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Extreme indoor temperature a growing health hazard in rural areas of India

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ABSTRACT

Climate change projections indicate that heavily populated regions across the globe will face a rising occurrence of more frequent, severe, and extended heat waves (HW), accompanied by prolonged periods of extreme heat. These events are poised to trigger widespread overheating in rural areas, leading to heat-related illnesses and mortalities. In this context, our study aimed to examine heat stress vulnerability, heat mitigation measures and indoor discomfort in rural areas. The study was carried out in the rural areas of Wardha district located in the Vidarbha region of Maharashtra, India. The census household survey method was adopted to collect quantitative data during the summer month of 2022. The environmental factors such as indoor temperature, relative humidity and dew point were measured for the period from 1st March 2022 to 30th June 2022. A total of 2,672 individuals (comprising 54 % men and 46 % women) reside in the census survey household (700 households), with 38 % of the population falling within the 21 to 40-year age group. People living in house with cement roofs were less affected with odds of 1.00 (0.78, 1.29) as compared to those with tin roofs. The highest indoor temperature was recorded in the tin roof house, reaching 40.0 °C, while cement slab houses recorded an average temperature of 38.5 °C. The highest temperatures ranged from 35 °C to 37 °C (May 11–18, 2022) and 35 °C to 38 °C (June 1–8, 2022). Notably, 80 % of individuals (2136) reported experiencing at least one self-reported Heat-Related Symptom (HRS), with symptoms such as fatigue (736), heavy sweating (679), intense thirst (518), dry mouth (364), leg cramps (255) and headache (238) were reported commonly. A small number of population experienced Severe Heat-Related Symptoms (HRS) like fainting (2), hallucinations (5) and paranoid feelings (6). While the majority exhibited Mild Heat-Related Symptoms (HRS). The mitigation strategies for extreme temperatures encompass seeking shade (1025), wearing light and loose clothing (881), drinking water frequently before feeling thirsty (802), drinking plenty of water (732), clothing removal for free air/airy dress (376) and covering head with a traditional scarf (253). Development of Heat Action Plan (HAP) will be a crucial step to avoid the HRS at local level. In the preparation of HAP engagement of local level stakeholder is very important for the effective implementation. The findings of the study will help policy makers to understand the implications of change in temperature and its consequences on the population.

1. Introduction

Global climate change is expected to cause an increase in the frequency and intensity of heat waves [1–4]. Climate change and its potential impacts on human health are increasingly draw attention in developed and developing countries [5–8]. In recent years, with the overarching threat of climate change, the rapid onset of extreme events such as increasing intensity and frequency of temperature, cyclones, and heavy precipitation has caught ample attention worldwide [9]. Increasing global average temperature is the most predictable outcome of the changing climate. The Intergovernmental Panel on Climate Change (IPCC) emphasized, with a high degree of certainty, that hot days and hot nights have become more frequent over most land areas [10]. Heat Waves (HW) are predicted to grow in intensity worldwide in the coming years, potentially resulting in sensitive heat stress and heat-related mortality if no adaptation measures are in place [11,12].

Rising temperatures driven by climate change can adversely impact individuals and communities through multiple pathways. High

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temperatures hamper daily life by reducing the ability to engage in physical activities for a longer duration and hamper work efficiency [13]. Increasing temperatures, especially during the summer months, impact human health and increase the risk for Heat-Related Illness (HRI) [14–16]. Consequently, the intense heat is a significant weather-related threat linked to increased heat-related illness and death across the world [17,18]. Extreme heat emergencies [19,20] are a regular occurrence for people exposed to a significant risk of heat-related mortalities and morbidity [11]. The World Health Organization (WHO) estimates that heat exposure will cause 38,000 and > 100,000 additional deaths per year during the 2030s and the 2050s, respectively [21,22]. Therefore, extreme temperatures or heat waves are considered a *"silent killer"* [19].

Worsening extreme heat events associated with climate change have increased the likelihood of increased exposure to extreme temperatures in the South Asia Region (SAR) [23]. In India, the five warmest years on record including the last year (2024), in descending order, were 2016 (+ 0.71 °C), 2009 (+ 0.55 °C), 2017 (+ 0.541 °C), 2010 (+ 0.539°C) and 2022 (+ 0.51 °C) [24], with addition to recent 2024 summer (as highest maximum temperature of 50.5 °C was reported at Churu (West Rajasthan) [25]. While the geographical location, climate, and latitude play a crucial role in temperature and related hazards. The Climate Monitoring and Prediction Group (CMPG) annual climate summary report of 2023 mentioned that 12 out of the 15 warmest years were experienced recently from 2009 to 2023 (15 years). The past decade (2013–2022/2014–2023) was also the warmest decade on record with the decadal averaged annual mean temperature anomaly of + 0.41 °C/+ 0.46°C [26].

An alarming frequency of HWs – defined by the Indian Meteorological Department (IMD) when temperatures are above 45 °C and Severe Heat Waves (SHW) when temperatures are above 47 °C [27] are reported in many regions of the Indian subcontinent. In India, 12,343 individuals are reported to have died because of the extreme HW (extreme temperature) from 1951 to 2021 [28]. However, Indian mortality data remains incomplete despite multiple government sources. Overall, the death registration is lower in vulnerable groups such as women, less educated people and the underprivileged castes in India [13]. Thus, the mortality from heat exposure is likely to have been much greater than was reported. The populations in rural India are particularly vulnerable. They often lack access to adequate healthcare facilities, have poor infrastructure and limited resources to cope with extreme heat events [29]. These factors increase their susceptibility to heat-related health risks (such as Heat Related Symptoms (HRS) and illness), making them a priority for targeted interventions. Many rural communities lack awareness of the risks associated with extreme heat events and are inadequately prepared to respond, causing severe losses, including material and life.

Indoor air temperature and relative humidity parameters are important environmental factors for understanding and determining heat-related symptoms (HRS) or heat-related illness (HRI) [30–34]. Consequently, the current research was designed to identify the most vulnerable categories of rural populations to heat stress, and to assess the potential impact of heat stress on human health in relation to indoor temperature and relative humidity, to evaluate how these factors are affected by house construction material, and to understand existing coping mechanisms practiced by the people to manage extreme indoor-outdoor temperatures. The study hypothesized that exposure to extreme heat during a prolonged summer period will significantly impact the severity and health outcomes associated with Heat-Related Illnesses (HRI). The goal was to assess human health and discomfort in extremely high temperatures, based on gender, type of work, type of house construction material, and environmental temperature.

2. Materials and methods

2.1. Study location

The study took place in Wardha District of Vidarbha provenance in the state of Maharashtra in southwestern India (Fig. 1). During March–June, the Vidarbha region of Maharashtra State experiences extreme temperatures, the maximum of which was equal to or greater than 45 °C between 1940 and 2021 [35–37], 57 persons were hospitalized during the summer between 2019 and 2023 mainly due to heat stroke [38]. Also, the neighbouring districts have experienced heat waves, such as Nagpur (469), Chandrapur (495), Yavatmal (516) and Amravati (508) between 1951 and 2022.

