IJHS

International Journal of Health Science (IJHS)

E-ISSN: 2827-9603
P-ISSN: 2827-9603

Research Article

Physiological Response of the Body to Heat Exposure in Workers

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Abstract: Heat is a prevalent and serious physical health risk for employees in a range of indoor and outdoor work settings. Heat stress at work alters physiological processes and has a variety of detrimental consequences on people's health and wellbeing. This study aimed to explore the physiological responses and impacts of heat exposure in outdoor workers. This study employed a literature review approach using Google Scholar, Wiley, and Pubmed databases. The results will be described through descriptive narratives and tables. Workers exposed to heat experience increased physiological reactions, including increased body temperature, heart rate, and blood pressure, especially those engaging in intense physical activity outdoors. Heat-related symptoms such as fatigue, excessive sweating, headaches, and muscle cramps can also occur in heat-exposed workers. These increased and altered physiological responses emphasize the importance of implementing preventative measures, such as managing work hours, maintaining hydration, and maintaining good health, to avoid heat-related illnesses and maintain workplace productivity.

Keywords: Physiological Responses; Heat Exposure; Workers; Heat Stress; Impact.

Received: September 12, 2025
Revised: October 29, 2025
Accepted: September 13, 2025
Published: November 24, 2025
Curr. Ver.: November 24, 2025

1. Introduction

Over the coming decades, global temperatures are projected to rise by 0.5 to 1.5°C, posing a threat to all living beings, including humans (Sankar et al., 2024). The global challenge posed by rising temperatures places workers at an increasing risk of heat-related morbidity and mortality. The literature indicates the existence of a thermoneutral environmental temperature zone between approximately 15°C and 25°C (for clothed individuals), within which heat exchange and core body temperature regulation are primarily achieved through the control of dry heat loss. Any human activity conducted outside this temperature range will be exponentially affected, leading workers to experience heightened physiological heat strain accompanied by reduced cognitive and physical performance. Specifically, the work environment is impacted by climate change, which poses health risks to millions of workers (Ioannou et al., 2022; Boonruksa et al., 2020). According to the International Labour Organization (ILO), assuming a global temperature increase of 1.5°C by the end of the 21st century, it is projected that by 2030, approximately 2.2% of total working hours and 880,000 working-life years will be lost due to occupational heat stress worldwide (Amoadu et al., 2023).

Heat is a common and significant physical health hazard for workers in various occupational environments, both indoors and outdoors. The combination of heat exposure from the work environment (whether from weather conditions or man-made heat sources) and body heat generated from metabolic processes (related to workload) can lead to an increase in internal body temperature. Without adequate heat dissipation, persistently high core temperatures can overwhelm the body's thermoregulatory capacity and result in adverse health outcomes. Outdoor workers, such as those in agriculture and construction, will be the most affected, accounting for 60% and 19% of global working hours lost to heat stress, respectively. Similarly, ongoing climate change acts as a "threat multiplier," increasing the incidence of fires and conflicts worldwide, thereby amplifying the exposure of first responders and soldiers to occupational heat stress (Ioannou et al., 2022; Aulia et al., 2023).

Heat-related illnesses are among the acute adverse effects of prolonged exposure to high temperatures. These effects vary, ranging from mild heat-related conditions and symptoms such as heat fatigue, heat rash, heat edema, heat cramps, and syncope, to severe heat injuries that can result in death, including exertional heat injury, exertional rhabdomyolysis, and heat stroke. The incidence of cardiac-related symptoms and diseases increases when environmental temperatures are higher, particularly among individuals engaged in physically demanding work in extremely hot environments. In addition, hot weather is positively associated with work-related injuries, most of which involve increased fatigue, reduced alertness, diminished psychomotor ability, and loss of concentration (Boonruksa et al., 2020; Vallennie et al., 2024).

