Dialogues in Health 6 (2025) 100203

Contents lists available at ScienceDirect

Dialogues in Health

journal homepage: www.elsevier.com/locate/dialog

Impact of Heat on Human and Animal Health in India: A Landscape Review

Sandul Yasobant [a,b,c,d,*], K. Shruti Lekha [b], Poonam Trivedi [b], Shruti Krishnan [b], Chinmayee Kator [b], Harleen Kaur [b], Mudita Adaniya [b], Anish Sinha [e], Deepak Saxena [a,b,c]

[a] Department of Public Health Science, Indian Institute of Public Health Gandhinagar (IIPHG), Gujarat, India
[b] Centre for One Health Education, Research & Development (COHERD), Indian Institute of Public Health Gandhinagar (IIPHG), Gujarat, India
[c] School of Epidemiology & Public Health, Datta Meghe Institute of Medical Sciences (DMIMS), Wardha, India
[d] Global Health, Institute for Hygiene & Public Health, University Hospital Bonn, Bonn, Germany
[e] Department of Public Health Programme, Indian Institute of Public Health Gandhinagar (IIPHG), Gujarat, India

ARTICLE INFO

Keywords:
Climate change
Mortality
Morbidity
Heat wave
One Health

ABSTRACT

Climate change presents a significant global public health challenge for animals and humans. Due to geography, climate, population, and urbanization, India is vulnerable to extreme heat. This review aims to explore the impact of heat on human and animal health in India. The publications on this topic were retrieved from PubMed and Google Scholar using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Out of 219 articles extracted, 44 were reviewed. The review included articles published in the last ten years, regardless of design. Half of the 44 articles were original studies; the rest were perspective, opinion, review studies, editorial, or commentary papers. The present review shows how heat adversely affects human health, increasing mortality and morbidity, especially during heat waves. Heat-related health issues in India include increased hospital admissions for cardiorespiratory diseases, mental health problems, reduced productivity, and agricultural yields. Vulnerable groups like workers, pregnant women, and children require targeted interventions. Limited evidence exists on the impact of heat on animals, but studies show increased health problems due to high temperatures. Targeted interventions are needed to prevent heat-related mortality and morbidity in India.

1. Introduction

The 2030 Agenda for Sustainable Development acknowledges climate change as one of the most significant challenges, recognizing its substantial impact on human health and the physical environment, including social, economic, and healthcare structures [1]. This phenomenon not only intensifies existing threats but also jeopardizes the progress achieved in healthcare over the years. Further, the changing climate leads to more frequent and severe weather events such as storms, extreme heat, floods, droughts, and wildfires [1].

Climate change leads to increased variability in global temperature distribution, resulting in more frequent extreme temperatures, identified by the World Health Organization (WHO) as the primary cause of weather-related mortality. Excessive heat places a cumulative physiological burden on the human body, exacerbating major global causes of mortality such as respiratory and cardiovascular diseases, diabetes mellitus, and renal issues [2]. Additionally, it can swiftly impact large populations, triggering short-lived but significant public health crises and widespread socio-economic consequences [2]. Further, temperature changes and altered rainfall patterns may influence the insect's survival, distribution, and behavior, leading to changes in the spread of infectious diseases [3]. Moreover, it can expose individuals to contaminated foods, leading to the risk of foodborne diseases.

The impact of temperature variations extends beyond human health to animals and environmental well-being. The research reported that rising temperatures alter the spatial distribution and intensity of prevailing pests and diseases, impacting livestock productivity and, in extreme cases, leading to animal mortality [4]. Further, temperature also influences cattle diseases, as the development stages of various vectors depend on it [5].

While climate change affects all countries globally, developing nations like India face heightened vulnerability due to diverse geography, climate, culture, burgeoning population, and rapid urbanization [6]. In 2019, India ranked as the 7th most impacted country by climate change-

* Corresponding author at: Centre for One Health Education, Research & Development (COHERD), Indian Institute of Public Health Gandhinagar (IIPHG), Opp. Air Force Head Quarters, Nr. Lekawada, 382042 Gandhinagar, Gujarat, India.
E-mail address: yasobant@iiphg.org (S. Yasobant).

https://doi.org/10.1016/j.dialog.2024.100203
Received 26 August 2024; Received in revised form 28 December 2024; Accepted 30 December 2024
Available online 3 January 2025

induced extreme weather events, resulting in 2267 fatalities and economic losses totaling 66,182 million US$ PPP [7]. Moreover, the global temperature is expected to reach unprecedented levels, with a 98 % probability that, within the next five years, either one year or the entire span will set new warmth benchmarks [8].

Despite the significant threats posed by temperature variation and climate change to human and animal health, there is a lack of evidence synthesis on the impact of heat on these health issues in India. A deeper understanding of the relationship between heat and human and animal health can contribute to developing evidence-based preventive strategies and policies. The present review aims to summarize the impact of heat on human and animal health in India.

2. Methods

2.1. Operational definitions

- Heat [9]: Heat refers to elevated ambient temperatures exceeding a location-specific threshold, typically measured as the daily maximum, mean, or heat indices over a specified period.
- Human Health [10]: Human health refers to a state of complete physical, mental, and social well-being and is not simply the absence of disease or infirmity.
- Animal Health: Animal Health refers to the state of well-being in animals where they are free from diseases, injuries, and physical discomfort, allowing them to grow, reproduce, and perform their ecological and economic roles effectively.
- One Health [11]: One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognises that the health statuses of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent.

2.2. Search strategy

Databases like PubMed and Google Scholar were used to identify literature and policy documents. Keywords like ‘climate change,’ ‘Heat’, ‘impact of Heat’, ‘impact of climate change’, ‘health’, ‘human health’, ‘animal health’, and ‘India’ were used to search the literature. The search was limited to the last 10 years, and the English language was specified. Several Boolean operators and filters were used to select articles in PubMed. Similar search key terms were also used for Google Scholar without Boolean operators.

2.3. Inclusion and exclusion criteria

Inclusion criteria: The review included papers or policy documents that focused on the impact of heat on human or animal health.

Exclusion criteria: The papers or documents that mentioned estimating the impact of climate change or only cold on health were excluded from the review. Also, papers where there was no clarity on the increased temperature effect were excluded from the full review.

2.4. Type of the study included in the review

The published literature included in the review consists of primary studies, review papers, policy briefs, and commentaries. All the literature focuses on the impact of heat on human or animal health. The policy documents focused on the interventions and measures undertaken to manage the heat or rise in ambient temperature or its impact on health.

2.5. Identification of the studies

The PRISMA Guidelines were followed to assess and report the current study [12].

2.6. Selection of studies

The reviewers (SY, PT, and SL) independently searched the database and screened the retrieved studies against the inclusion criteria, initially based on the title and abstract and then on full texts. A final list of all the independently extracted articles was prepared for further analysis.

2.7. Data extractions

The extracted data from eligible studies were summarized, including basic details, study type, location, authors, years, and the impact on human and animal health. This information was analyzed and presented in a tabular descriptive format.