A majority of the population in Wardha District engages in agricultural occupations, rendering them dependent on outdoor labour and consequently increasing their exposure to extreme summer heat. Census data, 2011 for Wardha District suggests that 132,989 persons (21.86 %) worked as cultivators, and 282,170 (46.39 %) worked as agricultural laborers [39]. 29 % of farmers are small landholders (1.0–2.0 acres of land) and 34 % are semi-medium (2.1–4.0 acres of land) landholders [40]. A total of 17,607 households receive employment under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) consisting of 32,262 individuals for the financial year 2021–2022 [41].

Since investigations conducted on a regional level are crucial for understanding temperature variations, this study of the Wardha District was conducted in five villages that are grouped into four areas based on local geographic characteristics: such as i) an area close to bodies of water, ii) an upper catchment/hilly area and iii) a plain/flat area. Two villages were selected for study in an area near bodies of water (total of 217 households and 815 inhabitants), one village was selected for study in an upper catchment/hilly area (61 households, 218 inhabitants), two village was selected for study in a plain/flat area (422 households,1637 inhabitants).

2.2. Study protocol

The study took place in two phases. The first phase consisted of a general household survey conducted during the hottest months of April and May of 2022. The survey was designed to gather perspectives on high temperature, discomfort due to high temperature, and immediate impacts due to high temperature, and to obtain information on age, sex, socio-economical characteristics, type of house roof, persons having any pre- existing health conditions, and self-reported HRS/HRI among the household members. All questions on thermal comfort, self-reported HRS and pre-existing health problems were asked in the binary answer format (such as yes and no).

Before data collection, a general meeting was held in each village with village stakeholders such as the village head (Sarpanch- head of the village/Sarpanch of a Gram Panchayat level), Deputy-Sarpanch (Deputy Sarpanch of a Gram Panchayat level), ASHA (Accredited Social Health Activist) workers and village development committee (A group of elected or appointed community members who plan, implement and oversee local development projects at the village level). A detailed discussion was held on study objectives, methods of data collection and the importance of the study. Necessary permissions were obtained from the village head and individuals involved in the data collection. The written informed consent form (hard copy) was given to the administrative office at each village explaining the importance of the study, its objective and methods of data collection. Once the oral permission was given by the Gram Panchayat office, then the data collection was started in the study villages.

After permission from village authorities was obtained, the household survey, which lasted between 45 and 60 min, was administered to household members between the ages of 18 and 75 years, who were willing to participate in the study. Respondents included at least two

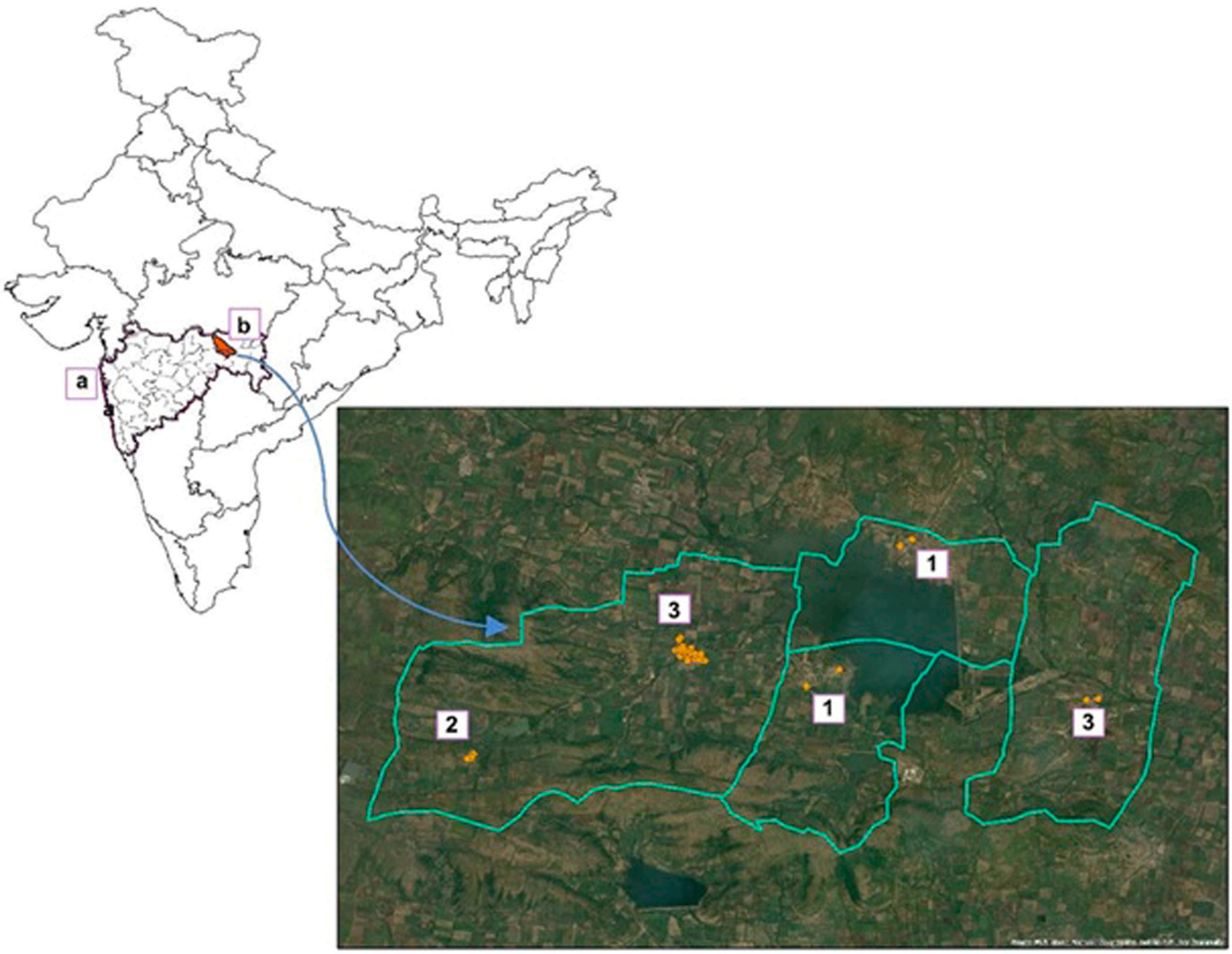

Fig. 1. The location of the study area. Maharashtra state (a) is outlined on the map of India, and Wardha District is indicated in red (b) the areas that were included in the study. Here "1" to indicate the area (villages) close to water bodies, "2" indicate the upper catchment/hilly area and "3" indicate the plain/flat area.

individuals (one male and one female) from each household. Individuals younger than 18 years and older than 75 years were not interviewed. Interviews were conducted in the local language (Marathi) and were administered to a total of 2672 individuals living in 700 households.

2.3. Data collection tool

This quantitative descriptive research study was conducted in five villages of Arvi block of Wardha district of Maharashtra, India. The census household survey included key questions covering topics like roof type, electricity connection, summer electricity supply and outages, water availability, cooling devices, primary occupation, ration card type, and self-reported Heat-Related Symptoms (HRS) in summer months. The questionnaire features dichotomous, multiple choice, and numerical questions. The pre-testing of the tool was conducted with aimed to validate the questionnaire, refine the question flow, check for issues, and improve the translation in a non-sample village with 30 households. The pre-test also helped to identify and address potential errors, ensuring the tool's validity and reliability.

