Understanding Sex Differences in Temperature-Related Mortality Evidence from the Spanish population with long-term care needs

Albert Prades-Colomé[1,2,3] & H.M. Hernández-Pizarro[1,2]

[1] CRES, Universitat Pompeu Fabra
[2] TecnoCampus,Universitat Pompeu Fabra
[3] Ministry of Social Rights and Inclusion, Generalitat de Catalunya

June 15, 2026

Motivation: temperature is a growing mortality risk

- Extreme temperatures are a major and rising source of mortality, projected to worsen with climate change.
- Non-optimal temperatures account for **5-12% of all deaths** in Europe and the US (Burke et al., 2025).
- Vulnerability is **not uniform**: age is a very strong risk factor: ∼90% of heat deaths in Europe are among those aged 65+.
- **Older adults with LTC needs are a very vulnerable group** (age+frailty+autonomy limitations), but remains underexamined, as the literature is dominated by general-population studies.

Motivation: what do we know about sex differences?

- Evidence is **mixed**: Recent meta-analyses suggest a **modest female excess risk during heat events**, while some studies report **higher cold-related mortality among men**. Overall, findings remain highly heterogeneous across populations and settings.
- Proposed explanations include **physiological mechanisms**: thermoregulation, sweating capacity, cardiovascular responses and postmenopausal changes.
- Yet recent evidence suggests that apparent biological differences often shrink once **body size, fitness and aerobic capacity** are taken into account.
- **Social mechanisms may explain these differences.** Women's high heat exposure may reflect economic gaps and caregiving roles, while men's cold-related mortality links to health behaviors and lower healthcare use.

Objectives & Contribution

Objectives

1. Estimate the causal effect of temperature on daily mortality in the Spanish LTC population, a highly vulnerable group with directly observed frailty and autonomy limitations.
2. Examine whether temperature effects differ by sex, contributing to the debate on sex-heterogeneity in climate vulnerability.

Contribution

- First causal evidence on the full temperature-mortality relationship among individuals in the Spanish LTC system.
- New evidence on sex differences using individual-level information on diagnoses and functional status (and others), assessing whether gaps persist once underlying vulnerability is observed.

Data

1) Population data (Catalan LTC administrative records)

- **Coverage:** adults aged 60+ with LTC needs, 2016-2023 (n=252,364)

Data cleaning process

- **Variables:** mortality, dependency grade, diagnostics, age, sex, marital status, wealth, municipality.

2) Meteorological and environmental data

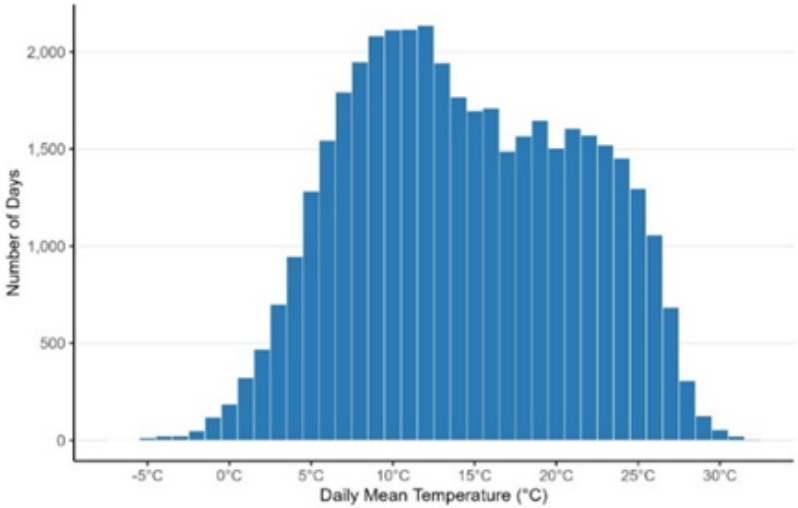
- **Source:** 80 weather stations (AEMET), grouped in 14 isotermic regions defined by METEOCAT.

Map

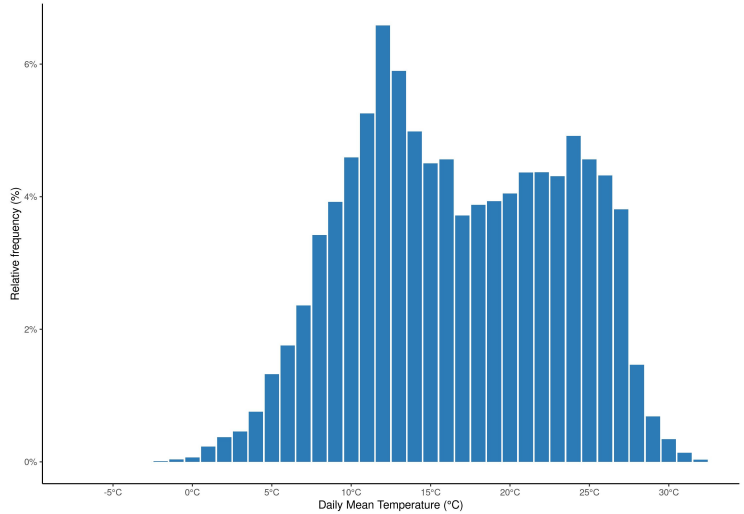
- **Variables:** daily avg. temperature, precipitation, humidity, wind speed, and pollutants ($PM_{2.5}$, PM_{10}, O_3).
- **Temp. binning:** absolute 3°C bins, or relative z-score bins based on the region-month historical distribution, measuring SD from the monthly mean.

