of death data from 11 cities in China found that respiratory deaths accounted for 12.79% of all-cause deaths during heat waves [9]. A study from the United States also found that the risk of respiratory death increased by 5.9% during heat waves compared with non-heat-wave days [10]. Another US study found that for every 10°F increase in average daily summer temperatures, respiratory-related hospitalizations increased by 4.3% in 213 counties where daily temperatures were recorded [11].

Maternal and child health is one of the most important global public health issues in contemporary society and human development and is also an important part of the United Nations Millennium Development Goals [12]. Another threat to human health from heat exposure is the threat to pregnant women and newborn babies. During pregnancy, physiological changes in the body reduce a pregnant

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woman's ability to regulate her body temperature, making her more vulnerable to heat-related adverse health effects. Exposure to heat increases a pregnant woman's body core temperature and heart rate, causing fetal heart rate tachycardia and uterine contractions. In severe cases, it will cause many adverse effects, such as premature birth. Studies have shown that heat exposure increases dehydration and the secretion of antidiuretic hormone and oxytocin, leading to preterm birth [13]. Clinical research shows that a high fever during pregnancy can cause birth defects in babies. Heat exposure also has adverse effects on newborn health, and the leading cause of neonatal morbidity and death is preterm birth. Preterm birth (PTB) is defined as the birth of an infant before 37 weeks gestation and can be associated with a variety of acute morbidity or mortality, as well as long-term physiological defects [14]. In recent years, an increasing number of studies have demonstrated a strong association between heat exposure and preterm birth. A systematic review of data from 20 study groups showed that there are clear seasonal patterns in birth outcomes, with preterm birth rates significantly higher in summer and winter than in other seasons [15].

3. Analysis of the impact of extreme heat exposure on human mental health

Climate change is not only a threat to the natural environment. It's also a mental health crisis [16]. Some studies suggest that heat waves can increase the risk of suicide and mental health-related hospital admissions in the general population [13, 17]. Studies have found that temperature can increase the incidence of suicide, mania, depression, schizophrenia, and other conditions. According to a meta-analysis, suicide rates increase by 1% for every 1°C increase in local ambient temperature above the threshold [18]. Temperature changes affect mental health by influencing physiological changes in people. For example, changes in the body's blood flow to remove heat and changes in the functioning of the central nervous system can lead to cognitive and emotional changes [19]. As temperatures rise, the risk of dying from mental illness increases [17, 20]. In many cases, medications used to treat mental illness can reduce the body's ability to regulate its temperature at high temperatures, further exacerbating underlying health conditions. A review of New York State An analysis of death data from psychiatric hospitals from 1950 to 1984 showed that the mentally ill were twice as likely to die during heat waves as the general population. And the mortality rate was even higher when high doses of antipsychotic drugs were widely used in the 1970s. The study found that both having a mental illness and taking antipsychotic drugs during a heat wave were associated with an increased risk of death [21].

Heat exposure not only has a negative impact on people suffering from mental illness, but can also harm the mental health of the general population. When the temperature is too high, psychological discomfort and negative emotions increase in the general population. Extreme heat can affect mental health by affecting people's sleep. Clinical evidence shows that sleep and mood are closely linked, that almost all psychiatric and neurological disorders are associated with sleep problems, and that sleep disorders can lead to new mental health problems [22]. Some research on sleep conditions during heatwaves shows that high temperatures during heatwaves can lead to sleep disturbances such as reduced sleep and frequent sleep interruptions. Lack of sleep can cause people to be irritable, depressed and have difficulty regulating impulsivity, and research shows that sleep deprivation can also amplify negative emotions that disrupt time and cause the brain to inappropriately regulate emotional responses to negative stimuli, triggering a range of mental health problems [19]. And sleep is often thought to have a two-way relationship with mental health. Although insomnia increases the likelihood of anxiety and depression, the occurrence of these mental disorders also increases the likelihood of new-onset insomnia [23].

Extreme heat has direct and indirect consequences on mental health, both now and in the future. These effects can be influenced by a variety of circumstances. This is because climate change affects people in many different ways, often not as a result of a single event. It affects mental health through social changes such as reduced economic output, increased conflict and violence, etc [16]. In result, the negative effects of some psychiatric medications and the decreased behavioral flexibility of individuals with mental illness can help to explain some of the consequences of heat exposure on human mental

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health. In addition, sleep disturbances caused by heat exposure-related changes in human central nervous system signaling may further increase the burden on human mental health.

