Mortality risk attributable to high and low ambient temperature: a multi-country study

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Summary

Background: While a few studies have estimated premature deaths attributable to either heat or cold in selected countries, none so far has offered a systematic assessment over the whole temperature range in populations exposed to different climates.

Methods: We collected data for 384 locations in Australia, Brazil, Canada, China, Italy, Japan, South Korea, Spain, Sweden, Taiwan, Thailand, UK, and USA, totalling 74,225,200 deaths in different periods between 1985 and 2012. A standard time series Poisson model was fitted in each location controlling for trends and day of the week. The temperature-mortality relationships were estimated with a distributed lag non-linear model over 21 days of lag, and then pooled in a multivariate meta-regression including country indicators and temperature average and range. Attributable deaths were calculated for heat and cold, defined as temperatures above and below the optimal temperature corresponding to point of minimum mortality, and for moderate and extreme temperatures, defined using cut-offs at the 2.5th and 97.5th temperature percentiles.

Findings: In total, 7.71% (95% CI: 7.43–7.91%) of mortality is attributed to sub-optimal temperature in the selected countries within the study period, with substantial differences between countries, from 3.37% in Thailand to 11.47% in Italy. The temperature percentile of minimum mortality varies from around 60th in tropical areas to around 80th–90th in temperate regions. Most of the attributable deaths are due to cold, with a fraction of 7.29% (7.03–7.49%), compared to 0.42% (0.39–0.44%) due to heat. Extreme cold and hot temperatures are only responsible for 0.86% (0.84–0.87%) of total mortality.

Interpretation: Most of the temperature-related mortality burden is attributable to the contribution of cold. The impact of days of extreme temperature is far less than that attributable to milder but sub-optimal weather. This evidence has important implications for the planning of public health interventions to minimise the health consequences of adverse temperatures, and for predicting the future impact under climate change scenarios.

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Background

In the last few years, numerous epidemiological studies have provided evidence on the association between ambient temperature and mortality or morbidity outcomes.1,2 Interest in this topic has increased following dramatic episodes of extreme weather, and in response to recent reports on climate change.3-5 Although consensus exists among researchers that both extremely cold and extremely hot temperatures affect health, their relative importance is a matter of current debate, and other details of the association are still unexplored. For instance, little is known about the optimal temperature corresponding to the minimum effect for a specific health outcome. Also, while most of the research has focused on extreme events, no study has offered a comparative assessment on the contribution of moderately high and low temperatures. The underlying physiological mechanisms linking exposure to non-optimal temperature and mortality risk have not been completely elucidated. Heat stroke and hypothermia only account for a minor part of the excess deaths following hot and cold days, respectively, and high and low temperatures have been associated with an increase in risk for a wide range of cardiovascular, respiratory and other causes, suggesting the existence of multiple biological pathways.6-9 Ultimately, ambient temperature represents an important risk factor and further investigations are needed to strengthen our understanding on the associated health effects. This information is paramount to plan suitable public health interventions and provide reliable predictions on the impact of climate change.

Epidemiological studies on the topic face important challenges in modelling temperature-health dependencies. First, the dose-response relationship, inherently non-linear, is also characterised by different lag periods for heat and cold: the excess risk due to heat is typically immediate and occurs within few days, while effects of cold have been reported to last up to three/four weeks.6,7 Second, the association is heterogeneous across populations, due to acclimatisation, different adaptation responses and variability in susceptibility factors.10-12 Modelling such complex patterns requires the adoption of sophisticated statistical models. Also, while most studies have quantified the association in terms of relative risk, only few have provided estimates of the attributable burden, either as absolute excess (numbers) or relative excess (fractions) of deaths.13-19 The evidence on the attributable risk of temperature is very often limited to extreme events, in particular heat waves,17,18 while fewer investigations have reported figures from dose-response relationships estimated in models with temperature as a continuous variable.13,14 This study aims at quantifying the total mortality burden attributable to non-optimal ambient temperature, and the relative contributions from heat and cold and from moderate and extreme temperatures. The analysis is based on recent advances in statistical modelling to account for the complex and heterogeneous temperature-mortality dependency.

