Science of the Total Environment 571 (2016) 27–33

Contents lists available at ScienceDirect

Science of the Total Environment

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

The burden of extreme heat and heatwave on emergency ambulance dispatches: A time-series study in Huainan, China

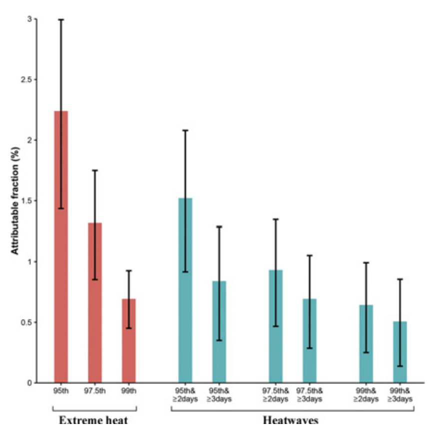
Jian Cheng [a], Zhiwei Xu [b], Desheng Zhao [a], Mingyu Xie [a], Heng Zhang [a], Shusi Wang [a], Hong Su [a,*]

[a] *Department of Epidemiology and Health Statistics, School of Public Health, Anhui Medical University, Hefei, Anhui 230032, China*
[b] *School of Public Health and Social Work, Institute of Health and Biomedical Innovation, Queensland University of Technology, Kelvin Grove, Brisbane, Qld, 4509, Australia*

HIGHLIGHTS

- Evidence on extreme heat events and emergency ambulance dispatches is sparse.
- Impacts of extreme heat events were assessed under different temperature metrics.
- More severe extreme heat was associated with higher relative risk.
- Impacts of heatwaves marginally fluctuated between different heatwave definitions.
- Lower attributable risk was found with more severe extreme heat or heatwaves.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 May 2016
Received in revised form 7 July 2016
Accepted 15 July 2016
Available online 22 July 2016

Editor: D. Barcelo

Keywords:
Heat
Heatwave
Ambulance dispatches
Time-series analysis

ABSTRACT

Background: Although studies have well documented increased mortality risk during extreme heat and heatwaves, few have examined their impacts on emergency ambulance dispatches under different temperature metrics. Additionally, evidence on the attributable risk of emergency ambulance dispatches due to extreme heat and heatwaves is scarce around the world.

Methods: A distributed lag nonlinear model (DLNM) was applied to quantify the impact of extreme heat and heatwaves on emergency ambulance dispatches in Huainan, China, during 2011–2013. Several local extreme heat and heatwave definitions were tested by using percentile of daily mean temperature (i.e., 95th, 97.5th and 99th) and duration (i.e., ≥ 2 consecutive days and ≥3 consecutive days). The fraction of emergency ambulance dispatches attributable to extreme heat and heatwaves was also quantitatively estimated.

Results: Both extreme heat and heatwaves were significantly associated with increases in emergency ambulance dispatches, and their effects appeared to be acute. For extreme heat effects, the relative risks (RRs) of emergency ambulance dispatches at lag0 steadily increased from 95th percentile of daily mean temperature (1.03, 95% confidence interval (CI): 1.01–1.05) to 99th percentile (1.07, 95% CI: 1.05–1.10). For heatwave effects, we observed that RRs of emergency ambulance dispatches at lag0 fluctuated between 1.03 and 1.05 across different heatwave definitions. Notably, the fraction of emergency ambulance dispatches attributable to extreme heat decreased with higher percentile of daily mean temperature, dropping from 2.24% (95% CI: 1.41%–2.99%) at 95th percentile to 0.69% (95% CI: 0.45%–0.92%) at 99th percentile. Likewise, we found that heatwaves with higher intensity and (or) longer duration accounted for lower fraction of emergency ambulance dispatches, varying between 0.51%–1.52%.

* Corresponding author at: Department of Epidemiology and Health Statistics, School of Public Health, Anhui Medical University, 81 Meishan Road, Hefei, Anhui Province 230032, China.
E-mail address: suhong5151@sina.com (H. Su).

http://dx.doi.org/10.1016/j.scitotenv.2016.07.103

Conclusions: Our findings may have important implications for the development of local heat warming systems and public health interventions to lessen the impact of extreme heat events on population health.

1. Introduction

In past few decades, many epidemiological studies showed detrimental impact of extreme weather on human health (Gasparrini et al., 2015; Chen et al., 2013). Recent reports about climate change have consistently suggested that global mean temperature rise is unequivocal in the 21st century, and consequently, the frequency, duration and geographic extent of extreme temperature events are likely to increase (IPCC, 2013; WHO, 2008; Meehl and Tebaldi, 2004).

