Environment International 116 (2018) 30–38

Contents lists available at ScienceDirect

Environment International

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

Effectiveness of National Weather Service heat alerts in preventing mortality in 20 US cities

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ARTICLE INFO

Handling Editor: Martí Nadal

Keywords:
Extreme heat
Heat warnings
Early warning systems
Public health
Climate change

ABSTRACT

Background: Extreme heat is a well-documented public health threat. The US National Weather Service (NWS) issues heat advisories and warnings (collectively, "heat alerts") in advance of forecast extreme heat events. The effectiveness of these alerts in preventing deaths remains largely unknown.

Objectives: To quantify the change in mortality rates associated with heat alerts in 20 US cities between 2001 and 2006.

Methods: Because NWS heat alerts are issued based on forecast weather and these forecasts are imperfect, in any given location there exists a set of days of similar observed heat index in which heat alerts have been issued for some days but not others. We used a case-crossover design and conditional logistic regression to compare mortality rates on days with versus without heat alerts among such eligible days, adjusting for maximum daily heat index and temporal factors. We combined city-specific estimates into a summary measure using standard random-effects meta-analytic techniques.

Results: Overall, NWS heat alerts were not associated with lower mortality rates (percent change in rate: −0.5% [95% CI: -2.8, 1.9]). In Philadelphia, heat alerts were associated with a 4.4% (95% CI: -8.3, −0.3) lower mortality rate or an estimated 45.1 (95% empirical CI: 3.1, 84.1) deaths averted per year if this association is assumed to be causal. No statistically significant beneficial association was observed in other individual cities.

Conclusions: Our results suggest that between 2001 and 2006, NWS heat alerts were not associated with lower mortality in most cities studied, potentially missing a valuable opportunity to avert a substantial number of heat-related deaths. These results highlight the need to better link alerts to effective communication and intervention strategies to reduce heat-related mortality.

1. Introduction

There is a well-established association between high ambient temperature (i.e., heat) and higher rates of mortality in the US and around the world (Anderson and Bell, 2009; Gasparrini et al., 2015; Guo et al., 2014; Medina-Ramon and Schwartz, 2007). Globally, the public health burden of exposure to heat is substantial. In the United States (US), a recent analysis found that 0.35% (95% CI: 0.30, 0.39) of the approximately 22 million deaths that occurred in 135 communities between 1985 and 2006 were attributable to heat (Gasparrini et al., 2015), or approximately 3642 deaths per year.

The growing recognition of the dangers of heat has prompted communities around the world to develop heat early warning systems to provide advance notice to public health and emergency management officials, as well as to the general public, when a period of dangerous heat is forecast to occur (Lowe et al., 2011). In the US, in an effort to mitigate the harmful impacts of heat on health, local offices of the US National Weather Service (NWS) issue heat alerts in advance of forecast extreme heat events. These alerts are communicated to the public through local media outlets and currently contain recommendations that members of the public can use to protect their health, such as wearing light-colored clothing and drinking plenty of water. In addition, NWS heat alerts may trigger a cascade of local interventions aimed at protecting the public from the health impacts of heat. For example, heat alerts may activate elements of local heat response plans, such as additional messaging or the opening of cooling centers (Arizona Department of Health Services, 2016; Sheridan and Kalkstein, 2004; Wisconsin Climate and Health Program, 2016). While heat alerts are

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https://doi.org/10.1016/j.envint.2018.03.028
Received 22 November 2017; Received in revised form 1 March 2018; Accepted 19 March 2018

Fig. 1. US cities included in this study.

expected to be an important tool for communicating risk and preventing deaths during extreme heat events, the evidence regarding whether such alerts yield measurable health benefits is sparse (Benmarhnia et al., 2016; Chau et al., 2009; Ebi et al., 2004; Toloo et al., 2013).

Local offices of the NWS typically issue heat alerts based on forecasts of the heat index, a measure of human discomfort that incorporates both temperature and relative humidity. Current guidance at the national level suggests issuing a heat advisory (a heat alert issued when less extreme heat is forecast) when the heat index is expected to meet or exceed 100 °F (northern US) or 105 °F (southern US), and an excessive heat warning (a heat alert issued when more extreme heat is forecast) when the heat index is expected to meet or exceed 105 °F (northern US) or 110 °F (southern US). These criteria are provided as guidelines to each of the 122 local NWS offices and may be adapted to local needs (Hawkins et al., 2017).

While the exact criteria used to issue heat alerts varies across the jurisdictions of local NWS offices, a key commonality across jurisdictions is that heat alerts are issued based on *forecasts* of future weather conditions. Furthermore, in addition to using information from forecast models, NWS forecasters are encouraged to use their experience and judgment in making the decision to issue a heat alert (Hawkins et al., 2017). Because forecasts do not perfectly predict observed temperatures (Zhang et al., 2014; Åström et al., 2015) and NWS forecasters are encouraged to use their judgment instead of adhering strictly to any criteria, heat alerts are sometimes issued for days that turn out to have an observed heat index below the regional guidelines described above. For example, in a city where heat advisories are issued when the heat index is forecast to exceed 100 °F, a heat alert would likely be issued for a day that is forecast to be 101 °F, yet it is possible for the heat index actually observed on that day to be slightly below 100 °F due to uncertainty in the forecast. Similarly, heat alerts are sometimes not issued for days that turn out to have an observed heat index above the regional guidelines (Vargo et al., 2015; Zhang et al., 2014). Thus, in each city for which heat alerts are issued, there exists a set of days with approximately equal observed maximum daily heat index, some of which have heat alerts and some of which do not. This data structure allows us to ask whether, among days of approximately equal observed heat index, the daily mortality rate is lower on days for which a heat alert was issued compared to days for which a heat alert was not issued. In other words, due to forecast uncertainty we are able to estimate the association between heat alerts and mortality while conceptually controlling for the influence of observed heat index through matching.

We used this natural experiment to evaluate whether NWS heat alerts were associated with lower rates of mortality across 20 US cities between 2001 and 2006. This analysis rests on the assumption that in any given location, two days of approximately equal observed heat index – one with a heat alert and one without a heat alert – will have the same rates of mortality except due to the effect of the heat alert, after controlling for any potential confounders. In secondary analyses we explored whether city-level characteristics, such as air conditioning (AC) prevalence and population characteristics, are associated with the effectiveness of heat alerts in preventing mortality. Additionally, we estimated the number of deaths actually and potentially averted by heat alerts in these 20 cities between 2001 and 2006, assuming that the observed associations were causal.

2. Methods

2.1. Study sites

To evaluate the effectiveness of heat alerts we linked daily data on heat alerts (available starting in 2001) with daily mortality data (available through 2006). We selected for analysis the 20 US cities for which local offices of the NWS issued the largest number of heat alerts between 2001 and 2006 and on which we could obtain daily mortality data (Fig. 1).

2.2. Data sources

2.2.1. Heat alerts

We obtained text files of all NWS non-precipitation products (the technical term for NWS messaging) issued in the US between April 1st and October 31st during the years 2001 to 2006 from the National Oceanic and Atmospheric Administration (NOAA) (NOAA, 2016). We developed a text parsing program to separate heat alerts from other types of messaging and to extract information on the location and date of each heat alert. We defined “heat alerts” as including both heat advisories (a type of heat alert issued when less severe heat is forecast) and excessive heat warnings (a type of heat alert issued when more severe heat is forecast). We assessed the performance of this program in a subset of nine cities by comparing program-generated results to results generated by manually reading the contents of each alert text file and recording the dates and locations of all heat alerts. We found that