BeBrit Extreme Heat Risk Project
City Case Study

Projections of Cause Specific Mortality and Demographic Changes under Climate Change in Lisbon Metropolitan Area

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INTRODUCTION

Studies have reported that global climate change threatens population health and well-being, particularly exposure to heat and cold events. Extreme temperatures, such as heat events, have been well documented. Most studies project that future increases in heat-related deaths will outweigh those due to cold. Several countries have shown reduced winter mortality due to milder winters. Portugal's temperature-attributable mortality projections are mostly related to total or non-accidental mortality. However, few data on temperature-related cause-specific mortality are available, which limits our knowledge of climate change effects on specific conditions, including health determinants. Based on RCP8.5 (Representative Concentration Pathways) greenhouse gas emissions scenario, metropolitan-specific climate projections for two 20-year periods, 1986–2005 and 2046–2065, were used considering low, medium, and high population scenarios to estimate the future impact of climate change on temperature-related, cause-specific mortality.

METHODS

Mortality Data

Daily data on cause-specific deaths in the LMA were obtained from Statistics Portugal (INE) for 1986–2005.

Causes of death were coded according to the International Classification of Diseases, ninth revision (ICD-9) and tenth revision (ICD-10), as follows: diabetes mellitus (ICD-9: 250 code series; ICD-10: E10-E14); ischemic heart diseases (ICD-9: 410–414; ICD-10: I20-I25); cerebrovascular diseases (ICD-9:430–438; ICD-10: I60-I69); and respiratory diseases (ICD-9: 460–519; ICD-10: J00-J99). During this period, diabetes mellitus (DM) caused 16,447 deaths; ischemic heart disease (HD) caused 64,618 deaths; cerebrovascular disease (CVD) caused 91,824 deaths; and respiratory diseases (RD) caused 37,422 deaths.

Temperature Projections

Projections of historical and future temperatures for the LMA were obtained from the Weather Research and Forecasting model (WRF). This model was used to dynamically downscale climate data from the Max Planck Institute for Meteorology Earth System Model (MPI-ESM) to a higher horizontal resolution (9 Km) climate grid. It is recognised as one of the most robust climate simulation models.

RCP8.5 greenhouse gas emissions were used as a reference for the current climate (1986–2005) and to simulate projections for the mid-term climate (2046–2065). The average, maximum, and minimum near-surface (2 m high) daily atmospheric temperatures for each location and climate were extracted for the LMA using the closest grid point in the model.

Estimation of Temperature–Mortality Relationships

Based on a previous study, a distributed lag non-linear model (DLNM) was used with a 21-day lag to quantify the relationship between daily temperature and mortality, as well as mortality and lag days. Assuming that daily cause-specific deaths (Y_t) follow a quasi-Poisson distribution, the model is of the form

$$Y_t \sim quasiPoisson(\mu_t)$$

$$\mu_t \equiv E(Y_t)$$

$$logE[Y_t] = \alpha + log\,(POP_t) + \delta_1 DOW_t + \delta_2 HOY_t + \delta_3 SEASON_t + ns(RH) + ns(TIME_t) + cb\,(x_{t-l}, \beta_l)$$

Projections of Exposure–Response Relationships and Attributable Mortality Rates

The strategy for projecting temperature–mortality associations was motivated by previous studies. We extrapolated the temperature–mortality curve for the historical period with projected temperatures for the future period. We assumed that future mortality trends resemble the historical annual series. Temperature threshold shifts and exposure–response function (ERF) slope reductions were also explored. We estimated these temperature–mortality relationships, backwards attributable fractions (AF) and attributable number (AN) due to non-optimal temperatures (below and above MMT), using the overall cumulative temperature–mortality association and the RR corresponding to daily temperatures (below or above MMT) for each lag day.

$$AF_{x,t} = 1 - e^{-\sum_{l=l_0}^{L} \beta_{x_{t-l},l}}$$

$$AN_{x,t} = AF_{x,t} \cdot n_t$$

RESULTS

Table 1 presents the distribution of the key variables considered in this study. During the historical period (1986–2005), a high proportion of deaths were due to cerebrovascular disease (CVD), with a daily mean (SD) of 12.57 (4.53) and 91,824 total deaths compared to other cause-specific deaths. The mean daily minimum and maximum temperatures for the same period were 13.43 °C and 18.52 °C, respectively. The mean daily temperature ranged from 3.4 °C to 34.7 °C, and its interquartile range was 12.5 °C–19.3 °C. For future projected temperatures (all year), the mean daily minimum and maximum temperatures for the projected period were 14.9 °C and 20.5 °C, respectively. The mean daily projected temperature ranged from 5.6 °C to 34.6 °C, and its interquartile range was 13.8 °C–21.2 °C.