Extreme heat and heatwaves are now the major public health concern, especially in the context of climate change. Although increasing body of epidemiological studies reported that extreme heat and heatwaves have substantially increased the risk of a wide range of cardiovascular, respiratory and other diseases, the current heat warning systems remain to be improved, and the characteristics of extreme heat impact on human health need to be further explored (Gasparrini et al., 2015; Tong et al., 2014). For example, previous research on the association of human health with temperature usually concentrated on death or hospital-based data (Gasparrini et al., 2015; Chen et al., 2013; Tong et al., 2015), and the health warning systems for extreme heat events in many parts of world have been or are going to be set up on this basis (Tong et al., 2015; WHO, 2015; Pascal et al., 2006). However, emergency ambulance dispatches, another important indicator of non-fatal and acute health events, have received less attention (WHO, 2015; Alessandrini et al., 2011; Sun et al., 2014). Ahead of death and hospital visits, emergency ambulance dispatches as a real-time database of health-related events could provide timely health information and has the potential to identify the early signs of extreme temperature impact (Bassil et al., 2011; Turner et al., 2013). Therefore, analysis of emergency ambulance dispatches, as a supplement to commonly used mortality and morbidity data, could bolster the capacity of traditional monitoring for population health, and further contribute to the understanding of health risk of extreme weather conditions. Even though the impact of extreme heat or heatwaves on emergency ambulance dispatches has been explored in just a few countries, such as Australia (Turner et al., 2013) and Japan (Onozuka and Hagihara, 2016), extreme heat or heatwave definition was set through a single intensity (e.g., a specific temperature or 99th percentile of daily mean temperature) and a fixed duration (e.g., ≥2 consecutive days or ≥3 consecutive days), causing great difference in effect estimates among studies. Since population acclimatization, climate and socio-demographic characteristics are diverse across different regions, it is hard to reach a universal definition of the extreme heat, as well as the heatwave, and their impacts depend on intensity and duration (Xu et al., 2016). Therefore, it is necessary to explore the impact of extreme heat events on emergency ambulance dispatches under different temperature metrics.

In addition, most previous studies quantifying temperature impact on human health have focused on relative risk (RR) or odds ratio (OR), which is ideal for summarizing temperature-health relation, but offers limited information on the true extent to which temperature affects health outcomes (i.e., attributable risk) (Gasparrini et al., 2015; Steenland and Armstrong, 2006). For example, a high RR may actually be interpreted as negligible impact of exposure, because of unusually low prevalence of exposure or very few exposed population. Estimation of fraction of emergency ambulance dispatches attributable to temperature, complementary to risk estimates of exposure-response association, is indispensable to the development of local public health interventions and effective management of emergency medical care systems. However, evidence in this respect is scarce around the world.

In this study, we aimed at quantifying the impact of extreme heat and heatwaves on emergency ambulance dispatches under different temperature metrics, and examining the burden of emergency ambulance dispatches attributable to extreme heat and heatwaves.

2. Material and methods

2.1. Study area and data collection

This study is carried out in Huainan, an inland city and located on the east of China. It has a typical subtropical climate, with four distinct seasons. The population of Huainan is approximately 2.43 million over an area of 2585 km^2 in 2013.

Daily record of emergency ambulance dispatches from July 2011 to December 2013 was provided by 120 Emergency Command Center in Huainan, China. This institute manages the pre-hospital services during 24 h, including conducting first aid for callers (emergency medical call: 120) and transporting the severe or acute cases to medical institutions. More detailed information regarding age, gender and diagnosis (e.g., disease category and severity) were not possible due to data availability based on confidentiality. Therefore, daily number of emergency ambulance dispatches for all causes was analyzed in this study. To examine the impact of extreme heat and heatwaves, we only used data during warm season (May–October). In regard to exposure variables, daily weather data on mean temperature, maximum temperature and relative humidity for the same period were obtained from Huainan Meteorological Bureau.

2.2. Definitions of extreme heat and heatwaves

A recent multi-city time-series study showed the impact of heatwave on mortality started to increase around the 95th percentile of daily mean temperature and rose alarmingly at the 99th percentile (Tong et al., 2015), we thus used different temperature metrics (intensity and duration) to define a local extreme heat and heatwave.

Intensity of 95th, 97.5th and 99th percentiles of daily mean temperature were the temperature thresholds, and an extreme heat refers to daily mean temperature above these thresholds.

A heatwave was defined using the combination of intensity (95th, 97.5th and 99th percentile of daily mean temperature) and duration (≥2 consecutive days and ≥3 consecutive days). For example, a heatwave is defined as a minimum of 2 consecutive days with daily mean temperature above 95th percentile.

2.3. Estimating the effect of extreme heat

Firstly, a natural cubic spline DLNM with quasi-Poisson distribution was used to investigate the effect of temperature on emergency ambulance dispatches up to lag 21 days. Specifically, we used a natural cubic spline with 5 degrees of freedom (*dfs*) for temperature and a natural cubic spline with 3 *dfs* for lag to capture the nonlinear temperature effect and the lagged effect. Other potential confounders, including relative humidity with a natural cubic spline of 3 *dfs*, long-term trend with a natural cubic spline of 4 *dfs* per year, within-season variation (by month) and day of week as a categorical variable (Huang et al., 2012), and public holidays as a binary variable were controlled (Tong et al., 2015).

