Assessing the harvesting effect following extreme temperature-related mortality in Italy

Vinod Joseph K J[1,2], Risto Conte Keivabu [2], Raya Muttarak[1], Emilio Zagheni[2], Stefano Mazzuco[3]

[1]*University of Bologna, Italy;* [2]*Max Planck Institute of Demographic Research, Germany;*
[3]*University of Padua, Italy*

Introduction

Temperature extremes are projected to become more frequent and intense as climate change continues and will be a tremendous public health concern in the coming years. Extreme temperatures and heat waves are the most significant direct effects of climate change on human health and mortality. High temperatures can cause heat exhaustion, heat stroke, and dehydration, leading to heat-related illness, hospitalization, and fatality. Older people, young children, and those with pre-existing medical conditions are most vulnerable to heat stress. Previous studies find that the relationship between mortality and temperature is either U-shaped or J-shaped, depending on the climatic zones and/or the sociodemographic subgroups studied (Barreca et al., 2016; Conte Keivabu, 2022) Heatwaves are also associated with increased mortality, particularly in urban areas where the urban heat island effect can lead to temperatures several degrees higher than the surrounding rural areas.

A handful of studies have estimated that exposure to high temperatures and extreme weather events is associated with increased mortality in the near term. In many cases, this increase can be counteracted by a much lower mortality rate than expected in the days and weeks following the exposure. To date, there is limited evidence on this phenomenon referred to as the 'harvesting effect', where exposure to extreme temperatures accelerates the mortality of individuals who are particularly vulnerable and severely ill. This study addresses the gap in the literature by investigating the effects of temperature variability on mortality exploiting granular mortality data for 107 provinces of Italy over the period 2011-2019. Although two provinces can be exposed to similar mean temperatures, they can experience significantly different daily and weekly temperature variations. We thus also investigate the effects of within-season weekly temperature variability on mortality. A focus on such a narrow interval of temperature variation allows us to detect any potential 'harvesting effect'. While between-seasonal temperature variation is mostly influenced by differences in winter and summer mean temperatures, within-seasonal temperature variation can result from deviations in daily and weekly temperatures from their seasonal means.

Data source and Methodology

For the study, we used Italian register data on the deaths of individuals aged above 60 from 2011 to 2019 provided by the ISTAT – Italian National Institute of Statistics (Istituto Nazionale di Statistica). We aggregated daily deaths for the population aged 60 and above into eight age categories in the provinces, observing them weekly from January 2011 to December 2019. The total number of province-week-year-age group observations is 400,608, corresponding to the weekly time series of eight age categories across 107 provinces, spanning nine years. Also, we combined the death count information on the population exposure for each age group, province and year divided by the number of weeks in the data.

We use the temperature data provided by the E-OBS, and it comprises complete and reliable daily data on all Italian provinces from year 1950 collected by local meteorological stations and interpolated to the whole Italian territory (Cornes et al., 2018). To integrate the weekly mortality data with temperatures, we proceeded in two steps. First, we calculated the average values of the temperature grids falling within each province to produce average daily temperature values for each province. Secondly, we utilized the daily average temperature recorded in each province to construct weekly temperature bins based on percentiles of the province-specific temperature distribution. Specifically, we created nine temperature bins to account for the number of days in which the provincial temperature falls below and equals the 1st percentile, from the 1st to the 5th percentile, from the 5th to the 10th percentile, from the 10th to the 25th percentile, above the 25th but below the 75th percentile, from the 75th to the 90th percentile, from the 90th to the 95th percentile, from the 95th to the 99th percentile, and above the 99th percentile. The 25th and 75th percentile category, considered the comfort zone, (Conte Keivabu, 2022). been excluded from the analysis.