3. Results

A total of 219 articles were identified from the PubMed and Google Scholar databases. During the screening process, 49 duplicate articles were removed. After reading the abstract, of the remaining 170 articles, 55 articles were discarded based on inclusion and exclusion criteria. Reports assessed for eligibility were 115 articles, of which 38 articles without full text and 28 non-relevant articles were excluded. Hence, the remaining 44 articles were included in the review (Fig. 1).

Out of the 44 studies included in the present review, only 47.7 % were original articles; the rest, 38.6 % and 13.6 %, were reviews and perspective papers, respectively. Of the 44 articles reviewed, about 47.6 % were published in the last five years (2019–2023), while the rest, 51.3, were published between 2011 and 2018 (Table 1). Most of the primary studies documented the impact of heat on workers from informal sectors, such as salt pan workers, construction workers, and workers from the steel industry. A few studies also evaluated the impact of heat on vulnerable groups like women, children and elderly populations.

The original studies were conducted in different parts of India, such as Tamil Nadu, Chandigarh, Gujarat, Odisha, Madhya Pradesh, and

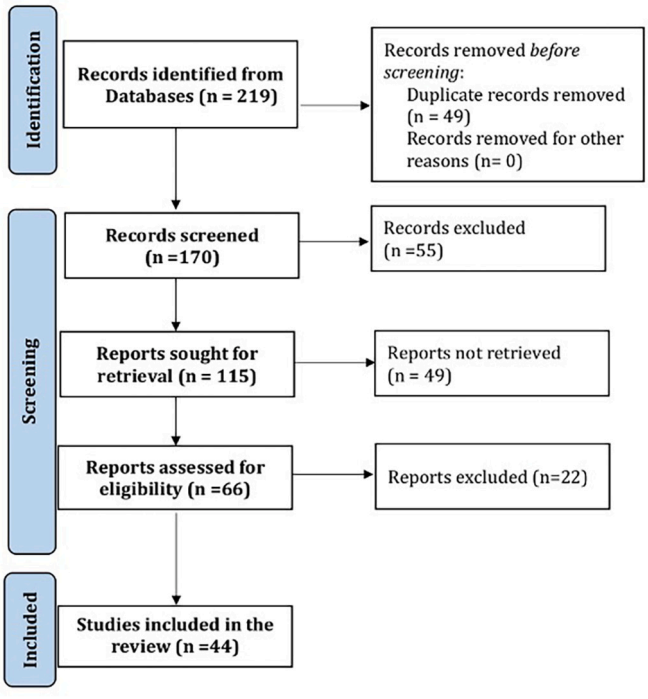

Fig. 1. PRISMA diagram

Table 1
Description of studies included in the review ($N = 44$).

Variable	N (%)
Year of Publication	
2011–2015	10 (22.7)
2016–2018	13(29.5)
2019–2021	12 (27.2)
2022–2023	09 (20.4)
Type of Study	
Primary Research	21 (47.7)
Commentary and Perspective	06 (13.6)
Review	17 (38.6)

many others. The included studies documented the impact of heat on different populations, such as women, workers etc. The findings of the studies are summarized below in detail (Table 2).

Most articles reported high temperatures as one of the major challenges for human health, while very few studies focused on the impact of heat on animal health. Heat impacts human health in many ways, including increased mortality and morbidity, impact on maternal and child health, infectious and non-infectious diseases, and malnutrition. The findings are summarized below in detail.

3.1. Impact of heat due to climate change on human health

Climate change affects health through many mechanisms, including heat, poor air quality, extreme weather events, and meteorological changes that alter vector-borne disease, reduce water quality, and reduce food security. However, the present review is focused on the impact of heat on human health. Most articles have documented heat's effects on mortality and morbidity.

3.2. Impact on mortality

Various studies found a substantial impact of rising temperature on mortality and morbidity. A survey conducted in north-central India observed that mortality increased by 33.3 % when the daily maximum temperature reached ≥40 °C compared to <38 °C. Inpatient and outpatient department visits also rose with the increase in temperature. These findings highlight the significant impact of rising temperatures on mortality rates and hospital visits in Gwalior [13]. Similarly, a study conducted in Ahmedabad reported a 43 % rise in mortality in Ahmedabad during the May 2010 heat wave compared to other years, a significant mortality rate ratio of 1.76 during the extreme heat wave period [14]. A study by Rathi et al. indicates a notable surge in all-cause mortality during days with temperatures ≥40 °C in Hyderabad. It was also observed that there was a 57 % rise in deaths attributed to non-infectious diseases [15]. Furthermore, total mortality increased by 33 % during the heat events, with a significant 43 % increase in deaths among individuals aged 12–59, predominantly affecting men in Maharashtra [16]. A study conducted in Surat reported a 20 % increase in all-cause mortality when temperatures reached ≥40 °C. Additionally, the study concluded that there is spatial variation in all-cause mortality at the zonal level associated with temperature [17].

3.3. Impact on morbidity

A community-based study in Odisha reported heat exhaustion, cramps, and heat stroke as the leading heat-related events among the study participants [18]. A survey conducted in Ahmedabad among slum dwellers reported an average of 20.1 % of Heat-related symptoms (HRS) and 11.9 % of Heat-related illnesses (HRI) among the study participants [19]. Various factors like Age over 60 years, pre-existing medical conditions, outdoor work location, and limited water access or information were found to increase the odds of HRS and HRI due to higher ambient temperatures in Ahmedabad [19,20].

Further, the literature also reported the indirect impact of heat, such as an increase in foodborne and waterborne infectious diseases and malnutrition. Water- and foodborne diseases like diarrhea, cholera, infective gastroenteritis, and Dysentery increased due to the shortage of clean drinking water, lack of hygienic practices, and unavailability of proper food storage facilities in remote areas mainly accelerated due to an increase in ambient temperature [21]. A warmer climate has been associated with increased bacterial proliferation, increasing the prevalence of diarrheal and waterborne diseases [22].

The studies also confirm the impact of heat on Non-Communicable Diseases (NCDs), including cardiovascular disease, cancers, respiratory issues, heat stroke, and chronic kidney disease associated with recurrent dehydration. Extreme temperatures cause cardio-pulmonary mortality problems due to allergens and pollutants [23]. Further, nonoptimal temperatures causing higher ambient temperatures contributed to excess cardiovascular diseases, as specified in a study by Shreya et al. [24]. Higher incidences of respiratory diseases due to heat are highlighted in a few studies [21,23,25,26].

Further, the effect of heat on mental health and occupational issues, such as animal and insect bites, are some of the significant outcomes of increased ambient temperature identified by the research conducted in different parts of India [16,27,28]. A study by Venugopal. et al. reported that informal workers exposed to chronic occupational heat stress had significantly higher adverse renal health outcomes than unexposed workers [29]. Moreover, in a study, significant associations between high-heat exposures and skin-related issues ($t = -2.3879$, $p = 0.0192$), inadequate toilet facilities, and self-reported adverse heat-related health symptoms (χ (2) = 4.03, $p = 0.0444$), and prevalence of genitourinary issues (χ (2) = 42.92, $p = 0.0005 \times 10(-7)$) was observed [30]. Another study among the construction workers of Ahmedabad found that women suffer the impact of heatwaves due to the use of solid fuel for cooking, lack of protective gear (headcover, hat), and traditional clothing, which makes it harder for them to cope with extreme heat in the indoor spaces. This rise in indoor temperature due to indoor air pollution is a growing concern in the today's era of Air pollution. [31].

