Productivity
Health surveillance
Health adaptation
Heat stroke
Health systems
Heat morbidity
Risk reduction
Heat mortality
Heat action plan
Health burden
Vulnerability mapping
Cool roof
Indoor exposure
Adaptation energy
Health care
Heatwave
Prevalence
Urban heat island
Adaptive capacity
Urban infrastructure
Outdoor exposure
Community outreach
Heat related illness
Temperature threshold

A review of Heat and Health research in India:

Knowledge gaps in building climate change adaptation responses

Prayas (Health Group) :

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May, 2022

आरोग्य, ऊर्जा, शिक्षण आणि पालकत्व
या विषयांतील विशेष प्रयत्न

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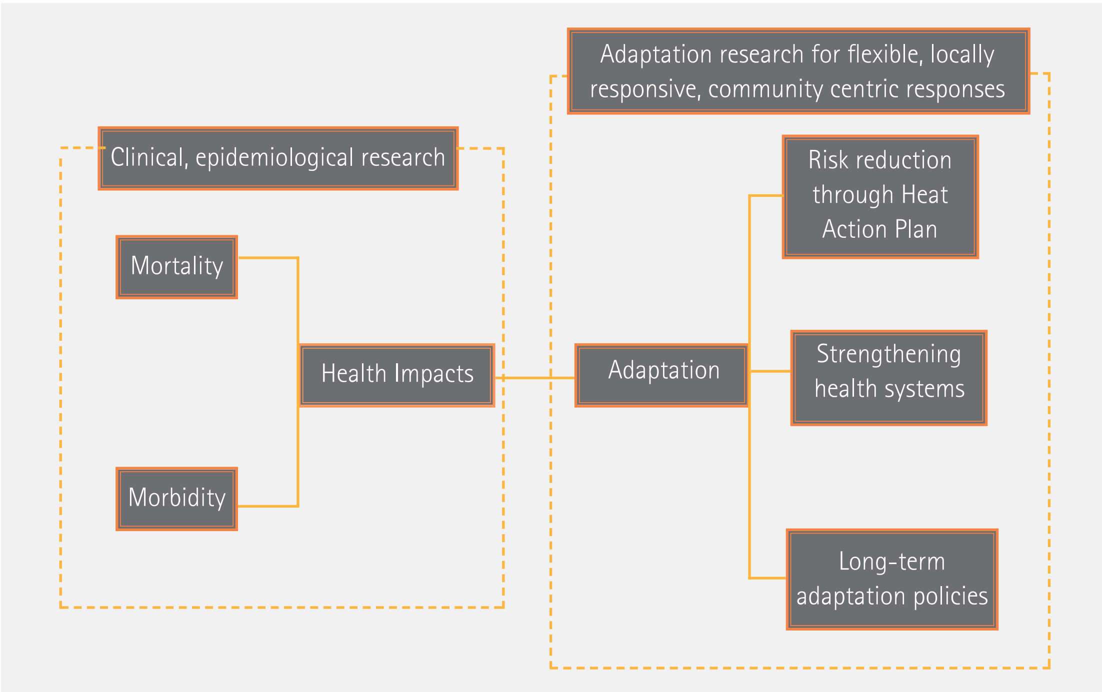
Summary

The recent report by Intergovernmental Panel on Climate Change spells out the high vulnerability of India to the impacts of global warming. The country will likely face rising temperatures and frequent, deadly heat waves in the coming decades. The health hazards, especially among vulnerable populations, can be significant. The situation calls for urgent and widespread actions for heat adaptation. These actions will greatly benefit if backed by ground-level knowledge about the needs and effective solutions.

With this perspective, we undertook a scoping review that aims at identifying gaps in India-specific research on heat-health impacts and adaptation. The review adopts a conceptual framework that considers two thematic domains important for the overall heat-health agenda - A) Research on the burden of heat-related illnesses/ heat mortality and its determinants, and B) Adaptation research, assessed for its potential to create flexible, locally responsive, and community-centric responses.



We searched for peer-reviewed journal articles and grey literature using PubMed, google search, cross-references, and government websites for this review. Given the specific focus of this review, we did not include studies that exclusively described heat stress measurement, bio thermal metrics influencing different health outcomes, and health impacts of extreme cold.

Gap analysis –

Indian research is dominated by studies that aim at understanding the health consequences of extreme temperature. The adaptation research has got very limited focus. We summarize the knowledge gaps below.

Clinical and epidemiological research on heat-health impacts

- The studies assessing the exposure-response relationship between extreme temperatures and mortality describe higher mortality risks at variable temperature thresholds. Analysis of risk factors linked to living and working conditions of people is needed to explain differences in temperature thresholds. There is little understanding of the role of adaptive capacity (type of housing, household ventilation, fans, air conditioning, access to water and electricity, access to health care, etc.) in reducing risk of heat related mortality / morbidity.
- Most studies assessing the burden of heat-related illnesses are from organized sectors or farmers. Studies should include populations from un-organized sectors, given their various vulnerabilities. More robust evidence on productivity losses due to heat is needed. Also, evidence is required on the health risks of indoor heat exposure.
- The evidence on heat-related morbidity is primarily cross-sectional. The self-reporting of heat-related illnesses in these studies raises concerns about reporting bias. Research on the extent/nature of severe heat-related illnesses is scanty.
- The modeling studies to forecast heat-health mortality need to include forward-looking assumptions on population dynamics, demography, and adaptive capacities.

Adaptation research

- The community's knowledge, perceptions, and beliefs about susceptibility to heat determines adopting of the protective health behaviors. Studies to explore these are lacking. Little is known about the community perspective of heat 'vulnerability' drivers. There is a need to identify approaches/mechanisms through which community stakeholders can be involved in vulnerability assessments.
- Pilot evaluation of the Heat Action Plan (HAP), Ahmedabad serves as an important piece of information on the utility of HAP in reducing mortality. However, there is limited evaluation of HAP implemented in other geographic regions and contexts. Whether/how much HAP benefits the most vulnerable communities remains unanswered. Also, information on mortality reductions achieved through HAPs does not provide actionable inputs for course corrections. Non-health indicators such as changes in behaviors, uptake of different interventions get minimal attention in HAP evaluations.
- As part of HAP, early warning systems and public awareness campaigns are implemented. Research aimed at understanding the pathways through which risk communication induces behavior change and the effectiveness of different approaches (e.g. content/mode of delivery) of awareness interventions is needed.
- At the national level, certain structural interventions are being rolled out (cool roofs advocated through the Indian Cooling Action Plan) to reduce heat hazards. Little is known about the feasibility and cost-effectiveness of such structural interventions in reducing adverse health impacts of heat.
- The extent of under-reporting or misreporting of heatstroke deaths remains unknown, raising concerns about health surveillance. There is a need for the availability of disaggregated information on heat-related mortality (by demographic and socioeconomic variables). It is also important to explore how complementary health information sources such as real-time tracking of health indicators, community surveillance, rapid surveys during heat waves, etc., can be developed and implemented successfully.

- The preparedness level of health care providers and health facilities to diagnose and manage heat-related illnesses remains less explored. Limited information about delays in accessing health care and its implications for fatality is available. Studies exploring these aspects are crucial for strengthening health system responses.
- Research on long-term adaptation policies (such as urban development, transport, land use, forest cover, electrification, water access, housing, cooling systems) and their linkages to heat-health is conspicuous by its absence.

This scoping review identifies several research gaps in the available literature from India. To take the research agenda forward, the prerequisite is easily accessible, reliable, and granular multi-disciplinary data. Such data available on unified, integrated platforms will also enhance the designing, monitoring, and evaluation of the interventions.

An important takeaway from this review is that there is very limited focus on adaptation. Prioritizing research on all three prongs of adaptation – risk reduction through community empowerment, health systems strengthening, and long-term policymaking; is crucial at this juncture.

