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Temporal and seasonal variations of mortality burden associated with hourly temperature variability: A nationwide investigation in England and Wales

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ABSTRACT

Background: Sudden temperature change has been linked with elevated short-term mortality, thus may become an important global health threat in the context of climate change. To date, however, little available temperature-mortality evidence has taken into account both intra- and inter-day temperature variability (TV), thus largely limiting the comprehensive understanding of mortality burden due to unstable weather. Moreover, seasonal and temporal patterns in TV-mortality associations were sparsely discussed, nationally and regionally.
Objectives: We aimed to assess the nationwide association of all-cause mortality with hourly temperature variability (HTV), quantify HTV-attributable mortality, and further explore the temporal and seasonal variations of mortality burden due to HTV in United Kingdom.
Methods: Fourteen-year time-series data on temperature and mortality were collected from 10 regions in England and Wales during 1993–2006, totally including 7,573,716 all-cause deaths. HTV was calculated from the standard deviation of hourly temperature records within two neighboring days (the current and previous day). A three-stage analytic approach was adopted to assess HTV-associated mortality burden. We first applied a time-series quasi-Poisson regression to estimate region-specific HTV-mortality associations, then pooled these associations at the national level using a multivariate meta-analysis, and finally estimated the HTV-attributable mortality fraction and illustrated its seasonal and temporal variations by conducting season- and period-specific analyses based on time-varying distributed lag models.
Results: We found strong evidence that large HTV exposure elevated short-term mortality risk in England and Wales, with a pooled estimate of 1.13% (95% confidence interval (CI): 0.88, 1.39) associated with a 1-°C increase in HTV. During the whole study period, HTV accounted for a national average attributable fraction of 2.52% (95% empirical confidence interval (eCI): 2.27, 2.76) of the total deaths. This HTV-attributable mortality estimate showed a significant temporal decrease ($p < 0.001$) from 2.72% (95% eCI: 2.58, 2.87) for 1993–99 to 2.28% (95% eCI: 2.13, 2.43) for 2000–06. Additionally, clear seasonal variations were observed for HTV-attributable mortality burden, with the largest estimate of 3.08% (95% eCI: 2.80, 3.38) in summer, followed by 2.71% (95% eCI: 2.44, 2.98) in spring, 2.40% (95% eCI: 2.16, 2.63) in autumn, and 2.00% (95% eCI: 1.81, 2.20) in winter.
Conclusions: Despite clear evidence observed for the reduction, mortality burden caused by large temperature variability remained to be a great public health threat in UK, especially in warm seasons. It highlighted the importance of specific interventions targeted to unstable weather as well as temperature extremes, so as to reduce climate-related mortality burden.

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1. Introduction

As a common environmental risk factor throughout human's lives and one of the greatest public health threats, temperature extremes have been linked with numerous health outcomes in large bodies of epidemiologic studies (Moghadamnia et al., 2017; Wang et al., 2017; Wu et al., 2016; Ye et al., 2012; Zhang et al., 2018b; Zhang et al., 2017c). Specifically, short-term temperature-mortality associations have been extensively investigated in diverse climate zones around the globe, including a number of large-scale multi-city, nationwide, and multi-country analyses (Anderson and Bell, 2009; Armstrong et al., 2011; Baccini et al., 2008; Gasparrini et al., 2015b; Guo et al., 2014; Ma et al., 2015; Scovronick et al., 2018). At an international scale, as recently reported by the Multi-Country Multi-City Collaborative Research Network, non-optimum temperature exposures could account for 7.71% (95% confidence interval: 7.43, 7.91) of total mortality based on data collected from 384 locations in 13 countries/regions during 1985–2012 (Gasparrini et al., 2015b). Under different climate change scenarios, the great temperature-related mortality burden is projected to persist worldwide, even in the end of the 21st century (Gasparrini et al., 2017; Hajat et al., 2014; Lee and Kim, 2016; Weinberger et al., 2017).

In addition to non-optimum temperature exposures, increasing epidemiologic evidence has demonstrated the adverse health impacts (i.e., morbidity and mortality) associated with unstable weather (e.g., large temperature variability) (Cheng et al., 2014). However, previous short-term investigations, including some multi-city and multi-country studies (Kim et al., 2016; Lim et al., 2015; Zhan et al., 2017; Zhou et al., 2014), have usually focused on the effects of intra-day diurnal temperature range (DTR) or inter-day temperature fluctuation (e.g., temperature change between 2 neighboring days), separately. Additionally, reported associations with inter-day temperature change have been far from consistent between studies (Onozuka and Hagihara, 2017; Vicedo-Cabrera et al., 2016; Zhan et al., 2017). Given the continuous process of health impacts related to both intra- and inter-day temperature variability, these separate assessments may largely hamper the comprehensive understanding of the overall health effects of temperature variability (Guo et al., 2016).