The impact of extreme heat on mental health is also reported in various studies. The evidence shows that exposure to heat can lead to increased suicide rates and aggressive suicide attempts [32]. Acute stress reaction and adjustment disorder, acute and transient psychosis and relapse of bipolar disorder, grief or depression, and schizophrenia are commonly observed in people exposed to extreme heat [32]. Recurrent disasters like floods and droughts due to temperature increases can cause an impact on mental health issues like post-traumatic stress syndrome, stress, or anxiety in people, mainly adolescents [33]. Moreover, the evidence indicates a rise in vector-borne diseases like dengue, chikungunya, Japanese encephalitis, lymphatic filariasis, Hemorrhagic fever with renal syndrome, and Zika virus due to high temperatures and extreme rainfall and climate change [32,34].

3.3.1. Impact on Human Reproductive health and malnutrition

Extended exposure to elevated temperatures is correlated with adverse pregnancy outcomes such as stillbirth, congenital disabilities, and preterm delivery. Additionally, high ambient temperatures are associated with pregnancy complications like gestational hypertension and preeclampsia [35]. Infections from floods, coastal water warming, and decreased regional crop yields contribute to malnutrition [32]. Research also indicates that increased heat contributes to dehydration and malnutrition among children [36]. Furthermore, studies have identified connections between high temperatures and nutritional deficiencies. The susceptibility of agriculture to climate change is linked to child malnutrition, with children in districts highly exposed to climate risks being more likely to suffer from stunting, wasting, being underweight, and anaemia compared to those in areas with minimal vulnerability [37].

Table 2
The summary of the studies reviewed.

Sr No	Authors	Study Design	Study Objective	Location	Population	Impact of cold/ heat/ both	Findings/ conclusion
1	Sorensen C et al. (32)	Review	Impact of climate change on women's health and need for gender-specific solutions for gender-based vulnerability.	India	Women	Heat	Climate change impacts health differently, affecting men and women due to underlying socioeconomic, cultural, and physiological factors. Climate change threatens to widen existing gender-based health disparities, especially in India and other low- and middle-income countries.
2	Talukder B et al. (33)	Primary study	Discuss the health impacts of climate change on smallholder farmers and make recommendations for governments.	Bangladesh, India and Malawi	Smallholder farmers	Heat	Climate change-related heat stress and humidity lead to risks for unprotected outdoor workers in unsafe conditions. The health effects of these conditions can lead to loss of work capacity, income, and livelihood opportunities and reduced productivity.
3	Dhimal M et.(20) al.	Review	To document how climate change has impacted and will impact the health and well-being of the people in the HKH region.	Hindu Kush Himalayan (HKH) region	Population of HKH region and Children under 5 Women	Heat	The rise in temperature due to climate change results in a rise in infectious and non-communicable diseases among the people residing in the HKH region.
4	Narain JP et al. (18)	Commentary or perspective	NA	NA	NA	Heat	The rise in temperature has resulted in dire health consequences so there is a need for mitigation and adaptation to tackle climate change
5	Dhara VR et al. (19)	Review	Assesses the health effects of climate change, including impacts on infectious diseases, vector-borne diseases, and extreme weather events.	India	NA	High ambient temperature	Rising ambient temperatures directly affect health and it may result in disasters that impact health and wellbeing of the society.
6	Padhy SK, et al. (29)	Review	Impact of climate change and global warming on the mental health	Global perspective, including India	1. Individuals in developing countries 2. Farmers 3. Individuals who have faced disasters	Heat	Increasing temperatures cause aggression and violent suicides Drought's cause farmer suicides, stress, and economic stressors.
7	Das R, et al. (34)	Review	The impact of heat stress on the health and performance of dairy animals.	India	Dairy animals [$]	Heat stress (HS)	HS suppresses the immune and endocrine system, thereby enhancing the susceptibility of an animal to various diseases.
8	Pawankar R, et al.(35)	Commentary or Perspective	Discusses the impact of COVID-19 on climate change, allergic diseases, psychosocial impact and One Health in the Asia Pacific region.	NA	NA	Heat and climate change	Climate change may cause extreme air temperatures, affecting work productivity and workers' mental health.
9	Venugopal V, et al.(26)	Primary research	Describe heat stress, heat-related symptoms, and kidney function among salt pan workers in Tamil Nadu, India.	Tamil Nadu	Salt pan workers	Heat	The heat-exposed workers had 2.3 times higher odds of reporting adverse health outcomes (84 %) than the unexposed workers.
10	Sahu M, et al. (36)	Review	Exploring the current evidence for important potential impacts of climate change on Indigenous health in the background of multiple disadvantages and how it engages with Indigenous perspectives and experiences	Global	N/A	Heat	Changing climate and rise in temperatures had both direct and indirect health-related impacts on indigenous health, and altered the epidemiological triad for various health-related events, causing the emergence and re-emergence of infectious diseases, and increased prevalence of chronic diseases and mental disorders.
11	Majumder J, et al.(30).	Commentary or perspective	Overview of the interaction between climate change and disasters and their association	India	Adolescents	Heat	Exposure to heat stress from unforeseen circumstances might cause severe

(*continued on next page*)

Table 2 (*continued*)