Communities have hitherto largely been passive recipients of adaption interventions. It has been proved in many health interventions that they can be important stakeholders in knowledge generation. Meaningful convergence of researchers, practitioners, and the community will help in flexible, effective, and sustainable adaptation responses. The review can be a stepping-stone to kickoff such a convergence.

Contents

Background

The sixth assessment report by Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2021) was released in August 2021. It warns that the globe will likely reach or surpass 1.5^{0}C of warming by mid-century. It also observes that limiting warming to close to 1.5°C, or even 2°C, will be beyond reach if immediate, rapid, and large-scale reductions in greenhouse gas emissions are not achieved. With continued climate change, processes to adjust to climate change or moderate harms (also termed as adaptation) will also be required.

Climate change impacts human health in many ways. IPCC conceptualized the health impacts of climate change through three primary pathways. 1) Direct impacts, which relate primarily to changes in the frequency of extreme weather, including heat, drought, and heavy rains, 2) effects mediated through natural systems, for example, disease vectors, water-borne diseases, and air pollution; and 3) effects heavily mediated by human systems, for example, occupational impacts, migration, undernutrition and mental stress. It is estimated that between 2030 and 2050, climate change will cause approximately 250,000 additional deaths per year from malnutrition, malaria, diarrhea, and heat stress alone. The estimated costs of direct health impact are between USD 2-4 billion per year by 2030.[1] With this scale of health impacts, the world will need to prepare and plan to cope with this enormous challenge

The diverse pathways through which climate change affects health imply that health and wellbeing impacts would be different for different countries and regions. These will be based on the geographic conditions, diversity in the ecosystem and human systems, the baseline prevalence of diseases, and the preparedness of health systems to identify and respond to different health issues. Therefore, health adaptation plans and policies would also need to be contextual.

India released the National Action Plan on Climate Change (NAPCC) with eight missions in June 2008. In 2015, India's response to climate change was broadened by introducing four new missions, including the Health mission. The National Action Plan for Climate Change and Human Health (NAPCCHH) was developed to provide a policy framework to protect the health of citizens of India against climate-sensitive illnesses. NAPCCHH seeks health adaptation plans for common climate-sensitive diseases (CSDs). A National Programme on Climate Change and Human Health (NPCCHH) was initiated in February 2019 under National Health Mission.

Given the alarming rise in temperatures in the recent past and worrisome predictions, the heat health conditions get priority attention in NPCCHH. (National Centre for Disease Control, Ministry of Health and Family Welfare, New Delhi, India & Shrivastava, 2020). India is one of the five countries with the highest exposure to extreme heat. During 2016-2020, there were, on average, 444 million more days of heatwave exposure of people over 65 years of age annually, compared to a 1986-2005 baseline. (Romanello et al., 2021) A report by the Union Ministry of Earth Sciences states that in a business as usual scenario of global emissions, India's average temperature will rise by 4.4°C (39.9°F) by 2100, while heatwaves will multiply by a factor of two or three and their duration will double compared to the 1976-2005 period. (Krishnan et al., 2020) Some areas within

1. https://www.who.int/health-topics/climate-change#tab=tab_1

the country are already getting exposed to deadly heat stress conditions, even at the current warming levels. Their occurrences with larger geographical footprint are projected to become commonplace even at the 1.5°C Paris Agreement temperature rise. Risks at 2°C warmings would be about twice as high compared to 1.5°C (Saeed et al., 2021).

Extreme temperatures pose several health risks, ranging from heat rash, heat edema, heat tetany, heat cramps, heat syncope, heat exhaustion, and heatstroke. (Ministry of Health and Family Welfare, Government of India, 2021) They also affect by putting strain on cardiovascular, respiratory, and renal system functioning. Individual attributes such as old age and underlying health conditions increase vulnerability to heat. (Li et al., 2015) In addition, there is also evidence of its impact on poor mental health outcomes (Liu et al., 2021) and external causes of death such as interpersonal violence, self-harm, drowning, and injuries. (Burkart et al., 2021) Physiological adaptation (or acclimatization) and adaptive capacity (such as household ventilation, fans, air conditioning, water) protect against health risks. However, there are limits to physiological acclimatization.

The determinants of heat health impacts - exposure, adaptive capacity, and population sensitivity - vary widely across regions and populations. Vigilant monitoring and flexible adaptation responses will be needed to tackle it. There is little room for adopting this approach in current systems, which function top-down. Involving communities becomes of paramount importance in such a situation. The central issue then becomes - how to involve people, activate them, inform them in a manner so that they take action.

The heat health adaptive responses in India are still in their early phase. A better understanding of knowledge gaps and needs would be valuable in prioritizing actions and setting the context for future research. We undertook a review of India-specific research on heat-health impacts from this perspective. The overall purpose of this scoping review was to gauge the focus of existing research and understand how it feeds to adaptation actions.

Report Outline –

- The Approach section describes the conceptual framework used to review the literature and review methods.
- The Findings section summarizes salient findings on
    - Evidence around heat-health impacts in India
    - Evidence around adaptation responses in the Indian context – (includes an overview of risk reduction responses through heat action plans and evaluation research; an overview of health adaptation actions initiated by the health department and research on health system strengthening, research that explores inter-linkages of long term policies and heat health impacts)
- The Research Gaps section discusses the knowledge gaps assessed through the proposed framework. The section also lists down some of the potential research questions.
- Way Forward
- Appendices section provides details of reviewed studies. The Appendices are available on the Prayas website.

Approach

The following framework was used to undertake this scoping review. We considered two thematic domains that are important for the overall heat-health agenda – health impacts due to heat and heat health adaptation

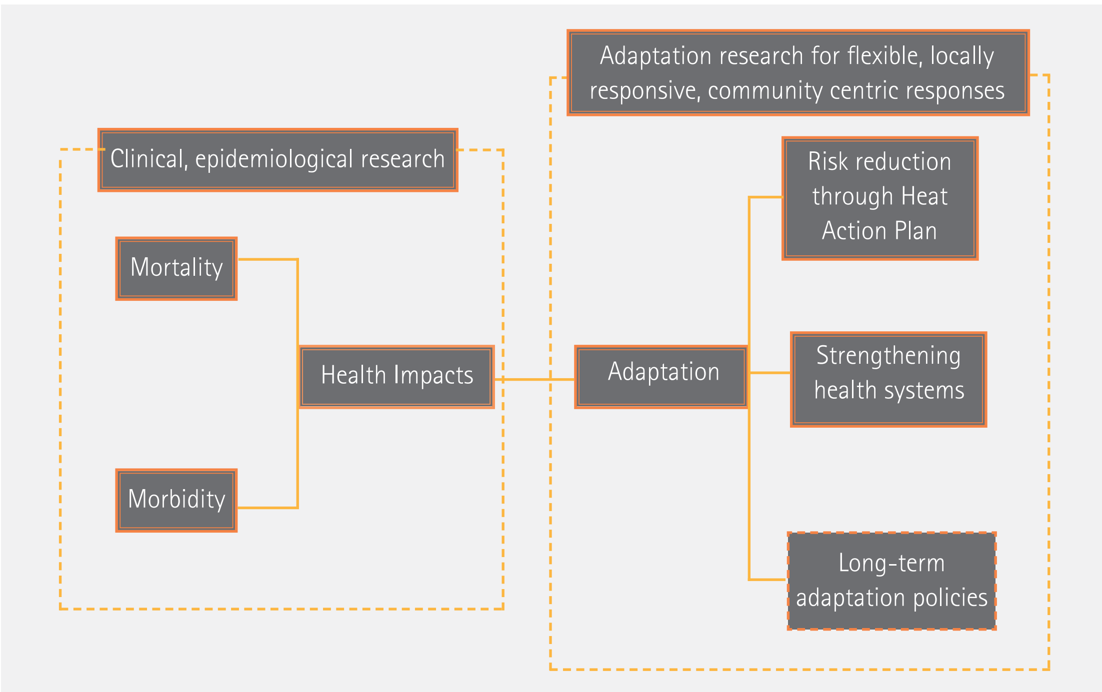
A. Clinical and epidemiological research was reviewed to understand the extent of the heat-health burden in India, its variability across geographies, and its determinants

B. The adaption research was assessed on its potential to create flexible, locally responsive, and community-centric responses. We assessed if and how the existing research informs the adaptation actions/strategies at the following levels.

