The Multi-Country Multi-City (MCC) Collaborative Research Network: an international research consortium investigating environment, climate, and health

Supplementary Data – Appendix

eTable 1. List of research articles published by the MCC Network by research topic

Temperature-related risks	
Reference	**Main findings**
Guo et al. Global variation in the effects of ambient temperature on mortality: a systematic evaluation. *Epidemiology*. 2014;25(6)781-789.	Cold and hot temperatures increased the risk of mortality in all the countries/regions. Cold effects were delayed and lasted for many days, whereas heat effects appeared quickly and did not last long.
Gasparrini et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *The Lancet*. 2015;386(9991):369-375. **[Awarded by the International Society for Environmental Epidemiology as the Best Environmental Epidemiology paper in 2015]**	Most of the temperature-related mortality burden was attributable to the contribution of cold. The effect of days of extreme temperature was substantially less than that attributable to milder but non-optimum weather.
Guo et al. Temperature variability and mortality: a multi-country study. *Environmental Health Perspectives*. 2016;124(10):1554-1559.	There was a significant association between temperature variability and mortality in all countries. Mortality risks were higher in hot areas when using short temperature variability exposures, also in moderate areas when using longer exposures.
Vicedo-Cabrera et al. Association of inter and intra-day temperature change with mortality. *American Journal of Epidemiology*. 2016;183(4):286-293.	The association between mortality and temperature variation is generally minimal compared with mean daily temperatures, although further research on intraday changes is needed.
Armstrong et al. Longer-term impact of high and low temperature on mortality: an international study to clarify length of mortality displacement. *Environmental Health Perspectives*. 2017;125(10):107009.	The results provide strong evidence that most deaths associated in daily analyses with heat and cold are displaced by at least 1 year.
Guo et al. Heat wave and mortality: a multicountry, multicommunity study. *Environmental Health Perspectives*. 2017;125(8):087006. **[Included in the 2019 Journal Impact Factor Collection of highly-cited papers in Environmental Health Perspectives]**	High temperatures create a substantial health burden, although their effects over consecutive days are similar to what would be experienced if days of high temperature occur independently. People in areas with less extreme weather are more sensitive to heat waves.
Lee et al. Mortality burden of diurnal temperature range and its temporal changes: a multi-country study. *Environment International*. 2018;110(1):123-130.	This study found that diurnal temperature range has significantly contributed to mortality in all the selected countries, showing a significant increase over time in USA, UK, Spain, and South Korea.
Kim et al. Suicide and ambient temperature: a multi-country multi-city study. *Environmental Health Perspectives*. 2019:127(11):117007.	The risk of suicide increased with increasing ambient temperature in many countries, but to varying extents and not necessarily linearly.
Yu et al. Seasonality of suicide: a multi-country multi-community observational study. *Epidemiology and Psychiatric Sciences*. 2020;29:e163.	Seasonal suicide patterns were largely heterogeneous in shape, amplitude, subgroup differences and temporal changes among different populations, as influenced by climate, demographic and socioeconomic conditions.
Roye et al. Effects of hot nights on mortality in Southern Europe. *Epidemiology*. 2021;32(4):487-498.	Hot night indices are strongly associated with cause-specific deaths.
Tobias A et al. Geographical variations of the minimum mortality temperature at a global scale: a multicountry study. *Environmental Epidemiology*. 2021;5(5):e169.	The geographical distribution of the minimum mortality temperature is driven mainly by the mean annual temperature. Populations seems to be adapted to the average temperature, although there is still more room for adaptation.
Urban et al. Evaluation of the ERA5 reanalysis-based Universal Thermal Climate Index on mortality data in Europe. *Environmental Research*. 2021;8:111227.	ERA5-based UTCI may be a useful tool for definition of life-threatening thermal conditions in locations where high-quality station data are not available.
Zhao et al. Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: a three-stage modelling study. *The Lancet Planetary Health*. 2021;5(7):e415-e425. **[Top 10th climate paper in 2021 for news and social media attention, by Carbon Brief]**	The first truly global assessment of health effects of non-optimal temperatures. The study found that both heat and cold are associated with a substantial mortality burden, which varies spatially and temporally.

