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ARAŞTIRMA / RESEARCH ARTICLE

Effect of Temperature on Gender-Specific All-Cause Mortality: A Study of the City in Northern India

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Abstract

Background: The populations of developing nations are more vulnerable to high heat due to poor public health infrastructure and their sensitiveness towards changing climate. Excess mortalities caused by high temperatures have been reported from many parts of the world, including India. In the recent future, more warming and frequent hot days during summer are expected.

Methods: An analysis was carried out to study the effect of maximum temperature (Tmax) on gender-specific all-cause mortality during the summer months (May and June) of 2011 to 2015 in Chandigarh city of India. The mortality is calculated at different thresholds of temperatures of ≤35°C, ≤38°C, <40°C, ≥40°C and ≥42°C. The average number of deaths at temperatures <40°C and ≥40°C were calculated at 99% significance. The Welch t-test is applied to test the significance.

Results: Tmax shows a high degree of association with all-cause mortality in both males and females. Male to female all-cause death ratio was found to be 1.67 for the study period. Daily Tmax of 40°C was found to be the point of inflexion as the number of mortalities at Tmax ≥40°C was significantly higher than those at Tmax below 40°C. The analysis also reveals an increase in the number of death among females at the threshold Tmax ≥40°C indicating higher vulnerability of females at higher temperatures of certain threshold.

Conclusion: A temperature of 40°C should be considered a threshold temperature for issuing heatwave alerts for Chandigarh, India. The increase in vulnerability at temperatures ≥40°C was more among the females.

Keywords: Heat, All-Cause Mortality, Chandigarh, Maximum Temperature.

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1. INTRODUCTION

Rising trends in temperatures and the increased incidence & severity of heatwaves have become more frequent and intense over the recent past. According to IPCC, the warming of the climate system is unequivocal. Since the 1950s, many of the observed changes are unprecedented over decades to millennia. The global mean temperature are expected to rise over the 21st century by 0.3°C to 4.8°C, based on concentration-driven different RCPs (Representative Concentration Pathways)1. Hence, it is expected to increase the intensity and frequency of warm days (heatwaves) during summertime across the globe. Unprecedented warming is impacting different sectors, including livelihoods. Developing regions, Africa, South America, the Middle East, and South Asia, may be highly affected primarily due to poor public health infrastructure and more vulnerable populations.2 The warmer and/or frequent hot days and nights have increased over most land areas and are likely to expand further into the 21st century. In India, the temperature has been predicted to rise by 1.7-4.9°C by the end of the 21st century under the different RCPs3,4. More extreme temperature and heatwave events are expected in the near future in the Northern part of India too.

The heat caused mortality have been reported in the past across the globe.5–13 Trends in India are also similar to those in many other parts of the world. More than 2,000 heat-related deaths were reported in India in 2015, with most deaths reported from Andhra Pradesh, Telangana, Punjab, Odisha and Bihar.14 Further an increasing trend in the number of heatwave days and in maximum temperature (Tmax hereafter) above 90th, 95th and 98th percentile has been reported over several parts of India. Among all the five decades of understudy, the highest decadal frequency of heatwave days was observed during the latest decade (2001–10)15,16. Varying number of deaths ranging from 393 (in 1997) to 2422 (in 2015) due to heatwave with an increasing trend from the year 1992 to 2015 have been reported in India5,14,17 .

In absence of information on cause-specific mortalities, all-cause mortalities are generally considered to study the associations between high temperatures and all-cause mortality in India and other parts of the world5,6,11,18–21. A significant relationship of high temperatures with increased mortality has also been reported in developing nations from tropical regions22. Some of these studies have established that high temperature-induced mortalities increase markedly after the temperatures cross certain thresholds5,9,22. More frequent warmer days were suggested in the near future, leading to more heat-related outdoor and indoor deaths23. However, research linking mortality to heat during the summer months is limited to a few numbers of cities in the country. The present research is the first study for Chandigarh city to establish thresholds of Tmax for heat-related all-cause mortality. The literature survey is placed in section 1. Section 2 deliberates the study area, data & methodology; and results & discussion are placed in section 3 & 4, respectively.