   1. Risk reduction through Heat Action Plans – Heat action plans aim to reduce the risk of exposure to extreme heat and reduce the risk of experiencing adverse health conditions due to heat. There are different components of HAP, such as early warning systems, vulnerability, and adaptive assessments, public awareness and community outreach, institutional mechanisms for risk reduction, etc.

   2. Strengthening health systems – This includes actions related to heat and human health surveillance, efforts to increase the capacities of health providers to diagnose and manage heat-related illnesses, health infrastructure preparedness, and efforts to improve health care access.

   3. Long-term adaptation policies– Sectoral policies that have implications for heat exposure and adaptive capacity play an important role. Policies related to urban development, land use, forest cover, electrification, water access, housing, cooling systems, and occupational health are essential in this context.



We identified relevant knowledge gaps through the above-mentioned conceptual framework. We also attempt to give pointers to further exploration by highlighting pertinent research questions, data points to be captured, and data access mechanisms.

The following table provides an overview of included literature relevant to the thematic domains described above.

Domain	Subdomain		No. of studies	Study locations
Clinical and epidemiological research on heat-health impacts	Heat-related mortality (N=22)	Historical trends in heatstroke deaths in India	4	Country-level analysis
		Risk of heat-induced mortality and vulnerable populations	15	City-level analysis From states –Maharashtra, Gujarat, Rajasthan, Uttar Pradesh, Odisha
		Future projections of heat mortality	3	State or city level projections Located in diverse climatic regimes in India
	Heat-related morbidity (N=17)	Studies among the working population	11	Study locations from states - Tamil Nadu, West Bengal, Gujarat
		Studies among urban and rural households	4	City/village level analysis from states - Odisha, Maharashtra, Gujarat
		Studies among hospitalized patients	2	Study locations from states - Tamil Nadu, Andhra Pradesh
Adaptation research	Risk reduction through Heat Action Plans (N=4)	Studies on early warning systems	1	City-level analysis From states –Maharashtra, Gujarat
		Studies on population-level vulnerability and adaptation assessment	1	Country-level analysis (taking district as a unit)
		Studies on the effectiveness of heat action plans or their components	2	City of Ahmedabad, Gujarat, and the state of Odisha
	Strengthening health systems (N=0)	-	0	-
	Long term adaptation policies (N=0)	-	0	-

Review methods

Relevant articles were searched using PubMed and Google search. We also identified articles through cross-referencing and by searching government websites. We looked for peer-reviewed journal articles as well as grey literature (published during the last decade, until December 2021). Being a scoping review, we did not focus on comprehensive searches from different databases.

India-specific studies describing heat-health impacts, its burden and associations, and health adaptation were included. We excluded the studies assessing heat exposure or heat stress but not linking it further to health impacts. Given the review's focus, we did not assess bio thermal metrics influencing different health outcomes.

We did not include studies about the health impacts of extreme cold for this review, as public health relevance of extreme cold is low for India. Only a few regions in India face very low temperatures. Also, as per IPCC predictions, the drop in temperatures (extreme cold) appears to be less likely a phenomenon for the country.

Findings

Section A: Clinical and epidemiological research on heat-health impacts

Heat-related mortality

India-specific research on heat-related mortality was categorized into the following broad themes- 1) Historical trends in heatstroke deaths (deaths due to exertion under direct sunlight, under extreme temperatures). 2) Risk of heat-induced mortality and its correlations (all-cause or cause-specific mortality such as cardiovascular and respiratory mortality used as a health outcome measure), and 3) future projections of heat-related mortality.

Historical trends in heatstroke deaths in India

These studies (n=4) have analyzed retrospective data on heat-specific deaths. Deaths due to exertion under direct sunlight were considered heat-specific deaths. Secondary data, regularly reported by the Indian meteorological department (regional offices) or other government sources, was the common source of information. These sources collect information on all extreme weather events and fatalities caused by them, including heatwaves.

The trend analysis studies reported annual/decadal heat-specific death counts or mortality rates over time without correlating them with temperature changes. Some studies have also analyzed the pattern of heatwave events. These mainly were country-level analyses, with a few studies examining state-level differences. The retrospective data spanned over a range of the past 15 to 50 years.

Findings

Over the years, the frequency, intensity, and duration of heatwaves were consistently rising all across the country. In contrast, the heat-specific fatality counts/rates show a spiked zig-zag pattern. Some years have recorded as high as 1500 deaths, while others recorded only a few. More recent years (the last two decades) show higher heat fatalities (Kumar & Singh, 2021). However, analysis spanning more extended periods shows no discernible rise or fall.

The state-level variation in reported deaths is starkly skewed, with only a few states (such as Andhra Pradesh, Telangana, Rajasthan, Odisha, Punjab) contributing majorly (Mallik et al., 2021). In states other than these, mortality rates due to other extreme weather events (such as flooding, lightning, and cyclonic storms) are much higher than heat-related mortality rates (Ray et al., 2021).

The studies also highlight the age and gender differences. Among the reported deaths, the proportion of working-age populations and men was much higher.

(For more details, see Appendix A-1: Historical trends in heatstroke deaths in India)

Risk of heat-induced mortality and vulnerable populations

The studies estimating the risk of heat-related mortality (n=15) can be broadly divided into two categories based on the analysis approaches. One was an ecological analysis of excess mortality. Under this analysis approach, the reported number of deaths during months of heatwaves for a particular year, as compared to those during the same months of earlier or later years. Excess mortality was considered to be attributed to the heatwave. These studies were done a decade back in cities known for attaining very high temperatures during summer (such as Nagpur, Ahmedabad).

The second approach commonly used was a time series analysis to assess the relationship between daily temperatures and daily mortality in a specified area. The risk was calculated using contrast measures such as temperature thresholds (varied criteria used for defining the thresholds) or temperature gradient (e.g., per degree increase in temperature). Most of these studies were located in cities in central or Northern India.

Outcome and exposure variables

The heat-related mortality risk was analyzed mainly by using all-cause mortality as a health outcome. More recent studies have used cause-specific mortality such as stroke, respiratory diseases (Fu et al., 2018), and non-infectious diseases (Ingole et al., 2012, 2015, 2017). Daily temperatures (maximum, minimum, average), heatwave as defined by different temperature thresholds, and duration were the commonly used exposure variables. Some studies also additionally considered relative humidity.

Disaggregated analysis

Age and gender were the most common covariates used to assess subgroup vulnerabilities. Only a few studies also looked at differences in mortality across residential location, ownership of agricultural land, house type, education, and occupation.

Findings

The ecological analyses document substantial all-cause mortality excesses during heatwave months than non-heat wave months. E.g., a study from Ahmedabad found 43.1% increase in all-cause deaths during May 2010 heatwave (G. S. Azhar et al., 2014). Another study from Nagpur found 30% and 14% extra-mortalities due to heatwaves in 2010 and 2014, respectively. (P. Dutta et al., 2020) The study locations were cities experiencing very high temperatures during summer. The observed findings imply risk despite the possible acclimatization of city dwellers to high temperatures.