Data and methods

Data and software

Time series daily data including mortality and weather variables were collected from 384 locations in 13 countries: Australia (three cities in the period 1988-2009), Brazil (18 cities, 1997-2011), Canada (21 cities, 1986-2009), China (15 cities, 1996-2008), Italy (11 cities, 1987-2010), Japan (47 prefectures, 1985-2012), South Korea (seven cities, 1992-2010), Spain (51 cities, 1990-2010), Sweden (one county, 1990-2002), Taiwan (three cities, 1994-2007), Thailand (62 provinces, 1999-2008), UK (10 regions, 1993-2006), and USA (135 cities, 1985-2009). Mortality is represented by daily counts of deaths for either all causes or, where not available, non-external causes only (ICD-9: 0-799; ICD-10: A00-R99). The exposure index was chosen as mean daily temperature, computed from central monitor stations either as the average between maximum and minimum or the 24-hour average. Additional information such as air pollution measures and humidity were collected in a subset of countries and used in sensitivity analyses. Details on data collection are provided in the WebAppendix. All the analyses were performed with the R software (version 3.0.3), using the packages dlnm and mmvmeta. The code is available on request from the first author.

First-stage time series model

A standard time series quasi-Poisson regression was first applied separately in each location, in order to derive estimates of location-specific temperature-mortality associations reported as relative risk (RR). The reader can refer to specific tutorials for technical details and terminology.20 Briefly, this first-stage regression included a natural cubic B-spline of time with 8 degrees of freedom (df) per year to control for seasonal and long-term
trends, and an indicator of day of the week. The association with temperature was modelled using a distributed lag non-linear model. This class of models can describe complex non-linear and lagged dependencies through the combination of two functions that define the conventional exposure-response relationship and the additional lag-response relationship, respectively. The latter is included to model the delay between the exposure occurrence and the associated increase in risk. Specifically, we modelled the exposure-response curve with a quadratic B-spline with three internal knots placed at the 10th, 75th, and 90th percentiles of location-specific temperature distributions, and the lag-response curve with a natural cubic B-spline with an intercept and three internal knots placed at equally spaced values in the log scale. The lag period is extended to 21 days in order to capture the long delay in the effects of cold and exclude deaths advanced only by a few days (harvesting effect). These modelling choices were tested in sensitivity analyses.

The association was then reduced to the overall temperature-mortality relationship, cumulating the risk over the lag period. This step reduces the number of parameters to be pooled in the second-stage meta-analysis, while at the same time preserving the complexity of the estimated dependency and thus avoiding unnecessary simplifications.

Second-stage meta-analysis

The estimated location-specific overall cumulative exposure-response associations were then pooled using a multivariate meta-analytical model. Previous studies have illustrated how climatological, socio-economic, demographic, and infrastructural factors play a role in modifying the association between temperature and mortality. In order to account for the main features of such effect modification, we included location-specific average temperature, temperature range and indicators for country as meta-predictors in a multivariate meta-regression. These effects were tested through a multivariate Wald test. Residual heterogeneity was tested and then reported by the multivariate extension of Cochran Q test and $I^2$ statistic.

The fitted meta-analytical model was then used to derive the best linear unbiased prediction (BLUP) of the overall cumulative exposure-response association in each location. The BLUP represents a trade-off between the location-specific relationship provided by the first-stage regression and the pooled relationship. This approach allows areas with small daily mortality counts or short series, usually characterised by very imprecise estimates, to borrow information from larger populations sharing similar characteristics.

Computation of attributable risk

The minimum mortality temperature (MMT), corresponding to a minimum mortality percentile (MMP) between the 1st and the 99th, was derived from the BLUP of the overall cumulative exposure-response association in each location. This value is then referred to as the optimal temperature, and considered as the reference for the computation of the attributable risk by re-centering the quadratic B-spline that models the exposure-response. For each day of the series in each location, the overall cumulative RR corresponding to each day’s temperature was used to compute the attributable deaths and fraction in the next 21 days, using a method previously described.

The total attributable number of deaths due to non-optimal temperatures is given by the sum of the contributions from all the days of the series, and its ratio with the total number of deaths provides the total attributable fraction. The components attributable to cold and heat were computed by summing the subsets corresponding to days with temperatures lower or higher than the MMT, respectively. These components were further separated into moderate and extreme contributions by defining extreme cold and heat as the temperatures lower than the 2.5th and higher than the 97.5th location-specific percentiles, respectively. These cut-offs are consistent with previous definition of extreme weather, such as heat waves. Moderate temperatures are defined as the ranges between the optimal temperature and these cut-offs. Other ranges were defined using cut-offs at the 10th, 25th, 50th, 75th and 90th percentiles.