2. STUDY AREA, DATA AND METHODS

2.1. Study Place

The current study was carried for Chandigarh, a Union Territory and combined capital for two states (Haryana and Punjab) in northern India (Figure 1). The city has a population density of 7900 persons per square km with 86.43% literacy. As per Census 2011, Chandigarh has a poor male to female sex ratio with 818 females per 1000 males, lower than all India figures of 940. The city experiences four seasons in a year, summer (mid-March to Mid-June), Monsoon or rainy season (late-June to September), post-monsoon autumn (September to November) and winter (December to February). During summer, May and June remain the hottest months with June being the warmest month (http://chandigarh.gov.in/knowchd_general.htm). Chandigarh bears a Health Index (HI) of 63.62. It needs further improvement, as Kerala takes first place in India with an HI of 74.01[24]. The city, like many other parts of India, has registered increasing trend in temperature during the summer months[25]. More extreme temperature and heatwave events are expected in the near future in northern parts of the country [23,26,27]human health and has been a subject of prior considerable attention. Hence, for the sustainable development and adaptation of the urban population to climate change, it is essential to find the trend and magnitude of temperature and precipitation over Indian cities. An endeavor has been made in the present study to find the trend and magnitude of temperature and precipitation over 139 major Indian cities with respect to different Koppen climatic zones using Climatic Research Unit datasets of last 115 years (1901–2015.

The current study may provide a guideline for issuing of warning for heat-related health impacts. The same may be extrapolated to other parts of India based on data availability and comparable analysis. Need for more such studies to quantify the location-specific thresholds have also been emphasized[17]. Hence, the current study considers Chandigarh, a city from North India for analysis of relationship between temperature and all-cause mortality.

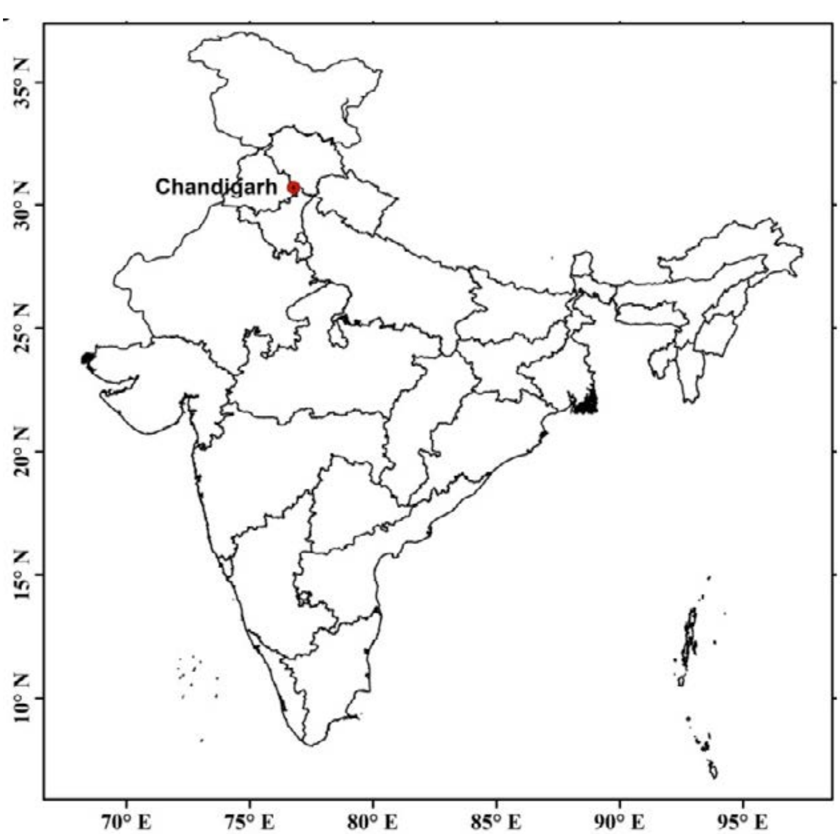
2.2. Study period and Data

Daily all-cause mortality data for May and June between 2011 and 2015 were obtained from the Registrar, Birth and Death, Chandigarh Administration office. The data were available for male and female mortalities only. The observed Tmax was obtained from the Meteorological Centre of India Meteorological Department (IMD), Chandigarh. Due to the unavailability of data on other factors such as exposure to sunlight, level of activity etc. which may influence mortality[28], the current study was restricted to the relationship between temperature and all-cause mortality during the summer months.

