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Mortality Risk Related to Heatwaves in Dezful City, Southwest of Iran

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ABSTRACT

BACKGROUND: We aimed to evaluate the impact of heatwaves on daily deaths due to non-accidental, cardiovascular and respiratory causes in the city of Dezful in Iran from 2013 to 2019.

METHOD: We collected daily ambient temperature and mortality and defined 2 types of heatwaves by combining daily temperature ⩾90th in each month of the study period or since 30 years with duration ⩾2 and 3 days. We used a distributed lag non-linear model to study the association between each type of heatwave definition, and deaths due to non-accidental, cardiovascular and respiratory causes with lags up to 13 days.

RESULTS: There was no discernible correlation in this area, despite the fact that heatwaves raised the risk of death from cardiovascular causes and lowered the risk from respiratory causes. On the other hand, the risk of total non-accidental mortality on days with the heatwaves is significantly higher than normal days. In main effects, the heatwaves have a significant relationship with the risk of total non-accidental mortality (in the first heatwave definition, Cumulative Excess Risk (CER) in $lag_{0\text{-}2}$ was 10.4 and in second heatwave definition, CER values in $lag_{0,\ 0\text{-}2,\ \text{and}\ 0\text{-}6}$ were 12.4, 29.2, and 38.8 respectively). Also, in added effects, heatwaves have a significant relationship with the risk of total non-accidental mortality (in the first heatwave definition, CER in $lag_{0\ \text{and}\ 0\text{-}2}$ were 1.79 and 4.11 and in the second heatwave definition, CER values in $lag_{0,\ 0\text{-}2,\ \text{and}\ 0\text{-}6}$ were 7.76, 18.35 and 24.87 respectively). In addition, heatwaves appeared to contribute to a cumulative excess risk of non-accidental death among the male group as well as the older adults.

CONCLUSION: However, the results showed that heatwaves could have detrimental effects on health, even in populations accustomed to the extreme heat. Therefore, early warning systems which monitor heatwaves should provide the necessary warnings to the population, especially the most vulnerable groups.

KEYWORDS: Climate change, health, disaster, heatwave, mortality

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Background

One of the growing natural hazards around the world is temperature rise, linked to climate change, and increasingly resulting in extreme temperature events called "heatwaves."[1] Various studies show that heatwaves have severe negative effects on human health.[2-5] Due to the increasing global temperature[5-8] and the subsequent increasing frequency and severity of the extreme weather events,[7,9] heatwaves became important health concerns worldwide.[5-7] Prior studies provide evidence that heatwaves are associated with increased risk of deaths, hospitalizations, and emergency visits.[10-19] Heatwaves are projected to increase in frequency, length, and intensity due to the continued climate change.[20,21]

Understanding the relationship between heatwaves and health is critical for better planning, mitigation strategies, preparedness, and timely response.[22] This is complex: the association between temperature and health outcome depends on climatic zone and latitude and it is therefore necessary to study the health impacts of heatwaves in different latitudes[23] and specific climatic conditions. Although

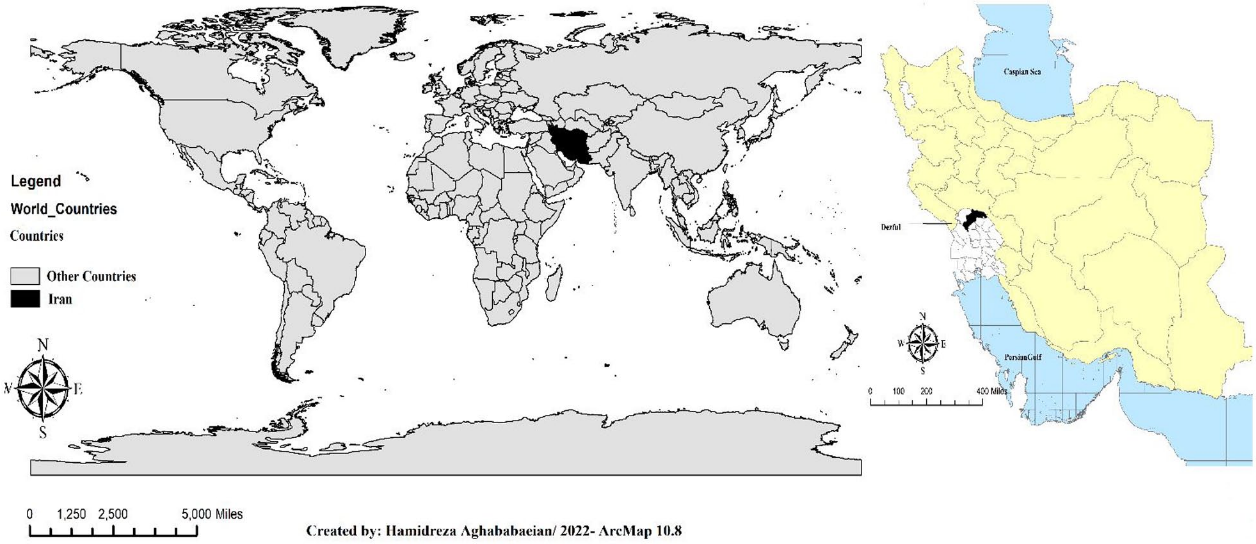

Figure 1. Map of world (left), Iran (right) included Dezful location.

the effects of heatwaves, especially health effects, have been assessed in several settings internationally, but most heatwave studies have been conducted in temperate or cold regions.[24-28]

There are limited studies on the effects of heatwaves on health in the Middle East in general and in Iran in particular.[27] In recent years, studies on the effect of heatwaves on health had been conducted by Sharafkhani et al,[16] Ahmadnezhad et al,[17] and Aboubakri et al[29,30] in 3 cold regions in Iran (Tehran, Urmia, and Kerman cities, respectively). These regions have a completely different climate from Khuzestan province and the city of Dezful, located in the southwest of Iran. There are few studies in developing countries that have examined the effects of heatwaves and their impact on public health in areas with hot climates or high-average temperatures.[14,31] For example, there were studies done in India, which has a hot climate, but the average, minimum, and maximum base temperatures of the studied cities differ than that of Dezful.[14,31] Although many studies have been carried out across the world on the effects of heatwaves on health, the harmful health consequences of this type of natural hazard in areas with hot climates have not been fully identified.[27] Dezful is a city in a region with hot and humid climate, where the temperature reaches above 50°C in the summer, one of the hottest cities in the world. Consequently, it is necessary to study and measure the effects of this natural disaster on the health of people in this city. This study aims to assess the effect of heatwaves on mortality as the most important health criterion.