Empirical confidence intervals (eCI) were obtained by Monte Carlo simulations assuming a multivariate normal distribution of the BLUPs of the reduced coefficients. Algebraic equations and details are provided elsewhere and summarised in the WebAppendix.

Role of the funding source
The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication after obtaining approval from all co-authors.

Results

Descriptive analysis

Table 1 summarises the data from each country, with the number of locations, study periods, total deaths and average temperature. The data set includes 74,225,200 deaths. As expected, the populations in different countries experienced a broad range of temperatures, with country-specific averages ranging from 6·5°C to 27·6°C. These temperatures are illustrative of regions characterised by different climates, from colder countries (Canada, Sweden, and to a lesser extent UK), more temperate latitudes in the Mediterranean (Spain and Italy), Far East (South Korea and Japan) and South Hemisphere areas (Australia), to tropical and sub-tropical areas (Brazil, Taiwan, and Thailand). Other larger countries (China and USA) include locations with a more heterogeneous climate.

Exposure-response associations

Figure 1 shows the overall cumulative exposure-response curves (BLUPs) in 13 cities selected to represent each country, with the corresponding MMT and the cut-offs for defining extreme temperatures. The corresponding graphs for all the 384 locations are reported in Figure S1 included in the WebAppendix. Also reported are the temperature distributions, highlighting how most of the hot temperature range, although characterised by a high RR, includes a small proportion of days. Table 2 reveals that the median MMP ranges around the 80th and 90th percentiles in most of the countries, with the exception of the tropical and sub-tropical areas of Brazil, Taiwan, and Thailand, where it appears to be around the 60th percentile. Inspection of the curves indicates that the risk increases slowly and linearly for cold temperatures below the MMT, although some locations (e.g. London and Madrid) exhibit a higher increase for extreme cold. In contrast, risk generally escalates quickly and non-linearly at high temperatures.

Results from the multivariate meta-regression indicate that, although significant, the residual heterogeneity is relatively low after country indicators, average temperature and temperature range are included as meta-predictors, with an $F$ of 36·3. While all three predictors significantly modify the temperature-mortality association either in single-predictor or full models, the country indicators explain a much higher proportion of heterogeneity (see Table S2 in the WebAppendix).

Attributable risk

The main results, consisting of the estimated attributable fraction computed as total and as separated components due to cold and hot temperature in each country, are reported in Table 2 (location-specific figures are reported in Table S4 of the WebAppendix). Overall, the total fraction of deaths due to both heat and cold is 7·71% (95%eCI: 7·43–7·91%), although it varies substantially between countries, with the highest attributable risk in Italy (10·97%), China (11·00%), and Japan (10·12%), and the lowest estimates in Thailand (3·37%), Brazil (3·53%) and Sweden (3·87%). Cold is responsible for most of the burden, while the fraction attributable to heat is more limited, with total estimates of 7·29% (7·03–7·49%) and 0-42% (0·39–0·44%), respectively. This difference is mainly due to the relatively high MMP, with most of the mean daily temperatures lower than the optimal value.

The attributable risk can be separated further into components related to moderate and extreme temperatures, as illustrated in Figure 2. Estimates for different temperature percentiles ranges are reported in Table S3 of the WebAppendix. In all the countries, most of the mortality risk attributable to temperature is due to moderate cold, with an overall estimate of 6·66% (6·41–6·86%). Extreme temperatures (either cold or hot) are responsible for a relatively small fraction, corresponding to 0·86% (0·84–0·87%). These results are consistent with the exposure-response relationships and temperature distributions illustrated in Figure 1: although the range corresponding to moderate cold shows a comparatively low RR, it includes the majority of the days in the series.
Sensitivity analyses indicate that results are not dependent on modelling assumptions (see Table S1 in the WebAppendix).

Discussion

This epidemiological study finds that temperature is responsible for advancing a considerable fraction of deaths, corresponding to 7.71% of mortality in the selected countries within the study period. Most of this mortality burden is due to days colder than the optimal temperature, with a fraction of 7.29%, compared to 0.42% attributable to heat. Also, the majority of deaths are due to exposure to mildly hot and cold temperatures, while the contribution of extreme days is comparatively low in spite of the higher relative risk. The study is based on the largest data set ever collected for evaluating temperature-health associations, including more than 74 million deaths from 13 countries. The analysis of data from 384 locations provides evidence on the temperature-related mortality risk in a wide range of climates and populations with different demographic, socio-economic and infrastructural characteristics. A strength of the study is the application of new flexible statistical models to characterise the temperature-mortality association and to pool estimates across locations. In particular, while previous studies relied on simplification of the exposure-response and/or the lag structure, the approach proposed here allows the estimation and pooling of non-linear and delayed dependencies and the identification of the temperature of minimum mortality.