(Appendix A-2– Risk of heat-induced mortality and vulnerable populations - ecological analyses)

The time-series analyses observed a non-linear association between temperature and all-cause mortality. The mortality risk spiked acutely at higher temperatures. The temperature thresholds at which mortality risk increased significantly varied across studies. E.g., the study from Ahmedabad found a substantial and significant increase in mortality rate starting from maximum temperature at 42° C (One degree temperature rise increased the risk by 9.56%) (Wei et al., 2021). The study from Varanasi found small mortality risks till 35°C. However, the risk increased by 21% for a daily maximum temperature above 37°C. (Singh et al., 2019) The study from a rural part of the Pune district (Vadu) found that temperature above a threshold of 31°C was associated with higher mortality (a one-degree increase in daily mean temperature increased the odds of mortality by 48%)

The studies used variable age brackets for dis-aggregated analyses. Some studies have used very wide age intervals, such as 5-44 (Singh et al., 2019) or 15-67 years (Ingole et al., 2017). The magnitude and significance level of age-specific mortality risk differed across studies. However, a common finding was the highest mortality risk among people over 65 years old ((Fu et al., 2018;

Singh et al., 2019; Wei et al., 2021). The younger age group (< 5years) was studied in only two studies and was found to have higher vulnerability. A study from a rural area did not see age as a significant risk factor. (Ingole et al., 2017). There were differences in gender analysis as well. The study by (Wei et al., 2021) found similar risk ratios for men and women; two other studies (Ingole et al., 2017; Singh et al., 2019) revealed higher vulnerability among women. These studies also report higher mortality risks associated with poorer socio-economic conditions as reflected by residential location, educational level, and occupation. A study by (Wei et al., 2021) also observed temporal heterogeneity. Compared to 1987-2002, later years (2003-2017) saw a lower mortality risk. The authors conclude that this could result from infrastructure, technological, behavioral, or physiological adaptation, or temporal differences in the population characteristics such as age structure, education, housing, access to health services, etc.

(For more details, see Appendix A-3 – Risk of heat-induced mortality and vulnerable populations - time series analysis)

Future projections of heat mortality

We found three studies that forecasted mortality due to an increase in heat waves in the future. A commonly used approach was calculating temperature-mortality relationships using historical all-cause mortality and heatwaves/temperature data. The estimated coefficient was then applied to the forecasted temperature to estimate mortality. There was less clarity on the assumptions used, particularly regarding changes in population dynamics.

Findings

The projection modeling studies on future heat mortality show a bleak picture. All the studies indicate a significant increase in mortality. However, the projected range of increase in mortality significantly differed across studies. Differential impacts were also predicted across places in India, with more significant increases in death rates in the northwest or southeast. (Climate Impact Lab, 2020).

(For more details, see Appendix A-4 – Future projections of heat mortality)

Heat-related morbidity

Most of the research on heat-related morbidity was in the form of surveys undertaken at workplaces to understand the burden of heat-related illnesses. Only a few were among rural and urban households.

Studies among the working population

The studies looked at occupational sectors such as brick kilns, steel industry, construction, migrant workers, traffic police, and agriculture. These were mostly cross-sectional assessments from southern states. They looked at the level of heat exposure at workplaces, loss of productivity, and the accompanying health issues. (n=11)

Health outcomes assessed

These studies collected information on health outcomes in the form of self-reported signs/symptoms (such as excessive sweating, thirst, tiredness, cramps, headache, nausea/vomiting, loss of appetite, fainting, or prickly heat/rashes). Many studies also conducted laboratory testing to assess renal function (glomerular filtration rate, urine specific gravity, renal ultrasound), cardio-vascular strain (pulse rate, blood pressure), and heat stress (core body temperature, sweating rate). Heat exposures were measured using a range of thermal indices, productivity was measured, in most of the studies, as perceived by the worker (e.g., perceptions about not achieving targets, taking longer time to complete tasks, loss of wages, absenteeism) (Krishnamurthy et al., 2017; Venugopal et al., 2015). Only one study calculated changes to productivity by actual measurement of tasks (Sett & Sahu, 2014).

Findings

Exposure of workers to temperatures exceeding recommended threshold limit values was a common finding. Substantial proportions of workers were observed to experience heat-related signs and symptoms and loss of productivity. These proportions varied widely across studies. Workers reported a range of mild to moderate symptoms - such as heavy sweating, intense thirst, dry mouth, headache, fainting, abdominal cramps, loss of coordination, dizziness, and blurred vision.

Occupational conditions such as direct exposures, long-term exposures, and moderate to high-intensity work were associated with higher reporting on heat-related symptoms. The physiological strain was observed to be more in the summer season. It was positively associated with heavy workloads and a longer duration of exposure (5 years and above). The type of job also mattered. (E.g., a study among female brick workers showed that cardiovascular strain was more in brick stackers or those carrying raw mud activities than brick molders and carriers. Frequent posture changes possibly impose extra load on the cardiovascular system. (B. Das, 2018) Gender also had a role to play. Men were more likely to be involved in heavy work in most occupations and therefore were more affected (Venugopal et al., 2021). Women reported that they had limited time to rest and take breaks due to the additional responsibility of household chores. In a study (Venugopal et al., 2016) among migrant construction workers, women reported a lack of access to toilets, leading to reduced water intake and increased holding time. This could have been an aggravating factor in the presence of heat stress. A large proportion of women (46%) in this study reported urinary tract infections and burning sensation while urinating.

Very few studies focused on adaptation. A study among traffic police (Raval et al., 2018) describes individual-level coping behaviors like drinking water, use of headcover, etc. However, the effect of such behaviors in reducing heat illnesses was not assessed. A qualitative inquiry by Dutta et al,(P. Dutta et al., 2015) among construction workers points to a lack of resources to protect workers from heat stress. Some studies have proposed workplace-level adaptation strategies. E.g., A study by Raval et al. (Raval et al., 2018) specifies the need for systemic level changes such as staggering duty hours, provision of appropriate personal protective gears, and rest places. A study among brick kilns workers highlights the need for identifying appropriate technological solutions rather than high-tech solutions. It also argues for a more participatory socio-culturally informed localized decision-making. (Lundgren-Kownacki et al., 2018).

(For more details, see Appendix A-5 – Heat morbidity studies among the working population)

Studies among urban and rural households

The evidence is mainly in the form of cross-sectional studies (n=4) among urban and rural households from areas known for very high temperatures during summertime. Two of these studies were based in remote villages in eastern Maharashtra. A study from Ahmedabad city, Gujarat, was specifically in the slum population. Another study from Bhubaneshwar and Cuttack city, Odisha, included both slums and non-slum populations. It selectively included individuals who spend most of the time indoors (e.g., women who do not perform outdoor work, pregnant/lactating women, older people (>60 years), children (<5 years), persons with disabilities, students, etc.

Study Outcomes

These studies looked at the prevalence of self-reported heat-related symptoms among household members, assessed the risk factors, and described adaptive behaviors at the individual or household level.

Findings

Across studies, the proportions reporting at least one heat-related symptom/illness varied from approximately 20 to 50%. The observed symptoms were mostly mild to moderate in nature and did not differ across areas (rural, urban non-slum, urban slum). In two studies, the symptom/illness reporting was higher among older people (>65 years). However, these studies did not observe a higher risk among young children. In some studies, men were reported to be at higher risk, but the confounding due to older age, outdoor work requirements, or pre-existing illness could not be ruled out. Pre-existing chronic diseases were reported as a risk factor by the majority of the studies. Notably, a substantial burden of pre-existing illnesses was seen irrespective of the study area.