2.4. Measurement of indoor temperature, relative humidity and dewpoint

The second phase consisted of indoor temperature measurements made in a subset of houses that participated in the census survey. These 42 households were selected, based on a willingness to have data loggers installed, presence of residents who reported at-least 10 self-reported Heat-Related Symptoms (HRS), residential stability to avoid the impact of migration of respondent families, and the diversified nature of household construction materials.

Before participating in the study (indoor measurements), all participants received a detailed informed consent form, with an explanation of the aims, objectives and duration of the research and confidentiality. After receiving the written informed consent (in the local Marathi language) from the head of the household in the study site, the installation of data loggers took place in February 2022 for 42 selected households. Subsequently, each of these households was monitored over a period of 255 days, from 1st March 2022 to 11th November 2022. However, for this paper, only data from the hot summer month period (i.e., 121 days, from 1st March to 30th June 2022) are analyzed.

In 12 households, only temperature was measured using a HOBO UX100-001 data logger (LI-COR Environmental, Bourne, MA, USA). In 30 households, temperature, relative humidity and dew point were measured, using a HOBO UX100-011 data logger (LI-COR Environmental, Bourne, MA, USA). Specifications for each device are listed in Table 1.

The data loggers were installed in a room where the maximum number of household members spent most of their time indoors. In five households, members spent most of their time in the hall room. In another five households, members spent most of their time in the bedroom and in 32 households, members spent the majority of their

Table 1
Technical specifications of data loggers (HOBO UX100-001 & HOBOUX100-011).

Data logger (Sensor)	HOBO UX100-001	HOBO UX100-011
Parameter	Temperature	Temperature, Relative Humidity & Dew Point
Temperature Sensor		
Temperature	− 20° to 70 °C (− 4° to 158 °F)	− 20° to 70 °C (− 4° to 158 °F)
Accuracy	± 0.21 °C from 0° to 50 °C (± 0.38 °F from 32° to 122 °F)	± 0.21 °C from 0° to 50 °C (± 0.38 °F from 32° to 122 °F)
Resolution	0.024 °C at 25 °C (0.04 °F at 77 °F)	0.024 °C at 25 °C (0.04 °F at 77 °F)
Response time	8 min in air moving 1 m/s (2.2 mph)	4 min in air moving 1 m/s (2.2 mph)
Drift	< 0.1 °C (0.18 °F) per year	< 0.1 °C (0.18 °F) per year
Temp Parameter	°C	°C
Environmental rating	IP50	IP50
RH Sensor		
Humidity range	Not Applicable	1–95 %
Accuracy	Not Applicable	± 2.5 % from 10 % to 90 % typical to a maximum of ± 3.5 % including hysteresis at 25 °C (77 °F); below 10 % and above 90 % ± 5 % typical
Resolution	Not Applicable	0.01 %
Response time	Not Applicable	10 s to 90 % in airflow of 1 m/s (2.2 mph)
Drift	Not Applicable	< 1 % per year typical
Logger Operating Range		
Logging	− 20° to 70 °C (− 4° to 158 °F); 0–95 % RH (non-condensing)	
Launch/readout	0° to 50 °C (32° to 122 °F) per USB specification	
Logging rate	1 s to 18 h, 12 min, 15 s	
Time accuracy	± 1 min per month at 25 °C (77 °F)	
Battery life	1 year, typical with logging rate of 1 min and sampling interval of 15 s or greater	
Battery type	One 3 V CR2032 lithium battery and USB cable	
Memory size	128 kB (84,650 measurements, maximum	
Download type	USB 2.0 interface	
Full memory download time	20 s	
LCD	LCD is visible from 0° to 50 °C (32° to 122 °F); the LCD may react slowly or go blank in temperatures outside this range	
Size	3.66 × 5.94 × 1.52 cm (1.44 × 2.34 × 0.6 in.)	3.66 × 8.48 × 2.29 cm (1.44 × 3.34 × 0.9 in.)
Weight	23 g (0.81 oz)	30 g (1.06 oz)

time in the hall cum bedroom place. The data loggers were situated at an approximate height of 1.5 m above the floor, taking care to place them where they remained unobstructed by furniture and were shielded from direct sunlight and any additional heat sources. The operational status of the data loggers was confirmed through a check after approximately four to five days post- installation to ensure precise data recording, and the batteries were periodically replaced with new ones. Data were recorded at 10-minute intervals and were retrieved and transferred to a laptop using HOBOware software every 15 days.

3. Data analysis

The raw data of census household survey was obtained in.CSV (Comma Separated Values) file and later cleaned and exported into the MS Excel. Later the Statistical Package for the Social Sciences (SPSS) software was used to analysis the quantitative data generated from the census household survey. The raw indoor air temperature, relative humidity and dew point measurements made every 10 min were exported to Microsoft Excel (MS Excel) and then aggregated hourly, daily, and monthly. Basic statistics (means, standard deviations) were calculated from responses to the household survey using Statistical Package for the Social Sciences (SPSS), and the P Value and Odds-ratios were calculated using the MS-Excel.

3.1. Results

The results presented here are based on the census household survey data and indoor temperature measurement data.

3.2. Demographics

Table 2 shows the total number of households, gender of residents, age groups and primary occupations of the residents for the study area. There are more males than females, and the majority of the survey population (52 %) falls in the 21–50 age-group, which is the working age group. Most people surveyed work on their own farm (45 %), followed by non-agriculture labourers (24 %) and agriculture laborers (13 %). Most of the occupations are based outdoors, which increases heat exposure.

Table 3 shows the types of roofs and the number of individuals in houses in the study area. Most of the households have tin roofs (45 %) with 1192 residents, followed by the cement slab (39 %) houses with 1062 residents and tile roof houses (14 %) with 371 residents. These data indicate that people are following the latest trend of using either tin or cement slab roofing materials and avoiding straw roofs which may be considered to be an indication of lower economic status. Only 3 % of households don't have an electricity connection, and 29 % of the participants mentioned that electricity was cut off for one to two hours during noon in summer months with irregular timing.

3.3. Temperature measurement

Table 4 shows the total number of households in which the data loggers were installed for the measurement of air temperature. Nearly 50 % of data loggers were installed in tin roof houses, 21 % in tile roof houses and 31 % in cement roof houses. Around 52 % of the inhabitants living in these households were in the 21–50 age group. Farming was the primary occupation reported by nearly 74 % of these households, followed by the number of households reporting agriculture labour as the primary occupation (17 %). Nearly 86 % of households have a desert cooler as their primary cooling device.

Figs. 2–4 illustrate the daily average indoor air temperatures from

Table 2
Demographic data of census survey households.