2.3. Selection criteria

We limited the study to the summer season (May and June), when higher temperatures are expected over the city. Further, the mortality is calculated at different thresholds of temperatures of ≤35°C, ≤38°C, <40°C, ≥40°C and ≥42°C. The finding of different thresholds for Tmax and related death may help in issuing the early warming issues by the disaster managers.

Fig. 1: Study area showing the geographical location of Chandigarh in India

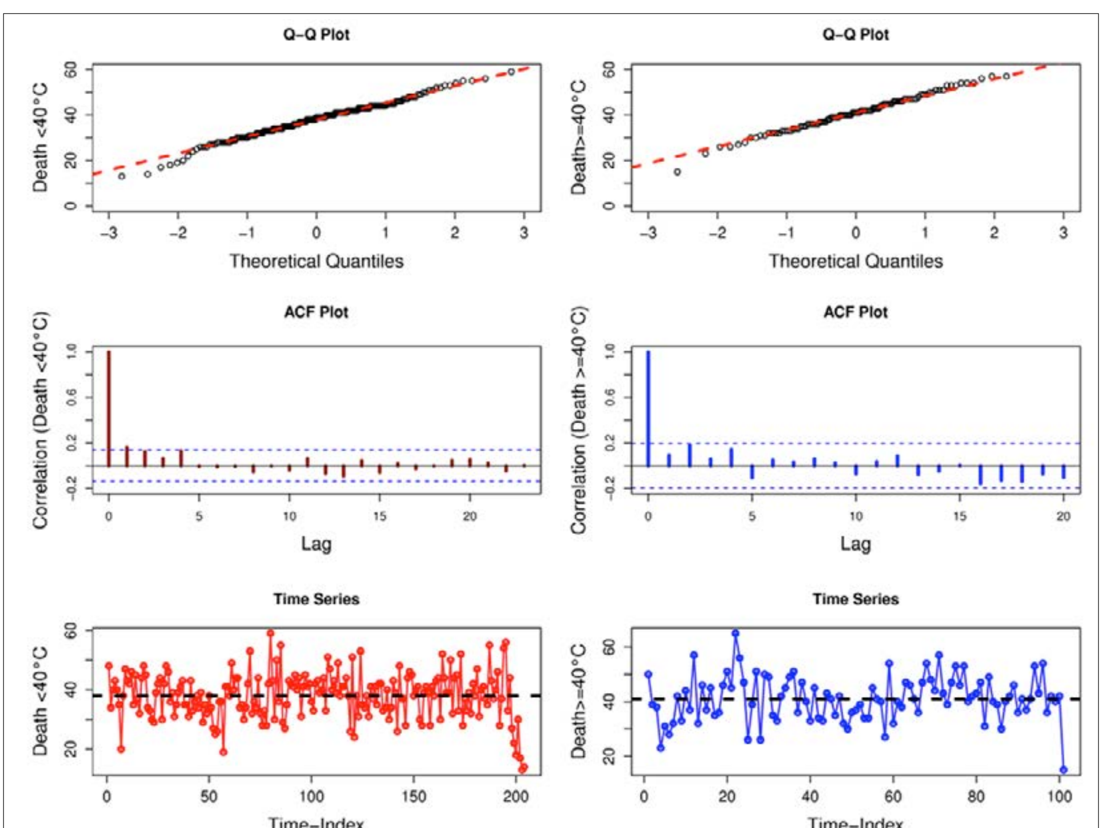


2.4. Methods for Analysis

The daily Tmax and all-cause mortality for the respective days were analysed to find the relationship during peak summer months (May and June) for the period 2011-2015. The data were analysed based on clustering methods. Further, the data were analysed to calculate the average number of mortalities (male and female, separately) per day for days with different Tmax thresholds. Simultaneously, the mortality rate per 0.1 million population is also calculated. The considered thresholds for the temperature were ≤35°C, ≤38°C, <40°C, ≥40°C, ≥42°C. Two independent samples considering the number of deaths at temperatures <40°C and ≥40°C were considered. The two thresholds have unequal sample sizes of 204 and 101, respectively. Quantile-quantile plot (QQ plot), autocorrelation function (ACF) and time series analysis were performed for both samples to assess whether the two groups are independent and fulfil the criteria for normality, stationarity and homogeneity. Figure 2 shows the theoretical quantile (Q-Q plot), ACF and time series plot for deaths at temperatures <40°C and ≥40°C to define whether the samples are independent or not. We plotted the theoretical quantiles, known as the standard normal variate (a normal distribution with mean equal to zero and standard deviation equal to one on the x-axis and the variables (number of death) on the y-axis). All points of both the samples lie on a straight line (evenly aligned with the standard normal variate) confirming it as a normal distribution.

A plot of the autocorrelation of a time series by lag, known as Auto Correlation Function (ACF) denoting the degree of correlation of the same variable between two successive time intervals was used for checking randomness in a data set. The randomness is ascertained by computing autocorrelations for data values at varying time lags (as shown in the x-axis of Fig. 4b). Further, the time series was plotted for death <40°C and ≥40°C concerning time (on the x-axis) which signifies that the time series is stationary. As the two samples were normally distributed and stationary, the significant test (Welch t-test) was carried at a 99% ($p<0.01$) confidence interval for both the samples.