Alahmad et al. Associations between extreme temperatures and cardiovascular cause-specific mortality: results from 27 countries. *Circulation*. 2022;147(1):35-46.	The exposure to extreme hot and cold temperatures was associated with a greater risk of mortality from multiple common cardiovascular conditions.
Madaniyazi et al. Seasonal variation in mortality and the role of temperature: a multi-country multi-city study. *International Journal of Epidemiology*. 2022;51(1):122-133.	Seasonality of mortality is importantly driven by temperature, mostly in temperate and continental climate zones. Warmer locations show stronger seasonal variations in mortality, mostly related to temperature risks.
Mistry et al. Comparison of weather station and climate reanalysis data for modelling temperature-related mortality. *Scientific Reports*. 2022;12(1):5178.	Reanalysis temperature from ERA5 products compare well to station observations, with similar non-optimal temperature-related risk estimates.
Wu et al. Global, regional, and national burden of mortality associated with short-term temperature variability from 2000-19: a three-stage modelling study. *Lancet Planetary Health*. 2022;6(5):e410-e421.	A substantial mortality burden was associated with temperature variability, showing geographical heterogeneity and a slightly increasing temporal trend.
Eunice Lo et al. Optimal heat stress metric for modelling heat-related mortality varies from country to country. *International Journal of Climatology*. 2023;43(12):5553-5568.	The optimal metric for modelling mortality varies from country to country. However, dry-bulb temperature performs similarly to humidity-based heat stress metrics in estimating heat-related mortality in present-day climate.
Masselot et al. Excess mortality attributed to heat and cold: a health impact assessment study in 854 cities in Europe. *The Lancet Planetary Health*. 2023:S2542-5196(23)00023-2.	Maps of mortality risks and excess deaths indicate geographical differences across Europe, such as a north-south gradient and increased vulnerability in eastern countries, as well as local variations due to urban characteristics.
Alahmad et al. Extreme Temperatures and Stroke Mortality: Evidence From a Multi-Country Analysis. *Stroke*. 2024. doi: 10.1161/STROKEAHA.123.045751.	Both extreme cold and hot temperatures are associated with an increased risk of dying from ischemic and haemorrhagic strokes.
Gao et al. Global, regional, and national burden of mortality associated with cold spells during 2000-19: a three-stage modelling study. *The Lancet Planetary Health*. 2024 Feb;8(2):e108-e116.	Cold spells are associated with substantial mortality burden around the world with geographically varying patterns.
Wen et al. Comparison for the effects of different components of temperature variability on mortality: a multi-country time-series study. *Environment International*. 2024;187:108712.	Our results indicated that intra-day temperature variability may explain the main part of the mortality risk related to temperature variability.
Zhao et al. Global, regional, and national burden of heatwave-related mortality from 1990 to 2019: A three-stage modelling study. PLoS Medicine. 2024;21(5):e1004364.	Heatwaves were associated with substantial mortality burden that varied spatiotemporally over the globe in the past 30 years. Locations with tropical climate or low incomes were observed with the greatest decline.

Assessment of vulnerability to non-optimal temperature

Reference	**Main findings**
Gasparrini et al. Temporal variation in heat-mortality associations: a multicountry study. *Environmental Health Perspectives*. 2015;123(11):1200-1207. **[Included in the Extreme Weather Collection of highly-cited papers in Environmental Health Perspectives, August 2019]**	We estimated a statistically significant decrease in the relative risk for heat-related mortality in 2006 compared with 1993 in the majority of countries included in the analysis.
Gasparrini et al. Changes in susceptibility to heat during the summer: a multicountry analysis. *American Journal of Epidemiology*. 2016;183(11):1027-1036.	This study suggests a reduction of heat-related mortality risk over the summer, which can be attributed to several factors, such as true acclimatization, adaptive behaviours, or harvesting effects.
Armstrong et al. The role of humidity in associations of high temperature with mortality: a multicountry multicity study. *Environmental Health Perspectives*. 2019;127(9):097007.	The absence of a positive association of humidity with mortality in summer is counter to expectations from physiologic studies, though consistent with previous epidemiologic studies suggesting little evidence for improved prediction by heat indices.
Sera et al. How urban characteristics affect vulnerability to heat and cold: a multi-country analysis. *International Journal of Epidemiology*. 2019;48(4):1101-1112.	Several city indicators modify the effect of heat, with a higher mortality impact associated with increases in population density, fine particles (PM2.5), gross domestic product and Gini index, whereas higher levels of green spaces were linked with a decreased effect of heat.

Sera et al. Air conditioning and heat-related mortality: a multi-country longitudinal study. *Epidemiology*. 2020;31(6):779-787.	There is an independent association between increased air conditioning prevalence and lower heat-related mortality risk. However, increased air conditioning explains only part of the observed attenuation.
Choi et al. Effect modification of greenness on the association between heat and mortality: a multi-city multi-country study. *EBioMedicine*. 2022;84:104251.	Cities with high greenspace value had the lowest heat-mortality relative risk, while the heat-related risk higher for cities with low greenspace.
Wu et al. Fluctuating temperature modifies heat-mortality association around the globe. *Innovation*. 2022;3(2):100225.	Temperature variability had a significant modification effect on the heat-mortality association, causing a higher heat-related mortality burden with increments of temperature variability.
Rai et al. Heat-related cardiorespiratory mortality: effect modification by air pollution across 482 cities from 24 countries. *Environment International*. 2023;174:107825.	Heat was associated with increased cardiorespiratory mortality. Moreover, the heat effects were modified by elevated levels of all air pollutants in most locations, with stronger effects for respiratory than cardiovascular mortality.
Wu et al. Temperature frequency and mortality: assessing adaptation to local temperature. *Environment International*. 2024;187:108691.	We observed a consistent decrease in the mortality risk as the normalized frequency of temperature increases across the globe, suggesting that populations can adapt to their local climate with frequent exposure.