Demographic Data	Total
No. of Households	700 (100.0 %)
Sex (Individual)	
No. of Male	1433 (53.6 %)
No. of Female	1239 (46.4 %)
Total Individuals	2672 (100.0 %)
Age-Group (Individual)	
Upto 10	247 (9.2 %)
11–20 age-group	410 (15.3 %)
21–30 age-group	541 (20.2 %)
31–40 age-group	477 (17.9 %)
41–50 age-group	364 (13.6 %)
51–60 age-group	270 (10.1 %)
61–70 age-group	266 (10.0 %)
71 and above	97 (3.6 %)
Total	2672 (100.0 %)
Primary Occupation (Individual)	
Farming	1206 (45.1 %)
Non-agriculture labour	631 (23.6 %)
Agriculture labour	350 (13.1 %)
Self employed	14 (0.5 %)
Petty business/trade	9 (0.3 %)
Traditional work	8 (0.3 %)
Local services	7 (0.3 %)
Pension	6 (0.2 %)
MGNREGA	4 (0.1 %)

Table 3
Type of roof household, total number of individuals, connection to the electrical meter and electricity cut off.

Type of Roof (Total Household)	Total
Cement Slab	270 (38.6 %)
Tin	315 (45.0 %)
Tile	100 (14.3 %)
Straw	15 (2.1 %)
Total	700 (100.0 %)
Total number of individuals in houses with each type of roof	
Cement Slab	1062 (39.7 %)
Straw	47 (1.8 %)
Tile	371 (13.9 %)
Tin	1192 (44.6 %)
Total	2672 (100.0 %)
Own electrical meter connection	
Yes	2591 (97.0 %)
No	81 (3.0 %)
Cut Off	
Afternoon (cut off) 1–2 h	740 (28.6 %)

Table 4
Roof type, household composition, primary occupation and type of cooling devices in houses where indoor temperatures were monitored (42 households).

Type of Measurement	Household & (%)
Temperature	42 (100.0 %)
Type of House	
Cement roof	13 (31.0 %)
Tile roof	9 (21.4 %)
Tin roof	20 (47.6 %)
Sex	
Men	92 (45/8 %)
Women	109 (54.2 %)
Age Group	
Up to 10 age-group	24 (11.9 %)
11–20 age-group	35 (17.4 %)
21–30 age-group	32 (15.9 %)
31–40 age-group	42 (20.4 %)
41–50 age-group	31 (15.4 %)
51–60 age-group	24 (11.9 %)
Above 60 age-group	14 (7.0 %)
Occupation	
Farming	31 (73.8 %)
Agriculture labor	7 (16.7 %)
Non-Agriculture occupation	2 (4.8 %)
Livestock (sale of milk)	2 (4.8 %)
Desert Cooler	
Yes	36 (85.7 %)
No	6 (14.3 %)

1st March 2022 to 30th June 2022 classified by type of roof house. Throughout the summer months the daily average and minimum indoor temperatures of tile roof hoses was generally lower than the daily average and minimum indoor temperatures of tin roof houses and cement roof houses, although there was a great deal of overlap throughout the summer. However, the daily maximum indoor temperatures of tin roof houses were consistently higher than houses with tile or cement slab roofs throughout the summer months.

Fig. 5 presents the diurnal changes in average hourly indoor air temperature between 1st March 2022 and 30th June 2022 (121 days) for each of the 42 houses. In each house, the indoor temperature begins to increase around 7 AM and remains elevated until 7 PM in the evening. The highest temperatures in all houses were recorded between 11 AM and 5 PM. During this time, there was considerable variation in the degree to which temperatures increased, but most peaked around 1 PM. This irregularity of indoor air temperature can be owed to the use of various cooling devices in houses and also because of the different roof types. The lowest air temperatures were recorded between 6 AM and 7 AM.

3.4. Strategies used to mitigate high temperatures

Table 5 shows the type and number of cooling devices used in households. The most commonly used method for managing the indoor temperature is the desert cooler (28 %) followed by the ceiling fan (27 %). In houses with cement slab roofs 27 % of households have a desert cooler, ceiling fans are also dominant in the houses with cement slab roofs (29 %). As table fans and standing fans are easy to move from one place to another, 24 % of households with tin roofs have ceiling fans and another 42 % have table fans. Each household was also asked about the total number of cooling devices they have, 58 % reported one cooling device, 18 % reported two cooling devices and 34 % reported three cooling devices.

The Fig. 6 shows the average indoor temperature ranges between 27 °C and 37 °C. The desert cooler consistently provides lower temperatures than the ceiling fan, confirming its effectiveness in cooling. Even the impact of cooling devices is more noticeable in hottest period of the months (April–May), as the difference between the two cooling methods is more distinct during peak summer.

The provided Fig. 7 is a time series plot comparing the daily minimum temperature (°C) recorded over time for two different cooling devices such as the ceiling fan (blue line) and the desert cooler (orange line) from 1st March 2022 to 30th June 2022. The indoor temperature increases gradually from early March to mid-May, peaking around mid-May and lightly declining in June. However, in many instances, the ceiling fan (blue line) appears slightly higher than the desert cooler

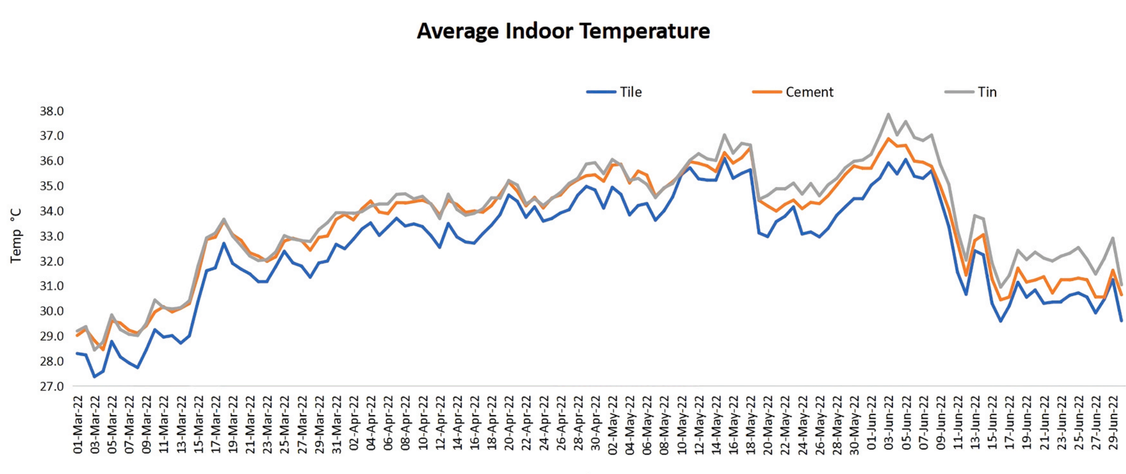

Fig. 2. Average daily indoor temperatures during March–June, 2022.