Occupational heat stress is also associated with a broad spectrum of adverse effects on human health and well-being. It is fair to state that heat exposure in the workplace is as old as human existence itself (Boonruksa et al., 2020). The impacts of climate change are likely to increase heat exposure and heat-related illnesses among people in equatorial climates and will particularly affect workers of low socioeconomic status engaged in manual labor. Workers who operate in hot environments or are exposed to extreme heat may be at risk of heat stress. Heat stress occurs when the body is unable to dissipate excess heat, resulting in an increase in core temperature and heart rate. The individual begins to lose focus and struggles to concentrate on a task while the body continues to retain heat. Consequently, work capacity, efficiency, and safety decline. The individual may also feel restless or nauseous and often loses the desire to drink. If cooling does not occur, the next stages often involve fainting and, in extreme cases, death (Aulia et al., 2023; Vallennie et al., 2024). Heat stress not only causes heat rash, heat fatigue, heat cramps, and heat stroke but also induces psychological and physiological changes that may affect worker performance (Kenny & Meade, 2025).

The physiological effects of extreme temperatures, both hot and cold, are closely related to the body's need to maintain its core temperature, ideally around 37°C (98.6°F). It is important to note that when the core temperature drops below 25°C (77°F) or rises to 45°C (113°F) or higher, it can lead to severe health consequences, including death. However, it has been speculated that humans may have evolved to adapt to hunting in hot conditions (Ioannou et al., 2022; Vallennie et al., 2024). Therefore, a comprehensive review of the body's response to heat exposure is necessary. This study aims to explore the physiological responses and impacts of heat exposure on outdoor workers.

2. Preliminaries or Related Work or Literature Review

Thermoregulation and Homeostatic Balance

The human body possesses a sophisticated thermoregulatory system designed to maintain core temperature around 37°C, regardless of environmental fluctuations. This process is primarily governed by the hypothalamus, which acts as the body's central thermostat. When exposed to high ambient temperatures, the hypothalamus triggers a series of physiological responses including vasodilation, increased sweat production, and elevated respiration rate to dissipate excess heat and restore homeostatic balance. Heat loss occurs through mechanisms such as radiation, convection, conduction, and evaporation. However, when heat gain exceeds the body's ability to lose heat, thermal imbalance occurs, leading to an increase in core temperature and potentially resulting in heat strain or heat-related illnesses (Flouris, 2019).

Cardiovascular and Metabolic Adaptations

During heat exposure, the cardiovascular system plays a critical role in facilitating thermoregulation. Peripheral vasodilation increases blood flow to the skin, promoting heat dissipation through sweating and convection. As a consequence, cardiac output and heart rate rise to compensate for the redistribution of blood volume from the core to the periphery. This physiological strain can reduce blood pressure and plasma volume, heightening the risk of dehydration and orthostatic hypotension. Simultaneously, metabolic rate and oxygen consumption increase to meet the body's energy demands, contributing to elevated internal heat production. In workers performing heavy physical labor, this dual load of environmental and metabolic heat can accelerate fatigue, impair muscular efficiency, and reduce overall work performance (González-Alonso, 2012).

Physiological and Psychological Impacts of Heat Stress

Prolonged exposure to high temperatures affects not only the body's physiological systems but also cognitive and psychological functioning. Physiologically, dehydration and electrolyte imbalances can impair renal function, reduce muscle endurance, and trigger heat-related conditions such as heat cramps, exhaustion, or heat stroke. Psychologically, thermal discomfort can lead to irritability, reduced concentration, and diminished cognitive performance, thereby increasing the likelihood of occupational accidents. Chronic heat stress has also been linked to long-term health risks, including cardiovascular strain and mental fatigue. Understanding these interconnected physiological and psychological responses is essential for developing effective heat management strategies and ensuring the well-being and productivity of outdoor workers (Taylor, et al. 2016).

3. Materials and Method

This research is a study employing a literature review approach to explore the physiological responses of the human body to heat exposure among workers. The article search method used in this study was conducted entirely via the internet. The databases utilized in this research consist of international journal databases that encompass a wide range of research articles from various countries around the world. The research articles included in this study are limited to those published within the last five years, specifically between 2020 and 2025. The keywords used in this research were derived from the study title, including "physiological response" OR "adaptation" OR "physiology" AND "heat exposure" OR "environmental heat" AND "workers." Additional keywords were also constructed based on synonyms and other related terms.