4. Adaptation and mitigation strategies.

Heat exposure has a serious impact on human health. In the absence of strong adaptation and mitigation measures, associated morbidity, mortality, and reduced worker productivity will increase with climate change [24]. Without action, annual heat-related deaths are projected to increase by 257% by 2050 compared to the annual baseline in 2000 due to climate change. Preventive measures to deal with high temperatures are therefore crucial. For injuries caused by high temperatures, timely adaptation measures are needed. Taking heat stroke as an example, the key to the successful recovery of heat stroke patients is early recognition and rapid cooling. The earlier the pathophysiological cascade from compensable to uncompensated thermotolerance is intervened with, the less likely an adverse outcome is. Therefore, it is important to apply cooling promptly when a heat injury occurs.

To actively and effectively address the health problems caused by high temperatures and reduce heat-related morbidity and mortality, all components of the health system need to work together. First, relevant departments need to develop an early warning and response system for heat waves before they occur. Health education to prevent and combat the early manifestations of heat stress is an extremely important public health strategy that needs to be repeated before each high-temperature event. Specific measures may include the implementation of public education activities in communities and schools to promote heat stress health education. Public service announcements are another option to inform the public about the dangers of excessive heat and how to recognize and react to it. The meteorological department should also expand and strengthen the local climate change monitoring system, provide timely warnings of extremely high temperatures, and promptly announce high-temperature warnings on public media to allow the public to take preventive measures in advance and reduce outdoor activities. The local health agency, meteorological department, social assistance agencies, and media promotion agencies will all complete this intervention strategy.

Some local governments have successfully implemented intervention and mitigation measures during heat waves, with effective results. For example, Chicago had fewer heat-related deaths during the 1999 heat wave than in 1995, in part due to local government interventions such as increasing the use of air conditioning and opening cooling centers [25]. The use of air conditioning is one of the most effective indoor cooling mechanisms for preventing heat-related illness and death. However, the use of air conditioning increases greenhouse gas emissions and exacerbates the urban heat island effect [26]. Therefore, more research is needed to determine the benefits and harms of air conditioning. In recent years, studies have shown that urban green spaces are an important measure to reduce the exposure of the population to high temperatures [27]. Urban green spaces have the ability to both absorb carbon dioxide and provide localized cooling, which helps to mitigate the negative effects of high temperatures and break the urban heat island effect. However, statistics show that only 42 (9%) of the world's 468 urban centers have extremely high levels of green cover. In other areas, urban greening is extremely low and there is still a lot of room for development in the future [28].

During a heat wave, the involvement of multiple parties is even more important. During extreme heat, the number of hospital admissions or emergency visits will increase. Hospitals will be under more pressure as a result of patients seeking treatment there for heat-related ailments and certain patients with underlying medical conditions that are made worse by temperature fluctuations. Therefore, hospitals must prepare plans in advance, activate emergency policies when hot weather arrives, and open outpatient clinics specializing in heat-reserializing to reduce medical pressure. Special attention should also be paid to vulnerable groups in hot weather. Encourage the elderly to stay indoors less during hot weather and to replenish water when they do go out. For people working outdoors, more sensitive and timely warnings should be provided at construction sites to protect outdoor workers from heat-related illnesses. For some chronically or mentally ill people, heat stress can exacerbate their condition. Patients, as well as their families and caregivers, should receive timely attention and appropriate medication to prevent further damage from heat injury.

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5. Conclusion

This review finds heat damage can cause many human health problems, increasing the incidence of HRIs and mortality, as well as causing premature births in pregnant women and compromising the health of newborns. People's mental health will also be affected by extreme heat, leading to death. Timely climate forecasting and adequate preparation before extreme heat events occur can effectively reduce the health impacts of heat exposure. A limitation of this review is that it did not narrow the review to a specific area and only screened one database. As a next step, we hope that future research can review studies on more databases to enrich our theoretical support. In addition, future research can further discuss domain-specific situations to test the generalizability of the results.

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