Sr No	Authors	Study Design	Study Objective	Location	Population	Impact of cold/ heat/ both	Findings/ conclusion
			with the mental health issues of adolescents with reference to India.				psychological impacts among adolescents.
12	Dutta P, et al. (17)	Primary Research	To explore the effects of heat stress on construction workers and begin to identify possible intervention points at both worker and policy levels.	Gandhinagar, Gujarat, India	Construction workers	Heat	59 % of labourers reported heat-related symptoms (Mild to Severe) compared to 41 % in winter. The symptoms include Heavy sweating, dry mouth dehydration, headache, loss of coordination, dizziness, blurred vision, and fainting were more prevalent during the summer months compared to the winter.
13	Krishnamurthy M, et al. (37)	Primary Research	To understand the impacts of heat stress on the health and productivity of workers working in high-heat industries	"Steel City" in Southern India	Worker's laboring in steel industries	Heat	High heat exposure and heavy workloads adversely affect the workers' health and reduce their work capacities
14	Venugopal V, et al. (38)	Primary research	Evaluate the association between occupational heat stress and renal health among workers in informal sectors in India.	Tamil Nadu	Workers engaged in informal occupational sectors	Heat	Informal workers exposed to chronic occupational heat stress had significantly higher adverse renal health outcomes than the unexposed workers.
15	Nori-Sarma A, et al. (39).	Primary research	To understand the health effects of heat waves with high baseline temperatures	Jaipur, Churu, Idar, Himmatnagar, and Mumbai		Heat	The risk of mortality was higher on heat wave days compared to non-heat wave days.
16	Bont J D et al. (40)	Primary research	To evaluate the association between heatwaves and all-cause mortality and quantify the attributable mortality fraction in India.	10 cities of India	NA	Heat	Heatwaves impact daily mortality; intense heat waves are linked with increased mortality risk.
17	Venugopal V, et al. (27)	Primary research	To investigate health implications of exposure to hot work environment and inadequate sanitation facilities at their workplace for women workers.	2 districts of Tamil Nadu & 2 South Indian states	Female workers (Brick kilns, steel and agriculture)	Heat	Significant associations between high-heat exposures and Sweat rate. Inadequate toilet facilities and high temperatures led to heat related health symptoms and prevalence of genitourinary issues.
18	Agarwal AK, et al. (10)	Primary research	To estimate the impact of high temperatures and heatwaves on morbidity and mortality by quantifying association between maximum temperature, hospital visits and mortality in a tertiary hospital during April–July 2016.	Gwalior, Madhya Pradesh	Patients from three states who attended the tertiary hospital	Heat	Prolonged exposure to extreme heat can cause heat exhaustion, heat cramps, heat stroke, and death, as well as exacerbate preexisting chronic conditions, such as various respiratory, cerebral, and cardiovascular diseases.
19	Azhar G, et al. (41)	Primary research	To understand climate change causes and impact on animals, human health and the environment in India.	N/A	N/A	Heat	Heat wave substantially affected all-cause excess mortality, even in the city.
20	K. R. Shivanna (42)	Commentary or perspective	To comprehend the ways in which global warming has contributed to the loss of species, spread of illness, rise in pollution and their influence on climate change.	N/A	N/A	Heat and cold	Increase in temperature due to climate change has an impact on human as well as environmental health.
21	V. Ramana, et al. (31)	Review	To understand common contagious conditions in India, their link to climate change and how healthcare providers can adopt preventive healthcare strategies with their cases.	N/A	N/A	Heat	A warmer climate has been associated with increased bacterial proliferation, which in turn increases the prevalence of diarrheal and waterborne diseases.
22	Sultan Y, Pillai K (43)	Review	To study the effects of wildfires on health and air quality in India.	N/A	N/A	Heat	There is a high association between climate change, high temperatures and wildfires having a significant impact on human health.
23	Upadhyay, R.C., et al. (44)	Primary Research	To study the effect of non-genetic factors like air temperature, humidity and THI on reproduction of buffaloes.	Karnal, Haryana	Murrah Buffaloes[$]	Heat	likely temperature rise due to global warming may negatively impact the

(*continued on next page*)

Table 2 (*continued*)

Sr No	Authors	Study Design	Study Objective	Location	Population	Impact of cold/ heat/ both	Findings/ conclusion
							reproductive functions of buffaloes
24	Tiwari, Ishwar, et al. (45)	Review	To synthesize evidence from relevant studies and identify research gaps to contribute to knowledge about South Asia's existing climate mitigation and adaptation strategies.	South Asia	Women and children	Heat	Infant mortality is significantly higher mortality for age groups 5–19 years and 20–59 years due to extreme temperature.
25	Shanmugam R, et al. (46)	Review	To examine the impact of heat stress on maternal, fetal, and neonatal health.	N/A	N/A	Heat Stress	Heat stress has an adverse impact on maternal and neonatal health, thereby impacting morbidity and mortality.
26	Shilpa S. et al. (47)	Review	To know Environmental pollutants and their effects on human health.	N/A	N/A	Heat and environmental pollution	Heat and associated environmental pollution lead to Respiratory, reproductive, neural, cardiovascular diseases and cancers.
27	Basavaraj Sajjanar, et al. (48).	Primary research	To identify the impact of heat shock on the genome expression of animals	Haryana	Cattle [$]	heat stress	Heat stress impacts the health of the cattle including their productivity.
28	Angela M. Lees, et al.(49).	Review	This review provides an overview of the dynamic relationship that exists between the thermal environment and bovines	N/A	Bovines [$]	heat	Increase in temperature impacts the health and productivity of the bovines.
29	Andrew Mertens, et al.(50).	Primary research	Examined whether high temperature and heavy rainfall were associated with increased all-cause diarrhea and water contamination	Tamil Nadu	Young Children	High temperatures and heavy rainfall	High temperature is associated with water borne diseases. There is high incidence associated with heavy rainfall due to rise in temperature.
30	Dutta P, et al. (51).	Primary research	To estimate the risk associated with heat waves during two major heat waves of Nagpur occurred in 2010 and 2014.	Nagpur	Residents of Nagpur	extreme heat	Heat is associated with health risks during heat waves.
31	Omid mazdiyasni, et al. (52)	Primary research	To assess the impact of heat wave on the mortality.	NA	NA	Heat wave	Moderate increases in mean temperatures may cause great increases in heat-related mortality.
32	Bidhubhusan Mahapatra, et al. (53)	Primary research	This study examined a) the association between the degree of vulnerability in agriculture to climate change and child nutrition at the micro-level), the spatial effect of climate vulnerability on child nutrition, and the geographical hotspots of both vulnerability in agriculture to climate change and child malnutrition.	N/A	children under 5 years of age, women from 15 to 49 years of age	Heat	Heat have an impact on the children health, it leads to conditions like malnutrition.
33	Gupta S et al.(54)	Review	The impact of HS on the immunity of calves during early life to adult lactating and dry cows.	N/A	dairy cattle [$]	heat stress	heat stress impacts immune function, reproductive health, and overall productivity of dairy cattle.
34	Sze Hang Fu, et al. (22)	Review	Quantify the effects of heat and cold on all medical, as well as on stroke, Ischemic heart disease(IHD),and respiratory diseases among adults aged 30–69 in India	N/A	Entire Indian population with focus on age groups (0–29,30–69,70 and above)	heat and cold	Heat has an impact on the mortality.
35	Shreya S. et al. (21)	Primary research	To investigate the association of CVDs and temperature in Puducherry	Puducherry	NA	cold and heat	Both cold and hot non-optimal temperatures contribute to excess CVD deaths.
36	Rathi S et al. (12)	Review	To assess the association between extreme heat and all-cause mortality for summer months (March to June) from 2006 to 2015 for the Hyderabad city population.	Hyderabad	NA	extreme heat	A significant increase in all-cause mortality at extreme temperatures.
37	Vijendra Ingole, et al. (13)	Review	To estimate the effects of heat and cold days on total and cause-specific mortality in the Vadu Health and Demographic	Maharashtra	N/A	Heat and Cold	High temperature associated with non infectious disease: heat stroke, cardiovascular diseases (cardiac arrest,

(*continued on next page*)

Table 2 (*continued*)