We then found that the temperature-emergency ambulance dispatches relation was a waterfall-shaped curve (reverse "J"), suggesting an approximately flat dose-response relation before a potential threshold (Supplementary Fig. 1). As temperature increase above different thresholds may lead to different effect estimates, we calculated the heat risk at cutoff (percentile) of daily mean temperature relative to another cutoff (Chen et al., 2013). Although the selection of these cutoffs for calculating the RRs is somewhat arbitrary, this is similar to previous studies (Chen et al., 2013; Li et al., 2014), and allows for a comparison of research findings. Thus, we adopted a high threshold-natural cubic spline DLNM (Guo et al., 2011; Li et al., 2014). Specifically, the temperature-emergency ambulance dispatches relation was modeled using a high threshold function with threshold at 25.6 °C (75th percentile of daily mean temperature), assuming the effect of heat is linear above the threshold (Chen et al., 2013). Finally, the cross-basis of temperature is specified through a high threshold function for the temperature space and natural cubic spline with 3 *dfs* for the lag space. The RR and 95% confidence interval (CI) of emergency ambulance dispatches at extreme heat (95th, 97.5th and 99th percentile) compared with 75th percentile of daily mean temperature were calculated (Chen et al., 2013).

2.4. Examining the effect of heatwaves

Heatwaves as the binary variables (yes/no) were included in distributed lag model (DLM) with quasi-Poisson distribution. A maximum lag of 21 days was used to track the delayed effect and identify potential harvesting effect (Gasparrini et al., 2015; Qiao et al., 2015). Potential confounding effects of humidity, days of the week, long-term trend, within-season variation (by month) and public holidays were adjusted for in DLM (Tong et al., 2015). The value of Akaike Information Criterion for quasi-Poisson distribution (Q-AIC) was applied to compare the goodness-of-fit of DLM among different heatwave definitions. The RR and 95% CI of emergency ambulance dispatches during heatwaves were also calculated under different heatwave definitions.

2.5. Calculating attributable risk

Under the framework of DLNM and DLM, attributable fraction of emergency ambulance dispatches for extreme heat and heatwaves were calculated from the relationship of temperature and emergency ambulance dispatches using a method recently proposed by Gasparrini et al., 2015. 95% empirical confidence interval (eCI) of attributable fraction were obtained by applying Monte Carlo simulating method, which is in detail described elsewhere (Gasparrini and Leone, 2014).

All statistical analyses were conducted in R software (version 3.2.2), and the "dlnm" package was applied to fit the DLNM and DLM. Sensitivity analyses were conducted to check the robustness of results: (1) changing *df* (4–6) for humidity and *df* (5–7) per year for long-term trend; (2) using a flexible function (natural cubic spline) with higher *df* (5–7) to model the relationship between temperature and emergency ambulance dispatches; (3) replacing daily mean temperature with daily maximum temperature to define the extreme heat and the heatwave to test whether the results would change substantially.

3. Results

3.1. Summary statistics of emergency ambulance dispatches

There were a total of 33,523 emergency ambulance dispatches in the warm season (510 days) during 2011–2013 in Huainan, China, and no missing values were found. Daily count of emergency ambulance dispatches ranged from 40 to 108, with the average at 65.7. Fig. 1 shows the comparison of average daily count of emergency ambulance dispatches during extreme heat and non-extreme heat days, as well as during heatwave days and non-heatwave days in Huainan, China. Overall, the number of emergency ambulance dispatches on extreme heat days was not only higher than that on non-extreme heat days, but also slightly increased with more severe extreme heat (i.e., higher temperature). The results were consistently found for the number of emergency ambulance dispatches on heatwave days across heatwave intensity and duration.

3.2. Temperature-emergency ambulance dispatches association

Fig. 2A presents the exposure-response relationship between emergency ambulance dispatches and mean temperature at different lags. It clearly shows that mean temperature above the threshold (25.6 °C, 75th percentile of daily mean temperature) was positively associated with emergency ambulance dispatches and its effects occurred on the same day of exposure (lag0). Fig. 2B shows the overall cumulative exposure-response curve, suggesting the risk of emergency ambulance dispatches increased linearly with mean temperature above 25.6 °C.

3.3. Lag structure of extreme heat effects

Fig. 3 shows the effect of extreme heat on emergency ambulance dispatches at different lags. The risk of emergency ambulance dispatches was the largest at lag0 and slightly increased with higher threshold, with RRs rising from 95th percentile of daily mean temperature (1.03, 95% confidence interval (CI): 1.01–1.05), to 97.5th (1.06, 95% CI: 1.04–1.08) and 99th (1.07, 95% CI: 1.05–1.10).

This figure also indicates that extreme heat effect continuously decreased before lag 13 and then increased up to lag 21. However, no significant harvesting effect was observed.

3.4. Heatwave effects

Table 1 presents the cumulative effect of heatwaves on emergency ambulance dispatches under different heatwave definitions. The heatwave effects were consistently found to be acute and RRs of emergency ambulance dispatches at lag0 marginally fluctuated between 1.03 and 1.05. The best model fit (the lowest Q-ACI value) is the model with heatwave defined as ≥2 consecutive days with daily mean temperature ≥95th percentile, while the strongest relationship was found between emergency ambulance dispatches and heatwave defined as ≥2 consecutive days with daily mean temperature ≥99th percentile. When a longer duration (≥4–6 consecutive days) was used to define a heatwave, we also observed that all models had higher Q-AIC value than the model with heatwave defined as ≥2 consecutive days with daily mean temperature ≥95th percentile, and heatwave defined as ≥2 consecutive days with daily mean temperature ≥99th percentile had the strongest impact (Supplementary Table 1).