People engaging in outdoor work (farm labor, MGNREGA labor) had a higher risk of heat-related illness. The risk increased for work that entailed direct exposure to the sun for a longer duration. Many households from slums and the rural area had tin roofs, and this factor, along with lack of cross ventilation, was associated with more reporting of heat symptoms. A study (Tasgaonkar et al., 2018) observed that the indoor temperature in houses with tin roofs is higher throughout the day than RCC roof houses; it even exceeds the outdoor temperature. Lack of regular electricity supply also had a positive association but was not statistically significant. The evidence also pointed at how heat exposures (and consequently chances of heat illnesses) increased at lower rungs of class-caste-education dimensions.

These studies also describe many adaptive behaviors. At an individual level, several practices were described - to keep hydrated (e.g., drink plenty of water), reduce longer/direct exposures to the sun (e.g. taking breaks, wearing protective clothes), etc. Practices such as water spraying, fans, coolers, covering the roof by crop residues, or painting roofs were adopted to reduce indoor temperatures. The use of one or more practices was found to have protective effects. However, there were economic barriers, and difficulties with access to water and electricity. It also had a gender dimension. For example, finding time to rest was a challenge for women having responsibilities at home and in the fields (Pradyumna et al., 2018). Media (TV, radio, newspaper) or a medical professional was vital for heat stress information. People experiencing heat-related symptoms appeared to have consulted health care providers (Pradyumna et al., 2018; Tran et al., 2013). Only one study described the role of social capital in coping with heat stress (such as having a positive relationship with neighbors, reliance on neighbors in time of need)

(For more details, see Appendix A-6 – Heat morbidity studies among urban and rural households)

Studies among hospitalized patients

These were (n=2) descriptive accounts of patients hospitalized for heat-related illnesses. They indicate multi-systemic involvement (neurological, renal, hepatic, coagulation abnormalities). Fever and neurological impairment was the most common presenting symptom. Mortality risk was observed to be very high (34%).

(For more details, see Appendix A-7 – Heat morbidity studies among hospitalized patients)

Section B: Adaptation responses

Risk reduction through heat action plans

Overview of heat action plans

India's adaptation responses to moderate heat-health impacts get primarily implemented through heat action plans (HAPs). India's adaptation responses to moderate heat-health impacts get primarily implemented through heat action plans (HAPs). The HAPs aim to reduce the health burden through issuing health warnings, encouraging planning and coordination across different sectors and departments, increasing public awareness, building capacities of health care providers, and raising resources to tackle the health impact of heat. Other key focus areas are strengthening health systems and ensuring timely health care access for heat-related illnesses.

The first heat action plan in South Asia was developed for the city of Ahmedabad, India, in 2013. The plan was developed through collaborative efforts from the city Municipal Corporation, academic institutions, and international organizations. A rigorous research-based approach was adopted to identify vulnerable communities and set up early warning systems while developing the action plan. Some of the key lessons on developing this local level HAP were - involving local administration, using local-level health and temperature data and monitoring, and evaluating implementation and impact. (National Disaster Management Authority, 2019)

In 2016, National Disaster Management Authority (NDMA) formulated the National Guidelines for preparing action plan-prevention and managing heatwaves to scale up the efforts to build heat resilience across India. The guidelines were revised in 2019. These guidelines aim to help states and cities to prepare HAP appropriately to address the local needs. NDMA is working with 23 highly vulnerable states and more than 130 districts/cities to develop heat action plans. (Natural Resources Defense Council, 2020) Several states and cities have their HAPs in place.

These are expected to lay out the plan for government engagement, describe state nodal agencies for coordinated efforts between different ministries and departments and across various organizations, and mention the roles and responsibilities of these departments. They are also expected to conduct geographic and population-level vulnerability assessments in the region through primary and secondary research. The state actions plans for Odisha (2020), Gujarat (2020), Telangana (2021), Andhra Pradesh (2020), Karnataka (2018), Haryana (2019), and Himachal Pradesh (2020) are available in the public domain. The city action plans are available for Ahmadabad, Gorakhpur, Hajaribauj, Patiala, Surat, Vadodara, and Vijayawada.

Typical state and city-level heat action plan contains information on heatwaves in India and the state, heat warning and communication, health impacts of heatwaves and how to prevent them, different departments and their roles and responsibilities in managing them, and examples of educational material for public awareness. Very few action plans (for example, Odisha) mention research conducted to identify regional temperature threshold analyzed using local mortality data. In addition, most of the action plans do not provide information about the vulnerable population in the region (other than known categories such as elderly and pregnant women, etc.) and actions specifically tailored to meet the needs of these vulnerable populations. IMD and NDMA have commissioned studies to identify percentile-based thresholds for 100 districts.

Research on population-based vulnerability and adaptation assessments

We found one study that assessed population-level vulnerabilities to heat. This study developed a district-level heat vulnerability index using demographic, socio-economic, and environmental vulnerability factors. Combined district-level data from several sources, including the most recent census, health reports, and satellite remote sensing data, was used. Principal component analysis (PCA) was applied on 17 normalized variables for each of the 640 districts to create a composite Heat Vulnerability Index (HVI) for India.

Findings

Of the total 640 districts, 10 and 97 were identified in the very high and high-risk categories, respectively. Mapping showed that the districts with higher heat vulnerability are located in the central parts of the country. These were less urbanized and had low literacy rates, access to water and sanitation, and the presence of household amenities. The index needs validation by heat exposure and health outcome data.

(For more details, see Appendix B-1: Studies on population-based vulnerability and adaptation assessments)

Research on Early Warning Systems

There was one study that specifically aimed at determining the temperature threshold in the city of Nagpur and Rajkot city for the effective implementation of an early warning system. City-specific data on daily maximum temperature and all-cause mortality data were used. World Meteorological Organization- World Health Organization (WMO-WHO) recommended percentile-based method was used to determine maximum temperature thresholds for summer heat early warning systems. It set 75th, 85^{th}, and 95th percentile values of maximum temperature as yellow, orange, and red alert thresholds.

Findings

The study notes association between all-cause mortality and extreme heat events, which was more profound at temperatures > 40.1°C. The temperature thresholds at which the warning system needs to be activated differed for each city (e.g., the threshold to activate red alert was 46°C and 44°C for Nagpur and Rajkot city, respectively). The authors also identify the need for the involvement of local stakeholders in decision-making around identifying the thresholds.

(For more details, see Appendix B-2: Early warning systems)

Research on the effectiveness of heat action plans or their components

The published literature on the evaluation of HAPs is scant. There were two studies; both considered mortality reduction as an evaluation outcome.

The study from Ahmedabad (pilot evaluation of Ahmedabad heat action plan) (Hess et al., 2018) evaluated the efficacy of the intervention - Heat Action Plan (HAP) in Ahmedabad implemented during 2014-15. The HAP comprised a suite of interventions such as educational campaigns, heat early warning system, pre-hospital setting preparedness, clinics, hospitals, and other interventions. The study used a pre-post (intervention) design. The efficacy was measured to reduce the risk of summertime all-cause mortality.

The other study was from Odisha (S. Das & Smith, 2012) defined as an interval of abnormally hot and humid weather, have become a prominent killer in recent years. With heat waves worsening with climate change, adaptation is essential; one strategy has been to issue heat wave warnings and undertake awareness campaigns to bring about behavioral changes to reduce heat stroke. Since 2002, the Indian state of Odisha has been undertaking a grassroots awareness campaign on \"dos and don'ts\" during heat wave conditions through the disaster risk management (DRM) and assessed the impact of the grass-root awareness campaign undertaken in Odisha during 1998-2010 as a part of the disaster risk management program.