Temperature exposure of the study population

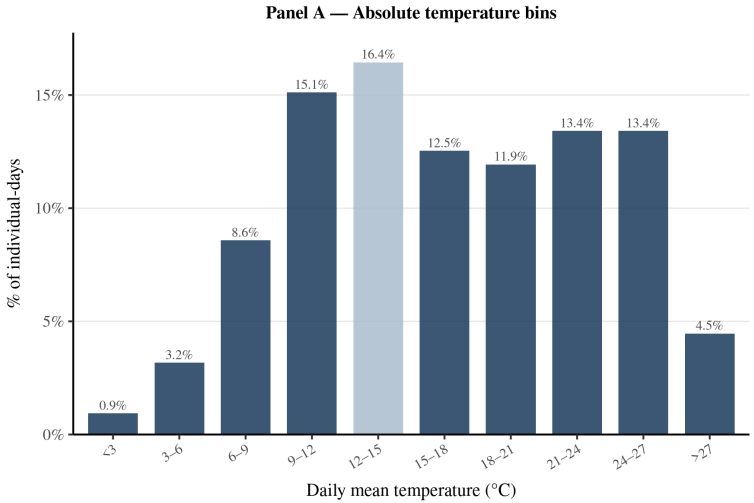
Daily mean temperatures across climatic regions



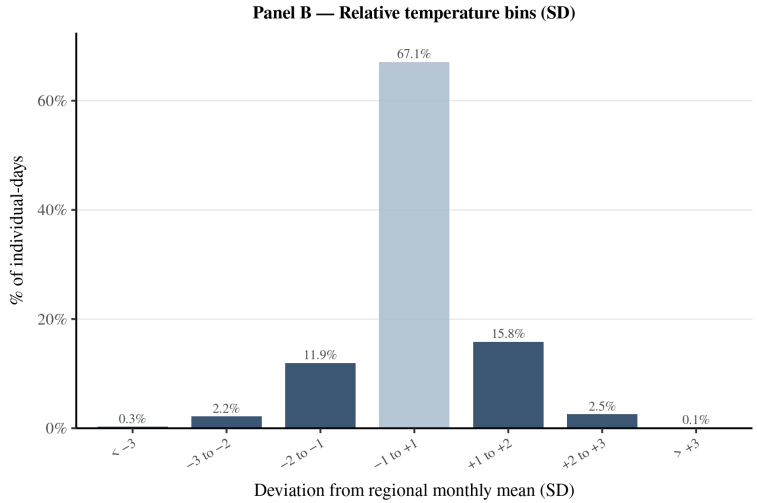
Individual exposure



Individual-days and region-days: absolute bins



Individual-days and region-days: relative bins



Empirical strategy: individual-day FE model

Individuals are observed from LTC system entry until death or December 2023 ($N = 160,047,707$).

$$Y_{it} = \sum_j \beta_j \, \text{Temp}_{jrt} + \theta \, \text{Precip}_{rt} + \rho \, X_{it} + \alpha_i + \lambda_{my} + \varepsilon_{it}$$

- **Outcome:** $Y_{it} = 1$ if individual i dies on day t; daily panel from LTC recognition until death or December 2023.
- **Temperature exposure:** $Temp_{jrt}$ counts days in the previous 30-day window, including t, where region r falls in bin j.
- **Controls and FE:** precipitation quartiles (Barreca et al., 2016), X_{it}: age (quadratic), LTC grade, ICD-10 diagnostics, α_i: individual FE , λ_{my}: month-by-year FE .
- **Heterogeneity by sex**: The model is estimated for the full sample and separately by sex.