Fig. 2: Quantile-Quantile plot (first row), ACF (2nd row) and time-series (3rd row) plot for death <40°C (left panels) and ≥40°C (right panels). The theoretical quantile in the first panel of the Figure is standard normal variate and autocorrelation at different lags are shown in the second panel.



3. RESULTS

Daily all-cause mortalities in May and June for 2011 to 2015, along with Tmax, are shown in Figure 3. Average daily Tmax during different months and an average number of all-cause mortalities per day along with mortality rate per 0.1 million of the population are given in Table 1. Average Tmax of different months during the period varied from 35.0°C (June 2011) to 40.5°C (June 2012). The average number of deaths per day was also found to fluctuate with the temperature. On average, there had been 39 deaths per day during the study period which comes out to be 4.3 persons per 0.1 million. Higher mortality (overall) was reported among the male population in the city, with a male to female death ratio of 1.67 for the study period. The data were further analyzed to calculate the average number of daily deaths, along with mortality rate (per 0.1 million population) for days with different Tmax thresholds (Table 2 and Table 2A respectively). On average, 37-38 deaths were observed for the days when Tmax remains below 40°C with a mortality rate of 3.5-3.6. However, at Tmax ≥40°C, the number of deaths count increased and was found to be 41-43 deaths (mortality rate of 3.9-4.1). The analysis was further performed for total death per day with the average of Tmax for the previous four days (including the day of death). A significant increase in the number of deaths (95% Confidence Interval, p-value = 0.0002462) was found when the average Tmax remained ≥40°C for four consecutive previous days.

4. DISCUSSIONS

The study found a positive relationship between Tmax and all-cause mortality in Chandigarh city of India. The number of daily all-cause mortalities generally increased or decreased with an increase or decrease in daily Tmax. However, there does not seem to be one to one relationship between the two. The hottest months during the study period (June 2012 and June 2014) recording the average Tmax above 40°C also recorded the highest number of deaths per day (43 each with a mortality rate of around 4.0 per 0.1 million of the population), which are about 10% higher than the average number of deaths during the entire period. Similar findings are reported for other cities in India[5,11]. Heatwave during 2015 were reported to cause 2248 numbers of deaths across India with 1677 deaths in the state of Andhra Pradesh alone [17].