Sr No	Authors	Study Design	Study Objective	Location	Population	Impact of cold/ heat/ both	Findings/ conclusion
			Surveillance System (HDSS) area in western India				myocardial infarction), respiratory diseases (asthma), kidney disease (acute renal failure).
38	Karin Lundgren-Kownacki,et al. (55)	Commentary or perspective	Evaluates both current heat risks and the potential future impacts of heat caused by climate change, for the people working at brick kilns in India	Chennai	Migrant populations working at brick kilns	heat risk	Climate change-induced heat drives feedback loops that increase hardships especially have adverse health effects for workers.
39	Swain S, et al. (15)	Primary research	to identify the factors associated with heat illness and the coping practices among city dwellers of Odisha, India during the summer.	Bhubaneswar and Cuttack, Odisha	Household respondent	Heat	Males were two times more likely to get heat illness than females due to the nature of occupation and outdoor activities.
40	Kathy V Tran, et al. (16)	Primary research	To know the Household Vulnerability to Extreme Heat among Slum Dwellers	Ahmedabad	Slum dwellers	Heat	Heat related symptoms and illnesses mainly heat rash, heat edema and heat exhaustion are common among slum dwellers.
41	Nanda L, et al. (28)	Primary research	To recognize the characteristics connected to heat vulnerability and the coping practices among Indian urbanites	Hilly (Angul) and coastal (Kolkata) areas.	Household respondent	Heat	Women suffer higher impact of heat waves compared to men.
42	Rathi SK et al. (56)	Primary research	To assess the effect of daily maximum temperature, relative humidity and heat index on spatial variability of all-cause mortality for summer months (March to May) from 2014 to 2015 for the urban population of Surat (coastal) city	Gujarat	N/A	Heat	Increasing mortality in relation to rising temperature was observed
43	Barun M et al. (57)	Primary research	To examine the Heat-Related Symptoms and Coping Strategies among Elderly	Kolkata, West Bengal	Elderly	Heat	In rural villages and slums of Kolkata, elderly women reported most heat related symptoms compared to men
44	Rajput P, et al. (58)	Commentary or perspective	NA	NA	NA	Heat	Heat stress due to climate change will have an impact on mental, physical and social wellbeing of populations.

Abbreviations: COVID-19: Coronavirus disease, CVD: Cardio Vascular Disease, HDSS: Health and Demographic Surveillance System, HKH: Hindu Kush Himalayan, HS: Heat Stress, IHD: Ischemic Heart Disease, THI: Temperature Humidity Index.

[$] Indicates the papers or publications looking at impact of heat on animals.

3.3.2. *Impact on occupational health*

The risk of exposure to heat or increased ambient temperature is a significant concern for many occupations. Several studies have found that occupational heat stress is associated with more significant psychological distress among workers [32]. Extreme air temperatures due to climate fluctuations can impact workers' productivity and mental well-being, requiring adjustments in both work conditions and the environment. This can increase stress and a higher risk of workplace injuries, especially in healthcare settings [38]. Moreover, heat strain symptoms like excessive sweating, thirst, dizziness, muscle cramps, headache, nausea/vomiting, fainting, or prickly heat/rashes, Urogenital symptoms, Productivity losses, and renal function loss are common among people from occupations who are exposed to extreme heat like the salt pan workers and workers of the steel industry [39,40].

Climate change-related heat stress and humidity lead to risks for unprotected outdoor workers in unsafe conditions, losing work capacity, income, livelihood opportunities, and reduced productivity [41]. The research on occupational workers indicates that the heat-exposed workers had 2.3 times higher odds of reporting adverse health outcomes (84 %) compared to the unexposed workers (95 % CI: 1.74–3.19; p-value $\leq$ 0.0001). 59 % of laborers reported heat-related symptoms (Mild to Severe) compared to 41 % in winter, whereas over 40 % of workers reported at least one symptom in either season [42]. The study also reported the impact of chronic occupational heat stress on adverse renal health outcomes among informal workers, including increased incidences of heat-induced illnesses, cardiovascular issues, and kidney diseases [43]. A study from Venugopal.et.al it was found that 82 % of workers reported thermal discomfort in their work locations, and about 61 % reported heat exposure as a significant problem during hot seasons. Women workers are exposed to high-heat environments at Indian workplaces, which increases the risk of heat-related health illnesses for women. Heat-related illnesses (heat stroke, heat exhaustion, heat cramps) and cardiovascular disease are common health issues seen in women workers [30].

3.3.3. *Impact of heat on animal health*

The present review reflects that there is minimal evidence of the impact of heat on animal health. However, a few studies have reported the adverse effects of high temperatures on animal health, including high mortality and morbidity. The prolonged heat exposure resulted in Mastitis and external parasite infestations among animals. Furthermore, heat stress negatively impacts dairy animals, resulting in reduced feed intake, decreased milk yield, lower milk quality, and an impact on reproductive performance [44]. The seasonal activities of animals have also been altered due to climate change. Over 1 billion animals were killed, endangering some species to extinction due to climate changes. An increase in vector-borne diseases was observed due to the increased vector population and decreased resistance in livestock due to extreme temperatures [45]. According to Upadhyay et al., the annual milk loss caused by thermal stress in India was 1.8 million tons, almost 2 % of the

country's total milk production. This loss amounts to a significant Rs. 2661.62 crores each year [46].

4. Discussion

The present review comprehensively examines influence of heat on human and animal health. Notably, in India, there is a discernible impact on human health, characterized by heightened morbidity and mortality during periods of elevated temperatures. Studies across various Indian states, including Ahmedabad, Hyderabad, Maharashtra, and Surat, have consistently documented increased mortality during heat waves. Similarly, a study in Australian cities reported that non-accidental and circulatory mortality significantly increased during heat waves [47]. A global modeling study in the heat related mortality highlighted that the excess mortality attributable to heatwaves were 0.94 % (95 % eCI: 0.68–1.19) of global fatalities throughout the warm seasons from 1990 to 2019, translating to 236 (95 % eCI: 170–300) deaths per 10 million inhabitants [48]. Various multi-country studies also documented the impact of temperature variation on human health. A study across 12 countries with diverse climates found that temperature variations increased mortality risk, even after adjusting for temperature effects. Short-term variations (0–1 day) posed higher risks in hot areas, while longer variations (0–7 days) were more hazardous in moderate climates than in hot or cold regions [49] In contrast, A multicounty observational study by Gasparrini et al. (2015) found that non-optimal ambient temperatures significantly contribute to excess mortality, with notable variations across countries. The majority of this burden was attributed to colder-than-optimal days (7.29 %) compared to warmer-than-optimal days (0.42 %) [50].

Further epidemiological research underscores the correlation between ambient temperature and adverse health outcomes, such as mortality and morbidity [51]. A study conducted on the analysis of 272 Chinese cities reported mortality risk associated with heat waves. The study reported that heatwaves could significantly increase the risk for mortality from total and cardiopulmonary diseases, including coronary heart disease, ischemic stroke (rather than hemorrhagic stroke), and chronic obstructive pulmonary disease [52]. A modeling study in two Chinese cities found that rising temperatures increased mortality from non-accidental and cardiovascular diseases, while lower temperatures had a protective effect on both. [53] Moreover, A review on the impact of heat on mortality and morbidity in low- and middle-income countries concluded that most studies (92.9 %) reported a positive association between heat and human morbidity or mortality. [54] Interestingly, a review by Saunik et al., [55] primarily focused on livelihood in addition to mortality and morbidity, whereas the current review scope is more about exploring the mortality and morbidity pattern emphasizing the human (reproductive, mental, and occupational) and animal health together. [55] Moreover, the review highlights the deleterious effects of rising temperatures on various diseases, encompassing heat-related illnesses, non-communicable diseases (NCDs), occupational ailments, reproductive disorders, and malnutrition. Instances of heat-related morbidities, such as heat cramps, heat strokes, hyperthermia, as well as cardiac and respiratory ailments, are emphasized. These findings align with international studies, with research from South Korea revealing a 14 % increase in cardiovascular-related hospital admissions during heatwaves [56] and reports from New York indicating a surge in respiratory admissions due to elevated temperatures [57]. Furthermore, exposure to extreme heat and precipitation events, particularly during summer time, has been associated with heightened asthma hospitalizations in Maryland [58]. A systematic review of the impact of heatwaves on health service demand in Australia also demonstrates a rise in emergency department visits for respiratory and cardiovascular conditions during heatwaves [59]. A study on the effect of heat waves on Ambulance attendance in Brisbane, Australia, also found an increase in ambulance calls by 18.8 % during heat waves [60]. A 2.5 % increase in all-cause hospitalizations was seen in Vietnam [61].