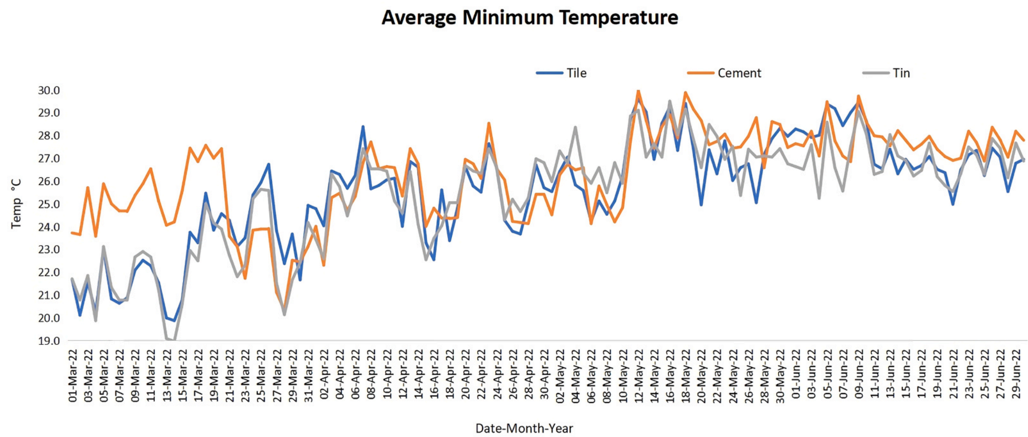

Fig. 3. Average daily minimum indoor temperatures during March–June, 2022.

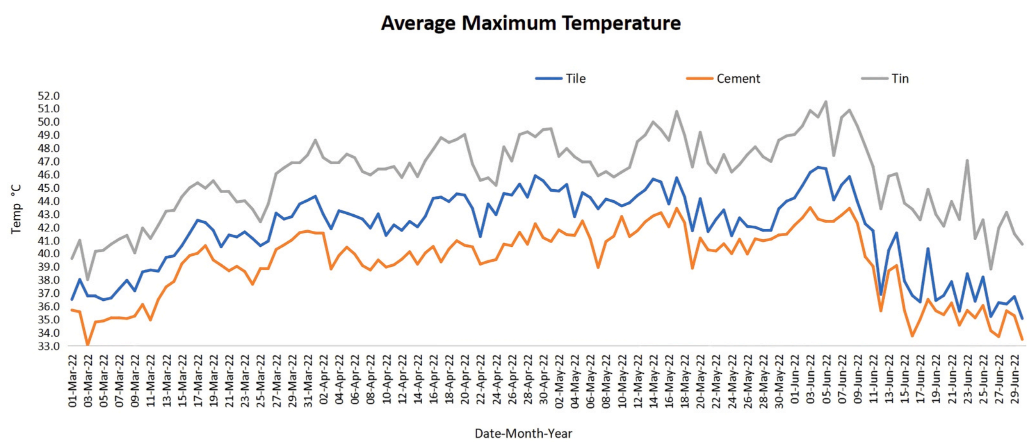

Fig. 4. Average daily maximum indoor temperature during March–June, 2022.

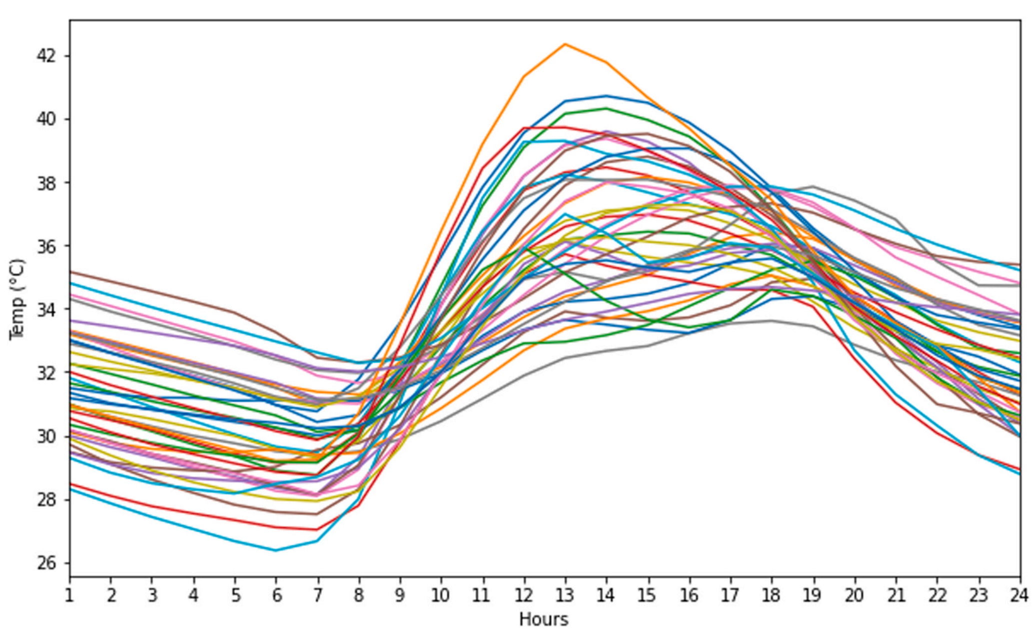

Fig. 5. Diurnal temperature variation (1st March 2022–30th June 2022) for 42 sample houses.

Table 5
Cooling devices.

Total Devices (Households)	Cement Slab	Tin	Tile	Straw	Total
Type of cooling Device (households)					
Desert Cooler	126 (27.6 %)	141 (27.5 %)	48 (29.6 %)	4 (18.2 %)	319 (27.6 %)
Ceiling Fan	134 (29.3 %)	125 (24.4 %)	38 (23.5 %)	6 (27.3 %)	303 (26.3 %)
Table Fan	179 (39.2 %)	214 (41.7 %)	73 (45.1 %)	10 (45.5 %)	476 (41.2 %)
Standing Fan	18 (3.9 %)	33 (6.4 %)	3 (1.9 %)	2 (9.1 %)	56 (4.9 %)
Total Number of Cooling Devices (In Number & %)					
1	146 (54.7 %)	183 (59.2 %)	57 (58.8 %)	9 (64.3 %)	395 (57.5 %)
2	54 (20.2 %)	51 (16.5 %)	15 (15.5 %)	2 (14.3 %)	122 (17.8 %)
3	65 (24.3 %)	72 (23.3 %)	25 (25.8 %)	3 (21.4 %)	165 (24.0 %)
4	2 (0.7 %)	3 (1.0 %)	0 (0.0 %)	0 (0.0 %)	5 (0.7 %)

(orange line), indicating that the desert cooler provided better cooling, leading to slightly lower temperatures. Overall, the impact of cooling is more noticeable in warmer months (April–May), as the difference between the two cooling methods is more distinct during peak summer.

The Fig. 8 shows the daily maximum temperature classified by the type of cooling devices used by the sample study house. As seen from the figure, during the initial period (1–10 March), the daily maximum temperature of desert cooler houses was slightly higher than that of ceiling fan houses. It can be due to the functioning of the household. After 10th March, the desert cooler houses had a lower temperature than the ceiling fan houses, reducing the indoor temperature by nearly 1–2°C. The average maximum temperature reached was 43°C. A ceiling fan alone does not provide significant cooling benefits at higher temperatures, as its temperature remains consistently higher than the desert cooler, but it plays an important role in indoor air circulation.