Materials and Methods

We use an ecological time series model to investigate the relationship between heatwaves and daily non-accidental (NAD), respiratory, and cardiovascular deaths in the city of Dezful from 2013 to 2019.

Climate and location of Dezful

Dezful is a city with a hot and humid climate,[32-34] located in the north of Khuzestan province in Southwest of Iran (Figure 1).[35] It is located 142 m above the sea level.[32,33] According to the 2016 census, Dezful had a population of 444 000. It has warm summers (sometimes sultry) and Mediterranean winters. The average annual rainfall in Dezful is about 400 mm.[32-34]

Average temperature in Dezful

The hot season lasts for 4.0 months, from May 23 to September 23, with an average daily high temperature above 40°C. The cool season lasts for 3.4 months, from November 26 to March 7, with an average daily high temperature below 22.77°C. Annual weather averages summary is provided in the Supplemental Material (Additional File 1: Appendix 1).[32-34]

Mortality data

We obtained daily mortality data between 2013 and 2019 from the Deputy of Health at the Dezful University of Medical Sciences. Cause-specific mortality was coded according to 10th revision of International Classification of Diseases (ICD-10): non-accidental (ICD-10: A00-R99), cardiovascular (ICD-10: I00-I99), and respiratory diseases (ICD-10: J00-J99). Daily deaths were then aggregated by age (<15, 15-64, 65-74, and ⩾75 years) and sex (male vs female).

Meteorological data

We obtained daily maximum temperature, minimum temperature, maximum relative humidity, and minimum humidity from the Islamic Republic of Iran Meteorological Organization. We calculated daily mean temperature by taking the average of maximum and minimum temperature, and daily mean relative humidity by taking the average of maximum and minimum relative humidity. We also obtained daily $PM_{2.5}$ and PM_{10} between 2013 and 2019 from the Khuzestan Department of Environment. Locations are provided in the Supplemental Material (Additional File 1: Appendix 2).

Definitions of heatwaves

Since there is no global consensus on the definition of a "heatwave," particularly in settings with average high temperatures. We considered 2 definitions based on prior studies.[17,25,36,37] For the first definition, we defined heatwave as daily maximum temperature ⩾90th percentile of maximum temperature in each month of the current study period with duration ⩾2 days as a Definitions of heatwave$_1$ (HW_1).[36-38] For the second definition, we defined heatwave as daily maximum temperature ⩾90th percentile of maximum temperature in data for a 30-year period from 1983 to 2012 with duration ⩾3 days as a Definitions of heatwave$_2$ (HW_2).[17] Details are provided in the Supplemental Material (Additional File 2: Appendix 1).

Design

We assessed both the main and added effect of heatwave on mortality.[15,39] The main effect of heatwave was used to investigate the effects of heat, and the added effect of heatwave was to examine the effects caused by heat persistence.[15,39] In this study, all the heatwaves in Dezful city occurred during the warm months from 21 March to 21 October (which is equal to the beginning of Farvardin month till the end of Mehr in the Persian calendar). We calculated the main effects as the risk of mortality at the median temperature among the heatwave days relative to the risk of death at the 65th percentile of annual temperature distribution, which temperature percentile was the percentile at the lowest risk of mortality (Supplemental Material Additional File 2: Appendix 2).[15,16] We calculated the added effect as the risk of deaths during heatwave days relative to non-heatwave days. Details are provided in the Supplemental Material (Additional File 2: Appendix 3). In the last decades, Dezful has been exposed to environmental pollutants from desert dust.[35,40] The results of previous studies indicate that human health is affected by environmental pollutants caused by dust storms. Therefore, the effects of these 2 environmental pollutants (PM_{10} and $PM_{2.5}$) were taken into consideration in this study.[40,41]

Statistical analysis

Given that the distribution of daily deaths follows the Poisson distribution, we estimated the association between heatwave and deaths using a quasi-Poisson regression combined with a distributed lag nonlinear model. The distributed lag nonlinear model allows us to model both the nonlinear and delayed effects of heatwave. We modeled the lag function using a natural cubic B-spline with 2 knots placed at equal intervals on the logarithmic scale of the lags up to 13 days.[15,16,39]

$$\text{LogE } [Y_t] = \alpha + \text{cb } (T_1, 2, 3) + \text{cb } (T_2, 2, 3) + \text{ns } (PM_{10}, df = 3) + \text{ns } (PM_{2.5}, df = 1) + \text{ns } (RH, df = 2) + \text{ns } (\text{Season}, df = 3) + \text{ns } (\text{Time}, df = 7) + \text{DOW} + \text{Holidays}$$

Where Y_t is the number of deaths on day t, T_1 refers to the main effect, that is a 2-dimensional natural spline with 2 degree of freedom (df) for temperature (T) and 3 df for lagged temperatures, with maximum lag as 13. T_2 refers to added effect, which is a binary variable assuming value 1 during the heatwave, with maximum lag as 13. Effect of potential confounders controlled by natural spline function. Relative humidity (RH) with 2 df, PM_{10} with 3 df [ns with 3 df is a linear term] and $PM_{2.5}$ with 1 df [ns with 1 df is a linear term]. Season means the variation during the warm season, that is adjusted by a natural spline with 3 df. The effect of time trend is adjusted by a natural spline with 7 df per year. The effects of days of week (DOW) and holidays are adjusted by including categorical variables in the models. We conducted all analyses in R software (version 3.5.1) with the Distributed Lag Non-linear Model (DLNM) package to model the nonlinear and delayed effects of heatwave. Details are provided in the Supplemental Material (Additional File 2: Appendix 4).[42,43]

Sensitivity analysis

In the 2 DLNM matrices constructed, the df for the variable and lags was selected based on the lowest Akaike Information Criterion (AIC) value. In both matrices, the degrees of lag freedom and degrees of variable freedom were tested between 2 and 5. We used the lowest Quasi-Akaike Information Criterion value to guide the selection of the degrees of freedom for the lags and variables. Details are provided in the Supplemental Material (Additional File 2: Appendix 4).