The review also sheds light on the impact of heat on mental health, with consistent findings indicating an increased risk of mental illnesses and suicide during periods of high temperatures. This corroborates with systematic reviews linking high ambient temperatures with adverse mental health outcomes and elevated suicide rates [62]. Moreover, the literature underscores the exacerbation of vector-borne diseases, food insecurity, chronic ailments (cardiac, kidney, mental, and skin diseases), and the socio-economic ramifications, particularly productivity loss, due to temperature variations. Further, the review also highlighted that Occupational workers are particularly vulnerable to heat-related illnesses, leading to decreased productivity. Similar findings are echoed in a scoping review, which outlines the association between heat exposure and productivity loss or costs [63].

While evidence regarding animal health in India remains limited, a notable increase in animal morbidity and mortality is attributed to high temperatures. The studies reported the associations between heat and infections, such as Mastitis and external parasite infestations. Similarly, a study from Italy corroborates the adverse effects of heat on animal health, particularly in dairy cows, manifesting as reduced feed intake, decreased milk yield, and compromised reproductive performance [64]. Further, the negative impact of heat stress on dairy animals, such as reduced feed intake, decreased milk yield, lower milk quality, and impact on reproductive performance, is also documented. The study findings are congruent with those of Liu J et al. The study concluded that the rising temperature and humidity affect dairy cows' body temperature and feed intake, affecting milk production and reproduction [65].

This review serves as the first comprehensive synthesis of the impact of heat on both humans and animals in India. Providing evidence on heat's effects on health offers valuable insights for policymakers and planners to develop evidence-based heat action plans to prevent heat-related mortalities and morbidities among vulnerable populations. Thus, One Health interventions like disease surveillance and zoonotic disease control become more important with the increased impact of heat on human and animal health. This will help us to reduce the risk of disease outbreaks and evade the risk of disease transmission between humans and animals.

The review underscores the multifaceted impacts of temperature fluctuations on human and animal health, emphasizing the imperative for comprehensive strategies to mitigate these adverse effects. The present review also sheds light on the detrimental effects of heat on the health of occupational workers, such as loss of work capacity, income, livelihood opportunities, and heat-related morbidities. This shows there is a need for a policy for the occupational safety of the workers to protect them from heat-related mortality and morbidities.

The present review also indicates the research gap in heat impacts on different populations and settings. The review highlighted the impact of heat on non-communicable diseases, including mental health, where very few original studies exist, which needs to be explored further. Although pregnant mothers and children are vulnerable to the high impact of heat, there is a dearth of original research on this domain, which calls for further investigation. Consequently, further research on the impact of heat on animals is clearly needed, especially considering projections of rising temperatures in the future.

This study has several limitations. First, due to the minimal number of animal health studies as compared to the human health impact, it is not advisable to generalize the facts that are gathered through this review. Second, we are aware of a larger number of papers on heatwave strategies focused on specific regions and parameters without specifying the health impacts on the targeted reviewed population. Therefore, those articles are excluded from the review. We plan to review these papers in the course of future research additionally. This paper is positioned as an introductory study, to show the importance of "heat impact on health of two different species i.e. human and animal from the One Health principles". Third, the included studies are not based on the confirmatory diagnosis of the heat impact, we have relied on the information that was provided by respective authors and published

information. Further, the potential variation in definitions used for heat thresholds across different studies, which has not been addressed in this review, and half of the studies were secondary studies.

5. Conclusion

While global temperatures are expected to continue rising in the future, this review highlights the pressing need for evidence-based interventions to mitigate the harmful effects of heat. It underscores the significant morbidity and mortality experienced by humans and animals during elevated temperatures, emphasizing the crucial role of policymakers and planners in crafting comprehensive heat action plans. The evidence presented highlights the multifaceted nature of heat's impacts, which extend from increased mortality and morbidity to adverse effects on mental health, productivity loss, and agricultural yields. Particularly vulnerable populations, including occupational workers, pregnant mothers, and children, face heightened risks, necessitating targeted interventions and further research to better understand and address these impacts. By implementing evidence-based strategies and investing in further research, policymakers can protect vulnerable populations and enhance resilience to the impacts of climate change.

Funding

The study is made possible by the generous support of the Natural Resources Defense Council (NRDC).

Ethical considerations

This is a secondary review; hence, ethical approval is not required.

CRediT authorship contribution statement

Sandul Yasobant: Writing – review & editing, Supervision, Conceptualization. **K. Shruti Lekha:** Writing – original draft, Validation, Resources, Formal analysis, Data curation. **Poonam Trivedi:** Writing – original draft, Supervision, Formal analysis, Data curation. **Shruti Krishnan:** Methodology, Investigation. **Chinmayee Kator:** Methodology, Investigation. **Harleen Kaur:** Methodology, Investigation. **Mudita Adaniya:** Methodology, Investigation. **Anish Sinha:** Supervision, Conceptualization. **Deepak Saxena:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We are grateful to the Natural Resources Defense Council (NRDC) team for providing their input/suggestions for the review.