Comparison with previous studies reporting attributable figures is limited by several factors, not least the variety of study designs and modelling approaches, and the use of alternative definitions of attributable risk measures. Studies focusing on specific events or periods with extreme temperatures indicate a mortality increase of 8.9-12.1% and 12.8% during heat waves and cold spells, respectively. Investigations extending the analysis to the whole summer season report estimates of 1.6-2.0% for attributable mortality due to heat. Publications proposing attributable risk measures for whole-year mortality, thus adopting a comparable denominator, suggest figures closer to those presented in this contribution; Hajat and colleagues reported that the all-cause mortality attributable to heat ranges between 0.37% and 1.45% in three European cities; Carson and colleagues estimated 5.4% of deaths were attributable to cold but none to heat in London.

Different underlying mechanisms have been postulated to explain the increased mortality risk associated with exposure to high and low ambient temperature. Physiological effects leading to heat-related deaths are not well known yet, and probably vary for different mortality causes. In the case of the association of heat with cardiovascular mortality, the cause accounting for the greatest burden, acute events seems to be triggered when the body exceeds its thermoregulatory threshold, following changes in heart rate, blood viscosity and coagulability, reductions in cerebral perfusion, and attenuated vasoconstrictor responsiveness. Heat also increases the mortality risk for other causes: a suggested mechanism is through the alteration of fluid and electrolytic balance in people affected by chronic diseases, or in groups with impaired responsiveness to environmental conditions. These sudden physiological responses are consistent with the steep, supra-linear increase in risk above the optimal temperature shown in Figure 1 and S1, associated with a comparatively high burden attributable to extremely high temperature. Biological processes underlying cold-related mortality primarily involve cardiovascular and respiratory effects. Exposure to cold has been associated with cardiovascular stress by affecting blood pressure and plasma fibrinogen, vasoconstriction and blood viscosity, and inflammatory responses, among others. Similarly, cold induces broncho-constriction and suppresses mucociliary defences and other immunological reactions, resulting in local inflammation and increased risk of respiratory infections. These physiological responses can persist for longer than those attributed to heat, and seem to produce mortality risks following a smoother, close-to-linear response, with most of the attributable risk occurring in moderately cold days.

The relative importance of heat and cold components in determining the overall mortality impact is striking: the comparison reported in Table 2 consistently suggests that cold is responsible for 77-97% of temperature-related mortality across countries. The median MMP appears to be as high as the 90th percentile in some populations, with the majority of days being colder than the optimal temperature. Research on the association between human health and ambient temperature has focused so far mainly on effects of extreme heat, and public health plans have implemented policies and interventions specifically designed almost exclusively for heat wave periods. This assessment suggests that public health policies and adaptations measures should be extended and re-focused to consider the whole range of effects associated with temperature, although further research is needed to clarify how much of the excess mortality related to each component is preventable. This study also provides a platform to improve and extend climate change impact predictions: the findings reported here
emphasise how a comprehensive assessment is needed for providing an appropriate estimate of the health consequences under alternative climate change scenarios.

Some limitations must be acknowledged. First, although this investigation comprises populations with markedly different characteristics and living in a wide range of climates, the findings cannot be interpreted as globally representative. Entire regions such as Africa or the Middle East are not included, and the assessment is mainly limited to urban populations. In addition, although results indicate a substantial inter-country variation in attributable risk to both heat and cold, the analysis does not characterise these differences, identifying determinants of vulnerability or resilience to the effects of temperature. These limitations will be addressed in future research, by extending the data set to populations living in other regions, and by collecting standardized measures of meta-variables on location-specific characteristics to be included in the second-stage meta-regression. Results from these analyses will complement the evidence provided in this contribution.