Findings

Extreme heat and HAP warnings after implementation were associated with decreased summertime all-cause mortality rates, with the largest declines at the highest temperatures. (RR = 0.95 (0.73-1.22) for maximum temperature > 40°C, and RR= 0.73 (0.29-1.81) for maximum temperature > 45°C). An estimated 1,190 (95% CI 162-2,218) average annualized deaths were reported to have been avoided in the post-HAP period. The study could not account for the confounders, such as air pollution, demographic shifts or changes in living conditions, etc. Individual components of the HAP were not assessed. This evidence has been a key input in designing and planning heat action plans at the national level.

The pilot phase of the Ahmedabad heat action plan, through qualitative methods, also documented some implementation barriers. The qualitative data indicates that there was less appreciation by the community that heatwaves are likely to increase and intensify with global warming. Screening for heat-related illness was not a routine practice by health care providers, and there was difficulty in reaching some of the most at-risk populations, such as slum residents. (Shah, 2015)

As observed in the study from Odisha, awareness campaigns were found to reduce mortality. A complementary effect was observed between the grassroots awareness program and concurrent media campaign. The study did not assess the effectiveness of different awareness media in changing 'peoples' behavior.

(For more details, see Appendix B-3 – Studies on the effectiveness of heat action plans or their components)

Strengthening health systems

Overview of health adaptation actions

In 2015, the MoHFW issued guidelines on the prevention and management of heat-related illnesses (HRI). Integrated Disease Surveillance Programme (IDSP), MoHFW was collecting and compiling the data on HRI and deaths due to HRI from April – July (March to July since 2019) every year from the heat vulnerable states. "National Action Plan on Heat-Related Illness" was prepared in July 2021, with the addition of a chapter on HRI in paediatric age group, hospital preparedness plan, new surveillance formats and its standard operating procedures and guidelines for investigation of suspected HRI deaths. The surveillance formats were revised to capture heatstroke cases instead of HRI and capture deaths due to suspected/confirmed heatstroke, deaths due to cardiovascular diseases (CVD) and all-cause deaths instead of suspected/confirmed HRI deaths

Research on strengthening of health systems

We did not find any literature on heat and human health surveillance, preparedness of health care providers or health infrastructure, or access-related issues.

Long term adaptation policies

It was beyond the scope of this review to undertake an in-depth assessment of long-term policies (such as urban development, land use, forest cover, electrification, water access, housing, cooling systems, and occupational health). In our search focused on heat health impact, we did not find any studies that explored inter-linkages of such policies and heat health impact.

Research Gaps

A. Clinical and epidemiological aspects of heat-related health impacts

Attributable risk of heat-related mortality and risk factor analysis

Most of the studies analyzing the risk of mortality due to extreme heat are based in cities in northern or central India. Representation of rural areas and southern states is conspicuously low. Variable temperature thresholds are observed at which the risk of mortality significantly increases. It is less clear why these differences exist. Whether similar variation in temperature thresholds will exist within a city, given inequities within cities (in adaptive capacities, heat exposure, and sensitivity of populations), remains unknown.

Most of the risk factor analysis is restricted to age and gender dis-aggregation. The age-specific analysis becomes challenging to interpret with variation in age brackets used in different studies. The studies provide evidence about higher risk among the elderly population. However, vulnerabilities of the young age group (< 5 years) remain unclear and need further exploration.

The vulnerabilities arising from socio-economic conditions, educational attainment, housing types, type of occupation, and neighborhood/locality remain unexplored in existing heat health literature. The existing studies are based among vulnerable populations (e.g. slums). However, their vulnerability as compared to the control group remains less understood. This knowledge will provide valuable inputs to infrastructure planning - an important aspect of heat adaptation over the long term. The assessment of intersectionality or marginalization at multiple levels (e.g., old-age women living in slums) is also missing in current studies. The studies do not explore the role of effect modifiers such as the level of air pollutants.

Heat-related illnesses and their prevalence in different subpopulations

All of the existing evidence from India on heat-related illnesses is cross-sectional. The single-point assessments do not throw any light on the possible temporality of heat-related illnesses. The health conditions and productivity losses within these studies are self-reported, raising concerns about reporting bias.

The studies based among the working population, by design itself, are biased to include a healthy working-age population. Some of them have excluded people with existing chronic diseases. These, therefore, are not very useful to assess the extent/nature of severe heat-related illnesses.

Most evidence comes from the organized sector (industries) or farmers. Un-organized sectors that are at higher risk of exposure to extreme heat (such as daily wage laborers, construction workers, street vendors, etc.), populations with unique vulnerabilities (such as old age homes, homeless) have limited/no representation in current literature. Minimal evidence exists on the burden of heat-related illnesses among indoor populations with higher vulnerability (old age, pre-existing conditions) or poor adaptive capacity.

Projections of future heat health burden

Climate change, in general, is expected to influence migration and urbanization in the future. These macro-level changes will further affect heat exposure and adaptation processes. For example, urbanization would increase the proportion of populations exposed to heat. The heat-health vulnerability of those who migrate and stay back is likely to be inequitable based on their access to infrastructure and technology. The burden of non-communicable diseases is on the rise in India. Along with the aging population, this can adversely impact the heat-health burden. On the other hand, acclimatization (physiological, behavioral, infrastructure, technology) provides protection from heat-related deaths. The current projections of heat-health impact do not appear to consider such forward-looking changes to population dynamics, demography, and adaptive capacities.

Table A-1: List of Potential research questions related to clinical and epidemiological aspects of heat-related health impacts

	Attributable risk of mortality due to heat	**Heat-related illnesses**	**Projections of future heat health burden**
Clinical and epidemiological aspects of heat-related health impacts	Understanding the role of adaptive capacity (type of housing, access to water and electricity, access to health care, etc.) in reducing heat-related mortality in urban and rural areas What is the risk of mortality due to indoor heat exposure, and which factors (socio-demographic, economic, medical, material, etc.) affect this risk? Understanding the combined health effect of rising temperature and other climate-sensitive stressors such as air quality, extreme weather events	Characterization of moderate and severe heat-related illnesses and their burden among vulnerable populations (those at higher risk of heat exposure, those with higher heat sensitivity, and poor adaptive capacity). Understanding physiological adaptation with exposure to significant fluctuations (variability) in temperatures	Modeling projections based on robust assumptions on demographic, epidemiological, and adaptive capacity parameters

B. Building flexible, locally responsive, community-centric adaptive responses

Risk reduction actions to protect from extreme heat

Early warning systems

Under heat action plans, warnings are issued by IMD when a particular temperature threshold is crossed. These warnings are valid for the next four days. The national guideline document recommends that cities estimate the heat-health threshold for their region to determine early warning. The document also provides an approach of correlating daily maximum temperature with daily mortality data (over 10-15 years) for dry and arid regions. However, the majority of the HAPs at the state and city levels do not have information about this

Knowledge about how heat warnings are acted upon is important. Extreme temperature creates discomfort, and people generally take adaptive actions taking cues from the level of discomfort. Modulating one's decisions and behaviors based on weather updates could still be a modern concept for Indian communities. People may be more tuned to rely on their judgments and past experiences for protection from temperature. It is necessary to understand how early warning systems harness the process of decision-making.

A systematic review on the 'Effectiveness of heat warning systems (HWS) in saving lives and reducing 'harm' concluded that the mere availability of HWS did not lead to behavioral changes. The review reported that the perceived threat of heat dangers to self/others was the main factor related to heeding warnings and taking proper actions (Toloo et al., 2013). Additionally, the kind of actions required at a particular temperature would vary across sectors and populations, based on the level of heat exposure in that setting, heat vulnerability of the people, and adaptive capacity (e.g., access to air conditioning, etc.). Currently, early warnings through HAP provide a set of blanket recommendations. Whether and how people apply these to specific contexts needs more exploration.

Equitable outreach of communication about early warning (risk communication) to the most vulnerable sections of society; acknowledging and addressing barriers such as illiteracy, digital divide, and language are essential while developing dissemination plans. Studies that assess communities' perceptions about the risk communication itself can provide helpful insight into the process.

