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Mortality burden of diurnal temperature range and its temporal changes: A multi-country study

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ABSTRACT

Although diurnal temperature range (DTR) is a key index of climate change, few studies have reported the health burden of DTR and its temporal changes at a multi-country scale. Therefore, we assessed the attributable risk fraction of DTR on mortality and its temporal variations in a multi-country data set. We collected time-series data covering mortality and weather variables from 308 cities in 10 countries from 1972 to 2013. The temporal change in DTR-related mortality was estimated for each city with a time-varying distributed lag model. Estimates for each city were pooled using a multivariate meta-analysis. The results showed that the attributable fraction of total mortality to DTR was 2.5% (95% eCI: 2.3–2.7%) over the entire study period. In all countries, the attributable fraction increased from 2.4% (2.1–2.7%) to 2.7% (2.4–2.9%) between the first and last study years. This study found that DTR has significantly contributed to mortality in all the countries studied, and this attributable fraction has significantly increased over time in the USA, the UK, Spain, and South Korea. Therefore, because the health burden of DTR is not likely to reduce in the near future, countermeasures are needed to alleviate its impact on human health.

1. Introduction

Diurnal temperature range (DTR, i.e., the intra-day temperature change) is a well-known weather-related risk factor for human health. Numerous studies have described a positive association between DTR and mortality (Cao et al., 2009; Lim et al., 2015; Tam et al., 2009;

Abbreviations: ARF, attributable risk fraction; DLNM, distributed lag non-linear model

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Vutcovici et al., 2014; Yang et al., 2013) and have reported that people who are elderly, less educated, female, or have cardiovascular or respiratory disease are more susceptible to DTR than others (Kan et al., 2007; Lim et al., 2012a; Yang et al., 2013). In addition, because DTR has been reported as an important meteorological indicator closely related to global climate change (Braganza et al., 2004; Kan et al., 2007; Yang et al., 2013), an in-depth investigation of the DTR-mortality relationship is important to comprehensively assess the future health impact of climate change.

Biological mechanisms through which a sudden change in absolute temperature might affect mortality have been described in previous medical and epidemiological studies (Garrett et al., 2009; Garrett et al., 2011; Greenberg et al., 1983; Keatinge et al., 1984; Martinez-Nicolas et al., 2015; Qiu et al., 2013). Sudden changes in within-day temperatures may cause physiological health problems (Garrett et al., 2009; Garrett et al., 2011); unstable weather or temperature changes can lead to the onset of cardiovascular events brought on by increased workload. This can affect the respiratory system by triggering inflammatory nasal responses (Ballester et al., 1997; Carder et al., 2005; Graudenz et al., 2006; Hashimoto et al., 2004; Imai et al., 1999; Luurila, 1980). These mechanisms have been suggested as potential causes of increasing human mortality (Buguet, 2007; Guo et al., 2016).

Based on this biological evidence, previous studies have tried to estimate the risk of DTR on mortality (Lim et al., 2015; Tam et al., 2009; Vutcovici et al., 2014). However, most previous studies assessed the risk of DTR using only relative risk (RR), not the attributable risk fraction, which can quantify the mortality burden. Furthermore, because a majority of the previous studies were conducted in single cities or single countries and used different statistical methods (Kan et al., 2007; Lim et al., 2012a; Yang et al., 2013), results of these studies might have limited applicability on a multi-country scale.

Most previous studies estimated the risk of DTR on mortality using historical data (Kan et al., 2007; Lim et al., 2012a), and the estimated impact of DTR was assumed to be consistent over time. However, this assumption might not be suitable for predicting the health impact of climate change because several factors, including intrinsic biological (e.g., disease/nutrition status) and extrinsic factors (e.g., forecast and infrastructure improvements, local environment, or social system conditions), can modify the population's vulnerability to absolute temperature and rapid temperature change within a day (Gasparrini et al., 2015a; Linares et al., 2014; Wu et al., 2014). Therefore, it is important to assess temporal change in the DTR-related mortality relationship to examine whether people are adapted or mal-adapted to DTR.