Subgroup analysis

To examine whether the effects of heatwave are varied by personal characteristics, we did subgroup analysis by age group (<15, 15-64, 65-74, and ⩾75 years) and sex (male vs female).

Results

Descriptive results

Table 1 shows the meteorological, heatwaves, and mortality characteristics of Dezful city and the study population, and heatwaves during the warm season from 2013 to 2019. The mean number of total non-accidental daily mortality in Dezful during the study period was 8.33 ± 3. The daily temperature and humidity during the same period in Dezful were 24.6°C ± 9.3°C and 51.2% ± 21.2%, respectively. Other mortality, meteorological, and heatwaves characteristics are provided in Table 1.

Table 1. Mortality, meteorological, and heatwaves characteristics of Dezful city (2013-2019).

VARIABLE	VALUE
Daily death number by causes (number) mean (SD)	
Non-accidental	8.3 (3)
Respiratory	0.6 (0.6)
Cardiovascular	3.5 (1.9)
Daily death number by age (years) mean (SD)	
<15	1.1 (1.1)
15-64	2.8 (1.7)
65-75	1.1 (1)
⩾75	3.1 (1.8)
Daily death number by gender (number) mean (SD)	
Male	4.8 (2.2)
Female	3.4 (1.9)
Daily temperature (°C): Mean (SD)	
Daily temperature	24.6 (9.3)
Minimum temperature	17.1 (7.8)
Maximum temperature	33 (10.7)
Daily relative humidity (%): Mean (SD)	
DRH	51.2 (21.2)
Heatwaves characteristic	
Number per year [mean (min, max)]	
HW_1	6 (2, 7)
HW_2	6.6 (2, 8)
Average heatwave intensity (°C) [mean (min, max)]	
HW_1	44.7 (35.5, 51.2)
HW_2	47.9 (47, 51.2)
Average heatwave duration (day) [mean (min, max)]	
HW_1	2.6 (2, 6)
HW_2	4.1 (3, 13)
Start date of heatwave (earliest, latest)	
HW_1	28 Mar, 10 Oct
HW_2	11 Apr, 30 Sep

Abbreviations: °C, Centigrade; DRH, daily relative humidity; HW_1, heatwave definition 1 was defined as daily maximum temperature ⩾90th percentile of maximum temperature in each month of the current study period with duration ⩾2 days; HW_2, heatwave definition 2 was defined as daily maximum temperature ⩾90th percentile of maximum temperature since last 30 years ago [1983-2012] with duration ⩾3 days; SD, standard deviation.

The model results

Table 2, show the Cumulative excess risk in Dezful for non-accidental, cardiovascular and respiratory deaths (Supplemental Material Additional File 3: Appendix 1 and 2). As these table and figures shows, heatwaves were not related to cardiovascular and respiratory mortality, but in the main effects, the HW_1 heatwaves significantly increased the excess risk of NAD in lag_{0-2} (10.43; 95% CI: 0.63, 20.59); and in addition, regarding HW_2, heatwaves significantly increased the excess risk of NAD in lag_0 (12.48; 95% CI: 2.81, 23.05), lag_{0-2} (29.20; 95% CI: 8.99, 50.88) and lag_{0-6} (38.86; 95% CI: 3.35, 76.44).

Also, in the added effects of the HW_1, the excess risk of non-accidental death increased significantly in lag_0 (1.79; 95% CI: 0.02, 3.59) and lag_{0-2} (4.11; 95% CI: 0.44, 7.83). In addition, regarding HW_2, heatwaves significantly increased the excess risk of non-accidental death in lag_0 (7.76; 95% CI: 1.88, 13.99), lag_{0-2} (18.35; 95% CI: 5.99, 31.25) and lag_{0-6} (24.87; 95% CI: 2.96, 47.56).

Figures 2 and 3 also shows the Cumulative excess risk of non-accidental death for the city of Dezful based on age and sex. As shown in this figures, in main and added effects, heatwaves significantly increased the excess risk of non-accidental death in people equal or more than 75 years old and the male group.

In this regard, in the main effect and added effects, HW_1 increases the excess risk of non-accidental death in the male group (Main effects: lag_{0-2} (13.56%; 95% CI: 0.48, 27.27), and Added effects: lag_{0-2} (13.56%; 95% CI: 0.48, 27.27)). In addition, the main effects of the HW_2 significantly increased the excess risk of death for people over 75 years old and was determined in the lag_0 (15.84%; 95% CI: 0.47, 33.57) and lag_{0-2} (32.53%; 95% CI: 0.67, 68.17). For the male group, there was a significant increase in the excess risk for lag_0 (17.83%; 95% CI: 4.58, 32.75) and lag_{0-2} (39.61%; 95% CI: 12.15, 69.77). In addition, in the added effects of the HW_2, the excess risk of death for people over 75 years old in lag_0 (9.47%; 95% CI: 0.14, 19.67) and lag_{0-2} (19.91%; 95% CI: 0.41, 40.81) increased significantly. This noteworthy increase was also evident in the male group in the same conditions in the lag_0 (11.25%; 95% CI: 3.27, 19.84), lag_{0-2} (25.23%; 95% CI: 8.59, 42.86) and lag_{0-6} (30.53%; 95% CI: 1.35, 61.12) (Supplemental Material Additional File 3: Appendix).