Regarding the lag structure for heatwaves effect, RRs presented a downward trend and a subsequent upward trend within a lag of 21 days, but there was no significant harvesting effect (Supplementary Fig. 2).

3.5. Attributable risk

Fig. 4 shows the proportion of emergency ambulance dispatches attributable to extreme heat and heatwaves. Extreme heat with higher temperature threshold was responsible for lower proportion of emergency ambulance dispatches, varying from 2.24% (95% CI: 1.41%–2.99%) at 95th percentile to 0.69% (95% CI: 0.45%–0.92%) at 99th percentile. Similarly, a heatwave defined as higher intensity or longer duration accounted for lower proportion of emergency ambulance dispatches, and the attributable proportion was between 0.51%–1.52% (Fig. 4). The decreasing pattern in attributable proportion was also noted when defining a heatwave with longer duration (≥4–6 consecutive days) (Supplementary Fig. 3).

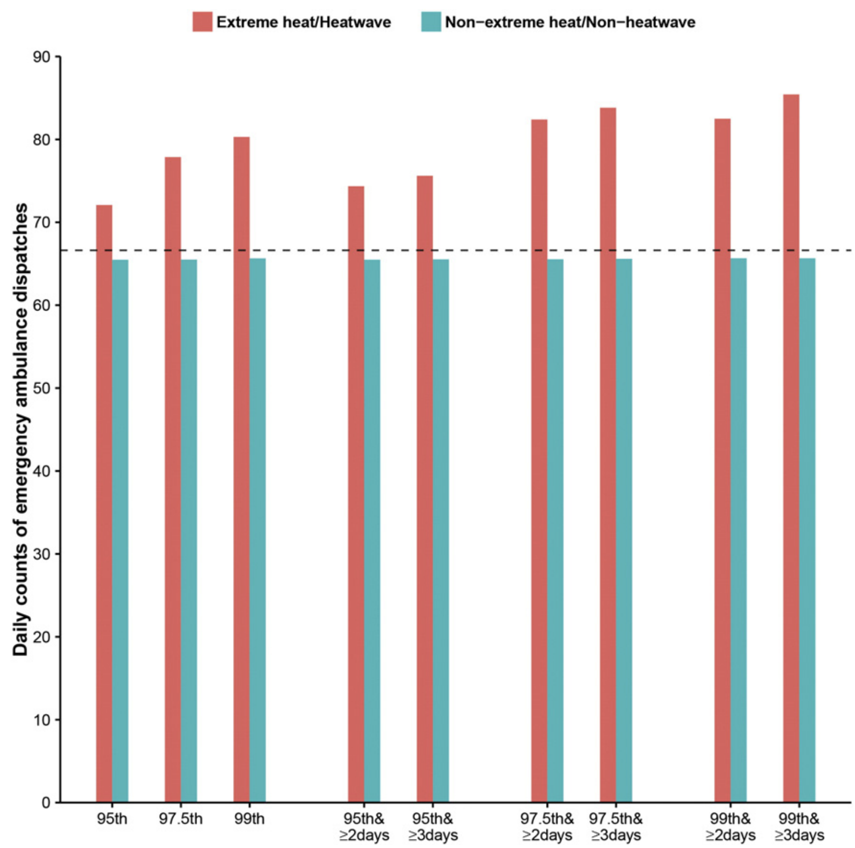


Fig. 1. Comparisons of average daily count of emergency ambulance dispatches between Extreme heat/Heatwave days and non-extreme heat/Non-heatwave days. The dotted line is the average (66.7) of daily count of ambulance dispatches. Extreme heat refers to daily mean temperature above 95th, 97.5th and 99th percentile. A heatwave was defined using the intensity (95th, 97.5th and 99th percentile) and duration (≥2 days and ≥3 days).

3.6. Sensitivity analysis

Several sensitivity analyses were conducted by changing *df* (4–6) for humidity (Supplementary Fig. 4), *df* (5–7) per year for long-term trend (Supplementary Fig. 5), which produced similar results. When using a non-linear function (natural cubic spline) with higher *df* (5–7) to model the temperature-emergency ambulance dispatches relation, and daily maximum temperature as an alternative to daily mean temperature to define an extreme heat and a heatwave, the results only differed little (Supplementary Figs. 6, 7).

4. Discussion

This is the first time-series study using different temperature metrics and attributable risk measure to comprehensively assess the impact of extreme heat and heatwaves on emergency ambulance dispatches. We found several novel findings: (i) both extreme heat and heatwaves were significantly associated with increased risk of emergency ambulance dispatches, and their effects appeared to be acute; (ii) More severe extreme heat was associated with a higher risk of emergency ambulance dispatches; (iii) Risk of emergency ambulance

