European Population Conference (EPC) Abstract

Extended Abstract

Topic & Background

This study focuses on the impact of heatwaves on mortality in Mexico, where annual temperatures have increased nearly 2°C since 2000. It is expected that heat-related shocks will make up a greater share of extreme temperature mortality in the future [1], [2]. As one of the largest (in terms of geography and population) countries in Latin America, it is also marked as highly vulnerable to climate change with mixed access to mechanisms for adaptability and a changing population age composition [3], [4].

Mexico is a country with high socioeconomic inequality, an important factor driving health and demographic outcomes such as disease burden, healthy life years, and life expectancy [5]. Heat-related morbidity and mortality has escalated enough that Mexico's Ministry of Health began reporting heat-related deaths, reflecting the threat to health and longevity [6]. Although the association between extreme temperatures and mortality has been well documented over the last couple of decades, many studies have focused on high income countries, often regions with more access to adaptation mechanisms, the most notable of which is air conditioning [7], [8]. Prior studies focused on mortality under extreme temperatures have highlighted vulnerability by age groups, where the youngest and oldest age groups contribute the most to mortality [9], [10], [11]. Studies have found differing impacts on sex depending on context, suggesting a continued need to understand how context shapes the risk of heat-related mortality by sex, which we explore in this study [10], [12] [13], [14]. This study builds on recent temperature-mortality research in Mexico from Cohen and Dechezleprêtre (2022) and 2013 study by Guerrero Compeán and contributes to a growing field of knowledge focused on LMICs and outcomes highlighting the range of impacts in heterogeneous populations [15], [16].

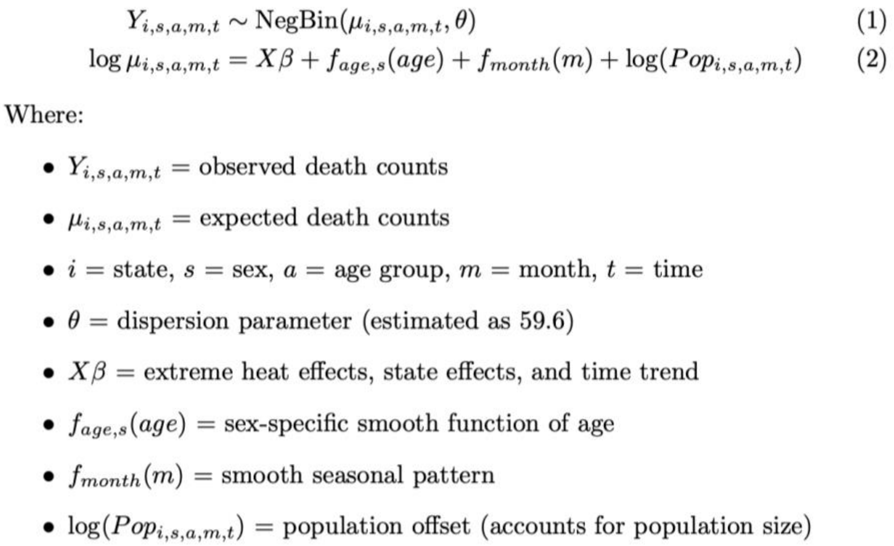
The research objectives of this study are to move from a state-month to municipality-week level analysis of heatwaves in 2023. Our preliminary findings at the state-month level suggest that geography (e.g., urbanization) may drive some of the variation in excess mortality by states. We will extend this analysis to the municipality-week data and use continuous temperature as a predictor of mortality to assess whether urban-rural differences, climate zones, or elevation may explain some of the heterogeneity in heat vulnerability across Mexico.

Data:

We combine publicly available mortality data from Mexico's National Institute of Statistics and Geography (INEGI), population data for rates from Mexico's Council on Population (CONAPO), and temperature data from the National Commission on Water, (CONAGUA) between 2000-2023 for this analysis. We use a subset of the data to build a time series, accounting for the impact of gradually increasing temperatures, Mexico's aging population and other time varying factors.

Methods:

For our preliminary analysis, we estimate excess mortality during heatwaves in 2023, following methods used by Aburto et al. in a 2021 study estimating excess mortality [17]. We defined heatwaves as state-months where mean temperature exceeded the state-specific 99th percentile from 2000-2022. We model death counts using a Generalized Additive Model (GAM) with a negative binomial distribution to account for overdispersion. The model included extreme heat indicators, and three-way interactions with age and sex to capture differential vulnerability alongside state fixed effects, a linear time trend to capture mortality improvements, and smooth terms for age and seasonal patterns. The model is specified as:



$$Y_{i,s,a,m,t} \sim \mathrm{NegBin}(\mu_{i,s,a,m,t}, \theta) \tag{1}$$

$$\log \mu_{i,s,a,m,t} = X\beta + f_{age,s}(age) + f_{month}(m) + \log(Pop_{i,s,a,m,t}) \tag{2}$$

Where:

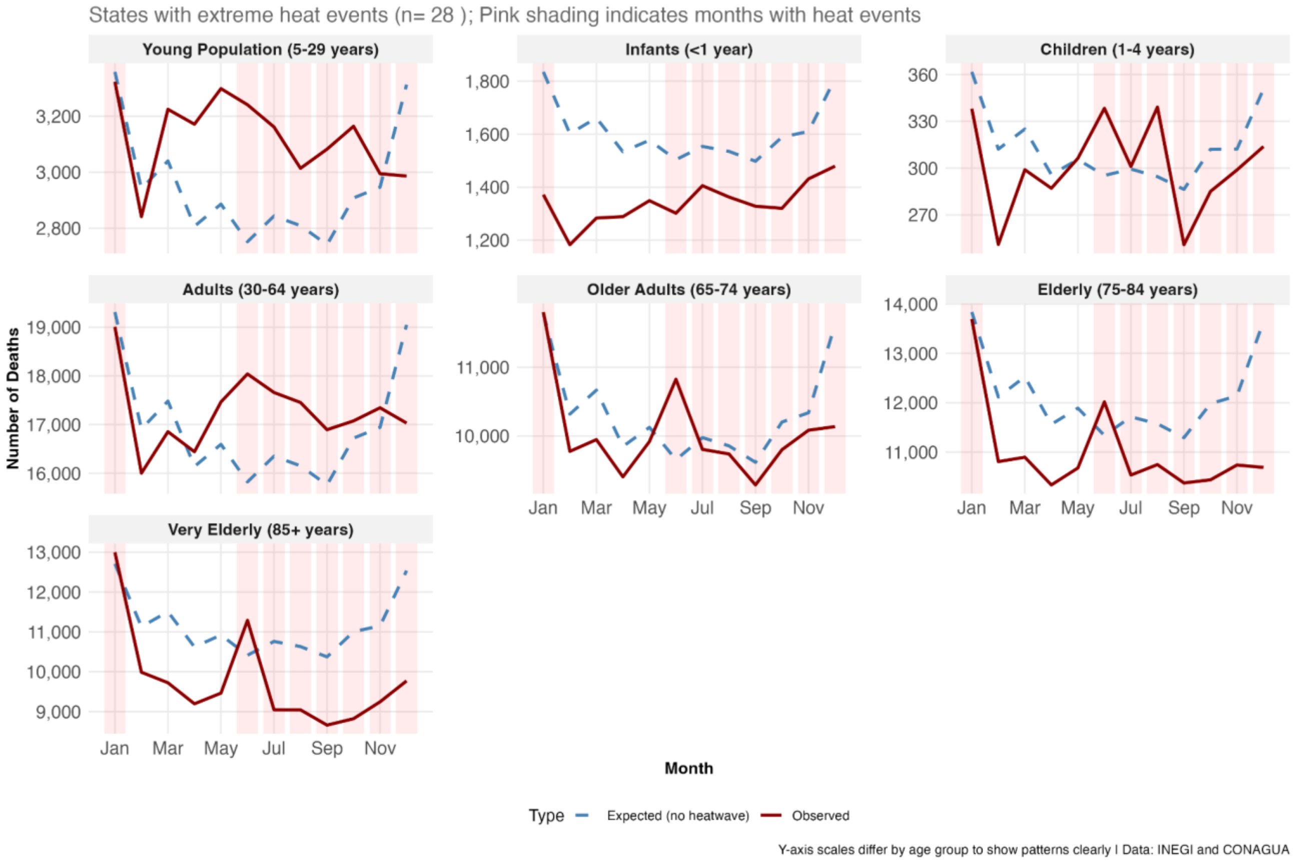
- $Y_{i,s,a,m,t}$ = observed death counts
- $\mu_{i,s,a,m,t}$ = expected death counts
- i = state, s = sex, a = age group, m = month, t = time
- θ = dispersion parameter (estimated as 59.6)
- $X\beta$ = extreme heat effects, state effects, and time trend
- $f_{age,s}(age)$ = sex-specific smooth function of age
- $f_{month}(m)$ = smooth seasonal pattern
- $\log(Pop_{i,s,a,m,t})$ = population offset (accounts for population size)

We trained the model on 60 months (2015-2019 epidemiological years to avoid COVID-19 year disruptions) and predicted expected deaths for each state-sex-age-month combination in 2023 in the absence of a heatwave (using a binary heatwave indicator). Excess mortality was estimated as the difference between the observed and predicted deaths. To expand on this higher level estimation, we will look at the municipality-level data and weekly deaths to better understand whether some of the excess deaths and differences by region can be explained by geography. Similar to key studies in the literature, we will also use temperature as a predictor of mortality to further refine and model the temperature - mortality relationship in this context.

Preliminary Results and Next Steps:

Figure 1 summarizes the preliminary results of estimated excess deaths across seven age groups. Across the 28 federal entities that experienced heatwaves in 2023, we find net excess mortality under all models fitted.This excess was driven by states experiencing recurrent heatwaves, the working age populations (30-64), and both sexes.

Figure 1. Age-specific death counts (observed versus expected) in 2023



The initial hypothesis which anticipated that more vulnerable age groups (the two age groups aged 75+ and <1) would be the most sensitive to extreme heat events did not manifest through net positive excess deaths. These estimates for these age groups had the most fluctuation throughout and are likely sensitive to extreme heat, and we discuss why these may not present as expected. Young and working age groups experienced the highest positive excess mortality during heatwaves. This study did not show a significant difference in excess by sex; we observed a similar pattern of excess that peaked in June and began declining over time, although females had the highest negative excess (n= -859) compared to males in any month (n= -1,674). There is a lot of variation by state across the country with some of the most populous entities at the extremes (Mexico City with negative excess and Nuevo Leon with highest positive excess).

While our current state-month analysis provides evidence of excess mortality during extreme heat events in Mexico, we will further enhance the spatial and temporal resolution to distinguish the effect of urban and rural settings on vulnerability during heatwaves. We will combine high resolution weekly mortality data at the municipality level paired with temperature data. Extending our current model to include continuous temperature as a predictor of mortality will better characterize the temperature and mortality relationship by quantifying mortality risk at each degree of temperature increase. This study will highlight age-specific and regional vulnerabilities to climate shocks such as heatwaves in Mexico.

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