Discussion

In this study, we found that heatwaves are associated with a higher excess risk of non-accidental mortality in Dezful city, which has much higher base temperature than most previous studies about heatwaves and health.

Our results are similar to the findings of some other studies with the same temperature and cold regions.[27,44,45] In this regard, Linares[46] stated that, in Spain increasing each Celsius degree of daily maximum temperature from the threshold of

Table 2. The cumulative excess risk of non-accidental, respiratory, and cardiovascular deaths due to heatwaves.

DEATH	LAG DAY	HEATWAVE DEFINITION 1[a]		HEATWAVE DEFINITION 2[b]	
		MAIN EFFECT	ADDED EFFECT	MAIN EFFECT	ADDED EFFECT
Non-accidental N = 13441	0	4.60 (−0.12, 9.56)	**1.79 (0.02, 3.59)*** **	**12.48 (2.81, 23.05)*** **	**7.76 (1.88, 13.99)*** **
	0-2	**10.43 (0.63, 20.59)*** **	**4.11 (0.44, 7.83)*** **	**29.20 (8.99,, 50.88)*** **	**18.35 (5.99, 31.25)*** **
	0-6	12.78 (−4.47, 30.55)	5.18 (−1.31, 11.76)	**38.86 (3.35, 76.44)*** **	**24.87 (2.96, 47.56)*** **
	0-13	8.17 (−23.01, 40.18)	3.10 (−8.75, 15.08)	21.96 (−40.19, 87.41)	14.09 (−24.78, 54.24)
Cardiovascular N = 6470	0	2.56 (−3.04, 8.50)	0.89 (−1.22, 3.05)	8.95 (−2.50, 21.77)	5.30 (−1.76, 12.87)
	0-2	5.64 (−6.03, 17.83)	2.02 (−5.32, 10.43)	19.42 (−4.64, 45.68)	11.70 (−3.18, 27.41)
	0-6	6.46 (−14.16, 27.82)	2.50 (−5.32, 10.43)	21.27 (−21.16, 66.77)	13.35 (−13.10, 40.98)
	0-13	5.88 (−31.65, 44.63)	1.98 (−12.33, 16.46)	13.82 (−61.75, 94.35)	8.25 (−39.19, 57.61)
Respiratory N = 1165	0	0.01 (−18.20, 22.23)	−0.90 (−8.19, 6.97)	1.29 (−30.56, 47.77)	1.10 (−22.09, 25.54)
	0-2	−3.48 (−41.83, 41.34)	−3.30 (−18.59, 12.92)	−6.65 (−74.65, 84.77)	−8.34 (−53.18, 45.67)
	0-6	−16.22 (−84.71, 61.31)	−8.48 (−36.75, 20.10)	−41.40 (−163.9, 114.1)	−30.91 (−112.1, 63.4)
	0-13	*−15.59 (−142.01, 125.8)*	−7. 96 (−57.8, 44.1)	−48.74 (−278.1, 236.2)	−34.33 (−184.7, 137.8)

Bold typeface with ***: indicates statistical significance at $P < .05$.
[a]Heatwave definition 1 was defined as daily maximum temperature ⩾90th percentile of maximum temperature in each month of the current study period with duration ⩾2 days.
[b]Heatwave definition 2 was defined as daily maximum temperature ⩾90th percentile of maximum temperature since last 30 years ago [1983-2012] with duration ⩾3 days.

37°C could increase the risk of mortality by 10.3%. Also, similar results were found in studies conducted in Brazil[47] and India.[14,31] In these studies, which examined the effect of heatwaves on the mortality of 4 cities with high average temperatures, Azhar et al[14] and Nouri Sarma[31] found that the risk of death on days with heatwaves has increased significantly. This shows that high temperatures, even in communities that are adapted to the extreme heat, can have adverse effects on the health of the exposed people. The heat-related deaths may occur in exposed humans due to increased blood viscosity, and known clinical syndromes such as heatstroke, dehydration, and cardiovascular diseases.[14,31,48,49] Moreover, the results show that heatwaves significantly increase the risk of non-accidental death in the male group and those over the age of 75. The results of most similar studies support the findings of this study on the stronger effect of heatwaves on the risk of death of the elderly.[15,50-52] This might be due to the reduced capacity of elderly to regulate temperature and taking medication that can intervene with the natural sweating process.[53,54] The studies in line with Thermoregulation in older adults' state that with increasing age, the activation of dilation process of skin vessels and sweating following an increase in body temperature against heat stress decreases, and consequently, body heat storage and core temperature are higher in older adults compared to younger adults during environmental heat exposure.[55]

In terms of the greater effects of heatwaves on the increased risk of death in the male group, in some studies the male group had a higher risk of death than females[19,44]; however, in other studies, females were more likely at risk of death from heatwaves than the male group.[15,52] These differences may be related to the lifestyle, economic context, and social and cultural characteristics of the people of each community.[15] Importantly, any change in any of the above cases can change the vulnerability of men and women to heatwaves. In this regard, the studies show that people who work under the sun or in hot weather, especially during heatwaves, are more at risk, so maybe in this region, because men are more exposed to heatwaves and hot weather while working outside, they are more at risk.[56,57]

Although elevated ambient temperature is associated with airway hyper-responsiveness, fluid and electrolyte imbalance, increased heart rate, and plasma cholesterol, the cardiovascular and respiratory effects of exposure to heatwaves are inconsistent in several studies.[28] The results of this study show that heatwaves can increase the risk of cardiovascular death in all lags. However, for respiratory death, this increase occurred only slightly in the lag_0. But in other lags, the risk of respiratory deaths was reduced, although the consequences of these deaths were insignificant. In this regard, Ahmadnezhad et al[17] in Iran and Woo et al[51] in Australia had also discussed the risk of cardiovascular death in heatwaves and had noted that the risk of death is more due to respiratory diseases. So it is possible to say that the risk of respiratory death in areas with colder temperatures is higher than in areas with hot temperatures.[17]

