

Corresponding author(s): Yong Ge

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Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

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|-------------------------------------|-------------------------------------|--|
| ☐ | ☒ | The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement |
| ☐ | ☒ | A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| ☐ | ☒ | The statistical test(s) used AND whether they are one- or two-sided
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☐ | ☒ | A description of all covariates tested |
| ☐ | ☒ | A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| ☐ | ☒ | A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| ☐ | ☒ | For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
<i>Give P values as exact values whenever suitable.</i> |
| ☒ | ☐ | For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| ☒ | ☐ | For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| ☒ | ☐ | Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection The code for processing weather data on GEE can be found via <https://code.earthengine.google.com/7930812b7dc7890ead53bccff2f7caee>.

Data analysis R version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria) and Python version 3.9.4 were used to perform data collection and analyses. The model built by this study has been made openly available for further use at <https://doi.org/10.5281/zenodo.15747164>.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The data used to interpret the findings in this study are available publicly. The all-cause mortality records from Eurostat can be downloaded from <https://ec.europa.eu/eurostat/>. The ERA5-land data were downloaded from <https://cds.climate.copernicus.eu/>. The hourly Humidex data generated in this study have been deposited in the Zendo database (<https://doi.org/10.5281/zenodo.15747415>). The data from the new MPI grand ensemble with CMIP6 were accessed from <https://>

esgf-metagrid.cloud.dkrz.de/search. The future gridded population projections were derived from the Gridded Population of the World (<https://sedac.ciesin.columbia.edu/data/set/popdynamics-1-km-downscaled-pop-base-year-projection-ssp-2000-2100-rev01/data-download>). The Eurostat (<https://ec.europa.eu/eurostat/>) and the Office for National Statistics (<https://www.ons.gov.uk/>) provide associated population projections. The history gross domestic products (GDP) were sourced from Eurostat (<https://ec.europa.eu/eurostat/>). Future GDP projections were extracted from <https://gcp-tsukuba.github.io/SSP-downscale/>.

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender	Not applicable
Reporting on race, ethnicity, or other socially relevant groupings	Not applicable
Population characteristics	Not applicable
Recruitment	Not applicable
Ethics oversight	Not applicable

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☒ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Quantitative observational and modeling study
Research sample	The relationship between heat and mortality was analyzed across 989 NUTS3-level regions in 34 European countries. Future heat-related mortality was projected for 30 European countries with available data. We used Eurostat mortality records from the summers (weeks 22-35) of 2010-2019 at the NUTS3 level. Missing data in some regions were addressed by using the finest available spatial units. Population data were categorized into three age groups (0-14, 15-64, and 65+ years). Climate data were derived from ERA5-land and MPI-CMIP6 projections, incorporating a population-weighted approach. Future population projections were based on Eurostat EUROPOP2019, Gridded Population of the World v4 and Gridded gross domestic product (GDP) data under various SSP scenarios.
Sampling strategy	To quantify the heat-mortality relationship, we applied a distributed lag nonlinear model with a quasi-Poisson distribution, incorporating spatial and temporal variations. Missing data at the NUTS3 level were addressed by using the finest available spatial units. The model was trained using 2010-2019 data and validated with bootstrapping and cross-comparisons with prior studies. Future heat-related mortality projection were based on climate, population and socioeconomic data under four scenarios, including SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5.
Data collection	All the data used in this study are publicly available from data sources and processed in our manuscript by R and Python. The researchers were not blinded to experimental condition.
Timing	Historical heat-mortality relationships were observed during the summer (weeks 22-35) of 2010-2019. Projections of heat-related mortality extend to 2100.
Data exclusions	Data from 2020 to 2021 were excluded from the model's training and validation to mitigate the influence of the COVID-19 pandemic on mortality.
Non-participation	No participants were involved in the study.
Randomization	No applicable.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Plants

Seed stocks	No applicable.
Novel plant genotypes	No applicable.
Authentication	No applicable.