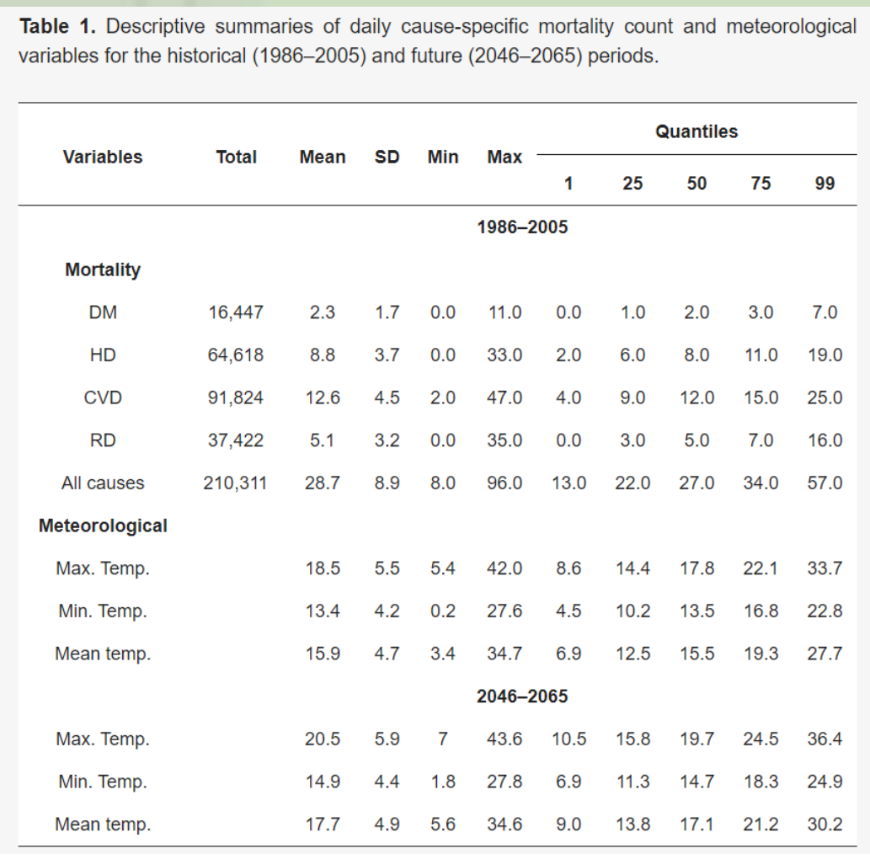
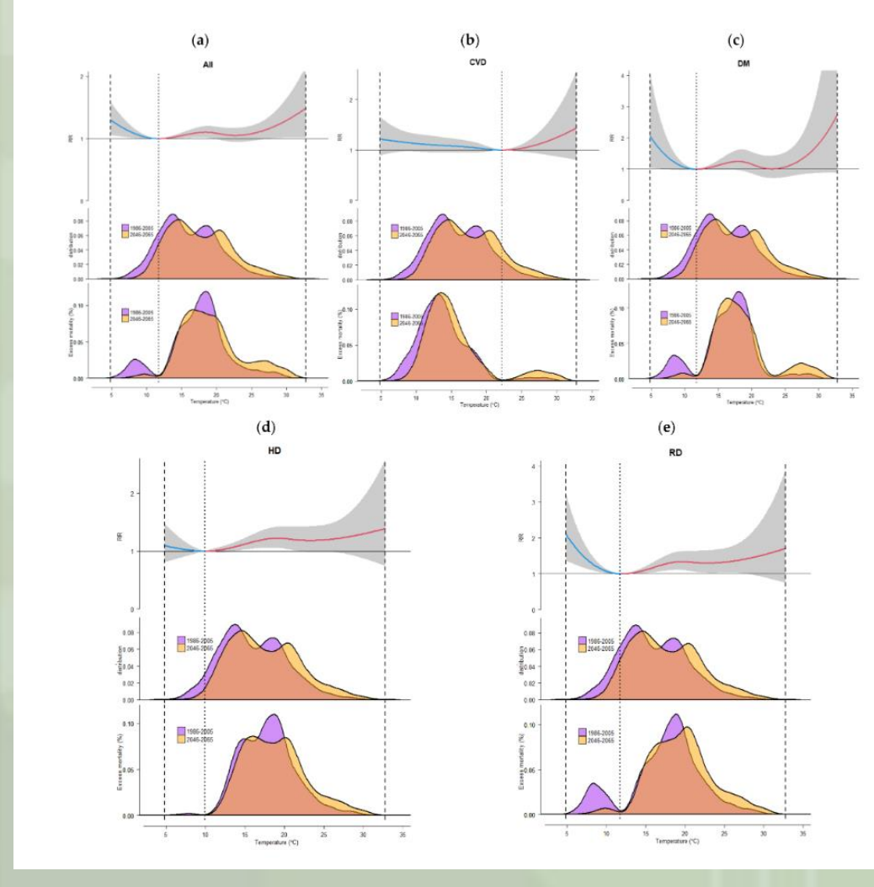