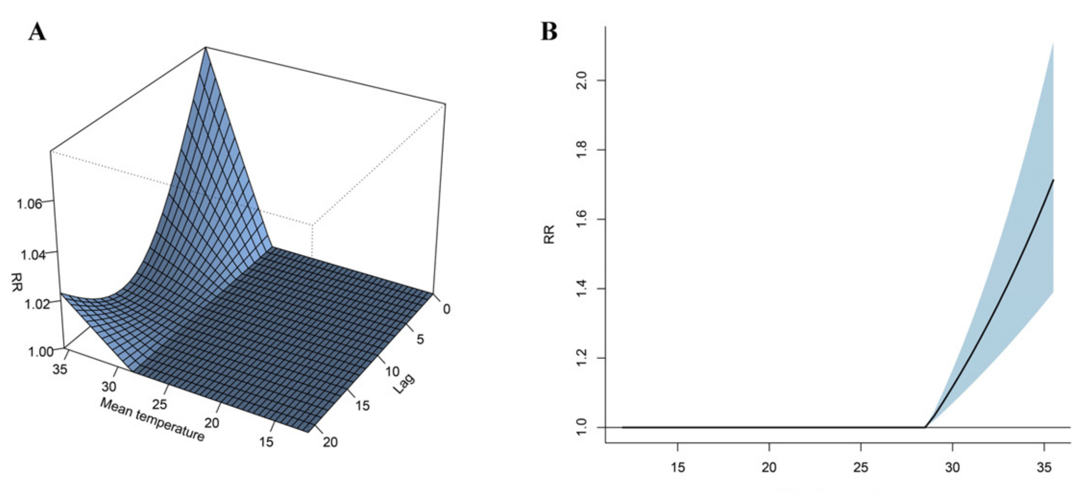


Fig. 2. The exposure-lag-response relationship between daily mean temperature and emergency ambulance dispatches (A), and overall exposure-response relationship between daily mean temperature and emergency ambulance dispatches (B).

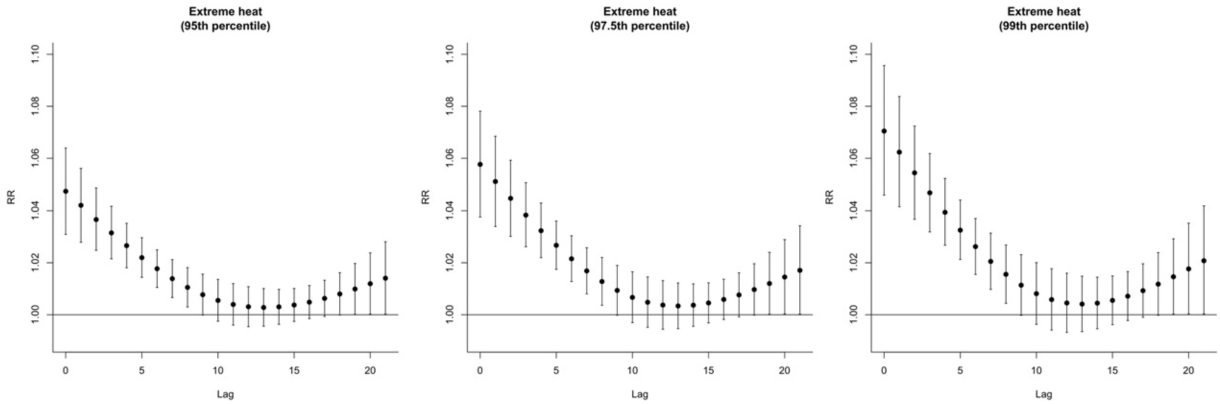


Fig. 3. The effect of extreme heat on emergency ambulance dispatches. Extreme heat refers to daily mean temperature above 95th, 97.5th and 99th percentile.

dispatches during heatwaves did not show a single increasing or decreasing pattern, but marginally fluctuated among different heatwave definitions; (iv) Fraction of emergency ambulance dispatches attributable to extreme heat decreased with higher intensity, and that attributable to heatwaves decreased with higher heatwave intensity and longer heatwave duration.

Emergency ambulance dispatches usually relates to acute health outcomes prior to hospital admissions or death events. In recent decades, many studies were designed to examine the impact of extreme heat or heatwaves on human health, most of which mainly focused on either mortality data or hospital-based data (Gasparrini et al., 2015; Chen et al., 2013; Tong et al., 2014), and the findings from these studies may not be fully extrapolated to other health-related outcomes or health seeking behaviors, such as emergency ambulance dispatches. As the climate change continues, extreme heat and heatwaves will become more intense, more frequent and longer-lasting, posing a great threat to population health in many aspects. Real-time emergency ambulance dispatches surveillance allows for early detection of residents' health demands and health status in a region, which complements the traditional population health monitoring system (Alessandrini et al., 2011). It is necessary to explore the impact of extreme heat and heatwave on emergency ambulance dispatches, and thus providing a broader view of health risk related to extreme weather.

The acute and adverse effects of extreme heat and heatwaves on emergency ambulance dispatches we observed in the present study is consistent with previous studies. For example, Turner et al. investigated the relationship between temperature and ambulance attendances in Brisbane, Australia, and found immediate effect for temperature rise and heatwaves (Turner et al., 2012, 2013). Also, a nationwide study in Japan suggested that extreme heat was positively associated with emergency ambulance dispatches (Onozuka and Hagihara, 2016). However, there were great differences in the effect size of extreme heat and heatwaves among these studies. This may be due to several reasons, including different temperature references used to estimate the risk of emergency ambulance dispatches and different extreme heat and heatwave definitions.