The research so far does not delve much into the above aspects.

Vulnerability and adaptive assessments

Vulnerability and adaptive capacity assessment (VAA) are essential components of heat action plans. However, the majority of the HAPs do not report assessments of populations that are most vulnerable to heat. Heat vulnerability assessments based on the geographical distribution of heat exposure can help geographical prioritization for action. But these may not adequately flag the populations at higher risk. A study by (G. Azhar et al., 2017) has proposed a composite Heat Vulnerability Index comprising demographic, socio-economic, and environmental vulnerability factors. However, the proposed index lacks validation with health outcomes. Such district-specific indices pertain to socio-economic development and access to basic amenities. These inform long-term planning to improve adaptive capacities at the district level. However, expanding the scope further, the VAAs also need to assess social capital and safety net mechanisms at the community level.

The vulnerability indicators are often based on epidemiological evidence of risk factors or drawn through expert consultation (G. Azhar et al., 2017). The community perspective of 'who is 'vulnerable' or drivers of heat 'vulnerability' often gets lost in the discourse around vulnerability. This process is essential for identifying vulnerable populations and intervening to influence collective understanding and action.

Studies on heat-related morbidity provide information about heat exposure and vulnerabilities of organized work sectors. More studies are needed among workers from the unorganized sector (e.g., construction workers, street vendors, waste pickers, drivers, manual laborers), sportspersons, people working in poorly ventilated indoor workspaces, uniquely vulnerable populations (e.g., old age homes, homeless) and among populations with overlapping risk factors (e.g., elderly urban poor).

HAP currently gets operationalized through a top-down decentralized mode. The district or city is a primary unit of implementation. The local realities of vulnerability are likely to differ not just between districts but within districts too. (e.g., a village/town gets a high number of temporary migrants for construction during a particular summer season.) This will remain uncounted and unaddressed in current systems. A system that allows flexibility in collecting indicators of vulnerabilities as per local context would do more justice in such a situation. More exploration of mechanisms that can be harnessed for this cause (e.g., panchayat raj, community surveillance) is needed. Guidance on an optimal and essential list of vulnerability indicators, which can further be adapted to the local context, will be helpful.

Public awareness and community outreach

Raising awareness about heat-health hazards and their prevention is a necessary step for bringing behavioral change at the community level. But the mere provision of information may not be sufficient. Building appropriate perceptions about one's susceptibility to severe heat-related illnesses, perceived ability to take protective actions, and strengthening access to support systems are also needed. The awareness level and perceptions are likely to vary across regions, based on heat stress levels in the past. Limited information is available on these aspects. The knowledge is important for refining existing messaging.

Currently, as part of HAP, public awareness campaigns are implemented. More evidence is required on the effectiveness of different approaches of these campaigns (content/mode of delivery) and their impact.

Assessing the effectiveness of heat adaption interventions

The HAP document and the National Guidelines for preparing HAP mention the need for monitoring and evaluation of HAP. Annual revision of HAP based on evaluation is recommended. However, very few such efforts are being undertaken. (Kotharkar & Ghosh, 2022)

The published literature so far appears to have focused more on health outcomes. Evaluation of the Ahmedabad heat action program (HAP) has served as a primary input for the rollout of heat action plans across the country. While the study provides many valuable insights, there are a few limitations. The study could not account for the confounders, such as air pollution, demographic shifts or changes in living conditions, etc. Individual components of the HAP were not assessed. The study does not throw light on health benefits gained by most vulnerable populations.

In general, relying on health outcome evaluation using pre-post comparison of mortality data has many limitations. Attributing the reduced mortality to heat interventions is difficult without information about confounders. Lack of granular data on mortality limits understanding on whether most vulnerable populations are getting benefitted or not. For sustained adaptation, improving community resilience through HAP is necessary. This outcome can be measured in terms of community engagement to build local adaptive responses. This outcome is often not considered in HAP evaluation.

Some HAPs propose cool-roofing as an intervention to adapt to rising temperatures (for example, Telangana, Ahmadabad). Studies have shown that cool-roofing can reduce the indoor temperature, urban heat island effect, and energy demands. Given these benefits, the national program for cool-roofing is being prepared. However, there is limited evidence on the role of cool-roofing in preventing heat-related morbidity and mortality.

Table B-1: List of Potential research questions related to risk reduction actions to protect from extreme heat

	Early warning systems	**Vulnerability and adaptation assessments (VAA)**	**Awareness and outreach**	**Evaluation of heat adaption plans**
Risk reduction actions to protect from extreme heat	What is the level of behavior change after early warning? Does it vary across different contexts and adaptive capacities? Does it vary based on individual risk perception? Is the access to risk communication equitable across all socio-economic groups? Is it understandable for all? Is it reaching the most vulnerable? What are the perceptions of the community about risk communication? Is the risk communication actionable?	What is the level of vulnerability and adaptive capacity among workers from unorganized sectors and populations with overlapping risk factors? What are community perspectives about drivers of vulnerability? How can local stakeholders (village panchayat) be involved in VAA? What institutional mechanisms / tools / data inputs can facilitate this process?	Is the community aware of signs and symptoms of severe heat-related illness that need emergency health care? Do the vulnerable populations feel they are susceptible to serious health risks of extreme heat? Do they think they can take actions at the individual and community level to reduce health risks? What are the most effective contents and modes of delivering the content to reach the vulnerable population?	Whether and to what extent do vulnerable sub-populations benefit from the HAP – both in terms of health and non-health impacts? Which community-level support systems/adaptation strategies facilitate coping with extreme temperatures?

Strengthening health systems

Health surveillance

Deaths directly resulting from extreme heat exposure are used as one of the indicators to evaluate heat action plans. However, it is known that direct attribution of heat (to death) underestimates the number of people who die from temperature extremes.(Sarofim et al., 2016) Heat-related deaths are often not reported if another cause of death exists, and there is no well-publicized heatwave. Such reporting biases need to be considered while interpreting these data. (National Disaster Management Authority, 2021)

Additionally, the skewness of data on heat-related deaths across states, incongruence in death counts reported across different studies/reports, and extreme variability between annual death counts raise concerns about the validity of this indicator. In the past, concerns about under-reporting (Mavalankar et al., 2019), and false reporting in states that offer monetary compensation for disaster-related deaths (Our Bureau, 2018) have been raised. Therefore, it is necessary to assess the extent of misreporting or under-reporting of directly attributed deaths. Some such efforts are underway. A standardized format is being developed to make a standardized system of heat death investigation (National Centre for Disease Control, Ministry of Health and Family Welfare, New Delhi, India & Shrivastava, 2020). It collects information on age, gender, occupation, socio-economic condition, work conditions before death (outdoor/indoor), pre-existing health conditions, etc. However, disaggregated information of heat-related mortality on these variables is unavailable in the public domain. Regular publication of this data would be helpful to plan relevant in-depth studies.

A large number of heat health studies from India use all-cause mortality data. The variability in the completeness of death reporting across regions is a known phenomenon in India. More under-reporting of mortality is seen in underdeveloped states and rural and remote areas. This biased under-reporting can play down the risk of heat-health risks in specific regions or particular populations. More comprehensive deliberations will be needed to identify opportunities to improve the quality and availability of mortality data.

Real-time data on heat health burden is of great value for responsive public health action. Additionally, such data inputs would make sense if lower-level health facilities (sub-center, PHC) have the capacity and flexibility to use the data for local planning. Some countries like the United States have built real-time trackers (CDC Heat & Health Tracker) using emergency room or hospital admissions during heat waves. Identifying appropriate real-time indicators that could be collected through routine health service delivery is important. Alternative processes, such as community surveillance mechanisms and rapid surveys to assess the burden of heat discomfort levels, can also be explored.