Table 6 shows the behaviours that respondents used for coping with indoor and outdoor heat stress. The heat mitigation behaviours adopted are very general and very few. Respondents reported drinking water from earthen pots, taking frequent breaks under in the shade of the trees or common places (community hall, temple), intake of Panna (Mango drink), keeping their own drinking water bottles with jut bag, and use of cotton clothing during the outdoor occupational activities and use of salt-sugar water for dehydration. Approximately 23 % of men and 24 % of women mentioned they seek relief in the shade for a while when there is intense heat. Over 20 % of the men and 20 % of women wear light/loose clothing during indoor and outdoor activities; 81 % of women and 82 % of men utilized light-colored garments/clothes during the summer months; and about 3 % of men and 4 % of women take baths twice a day. Our survey revealed that 89 % of the farmers carry their water bottles during outdoor physical activities. 93 % of people who were engaged in the sale of milk carry their water bottle when they start their work in the morning, 87 % of the individuals engaged in service activities they carry their water bottle at their place of work and 83 % of the non-agriculture labors carry their water bottles when they go to their worksite.

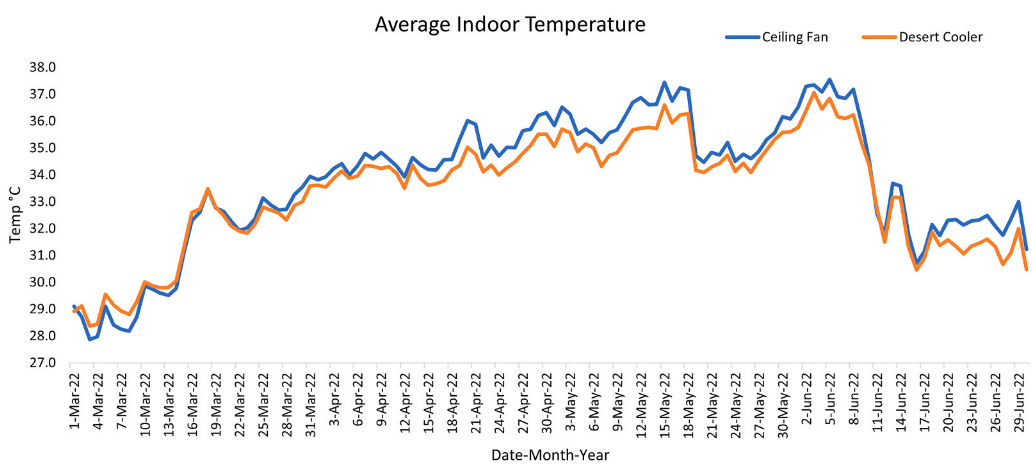

Fig. 6. Comparison of daily average temperature in households with different cooling devices.

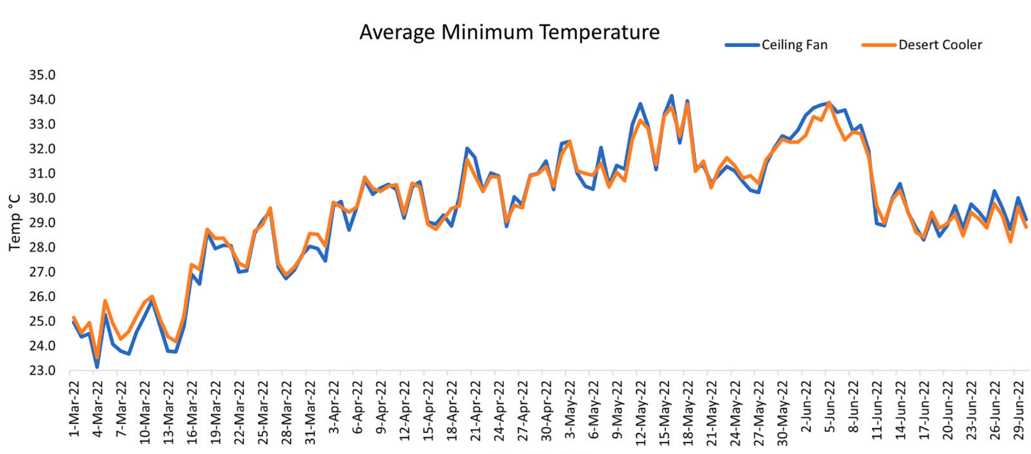

Fig. 7. Comparison of daily minimum temperature in households with different cooling devices.

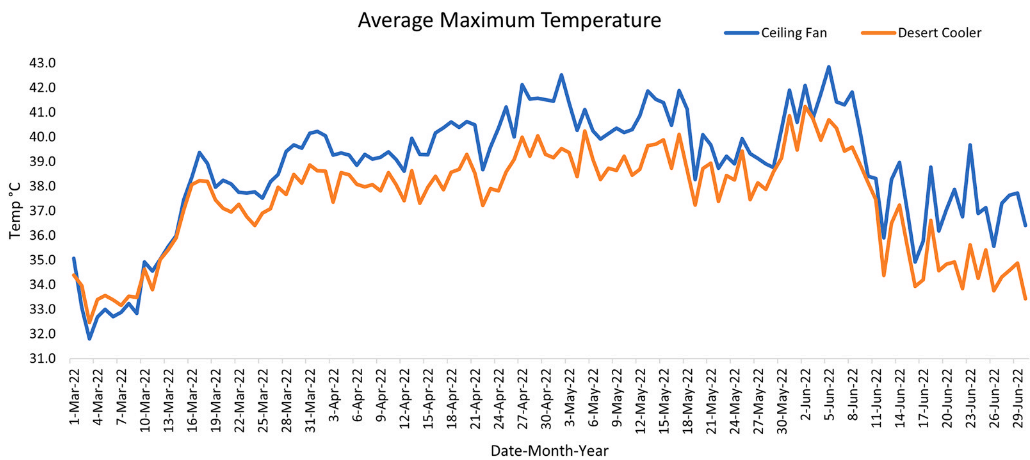

Fig. 8. Comparison of daily maximum temperature in households with different cooling devices.

Table 6
Heat mitigation behaviours.

Heat Mitigation Strategies	Men Person (%)	Women Person (%)	Total Person (%)
Get away to a shade for a while	545 (23.1 %)	480 (24.2 %)	1025 (23.6 %)
Wear light/loose clothing	484 (20.5 %)	397 (20.0 %)	881 (20.3 %)
Drink water frequently before feeling thirsty	437 (18.5 %)	365 (18.4 %)	802 (18.4 %)
Drink plenty of water	403 (17.1 %)	329 (16.6 %)	732 (16.8 %)
Clothing removal for free air/ airy dress	209 (8.8 %)	167 (8.4 %)	376 (8.6 %)
Cover head with traditional scarf	125 (5.3 %)	128 (6.4 %)	253 (5.8 %)
Bathe twice a day	80 (3.4 %)	73 (3.7 %)	153 (3.5 %)
Wear a cap/hat or cover head by *gamcha*	80 (3.4 %)	48 (2.4 %)	128 (2.9 %)
Total	2363 (100.0 %)	1987 (100.0 %)	4350 (100.0 %)
Clothing Color during outdoor			
Light	910 (82.3 %)	742 (81.4 %)	1652 (81.9 %)
Dark	196 (17.7 %)	170 (18.6 %)	366 (18.1 %)
Total	1106 (100.0 %)	912 (100.0 %)	2018 (100.0 %)

Table 7
Window opening patterns and location of cooling devices during the summer months.