A recent systematic review on heatwaves suggested that the health risk can be largely influenced by heatwave definition, especially the heatwave intensity (Xu et al., 2016). However, previous studies of temperature and emergency ambulance dispatches used a single definition of extreme heat or heatwave through intensity and duration, implying the magnitude of their impacts may be overestimated or underestimated (Turner et al., 2012, 2013; Onozuka and Hagihara, 2016). In this study, we used several local extreme heat and heatwave definitions based on temperature metrics to investigate how the risk of emergency ambulance dispatches would change. We found higher risk of emergency ambulance dispatches for more severe extreme heat, which is similar to the findings of studies in Pudong New Area, Harbin and Chongqing, China (Sun et al., 2014; Li et al., 2014). Regarding the immediate heatwave effect (lag0), we observed fluctuations in terms of risk of emergency ambulance dispatches among heatwave definitions, and the heatwave defined as ≥2 consecutive days with daily mean temperature ≥ 99th percentile had the greatest health impact. Similar results have also been reported in a coast region of China (Sun et al., 2014). Additionally, for the impact of heatwave on mortality, there is a general trend that the higher the intensity and the longer the duration of a heatwave, the greater the health impacts, although health risk marginally fluctuated among several heatwave definitions (Tong et al., 2014, 2015). In order to develop a local heatwave definition, a tiered health risk-based metrics based on the impact of heatwave on mortality and morbidity has recently been proposed (Tong et al., 2015). Similar to the study of Tong et al. (2014), we found the regression model using heatwave with a duration of ≥2 consecutive days produced a better model fit (Table 1). Furthermore, a study across multiple Australian cities consistently showed that the heatwave impact remained stable before the 95th percentile of daily mean temperature, and then significantly increased (Tong et al., 2015). Therefore, we believed that it is proper to choose a heatwave defined as ≥2 consecutive days with daily mean temperature ≥95th percentile as the trigger point of heat warming systems in study regions of Australia and China (Sun et al., 2014; Tong et al., 2014, 2015). But it is worth noting that this trigger point may be different in other areas due to differences in climate, socio-demographic characteristics and acclimatization of population, more

Table 1
Relative risk of emergency ambulance dispatches during heatwaves defined by a set of percentiles of temperature and durations.

Percentile	No. of consecutive days	No. of heatwave days	Q-AIC value	Relative risk (95% CI)			
				Lag0	Lag0–6	Lag0–13	Lag0–21
95th	≥2	17	3502.22	1.04 (1.03–1.06)	1.20 (1.13–1.26)	1.19 (1.11–1.27)	1.23 (1.13–1.35)
	≥3	12	3515.75	1.03 (1.02–1.05)	1.15 (1.09–1.22)	1.15 (1.07–1.23)	1.17 (1.06–1.29)
97.5th	≥2	10	3512.01	1.04 (1.02–1.05)	1.18 (1.11–1.26)	1.20 (1.11–1.30)	1.23 (1.10–1.38)
	≥3	8	3516.68	1.04 (1.02–1.05)	1.17 (1.11–1.25)	1.18 (1.09–1.30)	1.21 (1.07–1.36)
99th	≥2	5	3518.85	1.05 (1.03–1.07)	1.24 (1.14–1.35)	1.29 (1.13–1.48)	1.32 (1.11–1.59)
	≥3	4	3524.42	1.05 (1.03–1.07)	1.25 (1.13–1.39)	1.30 (1.10–1.52)	1.31 (1.06–1.63)