Short-term effects of air pollution

Reference	Main findings
Liu et al. Ambient particulate air pollution and daily mortality in 652 cities. *New England Journal of Medicine*. 2019;381(8):705-715. **[Included in the New England Journal of Medicine Notable Articles of 2019]**	The study shows independent associations between short-term exposure to PM10 and PM2.5 and daily all-cause, cardiovascular, and respiratory mortality in more than 600 cities across the globe.
Vicedo-Cabrera et al. Short term association between ozone and mortality: global two stage time series study in 406 locations in 20 countries. *British Medical Journal*. 2020:368:m108. **[Honourable mention by the International Society for Environmental Epidemiology to the Best Environmental Epidemiology paper in 2020]**	The study found clear associations between ozone and short-term mortality risks. The results suggest that ozone-related mortality could be potentially reduced by adopting stricter air quality standards.
Chen et al. Ambient carbon monoxide and daily mortality: a global time-series study in 337 cities. *The Lancet Planetary Health*. 2021;5(4):e191-e199.	The study found significant associations between ambient CO and daily mortality, even at levels well below current air quality guidelines.
Meng et al. Short term associations of ambient nitrogen dioxide with daily total, cardiovascular, and respiratory mortality: multilocation analysis in 398 cities. *British Medical Journal*. 2021;372:n534.	The study provides key evidence on the independent and linear associations between short term exposure to NO2 and increased risk of total, cardiovascular, and respiratory mortality.
Liu et al. Coarse particulate air pollution and daily mortality: a global study in 205 cities. *American Journal of Respiratory and Critical Care Medicine*. 2022;206(8):999-1007.	This study provides novel evidence on the robust and independent associations between short-term exposure to ambient PM2.5-10 and total, cardiovascular, and respiratory mortality, suggesting the need to establish regulatory limit for daily concentrations of PM2.5-10.
Masselot et al. Differential mortality risks associated with $PM_{2.5}$ components: a multi-country, multi-city study. *Epidemiology*. 2022;33(2):167-175.	This study found differential impacts of PM2.5 on mortality depending on its components. The results can contribute to the identification of more hazardous PM2.5 emission sources.
Liu et al. Interactive effects of ambient fine particulate matter and ozone on daily mortality in 372 cities: two stage time series analysis. *British Medical Journal*. 2023;383:e075203.	The findings of this study suggest a synergistic effect of PM2.5 and O3 on total, cardiovascular, and respiratory mortality, indicating the benefit of coordinated control strategies for both pollutants.
Min et al. Fluctuating risk of acute kidney injury-related mortality for four weeks after exposure to air pollution: a multi-country time-series study in 6 countries. *Environment International*. 2023;183:108367.	This study provides evidence that public health policies to reduce air pollution may alleviate the burden of death from acute kidney injury.
O'Brien et al. Short-term association between sulfur dioxide and mortality: a multicountry analysis in 399 cities. *Environmental Health Perspectives*. 2023;131(3):37002.	The analysis revealed independent mortality risks associated with short-term exposure to SO2, with no evidence of a threshold. Levels below the current WHO guidelines for 24-h averages were still associated with substantial excess mortality.

Stafoggia et al. Joint effect of heat and air pollution on mortality in 620 cities of 36 countries. *Environment International*. 2023;181:108258.	The results provide suggestive evidence of effect modification between air temperature and air pollutants on mortality during the warm period of the year across the selected locations.
Yu et al Ambient fine particulate matter and daily mortality: a comparative analysis of observed and estimated exposure in 347 cities. International Journal of Epidemiology. 2024;53(3):dyae066.	Mortality risks associated with daily PM2.5 exposure were consistent for both station-observed and model-estimated exposures, suggesting the reliability and potential applicability of the global PM2.5 product in epidemiological studies.