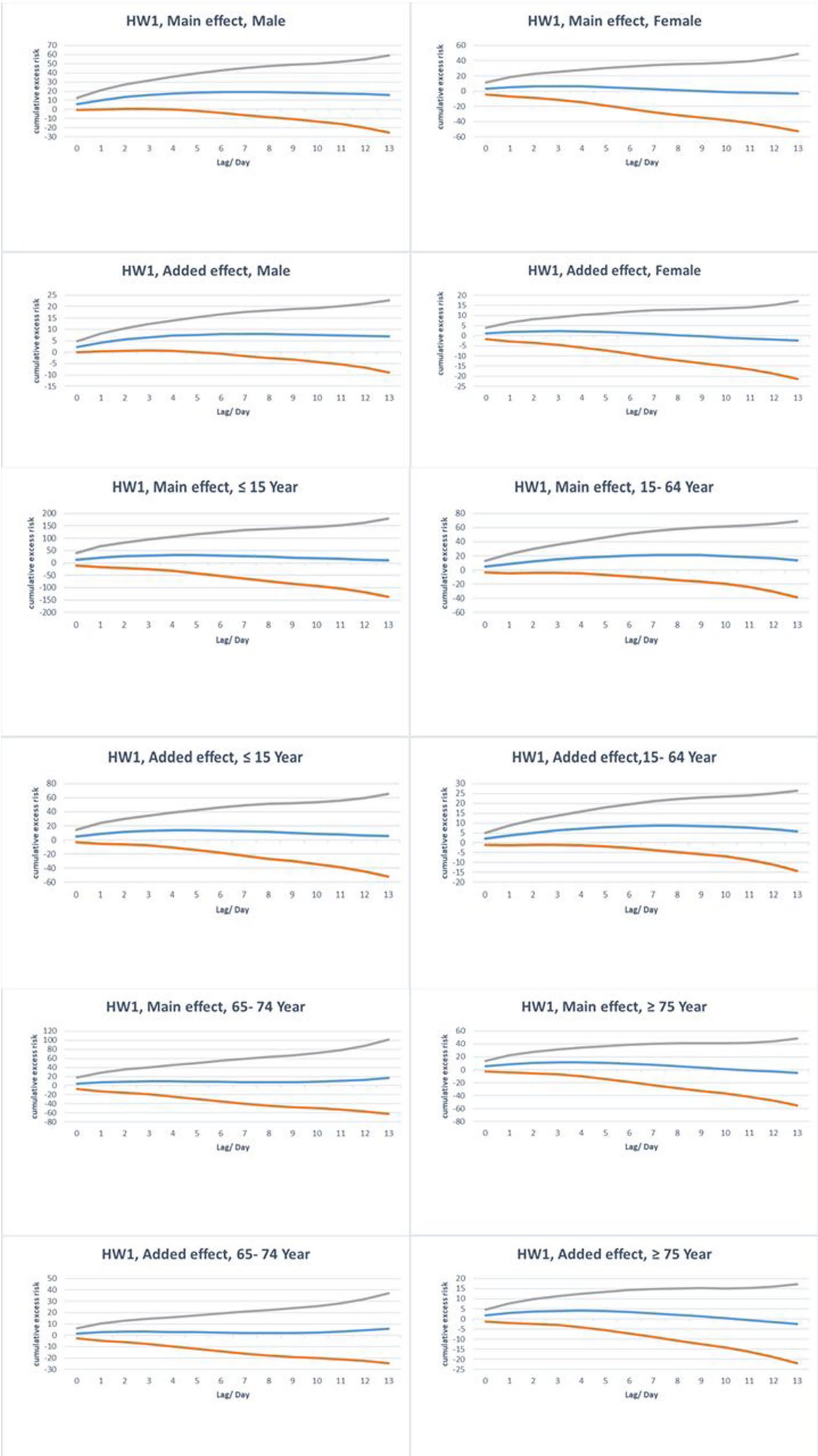

Figure 2. Cumulative excess risk of non-accidental death in Dezful based on age and sex by HW_1.