Fig. 3. Daily maximum temperature and daily all-cause mortalities for May and June from 2011 to 2015

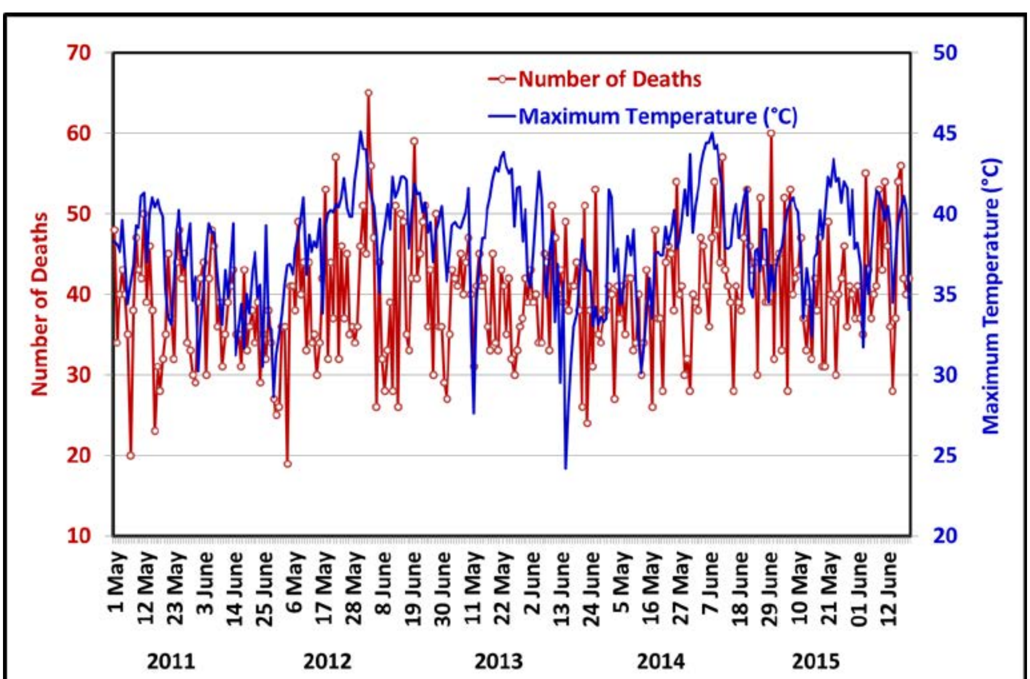


Table 1. Average daily Tmax and the average number of deaths per day for the months of May and June from 2011 to 2015.

Year	Month	Mean Tmax	Average Number of Deaths per Day		
			Male	Female	Total
2011	May	38.0	24.0 (4.1)*	13.8 (2.9)*	37.8 (3.6)*
	June	35.0	22.9 (3.9)	13.8 (2.9)	36.6 (3.5)
2012	May	38.5	24.2 (4.2)	14.2 (3.0)	38.5 (3.6)
	June	**40.5**	27.1 (4.7)	15.5 (3.3)	**42.5 (4.0)**
2013	May	39.4	25.5 (4.4)	12.7 (2.7)	38.2 (3.6)
	June	35.3	26.2 (4.5)	13.2 (2.8)	39.4 (3.7)
2014	May	37.2	24.2 (4.2)	13.6 (2.9)	37.8 (3.6)
	June	**40.3**	**27.6 (4.8)**	**15.5 (3.3)**	**43.1 (4.1)**
2015	May	39.0	25.6 (4.4)	14.0 (2.9)	39.6 (3.8)
	June	37.9	22.3 (3.8)	14.2 (3.0)	36.4 (3.4)
Average			25 (4.3)	14 (2.9)	39 (3.7)

*The figure in parenthesis shows mortality rate per 0.1 million of population.