This study employs secondary data derived from research articles that have been published in both nationally and internationally indexed journals. The research encompasses all previous studies relevant to the study's objectives. Furthermore, the secondary data in this research were also obtained from books and official publications issued by governmental institutions and Non-Government Organizations (NGOs) based on the predetermined topic.

Table 1. Keywords.

Database	Kata Kunci
PubMed	(((("heat exposure"[Title/Abstract]) OR ("heat stress"[Title/Abstract]) OR ("thermal stress"[Title/Abstract])) AND (("physiological response"[Title/Abstract]) OR ("body response"[Title/Abstract]) OR ("thermoregulation"[Title/Abstract]))) AND (("workers"[Title/Abstract]) OR ("occupational exposure"[Title/Abstract]) OR ("industrial workers"[Title/Abstract]) OR ("laborers"[Title/Abstract])))
Wiley	("heat exposure" OR "heat stress" OR "thermal stress") AND ("physiological response" OR "body response" OR "thermoregulatory response") AND ("workers" OR "occupational exposure" OR "industrial workers" OR "laborers")
Google Scholar	("heat exposure" OR "heat stress" OR "thermal stress") AND ("physiological response" OR "body response" OR "thermoregulation") AND ("workers" OR "occupational exposure" OR "industrial workers" OR "laborers")

Inclusion criteria are defined as the key characteristics of the target population that the researcher will use to answer the research questions. The inclusion criteria used in this study are as follows:

Studies that evaluate the physiological responses of the body to heat exposure among outdoor workers
Articles published between 2020 and 2025
Articles published in English
Articles available in full text
Original research articles

Exclusion criteria are defined as the characteristics of research samples that meet the inclusion criteria but possess additional attributes that may interfere with the success of the study or increase the risk of unfavorable outcomes. The exclusion criteria in this study include:

Review studies
Publications in journal proceedings or national and international conference abstracts
Journal publication periods exceeding five years

Data extraction in this study was conducted by categorizing data from the included studies to address the research objectives and both primary and secondary outcomes. The data were then summarized in a table containing the author's name, year of publication, country where the study was conducted, study title, research design, and research findings.

4. Results and Discussion

This study describes the physiological responses of the human body to heat exposure among workers, particularly outdoor workers. In addition, the secondary outcome was assessed based on the impact of heat exposure on the body. From the initial search, 48 articles were obtained from PubMed, 35 articles from Wiley, and 61 from Google Scholar. The selection process was carried out in stages, starting from the identification of articles matching the keywords, screening based on titles and abstracts, and full-text reading to ensure alignment with the focus of the narrative review. After excluding duplicates and sorting out irrelevant articles, a total of seven articles were obtained for further analysis.

Table 2. Findings from the Main Studies Analyzed.

No	Author	Article Title	Research Design	Physiological response	Impact
1	Mohammadian et al., (2020)	Evaluation of Occupational Exposure to Heat Stress and Physiological Responses of Workers in the Rolling Industry	Cross sectional	Changes in core body temperature and pulse when exposed to heat	-
2	Yoder et al., (2025)	Physiological responses to heat stress in groundskeepers: an observational field study	Observational study	Changes in urine consistency and characteristics	Acute kidney injury (AKI) characterized by an increase in SCr from AM to PM ≥ 0.3 mg· dL-1
3	Pal dan Patel, (2024)	Physiological responses to heat stress in rice transplanting workers in Northeast India and work-rest schedule recommendations	Observational study	Changes in saliva secretion characteristics and changes in temperature in the oral cavity. Oral temperature increased by 0.5 °C after 65 minutes of work, taking 15 minutes to return to normal at 27–28 °C	-
4	Boonruska et al., (2020)	Heat Stress, Physiological Response, and Heat-Related Symptoms among Thai Sugarcane Workers	Cross sectional	Increased systolic blood pressure, heart rate, and body temperature during work shifts, accompanied by dehydration and higher leukocyte levels, indicate greater physiological stress due to heat exposure.	Heat-related symptoms such as fatigue, excessive sweating, headaches, and muscle cramps were more common than among factory workers, reflecting higher physical workloads and environmental stress
5	Vallennie et al., (2024)	Impact of heat stress on health-related symptoms and physiological changes among workers at a palm oil mill in Mukah, Sarawak, Malaysia	Cross sectional study	There was a significant difference in the core body temperature of workers at these three work stations before and after work ($p<0.05$). Only the systolic blood pressure and heart rate	The most common symptoms experienced by workers due to heat exposure in the workplace include