References

[1] Organization WH. Climate change. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health; 2024. accessed October 27, 2023.
[2] Heat and Health. https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health; 2024. accessed April 8, 2024.
[3] Hunter PR. Climate change and waterborne and vector-borne disease. J Appl Microbiol Symposium Suppl 2003:94. https://doi.org/10.1046/J.1365-2672.94.S1.5.X.
[4] Sham M, Harun H, Bekere Hassenyusuf, Demri Hussen H, et al. An Open Access Journal Review on impact of climate change on livestock health and productivity BAOJ Nutrition Review Articlevol. 1; 2022.
[5] Nejash A. Impact of climate change on livestock health: A review. 2016. p. 6.
[6] World Bank. India: Climate change impacts. https://www.worldbank.org/en/news/feature/2013/06/19/india-climate-change-impacts; 2024.
[7] Unicef. Climate Change and Environmental Sustainability. India: UNICEF; 2024. https://www.unicef.org/india/what-we-do/climate-change. accessed April 8, 2024.
[8] Global Meteorological Organization. Global temperatures set to reach new records in next five years. https://wmo.int/news/media-centre/global-temperatures-set-reach-new-records-next-five-years; 2024. accessed April 8, 2024.
[9] Heatwaves and health: guidance on warning-system development. https://www.who.int/publications/m/item/heatwaves-and-health–guidance-on-warning-system-development; 2024. accessed December 27, 2024.
[10] Constitution of the World Health Organization. https://www.who.int/about/governance/constitution; 2024. accessed December 27, 2024.
[11] Tripartite and UNEP support OHHLEP's definition of "One Health". https://www.who.int/news/item/01-12-2021-tripartite-and-unep-support-ohhlep-s-definition-of-one-health; 2024.
[12] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. Preferred reporting items for systematic reviews and Meta-analyses extension for scoping reviews (PRISMA-ScR) checklist SECTION. Ann Intern Med 2018;169:11–2. https://doi.org/10.7326/M18-0850.2.
[13] Agarwal AK, Dwivedi S, Ghanshyam A. Summer heat: making a consistent health impact. Indian J Occup Environ Med 2018;22:57–8. https://doi.org/10.4103/ijoem.IJOEM_94_17.
[14] Azhar GS, Mavalankar D, Nori-Sarma A, Rajiva A, Dutta P, Jaiswal A, et al. Heat-related mortality in India: excess all-cause mortality associated with the 2010 Ahmedabad heat wave. PloS One 2014;9:e91831. https://doi.org/10.1371/journal.pone.0091831.
[15] Rathi K, Sodani R. Summer temperature and all-cause mortality from 2006 to 2015 for Hyderabad. India Afr Health Sci 2021;21:1474–81. https://doi.org/10.4314/ahs.v21i3.59.
[16] Ingole V, Rocklöv J, Juvekar S, Schumann B. Impact of heat and cold on Total and cause-specific mortality in Vadu HDSS—A rural setting in Western India. Int J Environ Res Public Health 2015;12:15298–308. https://doi.org/10.3390/ijerph121214980.
[17] Rathi SK, Desai VK, Jariwala P, Desai H, Naik A, Joseph A. Summer temperature and spatial variability of all-cause mortality in Surat City. India Indian J Community Med 2017;42:111–5. https://doi.org/10.4103/0970-0218.205216.
[18] Swain S, Bhattacharya S, Dutta A, Pati S, Nanda L. Vulnerability and adaptation to extreme heat in Odisha, India: A community based comparative study. Int J Environ Res Public Health 2019;16:5065. https://doi.org/10.3390/ijerph16245065.
[19] Tran K, Azhar G, Nair R, Knowlton K, Jaiswal A, Sheffield P, et al. A cross-sectional, randomized cluster sample survey of household vulnerability to extreme heat among slum dwellers in Ahmedabad, India. Int J Environ Res Public Health 2013;10:2515–43. https://doi.org/10.3390/ijerph10062515.
[20] Dutta P, Rajiva A, Andhare D, Azhar G, Tiwari A, Sheffield P, et al. Perceived heat stress and health effects on construction workers. Indian J Occup Environ Med 2015;19:151. https://doi.org/10.4103/0019-5278.174002.
[21] Narain J. Unravelling the health impact of climate change. Indian J Med Res 2016;143:1. https://doi.org/10.4103/0971-5916.178571.
[22] Dhara VR, Schramm PJ, Luber G. Climate change & infectious diseases in India: implications for health care providers. Indian J Med Res 2013;138:847–52.
[23] Dhimal M, Bhandari D, Dhimal ML, Kafle N, Pyakurel P, Mahotra N, et al. Impact of climate change on health and well-being of people in Hindu Kush Himalayan region: A narrative review. Front Physiol 2021:12. https://doi.org/10.3389/fphys.2021.651189.
[24] Shrikhande SS, Pedder H, Röösli M, Dalvie MA, Lakshmanasamy R, Gasparrini A, et al. Non-optimal apparent temperature and cardiovascular mortality: the association in Puducherry, India between 2011 and 2020. BMC Public Health 2023;23:291. https://doi.org/10.1186/s12889-023-15128-6.
[25] Fu SH, Gasparrini A, Rodriguez PS, Jha P. Mortality attributable to hot and cold ambient temperatures in India: a nationally representative case-crossover study. PLoS Med 2018;15:e1002619. https://doi.org/10.1371/journal.pmed.1002619.
[26] Sultan YED, Pillai KRA. Wild fires and climate change: health, air quality, wild fires and causes in India. Indonesian J Soc Environ Issues 2023;4:72–80. https://doi.org/10.47540/ijsei.v4i1.789.
[27] Dutta P, Rajiva A, Andhare D, Azhar G, Tiwari A, Sheffield P, et al. Perceived heat stress and health effects on construction workers. Indian J Occup Environ Med 2015;19:151. https://doi.org/10.4103/0019-5278.174002.
[28] Naghavi M, Wang H, Lozano R, Davis A, Liang X, Zhou M, et al. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the global burden of disease study 2013. Lancet 2015;385:117–71. https://doi.org/10.1016/S0140-6736(14)61682-2.
[29] Venugopal V, Latha PK, Shanmugam R, Krishnamoorthy M, Omprashanth R, Lennqvist R, et al. Epidemiological evidence from south Indian working population—the heat exposures and health linkage. J Expo Sci Environ Epidemiol 2021;31:177–86. https://doi.org/10.1038/s41370-020-00261-w.
[30] Venugopal V, Rekha S, Manikandan K, Latha PK, Vennila V, Ganesan N, et al. Heat stress and inadequate sanitary facilities at workplaces - an occupational health concern for women? Glob Health Action 2016;9:31945. https://doi.org/10.3402/gha.v9.31945.
[31] Nanda L, Chakraborty S, Mishra SK, Dutta A, Rathi SK. Characteristics of Households' vulnerability to extreme heat: an analytical cross-sectional study from India. Int J Environ Res Public Health 2022;19:15334. https://doi.org/10.3390/ijerph192215334.