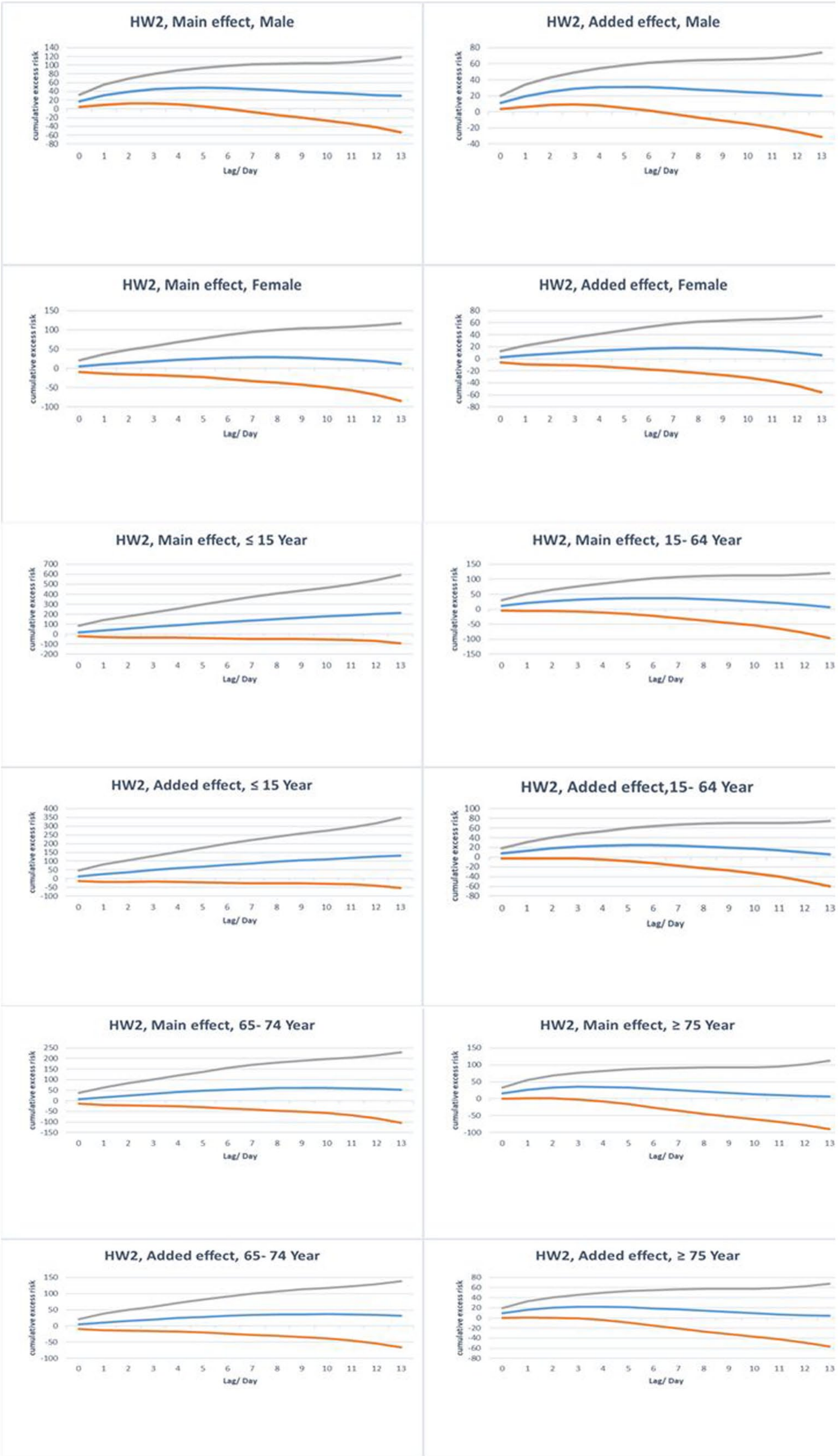

Figure 3. Cumulative excess risk of non-accidental death in Dezful based on age and sex by HW_2.

Some studies report a higher risk of respiratory death than cardiovascular death.[58] These differences in results are due to differences in the definition of heatwaves, heat intensity, and time and duration of heatwaves in each study.[59,60] Notably, due to the insignificant numbers of respiratory deaths, it was not possible to track the impact of heatwaves on daily mortality of this nature. Therefore, it is suggested that future studies investigate the relationship between heatwaves and specific deaths in more detail and for larger populations.

From these results, we also note the importance of choosing the correct definitions of heatwaves in each region. According to the type of definitions and their results, it is estimated that each community is required to determine a precise definition of heatwaves in its region. In this study, the 2 definitions of heatwaves did not produce the same results for mortality. Further studies need to examine various definitions of heatwaves and their relationship with key health indicators. Finally, in this study, the results show that the effects of heatwaves on the risk of death in the main effect are more remarkable than the added effect. In this regard Gasparrini and Armstrong[39] concluded in a study in some American cities, the risk of death due to heatwaves in the main effects is much higher than the added effects. To justify the results of the current study, it can be stated that the higher risk of death in the baseline effects versus the added effects may be due to the announcements of the high temperature early warning systems in Khuzestan province, followed by more compliance to the necessary measures by citizens to prevent health effects. Lin et al[61] also stated that people may be physiologically and psychologically adaptable to a higher temperature for more than a few days which may justify the results of this study. The results of the current study can be more strongly generalized by studying the impact of heatwaves by including more respiratory deaths.

Conclusion

As confirmed in this and other similar studies, people living in areas with extremely high temperature do experience risks to their health from heatwaves, despite the common misconception that people are not vulnerable to heatwaves in the tropics. The specific climate of each region, the degree of exposure, repetition of heatwaves, and body adaptation are important to understand in each setting, and it may be important for each setting to develop its own specific heatwave definition. In the context of global warming, especially in the Middle East and Iran, these findings can be of great help to policymakers in planning and subsequent policy-making to establish early warning systems. It is recommended that more studies need to be conducted on the effect of other definitions of heatwaves on public health in different regions. It is also recommended that other studies on specific causes of death be carried out in more detail, and over a longer period.

Limitations of the Study

We only considered the outdoor ambient temperature, and we did not know the exact location of deaths and temperature, because there may have been people at home who died there, as well. The current study may be short of having the ability to track the effect of heatwave events on cause-specific mortality events in terms of insignificant numbers of respiratory deaths. Also, in Dezful, the amount of ozone is not fully measured. Therefore, we could not evaluate the possible effects of ozone in this study. Finally, we only included the data from the city of Dezful and its surrounding suburbs in our study, because the life pattern, temperature and humidity of other cities in Khuzestan province may not be consistent with the city of Dezful and its suburbs.

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Author Contributions

HA, AOT, and MA designed the study; HA collected the data; HA, RSH, and MSY analyzed and interpreted the data. HA, AOT, AArdalan, RSH, CS, and AAsgary prepared the manuscript. All authors contributed to the drafting and final review of the manuscript. The author(s) read and approved the final manuscript.

Availability of Data and Materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Consent for Publication

Not applicable.

Ethics Approval and Consent to Participate

Current study was approved by the Ethics Committee of Tehran University of Medical Sciences (TUMS) Ethics Code: IR.TUMS.SPH.REC.1399.004, and also all methods were performed in accordance with the relevant guidelines and regulations. This study does not require informed consent directly from the patient since only unnamed archived data has been used. Therefore, the consent has been waived by the ethics committee. However, written permission was obtained from the competent authorities to use this data.

Supplemental Material

Supplemental material for this article is available online.