In summary, this study found a substantial impact of heat and cold on mortality, with attributable figures varying by country. The optimal temperature at which the risk is lowest is well above the median, and seems to be higher in colder regions. Cold is responsible for a higher proportion of deaths than is heat, while moderate hot and especially cold temperatures comprise the greater part of the total health burden.
Putting research into context

Systematic review

We searched the literature to identify articles reporting estimates on the impact of non-optimal ambient temperature on mortality, using attributable risk measures as the main effect summary. The search was performed in PubMed using combinations of the terms ("temperature", "heat", "cold") AND ("mortality", "death*") AND ("attributable", "impact"). Although several studies reported estimates of attributable risk, they adopted different definitions of summary measures and applied various designs and analytical methods, making the comparison difficult. Most of these investigations focused on heat-related health effects, while only few assessed the attributable component due to cold temperature. More importantly, these studies limited the evaluation to single cities or countries, and no study so far has provided a comprehensive assessment over populations exposed to different climates using consistent statistical approaches.

Interpretation

We found that non-optimal ambient temperature is responsible for a considerable excess in mortality, with important differences across countries. Although most of the research in the literature has focused on heat-related impacts, large part of the attributable deaths are due to cold temperature. Also, although much attention has been paid to extreme weather events, most of the impact occurs in moderately hot and in particular moderately cold days. This evidence is important to improve public health policies aimed at preventing temperature-related health consequences, and provides a platform to extend predictions on future impacts under climate change scenarios.
Contributors
AG, YG, MH, and BA set up the collaborative network. AG designed the study, collected and standardized the data and coordinated the work. AG, BA, and ML developed the statistical methods. AG conducted the statistical analysis and took the lead in drafting the manuscript and interpreting the results. BA provided substantial scientific input in interpreting the results and drafting the manuscript. YG, MH, EL, AZ, JS, AT, ST, JR, BF, ML, MDS, MLB, YLLG, CFW, HKan, SMY, MSZSC, PHNS, YH, and HKim provided the data, and contributed to the interpretation of the results and to the submitted version of the manuscript.

Declaration of interest
We declare that we have no competing interests.

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Tables

**Table 1: Descriptive statistics by country**

Number of locations, study period, total number of deaths, mean of the average location-specific temperature (with range of averages in parentheses).

<table>
<thead>
<tr>
<th>Country</th>
<th>Locations</th>
<th>Study period</th>
<th>Total deaths</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>3</td>
<td>1988 – 2009</td>
<td>1,177,950</td>
<td>18.1 (15.7 – 20.3)</td>
</tr>
<tr>
<td>Brazil</td>
<td>18</td>
<td>1997 – 2011</td>
<td>3,401,136</td>
<td>24.2 (17.7 – 27.4)</td>
</tr>
<tr>
<td>Canada</td>
<td>21</td>
<td>1986 – 2009</td>
<td>2,521,586</td>
<td>6.5 (2.6 – 10.7)</td>
</tr>
<tr>
<td>China</td>
<td>15</td>
<td>1996 – 2008</td>
<td>950,130</td>
<td>15.1 (7.4 – 23.7)</td>
</tr>
<tr>
<td>Italy</td>
<td>11</td>
<td>1987 – 2010</td>
<td>762,357</td>
<td>15.4 (12.2 – 18.4)</td>
</tr>
<tr>
<td>Japan</td>
<td>47</td>
<td>1985 – 2012</td>
<td>26,893,197</td>
<td>15.3 (9.1 – 23.1)</td>
</tr>
<tr>
<td>South Korea</td>
<td>7</td>
<td>1992 – 2010</td>
<td>1,671,024</td>
<td>13.7 (12.5 – 14.9)</td>
</tr>
<tr>
<td>Spain</td>
<td>51</td>
<td>1990 – 2010</td>
<td>3,479,910</td>
<td>15.5 (10.9 – 21.6)</td>
</tr>
<tr>
<td>Sweden</td>
<td>1</td>
<td>1990 – 2002</td>
<td>190,092</td>
<td>7.5 (7.5 – 7.5)</td>
</tr>
<tr>
<td>Taiwan</td>
<td>3</td>
<td>1994 – 2007</td>
<td>765,893</td>
<td>24.0 (23.2 – 25.2)</td>
</tr>
<tr>
<td>Thailand</td>
<td>62</td>
<td>1999 – 2008</td>
<td>1,827,853</td>
<td>27.6 (25.1 – 29.3)</td>
</tr>
<tr>
<td>UK</td>
<td>10</td>
<td>1993 – 2006</td>
<td>7,573,716</td>
<td>10.4 (9.5 – 11.7)</td>
</tr>
<tr>
<td>USA</td>
<td>135</td>
<td>1985 – 2006</td>
<td>22,896,409</td>
<td>14.9 (7.9 – 25.5)</td>
</tr>
</tbody>
</table>

**Table 2: Attributable mortality fraction by country computed as total and as separated components for cold and heat**

Country-specific median of the minimum mortality percentile (MMP) and fraction (%) of all-cause mortality attributable to temperature in each country. The latter is reported as total and as separated components due to cold and heat, with 95% empirical confidence intervals.