The decision to represent temperature exposures as bins serves several purposes. Firstly, it enables us to capture non-linear relationships between temperature and mortality, as previously described as U-shaped or J-shaped in the previous studies. Secondly, using weekly temperature exposures allows the capture of lagged responses to high temperatures. Lastly, employing percentiles from the temperature distribution within each province enables us to capture location-specific extreme temperatures, accounting for variations in temperature-mortality response functions across provinces that might vary due to the differences in the adaptation to the local temperature.

Statistical analysis

To estimate the effect of temperature variations on mortality among individuals aged 65 and above, we employ Poisson regression models with a logarithmic link, offsets as exposures and weekly covariates. The equation can be described as follows.

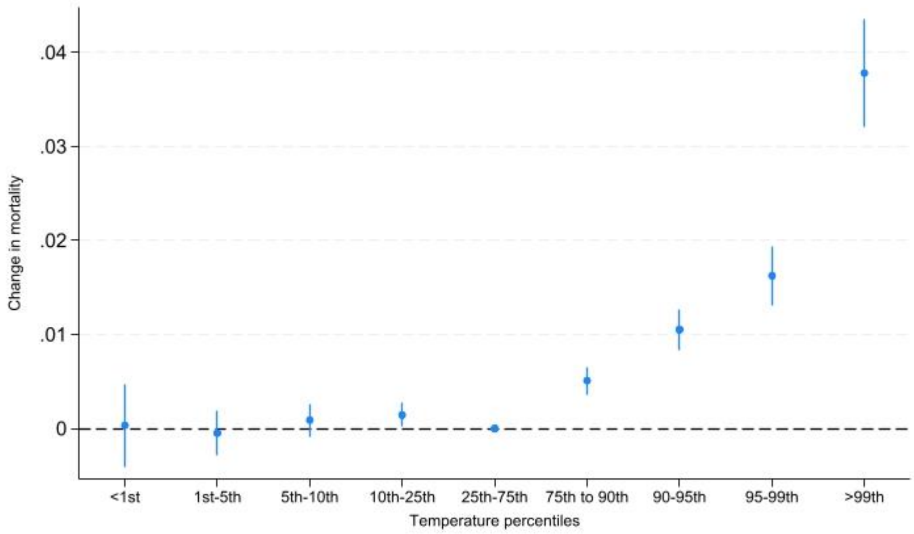
$$Log\left(Y_{pym}\right) = Log\left(E_{pym}\right) + \sum_{j} \theta_j TEMP_{pym} + \beta X_{pym} + \alpha_{pm} + \delta_{ym} + \sigma_{pl} + e_{pym} \qquad (1)$$

In the equation, Y_{pymg} denotes the count of deaths in province p, week m, year y. E_{pymg} is introduced as an offset term capturing the exposure to the risk of death in each province, year, week. $TEMP_{pym}$ represents the monthly temperature bins of the province specific percentiles in the temperature distribution that are $\leq 1^{st}$ percentile; $> 1^{st}$ and $\leq 5^{th}$; $> 5^{th}$ and $\leq 10^{th}$; $> 10^{th}$ and $\leq 25^{th}$; $> 25^{th}$ and $< 75^{th}$ $\geq 75^{th}$ and $< 90^{th}$; $\geq 90^{th}$ and $< 95^{th}$; $\geq 95^{th}$ and $< 99^{th}$; $\geq 99^{th}$. The days with temperatures falling within the 25th and 75th percentiles are set as the reference level and considered within the comfort zone. Also introduce α_{pm} to capture province-by-week fixed effects and δ_{ym} to capture week-by-year fixed effects, σ_{pl} is a province specific linear time trend and cluster standard errors at the province level to correct for autocorrelation within provinces over time. The fixed effects are utilized to control for potential time-varying factors and seasonal trends that may be correlated with temperature and mortality across all provinces observed over time.