[32] Padhy SK, Sarkar S, Panigrahi M, Paul S. Mental health effects of climate change. Indian J Occup Environ Med 2015;19:3–7. https://doi.org/10.4103/0019-5278.156997.
[33] Majumder J, Saha I, Saha A, Chakrabarti A. Climate change, disasters, and mental health of adolescents in India. Indian J Psychol Med 2023;45:289–91. https://doi.org/10.1177/02537176231164649.
[34] Dhara VR, Schramm PJ, Luber G. Climate change & infectious diseases in India: implications for health care providers. Indian J Med Res 2013;138:847–52.
[35] Sorensen C, Saunik S, Sehgal M, Tewary A, Govindan M, Lemery J, et al. Climate change and Women's health: impacts and opportunities in India. Geohealth 2018;2:283–97. https://doi.org/10.1029/2018GH000163.
[36] Sharma R, Lahariya C, Hossain MM. Impact of climate change, food insecurity, and COVID-19 on the health of neonates and children: A narrative review. Indian J Pediatr 2023;90:104–15. https://doi.org/10.1007/s12098-023-04757-9.
[37] Mahapatra B, Walia M, Rao CAR, Raju BMK, Saggurti N. Vulnerability of agriculture to climate change increases the risk of child malnutrition: evidence from a large-scale observational study in India. PloS One 2021;16:e0253637. https://doi.org/10.1371/journal.pone.0253637.
[38] Pawankar R, Thong BY, Recto MT, Wang J-Y, Abdul Latiff AH, Leung T-F, et al. COVID-19 in the Asia Pacific: impact on climate change, allergic diseases and one health. Asia Pac Allergy 2023;13:44–9. https://doi.org/10.5415/apallergy.0000000000000021.
[39] Krishnamurthy M, Ramalingam P, Perumal K, Kamalakannan LP, Chinnadurai J, Shanmugam R, et al. Occupational heat stress impacts on health and productivity in a steel industry in southern India. Saf Health Work 2017;8:99–104. https://doi.org/10.1016/j.shaw.2016.08.005.
[40] Krishnamurthy M, Ramalingam P, Perumal K, Kamalakannan LP, Chinnadurai J, Shanmugam R, et al. Occupational heat stress impacts on health and productivity in a steel industry in southern India. Saf Health Work 2017;8:99–104. https://doi.org/10.1016/j.shaw.2016.08.005.
[41] Talukder B, van Loon GW, Hipel KW, Chiotha S, Orbinski J. Health impacts of climate change on smallholder farmers. One Health 2021;13:100258. https://doi.org/10.1016/j.onehlt.2021.100258.
[42] Dutta P, Rajiva A, Andhare D, Azhar GS, Tiwari A, Sheffield P, et al. Perceived heat stress and health effects on construction workers. Indian J Occup Environ Med 2015;19:151–8. https://doi.org/10.4103/0019-5278.174002.
[43] Venugopal V, Lennqvist R, Latha PK, Suraya A, Jakobsson K, et al. Challenges in conducting epidemiological field studies evaluating associations between heat stress and renal health among workers in informal sectors: experiences from India. Environ Res 2021;200:111343. https://doi.org/10.1016/j.envres.2021.111343.
[44] Das R, Sailo L, Verma N, Bharti P, Saikia J, Imtiwati, et al. Impact of heat stress on health and performance of dairy animals: A review. Vet World 2016;9:260–8. https://doi.org/10.14202/vetworld.2016.260-268.
[45] Bush KF, Luber G, Kotha SR, Dhaliwal RS, Kapil V, Pascual M, et al. Impacts of climate change on public health in India: future research directions. Environ Health Perspect 2011;119:765–70. https://doi.org/10.1289/ehp.1003000.
[46] Upadhyay RC, Singh SV, Kumar A, Gupta SK, Ashutosh A. Impact of climate change on milk production of murrah buffaloes. Ital J Anim Sci 2007;6:1329–32. https://doi.org/10.4081/ijas.2007.s2.1329.
[47] Wang XY, Guo Y, FitzGerald G, Aitken P, Tippett V, Chen D, et al. The impacts of heatwaves on mortality differ with different study periods: A multi-city time series investigation. PloS One 2015:10. https://doi.org/10.1371/journal.pone.0134233.
[48] Zhao Q, Li S, Ye T, Wu Y, Gasparrini A, Tong S, et al. Global, regional, and national burden of heatwave-related mortality from 1990 to 2019: A three-stage modelling study. PLoS Med 2024;21:e1004364. https://doi.org/10.1371/JOURNAL.PMED.1004364.
[49] Guo Y, Gasparrini A, Armstrong BG, Tawatsupa B, Tobias A, Lavigne E, et al. Temperature variability and mortality: A multi-country study. Environ Health Perspect 2016;124:1554–9. https://doi.org/10.1289/EHP149.
[50] 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. The Lancet 2015;386:369–75. https://doi.org/10.1016/S0140-6736(14)62114-0.
[51] 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. WwwThelancetCom 2015;386:369. https://doi.org/10.1016/S0140-6736(14)62114-0.
[52] Yin P, Chen R, Wang L, Liu C, Niu Y, Wang W, et al. The added effects of heatwaves on cause-specific mortality: A nationwide analysis in 272 Chinese cities. Environ Int 2018;121:898–905. https://doi.org/10.1016/j.envint.2018.10.016.
[53] Lin H, Zhang Y, Xu Y, Xu X, Liu T, Luo Y, et al. Temperature changes between neighboring days and mortality in summer: A distributed lag non-linear time series analysis. PloS One 2013:8. https://doi.org/10.1371/journal.pone.0066403.
[54] Green H, Bailey J, Schwarz L, Vanos J, Ebi K, Benmarhnia T. Impact of heat on mortality and morbidity in low and middle income countries: A review of the epidemiological evidence and considerations for future research. Environ Res 2019;171:80–91. https://doi.org/10.1016/J.ENVRES.2019.01.010.
[55] Saunik S, Shaw R. Climate change and heatwaves in India: review of impacts on public health, livelihoods, and policy. Int J Environ Climate Change 2024;14:650–63. https://doi.org/10.9734/ijecc/2024/v14i114575.
[56] Kang SH, Oh IY, Heo J, Lee H, Kim J, Lim WH, et al. Heat, heat waves, and out-of-hospital cardiac arrest. Int J Cardiol 2016;221:232–7. https://doi.org/10.1016/J.IJCARD.2016.07.071.
[57] Lin S, Hsu WH, van Zutphen AR, Saha S, Luber G, Hwang SA. Excessive heat and respiratory hospitalizations in New York state: estimating current and future public health burden related to climate change. Environ Health Perspect 2012;120:1571–7. https://doi.org/10.1289/ehp.1104728.
[58] Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A. Environ Health 2016:15. https://doi.org/10.1186/s12940-016-0142-z.
[59] Mason H, King C, Peden E, Franklin C. Systematic review of the impact of heatwaves on health service demand in Australia. BMC Health Serv Res 2022;22:960. https://doi.org/10.1186/S12913-022-08341-3.
[60] Turner LR, Connell D, Tong S. The effect of heat waves on ambulance attendances in Brisbane. Australia Prehosp Disaster Med 2013;28:1–6. https://doi.org/10.1017/s1049023x13008789.
[61] Phung D, Chu C, Rutherford S, Nguyen HLT, Do CM, Huang C. Heatwave and risk of hospitalization: A multi-province study in Vietnam. Environ Pollut 2017;220:597–607. https://doi.org/10.1016/J.ENVPOL.2016.10.008.
[62] Thompson R, Lawrance EL, Roberts LF, Grailey K, Ashrafian H, Maheswaran H, et al. Ambient temperature and mental health: a systematic review and meta-analysis. Lancet Planet Health 2023;7:e580–9. https://doi.org/10.1016/S2542-5196(23)00104-3.
[63] Amoadu M, Ansah EW, Sarfo JO, Hormenu T. Impact of climate change and heat stress on workers' health and productivity: A scoping review. J Clim Change Health 2023:12. https://doi.org/10.1016/j.joclim.2023.100249.
[64] Vitali A, Segnalini M, Bertocchi L, Bernabucci U, Nardone A, Lacetera N. Seasonal pattern of mortality and relationships between mortality and temperature-humidity index in dairy cows. J Dairy Sci 2009;92:3781–90. https://doi.org/10.3168/jds.2009-2127.
[65] Liu J, Li L, Chen X, Lu Y, Wang D. Effects of heat stress on body temperature, milk production, and reproduction in dairy cows: A novel idea for monitoring and evaluation of heat stress — A review. Asian Australas J Anim Sci 2019;32:1332–9. https://doi.org/10.5713/ajas.18.0743.