<table>
<thead>
<tr>
<th>Country</th>
<th>Median MMP</th>
<th>Total (%)</th>
<th>Cold (%)</th>
<th>Heat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>83rd</td>
<td>6.96 (4.27 – 9.51)</td>
<td>6.50 (3.91 – 8.94)</td>
<td>0.45 (0.20 – 0.70)</td>
</tr>
<tr>
<td>Brazil</td>
<td>60th</td>
<td>3.53 (3.00 – 4.01)</td>
<td>2.83 (2.34 – 3.30)</td>
<td>0.70 (0.45 – 0.93)</td>
</tr>
<tr>
<td>Canada</td>
<td>81st</td>
<td>5.00 (3.83 – 6.07)</td>
<td>4.46 (3.39 – 5.48)</td>
<td>0.54 (0.39 – 0.66)</td>
</tr>
<tr>
<td>China</td>
<td>83rd</td>
<td>11.00 (9.29 – 12.47)</td>
<td>10.36 (8.72 – 11.77)</td>
<td>0.64 (0.47 – 0.79)</td>
</tr>
<tr>
<td>Italy</td>
<td>79th</td>
<td>10.97 (8.03 – 13.43)</td>
<td>9.35 (6.59 – 11.72)</td>
<td>1.62 (1.24 – 1.98)</td>
</tr>
<tr>
<td>Japan</td>
<td>86th</td>
<td>10.12 (9.61 – 10.56)</td>
<td>9.81 (9.32 – 10.22)</td>
<td>0.32 (0.27 – 0.36)</td>
</tr>
<tr>
<td>South Korea</td>
<td>89th</td>
<td>7.24 (4.45 – 9.73)</td>
<td>6.93 (4.12 – 9.44)</td>
<td>0.31 (0.15 – 0.45)</td>
</tr>
<tr>
<td>Spain</td>
<td>78th</td>
<td>6.52 (5.82 – 7.16)</td>
<td>5.46 (4.79 – 6.07)</td>
<td>1.06 (0.96 – 1.16)</td>
</tr>
<tr>
<td>Sweden</td>
<td>93rd</td>
<td>3.87 (3.20 – 12.93)</td>
<td>3.69 (3.21 – 12.61)</td>
<td>0.18 (0.04 – 0.65)</td>
</tr>
<tr>
<td>Taiwan</td>
<td>62nd</td>
<td>4.75 (3.26 – 6.06)</td>
<td>3.89 (2.50 – 5.31)</td>
<td>0.86 (0.12 – 1.50)</td>
</tr>
<tr>
<td>Thailand</td>
<td>60th</td>
<td>3.37 (3.06 – 3.63)</td>
<td>2.61 (2.31 – 2.88)</td>
<td>0.76 (0.65 – 0.86)</td>
</tr>
<tr>
<td>UK</td>
<td>90th</td>
<td>8.78 (8.00 – 9.54)</td>
<td>8.48 (7.72 – 9.25)</td>
<td>0.30 (0.25 – 0.36)</td>
</tr>
<tr>
<td>USA</td>
<td>84th</td>
<td>5.86 (5.50 – 6.17)</td>
<td>5.51 (5.17 – 5.82)</td>
<td>0.35 (0.30 – 0.39)</td>
</tr>
<tr>
<td>TOT</td>
<td>81st</td>
<td>7.71 (7.43 – 7.91)</td>
<td>7.29 (7.02 – 7.49)</td>
<td>0.42 (0.39 – 0.44)</td>
</tr>
</tbody>
</table>
Figures legend

*Figure 1: Overall cumulative exposure-response relationships in 13 cities*

These exposure-response relationships are computed as BLUP (with 95%eCI) in representative cities of the 13 countries, with related temperature distributions. The minimum mortality temperature (MMT) and the 2.5th and 97.5th percentiles are added as dotted and dashed lines, respectively.

*Figure 2: Fraction (%) of all-cause mortality attributable to moderate and extreme hot and cold temperature by country*

Extreme and moderate high and low temperatures are defined using the minimum mortality temperature and the 2.5th and 97.5th percentiles of temperature distribution as cut-offs.
References


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