				(HR) of workers at the boiler work station showed a significant difference between before and after work ($p<0.05$).	headaches and fatigue. However, statistical analysis using the Spearman Rho test showed no correlation between heat stress levels and physiological changes and health-related symptoms among research respondents ($p>0.05$).
6	Mac et al., (2021)	A modified physiological strain index for workplace-based assessment of heat strain experienced by agricultural workers	Cross sectional	Of the 23 workdays on which a participant experienced a maximum physiological stress index (PSI) of ≥ 7, 22 days were also classified as stressful by at least one other measure of high heat stress (core temperature [Tc] >38.5° C, sustained heart rate >(180 - age), and average heart rate > 115 bpm).	-
7	Meade et al., (2023)	Physiological responses to 9 hours of heat exposure in young and older adults. Part I: Body temperature and hemodynamic regulation	Experimental	Older adults experience a greater increase in heat storage and core temperature during exposure to hot and dry conditions throughout the day compared to younger people; core temperature increased by 0.3°C [0.1, 0.4] (adjusted for baseline) in the older group at hour 6 [37.6°C (0.2°C) vs. 37.9°C (0.2°C); P < 0.001] and by 0.2°C [0.0, 0.3] at the 9th hour [37.7°C (0.3°C) vs. 37.8°C (0.3°C)]	-

Physiological Response to Heat Exposure in Workers

Heat, as a fundamental form of energy, supports the optimal functioning of the human body, which typically maintains a temperature around 36.6°C. The hypothalamus, acting as the central thermostat, regulates these processes by triggering responses such as sweating, shivering, and adjusting blood flow to maintain a stable internal temperature. To preserve this optimal temperature, the human body employs various mechanisms to regulate heat loss, either by increasing or reducing it. Mechanisms of heat loss include radiation, conduction, convection, and evaporation. Environmental temperature, humidity, air movement, clothing, and body composition all influence these processes. The body retains heat through insulation mechanisms such as subcutaneous fat and hair and regulates heat loss through circulatory adjustments like vasodilation (increasing blood flow to the skin to release heat) and vasoconstriction (reducing blood flow to the skin to conserve heat). In response, the brain adjusts respiration rate, blood glucose levels, and metabolic rate to counter temperature variations, triggering physiological responses such as shivering and sweating to maintain optimal body temperature. Imbalance in thermal equilibrium can lead to overheating (Sankar et al., 2024; Amoadu et al., 2023).

Exposure to high environmental temperatures induces several physiological changes in the human body. Normally, the human body maintains its internal temperature at approximately 37.0°C, even when exposed to environmental changes, emotional fluctuations, or varying levels of physical activity. However, exposure to or working in hot environments can cause bodily stress. The body tends to heat up along with its surroundings. By pumping more blood to the skin and increasing sweat production, the body's internal "thermostat" maintains a consistent internal temperature. Nevertheless, body temperature begins to rise when the rate of "heat gain" exceeds the rate of "heat loss" in extremely hot environments, which may lead to heat-related illnesses. Therefore, an increase in core body temperature is one of the best indicators for detecting potential heat stress (Vallennie et al., 2024).