REFERENCES

1. Intergovernmental Panel on Climate Change (IPCC). IPCC data for eg Intergovernmental Panel on Climate Change (IPCC). 2021. https://www.ipcc.ch. Accessed January 2022.
2. Cheng J, Xu Z, Bambrick H, Su H, Tong S, Hu W. Heatwave and elderly mortality: an evaluation of death burden and health costs considering short-term mortality displacement. *Environ Int*. 2018;115:334-342.
3. Coates L, Haynes K, O'Brien J, McAneney J, de Oliveira FD. Exploring 167 years of vulnerability: an examination of extreme heat events in Australia 1844–2010. *Environ Sci Policy*. 2014;42:33-44.
4. Forzieri G, Cescatti A, e Silva FB, Feyen L. Increasing risk over time of weather-related hazards to the European population: a data-driven prognostic study. *Lancet Planet Health*. 2017;1:E200-E208.

5. Mora C, Dousset B, Caldwell IR, et al. Global risk of deadly heat. *Nat Clim Change*. 2017;7:501-506.
6. Royé D, Codesido R, Tobías A, Taracido M. Heat wave intensity and daily mortality in four of the largest cities of Spain. *Environ Res*. 2020;182:109027.
7. Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R, et al. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC; 2014.
8. Sheridan SC, Allen MJ. Changes in the frequency and intensity of extreme temperature events and human health concerns. *Curr Clim Change Rep*. 2015;1:155-162.
9. Schleussner C-F, Pfleiderer P, Fischer EM. In the observational record half a degree matters. *Nat Clim Change*. 2017;7:460-462.
10. Robine J-M, Cheung SL, Le Roy S, et al. Death toll exceeded 70,000 in Europe during the summer of 2003. *C R Biol*. 2008;331:171-178.
11. Filleul L, Cassadou S, Médina S, et al. The relation between temperature, ozone, and mortality in nine French cities during the heat wave of 2003. *Environ Health Perspect*. 2006;114:1344-1347.
12. Knowlton K, Rotkin-Ellman M, King G, et al. The 2006 California heat wave: impacts on hospitalizations and emergency department visits. *Environ Health Perspect*. 2009;117:61-67.
13. Dole R, Hoerling M, Perlwitz J, et al. Was there a basis for anticipating the 2010 Russian heat wave? *Geophys Res Lett*. 2011;38:n/a-n/a.
14. Azhar GS, Mavalankar D, Nori-Sarma A, et al. Heat-related mortality in India: excess all-cause mortality associated with the 2010 Ahmedabad heat wave. *PLoS One*. 2014;9:e91831.
15. Zeng W, Lao X, Rutherford S, et al. The effect of heat waves on mortality and effect modifiers in four communities of Guangdong Province, China. *Sci Total Environ*. 2014;482-483:214-221.
16. Sharafkhani R, Khanjani N, Bakhtiari B, Jahani Y, Entezarmahdi R. The effect of cold and heat waves on mortality in Urmia a cold region in the north west of Iran. *J Therm Biol*. 2020;94:102745.
17. Ahmadnezhad E, Naieni KH, Ardalan A, Mahmoudi M, Yonesian M, Naddafi K, Mesdaghinia AR. Excess mortality during heatwaves, Tehran Iran: an ecological time-series study. *J Res Health Sci*. 2013;13:24-31.
18. Basu R. High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environ Health*. 2009;8:40.
19. Bell ML, O'Neill MS, Ranjit N, Borja-Aburto VH, Cifuentes LA, Gouveia NC. Vulnerability to heat-related mortality in Latin America: a case-crossover study in São Paulo, Brazil, Santiago, Chile and Mexico City, Mexico. *Int J Epidemiol*. 2008;37:796-804.
20. Stocker TF, Qin D, Plattner G-K, Tignor MM, Allen SK, Boschung J, et al. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of IPCC the Intergovernmental Panel on Climate Change*. Cambridge University Press; 2014.
21. Field CB. *Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects*. Cambridge University Press; 2014.
22. Meehl GA, Tebaldi C. More intense, more frequent, and longer lasting heat waves in the 21st century. *Science*. 2004;305:994-997.
23. McMichael AJ, Wilkinson P, Kovats RS, et al. International study of temperature, heat and urban mortality: the 'ISOTHURM' project. *Int J Epidemiol*. 2008;37:1121-1131.
24. Moghadamnia MT, Ardalan A, Mesdaghinia A, Naddafi K, Yekaninejad MS. The effects of apparent temperature on cardiovascular mortality using a distributed lag nonlinear model analysis: 2005 to 2014. *Asia Pac J Public Health*. 2018;30:361-368.
25. Xu Z, FitzGerald G, Guo Y, Jalaludin B, Tong S. Impact of heatwave on mortality under different heatwave definitions: a systematic review and meta-analysis. *Environ Int*. 2016;89-90:193-203.
26. Moghadamnia MT, Ardalan A, Mesdaghinia A, Keshtkar A, Naddafi K, Yekaninejad MS. Ambient temperature and cardiovascular mortality: a systematic review and meta-analysis. *PeerJ*. 2017;5:e3574.
27. Campbell S, Remenyi TA, White CJ, Johnston FH. Heatwave and health impact research: A global review. *Health Place*. 2018;53:210-218.
28. Cheng J, Xu Z, Bambrick H, et al. Cardiorespiratory effects of heatwaves: a systematic review and meta-analysis of global epidemiological evidence. *Environ Res*. 2019;177:108610.
29. Aboubakri O, Khanjani N, Jahani Y, Bakhtiari B. Attributable risk of mortality associated with heat and heat waves: a time-series study in Kerman, Iran during 2005–2017. *J Therm Biol*. 2019;82:76-82.
30. Aboubakri O, Khanjani N, Jahani Y, Bakhtiari B. The impact of heat waves on mortality and years of life lost in a dry region of Iran (Kerman) during 2005–2017. *Int J Biometeorol*. 2019;63:1139-1149.
31. Nori-Sarma A, Anderson GB, Rajiva A, et al. The impact of heat waves on mortality in northwest India. *Environ Res*. 2019;176:108546.