Table 1. Descriptive summaries of daily cause-specific mortality count and meteorological variables for the historical (1986–2005) and future (2046–2065) periods.

Variables	Total	Mean	SD	Min	Max	Quantiles				
						1	25	50	75	99
						1986–2005				
Mortality										
DM	16,447	2.3	1.7	0.0	11.0	0.0	1.0	2.0	3.0	7.0
HD	64,618	8.8	3.7	0.0	33.0	2.0	6.0	8.0	11.0	19.0
CVD	91,824	12.6	4.5	2.0	47.0	4.0	9.0	12.0	15.0	25.0
RD	37,422	5.1	3.2	0.0	35.0	0.0	3.0	5.0	7.0	16.0
All causes	210,311	28.7	8.9	8.0	96.0	13.0	22.0	27.0	34.0	57.0
Meteorological										
Max. Temp.		18.5	5.5	5.4	42.0	8.6	14.4	17.8	22.1	33.7
Min. Temp.		13.4	4.2	0.2	27.6	4.5	10.2	13.5	16.8	22.8
Mean temp.		15.9	4.7	3.4	34.7	6.9	12.5	15.5	19.3	27.7
						2046–2065				
Max. Temp.		20.5	5.9	7	43.6	10.5	15.8	19.7	24.5	36.4
Min. Temp.		14.9	4.4	1.8	27.8	6.9	11.3	14.7	18.3	24.9
Mean temp.		17.7	4.9	5.6	34.6	9.0	13.8	17.1	21.2	30.2

Temperature–Mortality Associations in Historical and Future Periods

Figure 1a–e (top panel) display the pooled estimates from temperature–mortality (1986–2005) curves for all-cause and cause-specific mortality. The overall mortality risks are significantly higher at lower temperatures for all-cause deaths. For example, at a temperature of 6.9 °C (1st percentile), the RR is 1.10 (95% CI: 1.01–1.19) based on an MMT of 11.1 °C. Considering an extremely cold temperature (1st percentile) of 6.9 °C, the risk associated with RD was significant (RR = 1.33, 95% CI: 1.11–1.58) based on an MMT of 11.4 °C. By contrast, the risks associated with HD, CVD, and DM were statistically insignificant (**Figure 1**). Extreme heat (27.7 °C) was only significantly associated with RD, with an RR of 1.37 (95% CI: 1.03–1.82). The lag response from our model for temperatures associated with 6.9 °C and 27.7 °C shows a significant, immediate, and persistent association between extremely cold temperatures and lag days. The lag response to extreme heat was statistically significant over the 21-day lag period for all cause-specific temperature–mortality relationships.