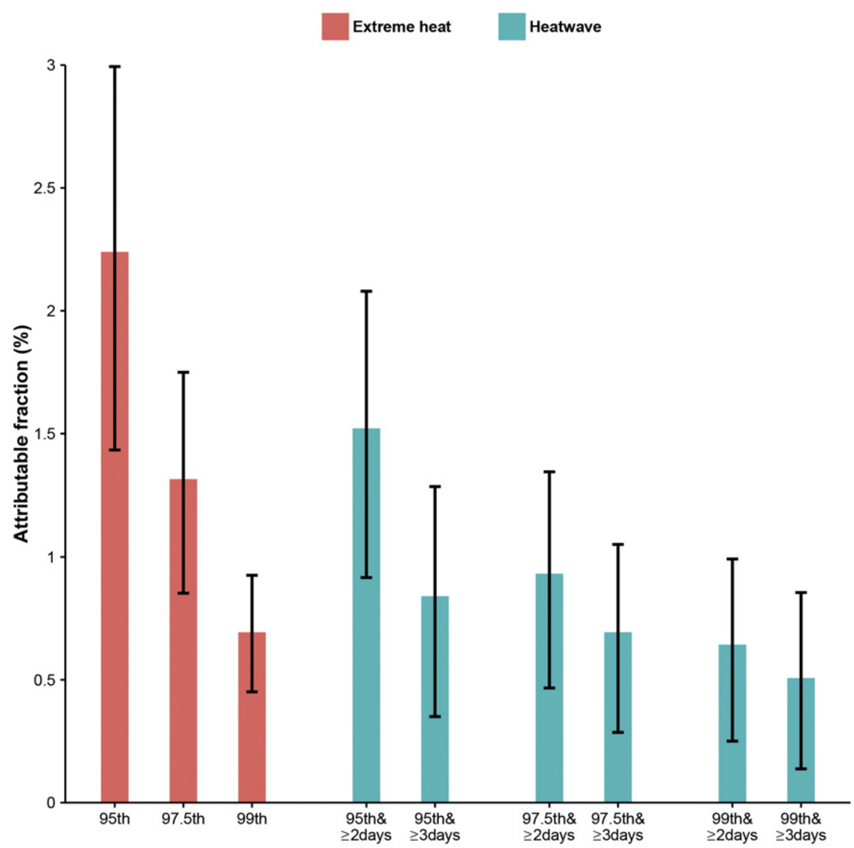


Fig. 4. Fraction of emergency ambulance dispatches attributable to extreme heat and heatwaves. Extreme heat refers to daily mean temperature above 95th, 97.5th and 99th percentile. A heatwave is defined using the intensity (95th, 97.5th and 99th percentile) and duration (≥2 days and ≥3 days). The length of line over the bar indicates the 95% empirical confidence interval (eCI).

studies in this respect are needed to complete local heatwave warming systems.

Interestingly, there is a general trend that the impact of heat continuously attenuated before a certain lag days, and then begun to climb (Fig. 3, Supplementary Fig. 2), which is consistent with many prior studies (Turner et al., 2012; Qiao et al., 2015; Gasparrini et al., 2016). The reason for this is probably due to short-term heat impact leading to rapid depletion of the pool of susceptible people, and the subsequent increase in the number of susceptible individuals. Also, heat harvesting effect was obvious in some diseases, such as respiratory disease and cardiovascular disease (Turner et al., 2012; Qiao et al., 2015), which could result in the U-shaped health risk curve in the lag structure for all-cause emergency ambulance dispatches. However, in the present study, we did not found evidence of significant harvesting effect of heat, and this may be attributable to the temperature reference used to estimate the heat effect. The reference value for creating the cross-basis function (i.e., dose-response function) of DLNM plays a key role in estimating the heath risk of heat. In this study, the selected temperature reference (75th percentile) is based on modelling strategy employed by previous studies (Chen et al., 2013), and did not suggest a precise threshold of heat stress, but a rough one (Supplementary Fig. 1). Therefore, the heat impact and potential harvesting effect might be affected by the selected temperature reference. After using higher temperature references (70-90th percentile), the degree of heat impact slightly increased, but there was still no significant harvesting effect of heat (data not shown). Nevertheless, given previous findings on the harvesting effect of heat on human health are not conclusive (Qiao et al., 2015; Gasparrini et al., 2016), and the heat threshold varies spatially (Gasparrini et al., 2016), it is needed to investigate whether or not the heat harvesting effect on emergency ambulance dispatches exists in other regions.

In this study, we also estimated the risk of emergency ambulance dispatches attributable to extreme heat. From 95th percentile of daily mean temperature to 99th percentile, there was a decreasing trend for attributable proportion of extreme heat, varying between 0.69%–2.24%. By comparison, Onozuka and Hagihara in Japan investigated the risk of emergency ambulance dispatches attributable to extreme heat (above 97.5th percentile), and found extreme heat was responsible for a lower fraction (0.29%, 95% CI: 0.26%–0.32%). (Onozuka and Hagihara, 2016) This indicates that the fraction of emergency ambulance dispatches attributable to extreme heat may be different between countries. Previous studies also found substantial between-country and within-country variations in attributable mortality risk to temperature (Gasparrini et al., 2015).

Although a few studies have estimated the health risk attributable to temperature (Gasparrini et al., 2015), the contribution of persistent extreme heat (i.e., heatwave) to the risk of emergency ambulance dispatches has not been explored yet. This study for the first time in China attempted to investigate the population health risk due to heatwaves. Among different heatwave definitions, the heatwave defined as ≥2 consecutive days with daily mean temperature ≥95th percentile accounted for the largest proportion of emergency ambulance dispatches, and the attributable fraction decreased with intensity and duration. These findings can be used in conjunction with a previously proposed tiered heat warming system when tailoring guidelines for defining a local heatwave and developing appropriate interventions to combat adverse health impact. The reason is that attributable fraction combines RR and the prevalence of exposure to measure the public health burden of a risk factor by estimating the proportion of health-related outcomes that would not have occurred absent an exposure (Steenland and Armstrong, 2006). It thereby has the capability of comparing benefits of some interventions and has important policy implications.

Several limitations of this study should be mentioned. First, this study is only conducted in an inland city of China, which means it should be cautious to generalize our findings to other regions with different climate, population's characteristic and socio-economic status. Second, we utilized the aggregated data to assess the extreme heat and heatwave impacts on emergency ambulance dispatches. More precise effect estimates might be achieved through spatial-temporal analysis. Third, as common to most time-series study, we used the monitored outdoor temperature to measure the individual exposure level, which inevitably induces exposure biases. Fourth, the emergency ambulance dispatches data were obtained from a local medical center (120 Emergency Command Center in Huainan, China), which records each dispatch due to a number of reasons through 120 Network Platform (Sun et al., 2014). Emergency ambulance dispatches data were effectively available in real-time, and each record contains the day and time when an emergency call was made. We therefore calculated the daily counts of all-cause emergency ambulance dispatches, which is useful to achieve a broader view of the impact of extreme temperatures on population health (Sun et al., 2014). However, since more detailed data information is unavailable, we were unable to analyze the impact of extreme heat and heatwaves on cause-, gender- and age-specific emergency ambulance dispatch, which may be of great interest when implementing target prevention measures. Fifth, previous studies showed that there were significant main and added effects of heatwave on human health (Xu et al., 2016). However, in this study, we only examined the main impact of heatwave on emergency ambulance dispatches, and the added effects of heatwave have not been analyzed, which warrants future research.