32. Geographical and climatic features of Khuzestan province: Meteorological Organization of Iran; 2019. http://khzmet.ir/image/climakh.pdf. Accessed October 2021.
33. Dezful General Information. Dezful Municipality; 2020. http://www.dezful.ir/fa-IR/DouranPortal/4652/page/%D8%AA%D8%A7%D8%B1%DB%8C%D8%AE%DA%86%D9%87
34. DEZFUL WEATHER AVERAGES SUMMARY: weatherbase; 2020. https://www.weatherbase.com/weather/weather.php3?s=59704&cityname=Dezful-Khuzestan-IranWEATHER
35. Aghababaeian H, Dastoorpoor M, Ghasemi A, Kiarsi M, Khanjani N, Araghi Ahvazi L. Cardiovascular and respiratory emergency dispatch due to short-term exposure to ambient PM10 in Dezful, Iran. *J Cardiovasc Thorac Res*. 2019;11:264-271.
36. Tong S, FitzGerald G, Wang X-Y, et al. Exploration of the health risk-based definition for heatwave: a multi-city study. *Environ Res*. 2015;142:696-702.
37. Tong S, Wang XY, Barnett AG. Assessment of heat-related health impacts in Brisbane, Australia: comparison of different heatwave definitions. *PLoS One*. 2010;5:e12155.
38. Beniston M, Diaz HF. The 2003 heat wave as an example of summers in a greenhouse climate? Observations and climate model simulations for Basel, Switzerland. *Glob Planet Change*. 2004;44:73-81.
39. Gasparrini A, Armstrong B. The impact of heat waves on mortality. *Epidemiology*. 2011;22:68-73.
40. Eskandari Z, Maleki H, Neisi A, Riahi A, Hamid V, Goudarzi G. Temporal fluctuations of PM(2.5) and PM(10), population exposure, and their health impacts in Dezful city, Iran. *J Environ Health Sci Eng*. 2020;18:723-731.
41. Aghababaeian H, Ostadtaghizadeh A, Ardalan A, et al. Global health impacts of dust storms: a systematic review. *Environ Health Insights*. 2021;15:11786302211018390.
42. Gasparrini A. Distributed lag linear and non-linear models in R: the package dlnm. *J Stat Softw*. 2011;43:1-20.
43. Gasparrini A. Modeling exposure-lag-response associations with distributed lag non-linear models. *Stat Med*. 2014;33:881-899.
44. Hajat S, Armstrong BG, Gouveia N, Wilkinson P. Mortality displacement of heat-related deaths: a comparison of Delhi, Sao Paulo, and London. *Epidemiology*. 2005;16:613-620.
45. Hajat S, Armstrong B, Baccini M, et al. Impact of high temperatures on mortality: is there an added heatwave effect? *Epidemiology*. 2006;17:632-638.
46. Linares C, Diaz J, Tobías A, Carmona R, Mirón IJ. Impact of heat and cold waves on circulatory-cause and respiratory-cause mortality in Spain: 1975–2008. *Stoch Environ Res Risk Assess*. 2015;29:2037-2046.
47. Diniz FR, Gonçalves FLT, Sheridan S. Heat wave and elderly mortality: historical analysis and future projection for metropolitan region of São Paulo, Brazil. *Atmos*. 2020;11:933.
48. Rooney C, McMichael AJ, Kovats RS, Coleman MP. Excess mortality in England and Wales, and in Greater London, during the 1995 heatwave. *J Epidemiol Community Health*. 1998;52:482-486.
49. Keatinge WR, Coleshaw SR, Easton JC, Cotter F, Mattock MB, Chelliah R. Increased platelet and red cell counts, blood viscosity, and plasma cholesterol levels during heat stress, and mortality from coronary and cerebral thrombosis. *Am J Med*. 1986;81:795-800.
50. Lin Y-K, Ho TJ, Wang Y-C. Mortality risk associated with temperature and prolonged temperature extremes in elderly populations in Taiwan. *Environ Res*. 2011;111:1156-1163.
51. Yu W, Mengersen K, Hu W, Guo Y, Pan X, Tong S. Assessing the relationship between global warming and mortality: lag effects of temperature fluctuations by age and mortality categories. *Environ Pollut*. 2011;159:1789-1793.
52. Son J-Y, Lee J-T, Anderson GB, Bell ML. The impact of heat waves on mortality in seven major cities in Korea. *Environ Health Perspect*. 2012;120:566-571.
53. Basagaña X, Sartini C, Barrera-Gómez J, et al. Heat waves and cause-specific mortality at all ages. *Epidemiology*. 2011;22:765-772.
54. Schifano P, Cappai G, De Sario M, et al. Susceptibility to heat wave-related mortality: a follow-up study of a cohort of elderly in Rome. *Environ Health*. 2009;8:50.
55. Meade RD, Akerman AP, Notley SR, et al. Physiological factors characterizing heat-vulnerable older adults: a narrative review. *Environ Int*. 2020;144:105909.
56. Bonafede M, Schifano P, Marinaccio A, et al. 0254 Outdoor temperature, air pollutants and occupational injuries risk: a systematic review of epidemiological studies and a case-crossover study. *Annali dell'Istituto Superiore di Sanita*. 2017;52:357-367.
57. Levi M, Kjellstrom T, Baldasseroni A. Impact of climate change on occupational health and productivity: a systematic literature review focusing on workplace heat. *Med Lav*. 2018;109:163-179.
58. D'Ippoliti D, Michelozzi P, Marino C, et al. The impact of heat waves on mortality in 9 European cities: results from the EuroHEAT project. *Environ Health*. 2010;9:37.
59. Medina-Ramón M, Schwartz J. Temperature, temperature extremes, and mortality: a study of acclimatisation and effect modification in 50 US cities. *Occup Environ Med*. 2007;64:827-833.
60. Vandentorren S, Bretin P, Zeghnoun A, et al. August 2003 heat wave in France: risk factors for death of elderly people living at home. *Eur J Public Health*. 2006;16:583-591.
61. Lin H, Zhang Y, Xu Y, et al. Temperature changes between neighboring days and mortality in summer: a distributed lag non-linear time series analysis. *PLoS One*. 2013;8:e66403.