	Total
Usually open your window when you cook during the summer months	
Yes	502 (87.2 %)
No	74 (12.8 %)
Total	576 (100.0 %)
Window Opening Pattern	
Always open almost	220 (32.0 %)
Closed whole night	14 (2.0 %)
Open a few hours prior to bedtime and closed in the middle of the night	125 (18.2 %)
Open a few hours prior to bedtime and closed when going to sleep	37 (5.4 %)
open a few hours prior to bedtime and kept open throughout the night	229 (33.3 %)
Open just before getting in bed and closed in the middle of the night	31 (4.5 %)
Open just before getting in bed and kept open throughout the night	31 (4.5 %)
Total	687 (100.0 %)
Position of Cooling Devices	
Anywhere in the bedroom where there is space	81 (25.3 %)
Far away from bed and/or blowing away from body so not to feel airflow	113 (35.3 %)
In front of an open window	62 (19.4 %)
Next to bed and or blowing towards body to feel airflow	64 (20.0 %)
Total	320 (100.0 %)

Source: Household Sampled Survey, 2022.

To reduce the heat stress and manage the indoor temperature, 87 % of households (502) usually open their windows during cooking time (Table 7). Furthermore, window opening was a frequent practice during the overnight hours. At night, 33.3 % of households reported that they open windows for a few hours before bedtime and kept them open throughout the night. Electric fans and desert coolers help for air circulation. Covering roofs with plant material left in a field after a crop has been harvested was reported by 25 % of households that have tin roof to reduce the indoor temperature. The use of white paint on roofs was reported by 4 % of the households. Other building alterations used to reduce indoor heat include maintaining a gap between wall and ceiling (for airflow), spraying water on the mud floor or wall, using traditional coolant paste for flooring inside the house, coating on the roof outside with crop residue and putting *Jute potli* (bag) on cement roofs.

3.5. Heat related symptoms and illnesses

Fig. 9 shows the frequency of several heat-related symptoms reported by men and women. Out of the 2672 sample size, 1657 individuals reported for at-least one Heat-Related Symptom (HRS). The number of HRSs (n = 3323) reported by men and women was higher than the total sample size because the same individuals reporting more than one HRS. Among the most highly reported HRS are fatigue (22 %), heavy sweating (20 %), intense thirst (16 %), dry mouth (11 %) and leg cramps (8 %). The most severe forms of HRS were fainting (reported by two women), hallucinations by five persons (three men and another 3 women), and paranoid feelings by six persons (three men and another three women. Other HRS reported include rapid heartbeat (19 persons) swelling of the face (14 persons), muscle cramps (10 persons), prickly heat/heat rash (10 persons) and vomiting (8 persons).

Table 8 indicates that men and women are equally likely to report at least one HRS. Younger people (those in the 21 to 30-year age group) are significantly less likely to report at least one HRS compared to older respondents. However, older individuals are equally likely to report at least one HRS, regardless of age. Individuals living in houses with straw roofs are significantly less likely to report at least one HRS than those living with other roof types. But individuals living in houses with cement slabs, tile roofs and tin roofs are equally likely to report at least one HRS. Finally, individuals who work as non-agricultural laborers, in the local service industry or others are significantly less likely to report at least one HRS compared to farmers. However, farmers and farm labourers are

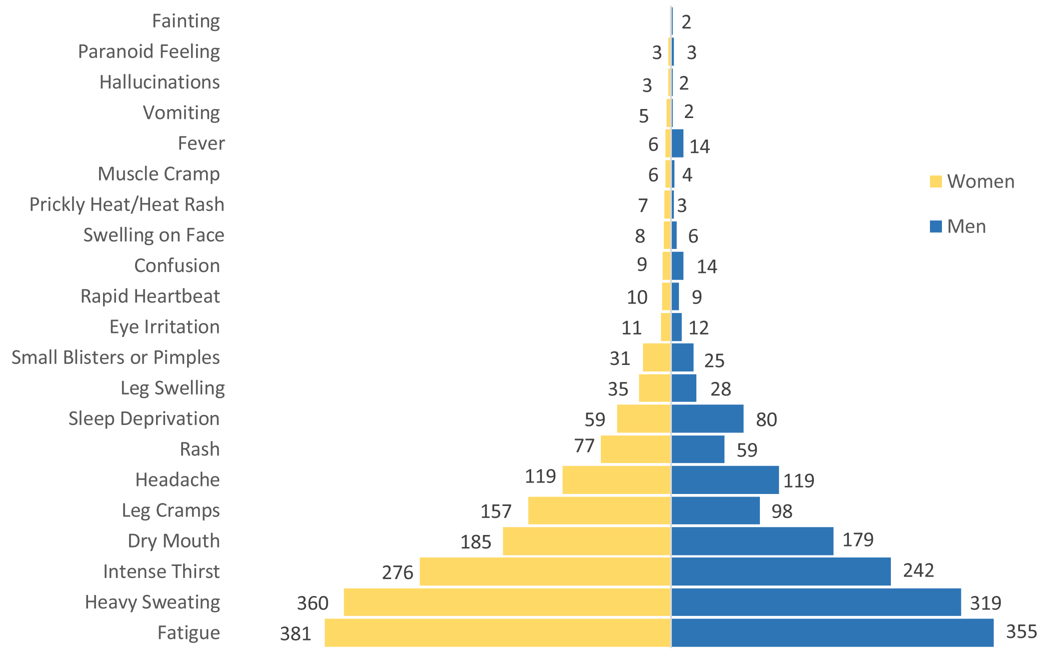

Fig. 9. The frequency of several heat-related symptoms reported by men and women.
Source: Census Household Survey, 2022.

Table 8
The odds ratios of having at least 1 HRS relative to gender, age, roof type and occupation.

Sex	At least 1 HRS	Per Cent (%)	Total	Odds Ratio	Lower CI	Upper CI	P-Value
Men (ref)	907	82.50 %	1099	0.96	0.76	1.2	0.72
Women	750	81.90 %	916				
Total	**1657**	**82.20 %**	**2015**				
Age Group							
21–30 age-group	417	76.90 %	542	0.60	0.42	0.8	0.00
31–40 age-group	417	87.40 %	477	0.81	0.54	1.2	0.29
41–50 age-group	300	82.60 %	363	0.85	0.57	1.3	0.29
51–60 age-group	215	79.60 %	270	0.70	0.46	1.1	0.43
61 & above (ref)	308	84.80 %	363				
Total	**1657**	**82.20 %**	**2015**				
Roof Type							
Cement Slab	668	82.50 %	810	1.00	0.78	1.3	0.99
Straw	24	63.20 %	38	0.36	0.18	0.7	0.00
Tiles	232	83.50 %	278	1.07	0.75	1.5	0.71
Tin (ref)	733	82.50 %	889				
Total	**1657**	**82.20 %**	**2015**				
Occupation							
Farmer (ref)	920	84.40 %	1090				
Agriculture labour	255	82.50 %	309	0.87	0.62	1.22	0.44
Non agriculture labour	452	79.40 %	569	0.71	0.55	0.93	0.01
Local services	3	42.90 %	7	0.14	0.03	0.62	0.01
Other	27	67.50 %	40	0.38	0.19	0.76	0.01
Total	**1657**	**82.20 %**	**2015**				

equally likely to report at least one HRS.s

4. Discussion

This study of heat stress in a rural area of Maharashtra state in southwestern India provides further information about the severe conditions facing millions of rural Indians during increasingly hot summers. There are several important results. The 121-day monitoring of heat stress providing an understanding of variability in indoor conditions over an entire summer period. The Important differences (over the 121-day period) in indoor heat were associated with roof type and occupation. Farmers and farm labourers are most likely to experience HRS. But there are no significant differences in the likelihood of reporting at least 1 HRS between men and women.