5. Conclusions

We found that both extreme heat and heatwaves increased the risk of emergency ambulance dispatches and their effects were acute. More severe extreme heat was associated with higher health risk, but was responsible for lower proportion of emergency ambulance dispatches. While heatwave impacts fluctuated between different heatwave definitions, proportion of emergency ambulance dispatches attributable to heatwaves decreased with intensity and duration. Considering that intensity, frequency and duration of extreme heat events are very likely to increase in the 21st century, it is urgently needed to have a comprehensive and systematic assessment on the impact of extreme heat and heatwave on human health to develop local heat warming systems and plan effective interventions.

Conflicts of interest

The authors declare no competing financial interest.

Acknowledgements

This work was funded by the Anhui Natural Science Fund (No. 1408085MH159). We would like to thank Huainan Emergency Command Center and Huainan Meteorological Bureau for providing data used in this study, and PhD Antonio Gasparrini for his valuable assistance in statistical analysis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scitotenv.2016.07.103.

References

Alessandrini, E., et al., 2011. Emergency ambulance dispatches and apparent temperature: a time series analysis in Emilia–Romagna, Italy. Environ. Res. 111, 1192–1200.
Bassil, K.L., et al., 2011. The relationship between temperature and ambulance response calls for heat-related illness in Toronto, Ontario, 2005. J. Epidemiol. Community Health 65, 829–831.
Chen, R., et al., 2013. Both low and high temperature may increase the risk of stroke mortality. Neurology 81, 1064–1070.
Gasparrini, A., Leone, M., 2014. Attributable risk from distributed lag models. BMC Med. Res. Methodol. 14, 55.
Gasparrini, A., et al., 2015. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet 386, 369–375.
Gasparrini, A., et al., 2016. Changes in susceptibility to heat during the summer: a multicountry analysis. Am. J. Epidemiol. 183, 1027–1036.
Guo, Y., et al., 2011. The impact of temperature on mortality in Tianjin, China: a case-crossover design with a distributed lag nonlinear model. Environ. Health Perspect. 119, 1719–1725.
Huang, C., et al., 2012. Effects of extreme temperatures on years of life lost for cardiovascular deaths: a time series study in Brisbane, Australia. Circ. Cardiovasc. Qual. Outcomes 5, 609–614.
IPCC, 2013. Summary for Policymakers. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.
Li, Y., et al., 2014. Extremely cold and hot temperatures increase the risk of diabetes mortality in metropolitan areas of two Chinese cities. Environ. Res. 134, 91–97.
Meehl, G.A., Tebaldi, C., 2004. More intense, more frequent, and longer lasting heat waves in the 21st century. Science 305, 994–997.
Onozuka, D., Hagihara, A., 2016. Spatial and temporal variation in emergency transport during periods of extreme heat in Japan: a nationwide study. Sci. Total Environ. 544, 220–229.
Pascal, M., et al., 2006. France's heat health watch warning system. Int. J. Biometeorol. 50, 144–153.
Qiao, Z., et al., 2015. Assessment of short- and long-term mortality displacement in heat-related deaths in Brisbane, Australia, 1996-2004. Environ. Health Perspect. 123, 766–772.
Steenland, K., Armstrong, B., 2006. An overview of methods for calculating the burden of disease due to specific risk factors. Epidemiology 17, 512–519.
Sun, X., et al., 2014. Effects of temperature and heat waves on emergency department visits and emergency ambulance dispatches in Pudong new area, China: a time series analysis. Environ. Health 13, 76.
Tong, S., et al., 2014. Development of health risk-based metrics for defining a heatwave: a time series study in Brisbane, Australia. BMC Public Health 14, 435.
Tong, S., et al., 2015. Exploration of the health risk-based definition for heatwave: a multi-city study. Environ. Res. 142, 696–702.
Turner, L.R., et al., 2012. Exposure to hot and cold temperatures and ambulance attendances in Brisbane, Australia: a time-series study. BMJ Open 2, e001074.
Turner, L.R., et al., 2013. The effect of heat waves on ambulance attendances in Brisbane, Australia. Prehosp. Disaster Med. 28, 482–487.
WHO, 2008. Protecting health from climate change-world health day 2008. http://www.who.int/world-health-day/toolkit/report_web.pdf?ua=1 (2016 (accessed 18.01.16)).
WHO, 2015. Heatwaves and health: guidance on warning-system development. http://www.who.int/globalchange/publications/heatwaves-health-guidance/en/ (2016, (accessed 18.03.16)).
Xu, Z., et al., 2016. Impact of heatwave on mortality under different heatwave definitions: a systematic review and meta-analysis. Environ. Int. 89-90, 193–203.