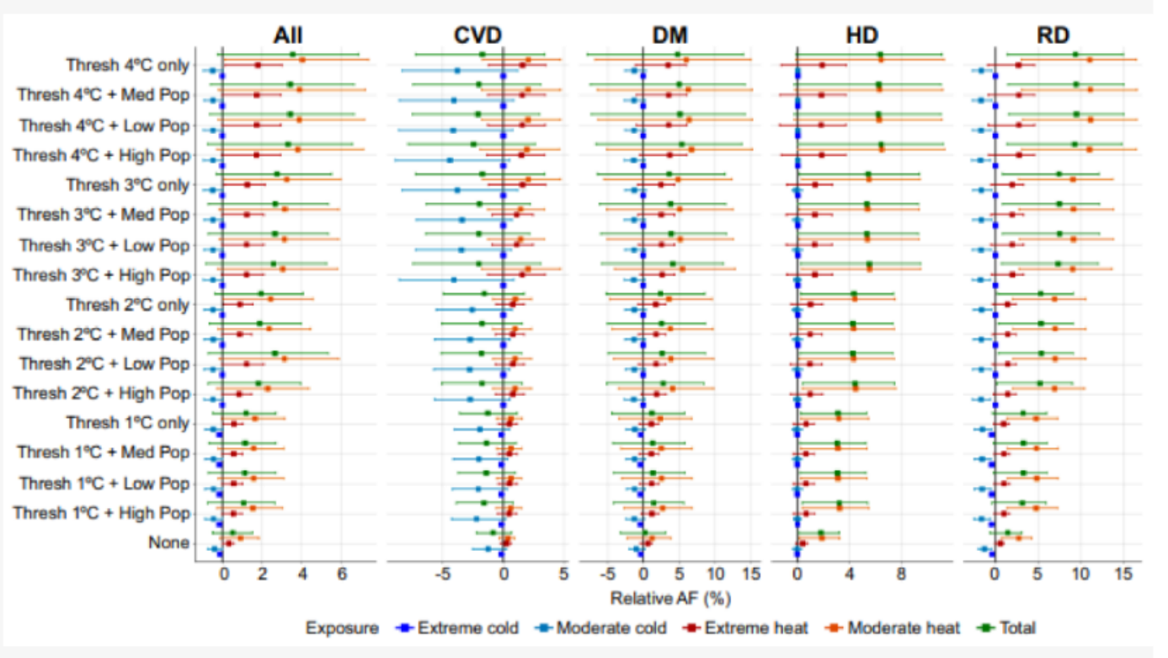
Net Differences in Excess Temperature-Related Mortality

Furthermore, we compared the net differences (change) in excess temperature-related deaths between the future and historical periods as percentage-relative AF (**Figure 2**).

The results show that for all causes with total exposure and no adaptation, the total net difference for all-cause excess mortality changed by 0.53% (95% CI: −0.5% to 1.51%). The significantly lower all-cause deaths in the future were attributed to extreme cold at a threshold of 1 °C and no population changes, an estimated net difference of −0.15% (95% CI: −0.26 to −0.02), a threshold of 1 °C and high population scenario of −0.15% (95% CI: −0.26 to −0.01), and a threshold of 1 °C and low population scenario of −0.15% (95% CI: −0.26 to −0.01).

For individuals with HD and total exposure to heat and cold, the net change in AF% without any threshold was 1.79% (95% CI: 0.04 to 3.18). The net difference in AF% for moderate heat was 1.86% (95% CI: 0.12 to 3.2) and 0.39% for extreme heat (95% CI: −0.16 to 0.76) without any threshold. The net difference in AF% due to HD is highest for moderate heat exposure with a threshold of 4 °C only and decreases slightly with increasing levels of population adaptation.

Figure 2. Net difference in excess mortality attributable to hot and cold temperatures in different adaptation scenarios and population changes. Mortality is expressed as the fraction of additional deaths (%) attributed to non-optimal temperature. CVD: cerebrovascular disease; DM: diabetes mellitus; HD: ischaemic heart disease; RD: respiratory disease; and All: all causes. The square represents the estimated difference, while the lines represent the 95% empirical confidence intervals (CIs). See **Supplementary Table S3** for numerical values.



CONCLUSIONS

In summary, this study highlights the significant impact of temperature on mortality risk in Portugal, particularly for chronic diseases. It considers several population projection scenarios in the Lisbon Metropolitan Area. The findings suggest that both low and high temperatures increase mortality risk. Cold temperatures contributed to all-cause and cause-specific deaths, including cerebrovascular diseases, diabetes mellitus, ischaemic heart diseases, and respiratory diseases. By contrast, high temperatures were the main cause of future mortality, with diabetes mellitus being the most affected. In a changing climate, this study's findings and methodology have important implications for monitoring and developing targeted prevention plans for non-communicable diseases.

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