Results

Table 1 presents the summary statistics of weekly provincial averages for the main variables spanning from 2011 to 2019. Firstly, we observe the distribution of days within the nine temperature bins. As expected, the highest average number of days is observed within the comfort zone (25th to 75th percentile). We notice a higher average and maximum number of days in the bin with temperatures ≥ 75th and < 90th percentile compared to temperatures between the 90th and 95th percentile, 90th and 95th percentile, and ≥ 99th percentile. Additionally, we provide the weekly average death counts and population exposures of individuals aged 65 and above for the pooled sample across the 107 provinces.

Figure 1 and Table 2 present the results of the analysis of mortality and temperature variation for the pooled sample. The results for the pooled sample reveal a J-shaped relationship between temperature variation and mortality among individuals aged 60 and above in Italy. Temperatures exceeding the comfort zone are associated with an increased mortality rate, with a more pronounced effect size observed in the most extreme temperature bins. Specifically, for hot days, we observe a larger effect size when temperatures are at or above the 99th percentile, representing an increase in the weekly mortality rate of approximately 38 per 1,000, 16 per 1,000 and 11 per 1,000, respectively, for the 95th - 99th and 90th - 95th percentiles.



Discussion of preliminary findings

This study explores the effect of exposure to weekly temperature variation on mortality of Italian population aged >=60 years over a nine-year period. We observe that exposure to extreme hot days drastically increases the weekly mortality rate in the Italian provinces. These results are vital for understanding the immediate impact on mortality rates and informing future public health policies and interventions. Extreme temperatures have a negative impact on health and mortality, and the associated health burden is expected to increase with climate change, especially under the most extreme scenarios of global warming. Currently, our study is in progress, and at the next stage of the analysis, we aim to explore the harvesting effect. Additionally, we plan to broaden our scope by considering absolute temperature values, incorporating various age categories, and breaking down the analysis by gender differences.

Table 1 Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Temperature variables				
≤ 1st percentile	0.069	0.458	0	7
> 1st and ≤ 5th percentile	0.282	0.862	0	7
> 5th and ≤ 10th percentile	0.350	0.858	0	7
> 10th and ≤ 25th percentile	1.054	1.727	0	9
> 25th and < 75th	3.513	2.849	0	9[1]
≥ 75th and < 90th percentile	1.053	1.843	0	7
≥ 90th and < 95th percentile	0.351	0.920	0	7
≥ 95th and < 99th percentile	0.282	0.917	0	7
≥ 99th percentile	0.070	0.474	0	7
Death counts				
Total deaths	13.081	16.369	0	301
Male deaths	6.138	7.765	0	144
Female deaths	6.943	9.496	0	170

Table 2 Temperature variations and mortality

Variables	Coefficient	Standard error
≤ 1st percentile	0.000	0.002
> 1st and ≤ 5th percentile	-0.001	0.001
> 5th and ≤ 10th percentile	0.001	0.001
> 10th and ≤ 25th percentile	0.001*	0.001
≥ 75th and < 90th percentile	0.005***	0.001
≥ 90th and < 95th percentile	0.011***	0.001
≥ 95th and < 99th percentile	0.016***	0.002
≥ 99th percentile	0.038***	0.003
Tot. Week-Year-Province-Age groups	4,00,608	
Province-Week FE	Yes	
Month-Year FE	Yes	
Province specific time trend	Yes	

Significance levels: ***p < 0.001, **p < 0.01, *p < 0.05

References

Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. S. (2016). Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century. Journal of Political Economy, 124(1), 105–159. https://doi.org/10.1086/684582

Conte Keivabu, R (2022). Extreme Temperature and Mortality by Educational Attainment in Spain, 2012–2018. Eur J Population 38, 1145–1182. https://doi.org/10.1007/s10680-022-09641-4

Cornes, R. C., van der Schrier, G., van den Besselaar, E. J. M., & Jones, P. D. (2018). An ensemble version of the E-OBS temperature and precipitation data sets. Journal of Geophysical Research: Atmospheres, 123(17), 9391–9409. https://doi.org/10.1029/2017JD028200

[1] Values above 7 are determined by the format of weeks used that do not include a 53rd week but sums to 52.