Sample characteristics

	Total	Males	Females
Individuals	252,364	96,568	155,796
Deaths (crude rate)	46.9%	55.5%	41.5%
Coupled (mostly married)	43.4%	63.5%	30.9%
Mean financial capacity (€)	14,505	15,778	13,764
	(9,198)	*(10,152)*	*(8,508)*
Mean LTC needs score (0-100)	55.3	55.5	55.3
	(7.9)	*(8.2)*	*(7.6)*
Grade I (ever)	37.6%	37.3%	37.9%
Grade II (ever)	39.3%	39.5%	39.2%
Grade III (ever)	26.4%	26.2%	26.6%

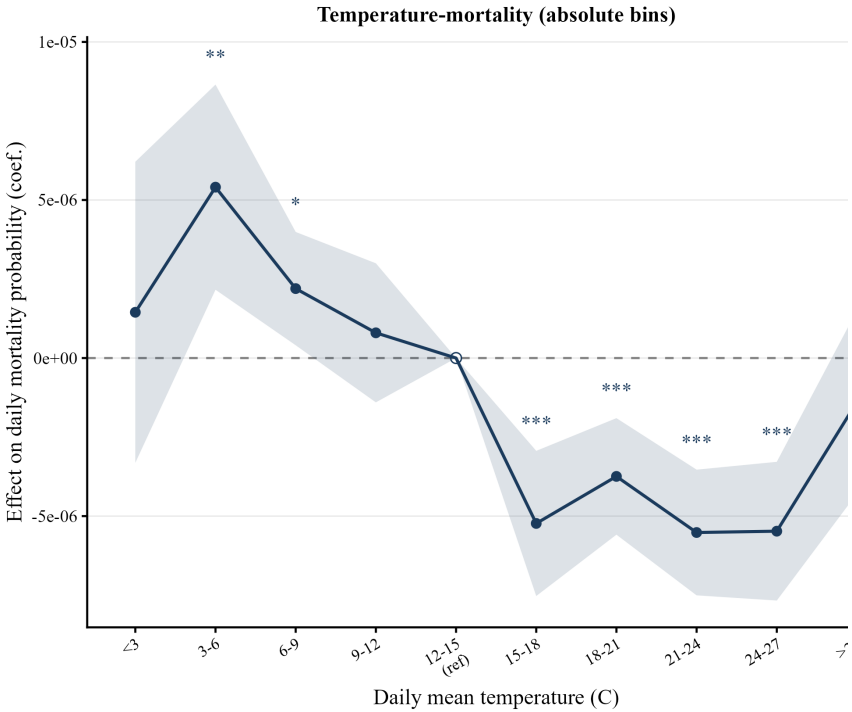
Neurological, osteoarticular and circulatory conditions are the most common, with relevant sex differences across diagnoses. $\simeq$ 60% individuals live in the Barcelona metropolitan area.

Diagnostic table Region table

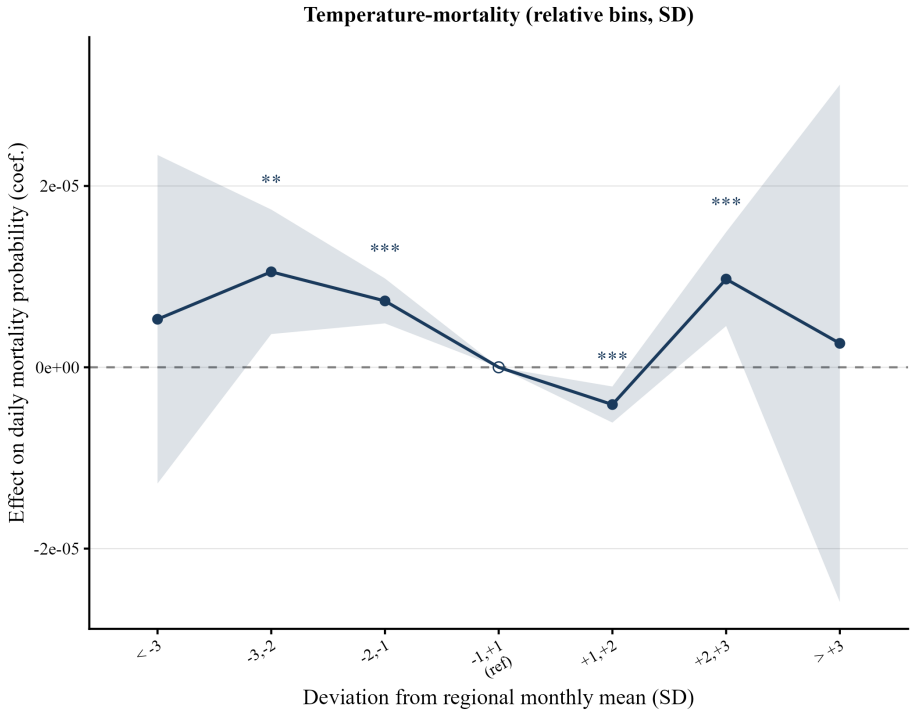
Baseline: temperature-mortality in the LTC population

Full sample (no sex interaction)