In this study, we assessed the percent increases in risks and the attributable risk fraction of DTR for 308 cities of 10 countries. We examined whether the excessive risks and attributable risk fractions changed during the study period. We used a Multi-Country Multi-City (MCC) Collaborative Network to assess the impact of weather on mortality using a multi-country data set referenced in previous papers (Gasparrini et al., 2015a; Gasparrini et al., 2016; Guo et al., 2014; Guo et al., 2016).

2. Material and methods

2.1. Data

Time-series data covering mortality and weather variables were collected from 385 locations in 10 countries: Canada (26 cities, 1986–2011), the United States (USA) (135 cities, 1985–2006), Brazil (18 cities, 1997–2011), Colombia (5 cities, 1998–2013), the United Kingdom (UK) (10 regions, 1990–2012), Ireland (6 regions, 1984–2007), Spain (51 cities, 1990–2010), Japan (47 prefectures, 1972–2012), South Korea (7 cities, 1992–2010), and Australia (3 cities, 1988–2009). For convenience of interpretation, the location is described as “city” in this study. The daily mortality count is the daily count of death for all causes. If a daily count of all causes of death was not available for a city, then death for non-external causes (ICD-9: 0–799, ICD-10: A00-R99) was used instead. The DTR was chosen as the exposure index, computed from monitoring stations as the difference between the daily maximum and daily minimum temperatures. Detailed information regarding data collection is provided in the Supplementary material (data details).

2.2. First-stage time series model

The first-stage time series model was divided into a two-step procedure. First, a time-series regression was applied, based on a generalized linear model using a quasi-Poisson distribution with parameters for DTR, the day of week, the seasonal long-term trend, the inter-day temperature change (the change in mean temperature between two neighboring days), and absolute temperature. We modeled the DTR-response curve with a linear function and the lag-response curve with two internal knots placed at equally spaced values on a log scale using a natural cubic B-spline with 14 days of lag. The inter-day temperature change was adjusted in the same way as DTR. We also modeled the temperature-response relationship using a quadratic B-spline with three internal knots (placed at the 10th, 75th, and 90th percentiles of location-specific temperature distributions) and a lag-response (up to 21 days) curve with natural cubic B-spline with three internal knots placed at equally spaced values on the log scale. This modeling approach was used in a previous multi-country temperature-mortality study using a distributed lag non-linear model (DLNM) (Gasparrini et al., 2010; Gasparrini et al., 2015b). Seasonal trends were adjusted using a natural cubic B-spline of time with eight degrees of freedom (df) per year (df = 8), and the day of week was included as an indicator variable. Results of the first stage estimated the association between DTR and mortality for each city.

2.3. Time varying distributed lag non-liner model

The DLNMs, described in the first-stage analysis, assumed that the exposure-lag-response associations between DTR and mortality in each location were constant across the whole study period. We also applied a time-varying DLNM with a linear interaction (Gasparrini et al., 2015a; Gasparrini et al., 2016) between DTR and year. Using the time-varying DLNM, we derived coefficients representing the exposure-lag-response association for the first and last year of the study period for each city. The set of four coefficients (the entire period, the first year, and the last year for each location) were reduced to one coefficient that modeled the overall cumulative associations between DTR and mortality. The sets of four coefficients were used to determine the lag-response relationships at the 99th percentile of the DTR reference at 0 °C DTR.

2.4. Second stage meta-analysis

We pooled one parameter of the overall cumulative exposure-response relationship and the four parameters of the lag-response relation. Multivariate random-effect meta-regression was used to pool the parameters by country. We used indicators of country as predictors in the meta-regression to country-pooled estimates and city-specific predicted parameters (Best Linear Unbiased Prediction, BLUP). The overall pooled coefficient (only for calculating excessive relative risk for all countries together) was estimated by meta-analysis without predictors. All analyses were performed using R software (version 3.3.1) packages dlnm and mvmeta (Gasparrini, 2011; Gasparrini et al., 2012; Gasparrini et al., 2010).

2.5. Attributable mortality risk faction

Overall cumulative relative risk estimated from BLUP for each city was used to compute the attributed number of deaths and the fraction of deaths over the following 14 days at each location. The total number