To better capture the short-term impact of unstable temperature patterns, several recent studies attempted to account for both intra- and inter-day temperature variability by generating the standard deviation of the minimum and maximum temperatures during exposure days (Guo et al., 2016; Zhang et al., 2017b). However, calculation of temperature variability in these studies depended on only several days' measurements (based on very few temperature records). As illustrated in a comparative time-series study in seven U.S. cities, estimates of temperature-related mortality could be influenced by temperature observation time and type (Davis et al., 2016). Therefore, previous TV-mortality studies may have overlooked the temporal variation in temperature, which may result in some biases and unstability in both exposure assessment and effect evaluation (Cheng et al., 2017; Zhang et al., 2017b). Motivated by these evidence, a multi-city study conducted in Australia developed another TV index based on hourly temperature measurements. Since hourly records are less aggregated series than daily temperatures, hourly TV could provide finer temperature information and a more reliable exposure estimation. It is argued that hourly TV could better capture the unstable patterns of short-term temperature, thus providing a complementary perspective for health risk assessment (Cheng et al., 2017).

Previously, a number of studies have explored the temporal changes in heat- and cold-mortality associations using the measurement of relative risk (Gasparrini et al., 2016; Onozuka and Hagihara, 2015) or attributable fraction of mortality (Lee et al., 2018a; Vicedo-Cabrera et al., 2018). These temporal variations could be associated with changes in vulnerability or adaptation of the population to temperature extremes (Gasparrini et al., 2015a; Vicedo-Cabrera et al., 2018). However, very sparse evidence has focused on the temporal analysis of mortality burden associated with intra- or inter-day temperature variability (Lee et al., 2018b). Additionally, seasonal patterns could be expected for temperature- and TV-attributable mortality because the climate prevalence (i.e., distribution characteristics of temperature) may vary between seasons (Yang et al., 2017). Hence, in order to comprehensively understand the TV-associated health burden, more sophisticated assessments are quite needed focusing the overall association, as well as its temporal and seasonal variations.

In this study, we performed a national analysis in England and Wales, United Kingdom based on fourteen-year time-series weather-mortality data during 1993–2006. We assessed the nationwide association of all-cause mortality with hourly temperature variability (HTV), and further explored the temporal and seasonal variations of mortality burden due to HTV.

2. Materials and methods

2.1. Data collection

2.1.1. Daily mortality and meteorological data

Daily mortality and weather data in 10 regions of England and Wales (Fig. S1 A) during 1993–2006 were collected from a previous multi-country study (Gasparrini et al., 2015a), which has also been made publicly available by Dr. Antonio Gasparrini on his personal web page (http://www.ag-myresearch.com/). This 14-year time-series dataset summarized regions-specific daily counts of all-cause deaths and meteorological records including daily minimum and maximum temperature, 24-h average temperature and relative humidity. A detailed description of these data can be found elsewhere in previous publications (Armstrong et al., 2011; Gasparrini et al., 2012b; Gasparrini et al., 2015b).

2.1.2. Region-specific hourly temperature data

Hourly temperature data in 10 UK regions between 1 January 1993 and 31 December 2006 were collected from the British Atmospheric Data Centre (BADC) (http://archive.ceda.ac.uk/). Specifically, we first extracted the data of all atmospheric monitoring stations from the obtained databases for UK hourly weather data (see details of this dataset in http://artefacts.ceda.ac.uk/badc_datadocs/ukmo-midas/WH_Table.html), then located them in each Government Office Region of England and Wales (as illustrated in Fig. S1 B). Finally, we aggregated the station-based hourly temperatures into regional-average measurements. In summary, a total of 4216 atmospheric monitoring stations were included for the aggregation of hourly temperature data, ranging from 65 in London to 850 in South West (Table S1).

2.2. Calculation of hourly temperature variability

To fully capture the mortality effect of short-term temperature variability, we took into account both intra- and inter-day temperature variability based on hourly records. We calculated the standard deviation of hourly temperatures within two days (the current and previous day) to characterize hourly temperature variability (HTV). For a specific day of the observed series, this method using the current and previous day's temperatures to calculate HTV could well incorporate the information of both DTR and temperature change between neighboring days (Zhan et al., 2017). Also, the aggregation from two days allows more flexible specifications on the lag patterns of HTV effects, which could largely facilitate the analysis of exposure-lag association within a period of multiple days (Zhang et al., 2017b). Hence, this newly developed temperature index was then used as the exposure of interest in our consequent data analysis.

2.3. Statistical analysis

A three-stage analytic approach was conducted to assess the