Relatively few studies have been conducted to determine indoor heat during the summer in rural areas of India. Overall, indoor monitoring in previous studies in rural Indian villages occurred over shorter periods of time than in the current study and involved monitoring a variable number of households. Mukhopadhyay et al. [42] studied 123 households in rural West Bengal for 24 h each. Likewise, Ravindra et al. [43] monitored indoor temperatures for 24 h, but for 31 households in rural Punjab. Garg et al. [44] monitored indoor conditions for a month, but for only a single rural school. Singh et al. [45] monitored 150 dwellings for 25 days during different seasons and in different climate zones. Pradyumna et al. [46] monitored 20 dwellings in rural Maharashtra for approximately 9 months. Only Tasgaonkar et al. [34] in another study located in rural Maharashtra have monitored indoor conditions for a period comparable with that of the current study, but in fewer households.

Studies of building characteristics indicate that the type of roof, wall, and flooring plays an important role in influencing the indoor temperature [47,48]. Previous research in rural areas of India generally conform to results reported here concerning indoor temperatures and roof types. In an earlier Maharashtra study, Pradyumna et al. [46] reported that indoor temperatures in houses with tin roof houses were hottest during the mid-day hours followed by houses with cement slab roofs, while houses with tile roofs were the coolest. Similar results have been reported in another earlier study of indoor temperatures in houses in rural Maharashtra [34]. Mukhopadhyay et al. [42] report that tin roofs in rural West Bengal houses are generally hotter than those with tile or cement slab roofs, but that the type of roof associated with the hottest indoor temperatures depends on the materials used to construct walls. This study indicated that individuals living in houses with cement slab roofs, tile roofs and tin roofs were equally likely to report at least 1 HRS. This is in apparent contradiction to previous reports from rural Maharashtra villages. Pradyumna et al. [46] noted that people living in houses with tin roofs were significantly more likely to report HRS than individuals living with other types of roofs. Exposure to extreme heat was reported by both the participants working outdoors and staying indoors. Like another study conducted in rural Maharashtra villages, this study found that farmers and farm labourers were the most likely people to experience HRS [49].

Many studies have indicated that women are more likely than men to be affected by climate change [50–53]. There are several reason behind the greater vulnerability of women to heat stress – and vulnerability to HRS: i) working women are exposed to outdoor temperature due to livelihood activities such as farmers, and agriculture labourers etc., ii) indoors, they are in front of Chullas (cooking area), which again generate the heat, **and** iii) due to rural cultural factors or practices**,** they **do** not sleep outdoors, which makes them more vulnerable **to the greater heat stress** [54].

Coping strategies used by the rural villagers who participated in this study are like those reported elsewhere for rural Indian villagers but it is unclear whether behavioural strategies offer rural villagers significant relief from the heat [46,55]. However, as in a previous study of rural Maharashtra villages [34], the current study shows that desert coolers provide important relief in villages located in low-humidity environments. Even desert coolers have evolved over a period of time. Earlier there was no speed control system for the older models of desert coolers; but currently, desert coolers have a speedometer and people find this device very useful. In addition, this cooler also is one of the best choices for managing the indoor temperature considering its availability and affordability

The results from this current research will help to shape suggestions that can contribute to the formulation of comprehensive guidelines for rural Heat Action Plans (HAPs). Being a temperature-sensitive district, Wardha district comes under the Heat Action Plan (HAP) which suggests the priority of the district when it comes to heat stress or heat waves and related hazards. In India, Heat Action Plans [56] have been initiated to introduce mitigation measures aimed at reducing heat related mortality and morbidity. At present, 17 state-level, 23 district-level, and approximately 11 city-level Heat Action Plans (HAP) have been introduced (Total 51). Unfortunately, most of the Heat Action Plans (HAPs) in India focus on the urban areas and have not focused on the rural areas and emphasize the need to create a comprehensive state-level rural heat action plan (HAP) for Maharashtra (India) [41]. A pilot study conducted in the Jalna district of Maharashtra (India) shows that 98 % of households said that heat health advisories are essential during the summer months in rural areas [54]. A small adaptation measure can help to reduce heat stress in indoor and outdoor environments.

5. Limitations of the study

One primary limitation of the study was the sample size. Only 42 houses were monitored for temperature, relative humidity and the dew point, which made it impossible to investigate regional differences in heat stress. The small sample size also limited the power of the statistical analysis of indoor temperature data. Secondly, outdoor temperatures were not monitored, so it was impossible to relate HRS to outdoor heat exposure. Data available from the India Meteorological Department (IMD) station at Pune showed gaps in hourly and daily interval data, so this information was not used.

6. Recommendations

This study reinforces the need to improve the current infrastructure, including developing of regular electricity and water supplies to address indoor heat exposure effectively. Additionally, the including of traditional-based practices in heat action plans can potentially reduce the health impact of HW in rural areas and should be locally specific to combat heat stress. There should be a collaboration between the IMD and the agriculture department to generate he heat advisories. The same platform can be used by the health department in collaboration with IMD can initiate the heat and health advisory process earlier and on a larger scale in the rural areas of India. Reliable mortality statistics and causes are essential for detecting outbreaks, prioritizing health issues, allocating resources, evaluating health programs, and addressing factors influencing mortality. They also support progress toward achieving health-related sustainable development goals by 2030 [57].

7. Conclusion

The results of the current study indicate that individuals living in rural indoor and outdoor environments are severely impacted by heat stress during the summer. People working outdoors adopt a diverse range of adaptation strategies to minimize the effects of heat stress on their health, both in their personal lives and at work. Many individuals take proactive steps in their workplace, including seeking adjusted work hours, carrying water bottles, changing their clothing, and covering their head and face with cloth. The design of housing is a determining factor in indoor temperature, and this, in turn, impacts human well-being.

Measurement of indoor temperature and impacts due to extreme heat in rural areas are available but on a small scale in India. The current knowledge gap must be filled by generating data through research focusing on the experiences of people living in smaller towns and rural India regarding the effects of rising temperatures, their impact on human health, indoor heat exposure and health risk. From the development perspective, the needs of local stakeholders are incompletely understood. These needs should be incorporated into local action plans to mitigate the heat-related impacts that marginalized people face in the rural landscape.

CRediT authorship contribution statement

Tasgaonkar Premsagar Prakash: Data collection, data curation, data cleaning, methodology, analysis. **Murari Kamal Kumar**: Conceptualization, study methodology, analysis.

Declaration of Competing Interest

The authors declare no competing interests.

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