Health impacts of climate change

Reference	Main findings
Gasparrini et al. Projections of temperature-related excess mortality under climate change scenarios. *The Lancet Planetary Health*. 2017;1(9)e360-e367.	This study shows the negative health impacts of climate change that, under high-emission scenarios, would disproportionately affect warmer and poorer regions of the world.
Guo et al. Quantifying excess deaths related to heatwaves under climate change scenarios: a multicountry time series modelling study. *PLoS Medicine*. 2018;15(7):e1002629.	This study provides a comprehensive characterisation of future heatwave-related excess mortality across various regions and under alternative scenarios of greenhouse gas emissions, assumptions of adaptation, and scenarios of population change.
Vicedo-Cabrera et al. A multi-country analysis on potential adaptive mechanisms to cold and heat in a changing climate. *Environment International*. 2018;111:239-246.	The findings suggest a decrease in heat and cold-related mortality impacts over the past decades, well beyond those expected from a pure adaptation to changes in temperature due to the observed warming.
Vicedo-Cabrera et al. Temperature-mortality impacts under and beyond Paris Agreement climate change scenarios. *Climatic Change*. 2018;150(3-4):391-402.	The results suggest that limiting warming below 2 °C could prevent large increases in temperature-related mortality in most regions worldwide.
Lee et al. Predicted temperature-increase-induced global health burden and its regional variability. *Environment International*. 2019;131:105027.	We observed that the projected temperature increase is highly correlated with daily temperature range at the location and vulnerability to temperature increase is affected by health expenditure, and proportions of obese and elderly population.
Lee et al. Projections of excess mortality related to diurnal temperature range under climate change scenarios: a multi-country modelling study. *Lancet Planetary Health*. 2020;4(11):e512-e521	This study suggests that, globally, diurnal range temperature-related excess mortality might increase under climate change, and this increasing pattern is likely to vary between countries and regions, with important policy implications.
Vicedo-Cabrera et al. The burden of heat-related mortality attributable to recent human-induced climate change. *Nature Climate Change*. 2021;11(6):492-500. **[Top 1st climate paper in 2021 for news and social media attention, by Carbon Brief; and Honourable mention by the International Society for Environmental Epidemiology to the Best Environmental Epidemiology paper in 2021]**	We find that one-in-three of warm-season heat-related deaths in recent decades can be attributed to anthropogenic climate change and that increased mortality is evident on every continent.
Luthi et al. Rapid increase in the risk of heat-related mortality. *Nature Communications*. 2023;14(1):4894.	A 1-in-100 year heat mortality event in 2000 is expected every 10-20 years by 2020, with even shorter intervals projected at 1.5 °C and 2 °C of warming. Without adaptation, these extreme heat events will become common.
Chen et al. Impact of population aging on future temperature-related mortality at different global warming levels. *Nature Communications*. 2024;15(1):1796.	The findings indicate that population aging constitutes a crucial driver for future heat and cold-related deaths, with increasing mortality burden for both heat and cold due to the aging population.
Domingo et al. Ozone-related acute excess mortality projected to increase in the absence of climate and air quality controls consistent with the Paris Agreement. *One Earth*. 2024;7(2):325-335.	We find that ozone-related deaths will increase between 2010-2014 and between 2050-2054, with attributable fractions increasing in all climate scenarios, except the single scenario consistent with the Paris Climate Agreement.
Madaniyazi et al Seasonality of mortality under climate change: a multicountry projection study. *The Lancet Planetary Health*. 2024;8(2):e86-e94.	A warming climate can substantially change the seasonality of mortality in the future, potentially increasing during warm seasons and sustained high during cold seasons, particularly in regions characterised by arid, temperate, and continental climate.

Other environmental hazards	
Reference	**Main findings**
Chen et al. Mortality risk attributable to wildfire-related PM2·5 pollution: a global time series study in 749 locations. *The Lancet Planetary Health*. 2021;5(9):e579-e587.	Short-term exposure to wildfire-related PM2·5 was associated with increased risk of mortality. Urgent action is needed to reduce health risks from the increasing wildfires.
Nottmeyer et al The association of COVID-19 incidence with temperature, humidity, and UV radiation - A global multi-city analysis. *Science of the Total Environment*. 2022;854:158636.	The results suggest that comparatively low temperatures and low absolute humidity were associated with increased risks of COVID-19 incidence.
Huang et al. Global short-term mortality risk and burden associated with tropical cyclones from 1980 to 2019: a multi-country time-series study. *The Lancet Planetary Health*. 2023;7(8):e694-e705.	Short-term exposure to tropical cyclones was associated with a significant mortality burden, with highly heterogeneous spatiotemporal patterns
Yang et al Mortality risks associated with floods in 761 communities worldwide: time series study. *British Medical Journal*. 2023;383:e075081.	This study found that the risks of all cause, cardiovascular, and respiratory mortality increased for up to 60 days after exposure to flood and the associations could vary by local climate type, socioeconomic status, and older age.
Huang et al. Tropical cyclone-specific mortality risks and the periods of concern: A multicountry time-series study. *PLoS Medicine*. 2024;21(1):e1004341.	The tropical cyclone-mortality risks and periods of concern varied greatly across tropical cyclone events, locations, and countries.