The human body operates optimally within a specific temperature range, reflecting its remarkable biological design. When the environmental temperature exceeds the core body temperature (CBT), the body begins to absorb heat. The hypothalamus regulates CBT by triggering thermoregulatory mechanisms such as sweating and vasodilation to expel excess heat. The sweating rate increases as sweat glands, activated by the sympathetic nervous system, produce more sweat for evaporative cooling. This heightened rate can lead to significant fluid and electrolyte loss, thus requiring adequate hydration. Moreover, metabolic rate and oxygen demand rise with increasing temperature, causing an elevated heart rate (HR) due to sympathetic activation and the need for increased blood flow through dilated peripheral vessels. Initially, heat exposure may cause a temporary increase in blood pressure (BP) due to vasoconstriction, but prolonged exposure typically leads to vasodilation and a subsequent drop in BP, potentially resulting in orthostatic hypotension. One indicator of dehydration is urine specific gravity (USG). When the body experiences dehydration from heat stress, USG increases, reflecting a higher concentration of solutes due to reduced water content. Elevated USG values indicate that the kidneys are conserving water, which is a common physiological response to dehydration. Therefore, monitoring USG can be an effective way to assess hydration status and the impact of heat stress on the body. Heat-induced dehydration reduces blood volume, leading to decreased blood flow and glomerular filtration rate (GFR), causing impaired renal function. The body's physiological response aims to eliminate excess heat (Sankar et al., 2024; Pal & Patel, 2024).

The musculoskeletal system can also be affected by prolonged heat exposure. Muscle strength and work capacity are influenced by heat imbalance, which can impair thermoregulation, reduce oxygen transport to tissues, and cause muscle fatigue, as the heat generated by muscles during activity far exceeds the heat dissipated. Furthermore, muscle activity increases muscle temperature, which in turn elevates core body temperature. Excessive muscle activity, high work intensity, and prolonged exposure to hot environments can result in insufficient oxygen supply to meet the metabolic demands of working muscles, leading muscles to rely on glycogen oxidation for energy. This process may cause lactic acid accumulation, a contributing factor to muscle fatigue (Aulia et al., 2023).

The Heat Stress Index (HSI) is a quantitative measure used to assess individuals exposed to high temperatures. This index helps estimate the level of heat stress workers may experience based on their surrounding environmental factors and physical activity levels. Prolonged exposure leading to heat-related illnesses (HRI) can occur when the body fails to cool itself effectively, resulting in conditions that range in severity from mild to life-threatening (Sankar et al., 2024; Pal & Patel, 2024). Research by Mohammadian et al. (2020) revealed that physiologically, increased heat tolerance is due to the ability to enhance sweating and reduce heart rate. Sweating primarily occurs in the body's core, with a decrease in skin temperature and salt concentration in sweat.

Impact of Heat Exposure on Workers

Workers operating in hot environments or exposed to extreme heat are at risk of experiencing heat stress. Heat stress occurs when the body fails to dissipate excess heat, leading to increased core temperature and heart rate. Affected individuals may lose focus and struggle to concentrate on tasks while their body continues to retain heat. Consequently, there is a decline in work capacity, inefficiency, and an increased risk of hazardous incidents. Workers may also feel anxious or ill and often lose the desire to drink. If cooling is not initiated, subsequent stages may include frequent fainting and, in extreme cases, death (Mohammadian et al., 2020).

Heat stress not only causes heat rash, heat exhaustion, heat cramps, and heat stroke but also induces psychological and physiological changes that can affect worker performance (Vallennie et al., 2024). Occupational heat exposure can impact employee health, including acute illnesses. Due to central nervous system disorders, impaired sweating or evaporation, and heat exposure elevating body temperature to 41°C, acute heat exposure may result in heat stroke. A rise in body temperature to at least 40°C, accompanied by nausea, headache, hallucinations, and loss of consciousness, are symptoms of heat stroke. In such cases, effective cooling is crucial for affected employees. Heat exposure can also cause heat syncope, characterized by short-term fainting, headache, and dizziness upon standing. This may result from temporary circulatory failure caused by peripheral venous pooling, reducing the diastolic return volume to the heart (Amoadu et al., 2023; Aulia et al., 2023).