Table 2: Average number of deaths at the different temperatures in Chandigarh

Tmax (°C)	Number of Deaths per day		
	Male	Female	Total
≤35	24	14	37
≤38	24	13	38
<40	24	14	38
≥40	26 (7.5)*	15 (9.5)*	41 (8.2)*
≥42	27 (12.5)**	16 (14.3)**	43 (13.2)**

Figures in parenthesis with * and ** show an increase in the number of deaths at temperatures ≥40 and ≥42°C, respectively, compared to the number of deaths at temperatures <40°C

Table 2(A): Same as Table 2 with mortality rate (per 0.1 million population)

Tmax (°C)	Mortality rate (per 0.1 million)		
	Male	Female	Total
≤35	4.1	2.9	3.5
≤38	4.1	2.7	3.6
<40	4.1	2.9	3.6
≥40	4.5	3.2	3.9
≥42	4.6	3.4	4.1

A significant increase in deaths was found when daily Tmax exceeded 40°C. A higher increase in number of female mortalities was found at Tmax ≥40°C than in the male population. The percentage increase in male, female and total mortalities, respectively at Tmax ≥40°C, was 7.5%, 9.5% and 8.2%; and that at Tmax ≥42°C was 12.5%, 14.3% and 13.2%. The average number of deaths at temperatures <40°C and ≥40°C were further subjected to statistical significance. The significance test (Welch t-test) found the two means statistically different at a 99% confidence interval (p<0.01, p-value = 0.001784), indicating a significant increase in the number of deaths at temperature ≥40°C. These findings are consistent with the study from India reporting an increase in death by 10 -13% in different cities[5,22].

Further analysis reveals that the average Tmax for all the days with number of deaths one standard deviation more than the average number of deaths was 39.7°C which further indicates that 40°C seems to be the point of inflexion above which significantly higher number of deaths are reported. Hence, a temperature of 40°C should be considered a threshold temperature for issuing heatwave alerts for the city. An intervention like an early forecast of heatwaves based on established thresholds, community awareness, health care capacity-building etc. may reduce mortality at higher temperatures[29].

The number of deaths among the males was higher at all the temperature thresholds (Table 2). This could, partially, be attributed to frequent and prolonged exposure of the male population to outdoor activities connected with their livelihood. Larger increase in female mortalities at temperatures ≥40°C and ≥42°C compared to male mortalities indicates an increase in vulnerability of the female population at higher temperatures. A study based on sex-stratified mortality due to heatwaves revealed that older women are at higher risk than men[22,30]intense and longer-lasting heat waves which can have severe health outcomes. The elderly are a high-risk population for heat-related mortality and some studies suggested that elderly women are more affected by extreme heat than men. This study aimed to review the presence of sex-specific results in studies performed on mortality in elderly (> 65 years old. Further, in developing nations like India, females stay indoors and perform household activities with poor infrastructures. They even suffer from a dearth of continued electricity, indoor sanitation and proper ventilation.

5. CONCLUSIONS

Current research analyses the effects of Tmax on daily all-cause mortality in the Chandigarh city of India for the period 2011-2015 during the summer months of May and June. The average number of deaths for all days with temperatures ≥40°C was found to be statistically higher than the average number of deaths for all days with temperatures <40°C indicating that 40°C is the point of inflexion for a higher number of all-cause mortalities; and could, therefore, be considered a threshold temperature for issuing heatwave alerts for the city. However, the increase in the number of deaths among the female population at temperatures ≥40°C was higher than that among the male population. This analysis shows the higher vulnerability of the male population on account of their higher outdoor exposures. However, the increase in vulnerability at temperatures ≥40°C was more among the females. The National Meteorological Service of the country- India Meteorological Department- issues the forecast for temperature on short, medium, extended, and seasonal periods. Based on the forecast of Tmax, the obtained threshold from the current research outputs may be applied to issue impact-based heatwave warnings. The disaster managers may use the same to disseminate for public use. For similar settings, the study may be replicated for determining the threshold for heatwave warnings of a place or a region. Further, more detailed data may be recorded by the concerned authority for detailed study.

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