The complexity and uncertainty of climate change impact demands a very close and careful watch on health outcomes as well as changes to socio-demographic-economic parameters. The availability of integrated multi-disciplinary data can enhance its use for research as well as decentralized planning. Public availability of such data can further aid evidence-informed actions.

Health system preparedness

The role of health systems is not limited to higher levels of health care only. Primary health care is equally important. A well-sensitized and aware health outreach worker, a paramedic, a nurse are critical in the timely referral of a serious patient. Research that assesses the abilities of health care providers to diagnose, refer or manage serious heat illnesses can give helpful feedback for strengthening health responses. Assessment of Infrastructural preparedness in terms of medications, ice packs, and ambulance availability is also necessary. Ministry of Health and Family Welfare (MOHFW) has developed a national action plan for heat-related illnesses. (Ministry of Health and Family Welfare, Government of India, 2021) It provides guidance on the management of heatstroke (clinical manifestations of various heat-related illnesses, suspecting heatstroke, laboratory workup, first aid, and referral), hospital preparedness plans during summer, and monitoring heat-related impacts (investigating suspected heat-related illness death, reporting of heat-related illness). More exploration will be needed to understand barriers to its implementation.

The health sector acts as a nodal agency that looks after the health aspects of heatwaves. As a nodal agency, its role will be to converge diverse players through advocacy and monitoring. This role requires different skill sets and close working with the community. Identifying the needs of various stakeholders for building their capacity to contribute to the efforts is necessary.

Access to timely and quality health care

Timely management is crucial if a person develops a major heat-related illness such as heat stroke. Inquiries at multiple levels – such as the abilities of communities to identify red flags, access of the community to appropriate and rapid transit mechanisms, and surge capacity of medical centers during heat waves – are needed to understand barriers to timely access to health care. This piece of information is essential while mapping vulnerability and adaptive capacities. However, limited information is available about delays in accessing health care and their impact on fatality.

Table B-2: List of Potential research questions related to strengthening of health system

	Heat Health surveillance	**Health system preparedness**	**Health care access**
Strengthening health system responses	What is the extent of under-reporting and misdiagnosis of direct deaths due to heat (e.g., heat stroke deaths) Exploring the feasibility of establishing real-time surveillance systems using indicators such as emergency ambulance calls during heat waves, hospitalizations, and emergency room visits during heat waves How can communities be involved to strengthen existing surveillance mechanisms? Establishing mechanisms to improve notifications by private health providers on heatstroke deaths	Assessing the preparedness of health systems to cope with heat-related illness. (e.g., abilities of health care providers to diagnose and manage heat stroke)	What are the facilitators and barriers to timely access to health care for severe heat-related illnesses? Identifying delays in accessing health care for a heatstroke patient.

Long term adaptation policies

In India, multiple agencies are involved in managing heatwaves and their effects.

Indian meteorology department (IMD), Ministry of Earth Sciences, is the nodal agency for providing current and forecast weather information in India. IMD introduced a system of exclusively heat-related warnings.

National Disaster Management Authority (NDMA) is the nodal agency that works on heat risk reduction through Heat action plans.

MoHFW is the nodal agency that looks after the health aspects of a heatwave. (National Centre for Disease Control, Ministry of Health and Family Welfare, New Delhi, India & Shrivastava, 2020) Currently, National Programme on Climate Change and Human Health, under MoHFW, collects and compiles data on heat-related illnesses from 23 vulnerable states.

At the national level, the Indian Cooling Action Plan (ICAP) (Ozone Cell, 2019) released in 2019 focuses on reducing the demand for air conditioning with cool roofs as a significant solution.

Synergistic action between MoHFW and MOEFCC (Ministry of Environment, Forest, and Climate Change) will benefit vulnerability assessments and adaptation actions. However, in the existing systems, such efforts are largely lacking.

In addition, policies related to urban development, transport, land use, forest cover, electrification, water access, housing, cooling systems, and occupational health have an important bearing on heat adaptation. It is essential to understand the linkages of these policies with heat action plans and assess how these benefit the risk reduction efforts. There needs to be a greater convergence among these agencies.

It was beyond the scope of this review to undertake an in-depth assessment of long-term policies that have relevance for heat adaptation. In our search, we did not come across any study that explored these linkages.

Way Forward

It is a foregone conclusion that India will likely face more frequent, prolonged, and intense heat waves in the coming decades. They will bring significant health risks and needs urgent attention. Responding to this, India has framed its policies and programs at the national, state, and city levels. However, the heat health adaptation responses are in their early phase of the rollout. There is a need to progressively add to the state and local level capacities. It is an opportune time to take stock of the situation and set a research agenda and priorities to strengthen the responses further. With this intention, this scoping review tries to bring forward knowledge gaps about heat-health impacts and adaptive responses.

The Indian literature mainly focuses on exploring mortality and morbidity risks at extreme temperatures. A critical gap is the little understanding of the role of adaptive capacity (type of housing, household ventilation, fans, air conditioning, access to water and electricity, access to health care, etc.) in reducing these risks. This knowledge is crucial for infrastructure planning and development over the longer term. The information can also provide inputs in designing studies on population-level vulnerabilities and appropriate targeting of heat action plans.

Empowering communities to take preventive actions is central to risk reduction envisaged through heat action plans. For this, it is important to know the community level processes (e.g. risk perceptions of vulnerable communities, their abilities to take preventive actions, their access to care), and how adaptation interventions influence them. This does not get addressed in existing research. Global data indicates that with proactive adaptation and higher investment in health systems, the risks of heat-related mortality and morbidity can be moderated even at 1.5 or 2-degree rise in earth's surface temperature.(IPCC, 2022) However, the needs of health system strengthening remain unexplored in the existing literature.

With this focus in mind, we propose prioritization of the following research agenda-

- Understanding the role of adaptive capacity among subpopulations in reducing heat-health risks and its application to early warnings
- Evolving vulnerability assessment methodologies that can incorporate community perspectives of drivers of heat health vulnerabilities.
- Understanding pathways through which risk communication (early warning signals) induces behavior change among the vulnerable population for taking preventive actions.
- Understanding how heat-health surveillance can be strengthened and what role communities can play in such surveillance
- Understanding treatment-seeking behaviors of people affected by extreme heat and provision of health care services for heat-related illnesses
- Understanding feasibility and cost-effectiveness of different structural intervention to minimize heat exposure and reducing adverse health impacts.

The present scoping review highlights India specific gaps in scientific knowledge. It also enlists potential research questions around identified priorities (mentioned in the section on 'Research Gaps'). These can kick start a discourse around setting the research agenda. Meaningful involvement of multiple stakeholders such as implementing agencies, public health and social science researchers, and community representatives will be key to take this agenda further. It will help in building more relevant, effective, and sustainable adaptation responses in the long run.

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It is a foregone conclusion that India will face more frequent, prolonged, and intense heat waves in the immediate future. The health hazards of extreme heat can be significant, especially among vulnerable populations. Adaptation actions to reduce health harms become necessary along with the continued focus on mitigation. The adaptive responses will greatly benefit if backed by ground-level knowledge about the needs as well as effective solutions.

The present review seeks to identify gaps in India-specific research on heat-health impacts and adaptation. It adopts a conceptual framework that considers two thematic domains important for the overall heat-health agenda - A) Research on the burden of heat-related illnesses/ heat mortality and its determinants, and B) Adaptation research, assessed for its potential to create flexible, locally responsive, and community-centric responses. The review provides important insights for prioritizing actions and setting the context for future research.

प्रयास

आरोग्य, ऊर्जा, शिक्षण आणि पालकत्व
या विषयांतील विशेष प्रयत्न