Heat exhaustion is another acute condition that may occur. Dehydration and a reduction in body fluids and electrolytes can cause this illness by decreasing circulating blood volume. Symptoms of heat exhaustion such as headache, nausea, vertigo, weakness, thirst, excessive sweating, irritability, and decreased urine output can occur up to ten times more frequently than other illnesses. Heat exposure accelerates heat transfer through evaporation. The eccrine ducts function to excrete sweat. Several non-follicular papulovesicular eruptions, known as miliaria or heat rash, occur due to the rupture of blocked eccrine ducts, releasing sweat into the epidermis or dermis (Aulia et al., 2023; Foster et al., 2020).

Heat rash is a condition of the integumentary system caused by prolonged exposure to high temperatures. It may occur when sweat ducts are mechanically blocked due to continuous skin perspiration that cannot evaporate from the epidermis. Lesions can become infected and develop into secondary diseases if treatment is delayed. Heat rash is characterized by reddish, itchy papules that commonly develop in sweat-prone areas such as the neck, face, or waist. Prolonged heat exposure can increase morbidity and mortality, particularly among individuals with reduced heat tolerance due to comorbid conditions such as diabetes or cardiovascular disease. People regularly exposed to heat are also more vulnerable to both acute and chronic illnesses (Aulia et al., 2023; Foster et al., 2020).

Research by Boonruska et al. (2020) demonstrated that systolic blood pressure (SBP), heart rate, and body temperature increased after work shifts among cutters and factory workers. The average SBP increased by 3.2 mmHg, heart rate by 8.5 bpm, left ear temperature by 0.6°C, and right ear temperature by 0.5°C ($p < 0.001$ for all). These results indicate higher cardiovascular and thermoregulatory strain among cutters, likely due to their heavier physical workload compared to factory workers, whose physiological changes were minimal and statistically insignificant. Conversely, urinalysis results showed a significant increase in dehydration among cutters, with the proportion of workers having a urine specific gravity (USG) of 1.030 rising from 16.7% before the shift to 53.3% after the shift ($p < 0.001$). The most common heat-related symptoms among cutters were weakness or fatigue (91.1%), excessive sweating (83.3%), headache (57.8%), skin rash (52.2%), and muscle cramps (52.2%). In contrast, factory workers most frequently reported weakness/fatigue (64.5%) and excessive sweating (52.7%) (Boonruska et al., 2020).

Heat stress refers to the body's inability to regulate its internal temperature and can be significant not only because it poses potential risks to physical health such as heat exhaustion or heat stroke but also because it may adversely affect mental health. High temperatures can increase discomfort, disrupt sleep, and alter daily routines, potentially leading to heightened stress, anxiety, and even cognitive impairment if unaddressed. These physical symptoms can have serious implications for mental well-being. Sleep disturbances caused by heat can contribute to mood fluctuations and exacerbate mental health conditions such as depression and anxiety. Moreover, psychosis, hallucinations, and other neuropsychiatric symptoms may occur in individuals with severe heat stroke. Chronic heat stress, when prolonged, can have substantial impacts on mental health. Continuous exposure to high temperatures, accompanied by physical discomfort and related sleep disturbances, can increase levels of stress and anxiety. Furthermore, these factors may worsen pre-existing mental health disorders or trigger new ones. Long-term exposure to high temperatures can also affect cognitive abilities such as memory, concentration, and intellectual performance (Rony & Alamgir, 2023).

5. Conclusion

Workers exposed to heat experience heightened physiological responses, including increased body temperature, heart rate, and blood pressure, particularly among those engaged in intense outdoor physical activity. Heat-related symptoms such as fatigue, excessive sweating, headache, and muscle cramps may also occur in workers exposed to heat. This condition underscores the importance of implementing preventive measures such as regulating working hours, maintaining proper hydration, and preserving overall health to prevent heat-related illnesses and sustain productivity in the workplace.

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