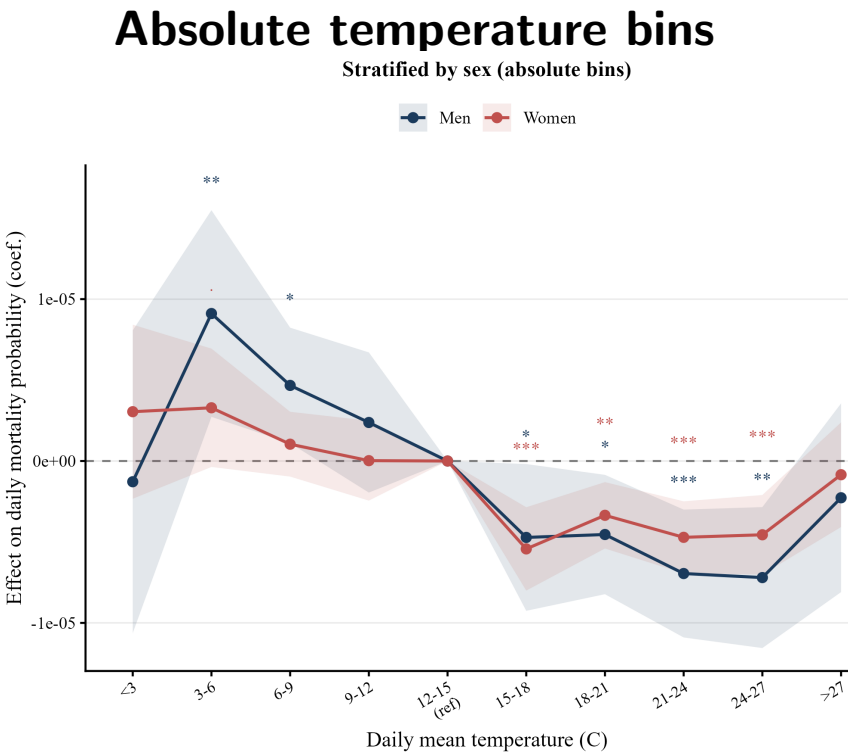
Absolute temperature bins

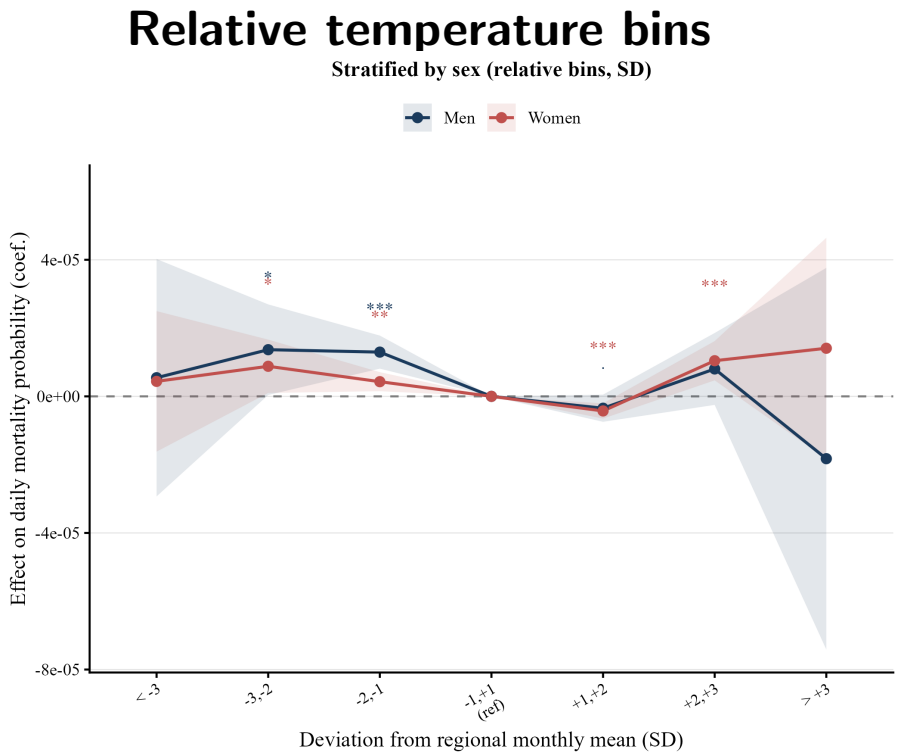


Relative temperature bins



Sex differences: stratified models





see Differences figure

Heterogeneity by wealth quartile

- **Q1 (high) vs Q4 (low):**
  - **Full Sample**: temperature–mortality curve is essentially the same for low- and high-income individuals, except at **extreme cold** (< -3 SD), where low-income mortality is higher.

    Fig.
  - **by Sex**: Driven by **males**; **no income differences among females**.

    Fig.
- **Male (Q1 or Q4) vs female (Q1 or Q4):**
  - **Q1 (high)**: Smaller effects. Sex gap essentially **absent** (small increase in cold-related for males).

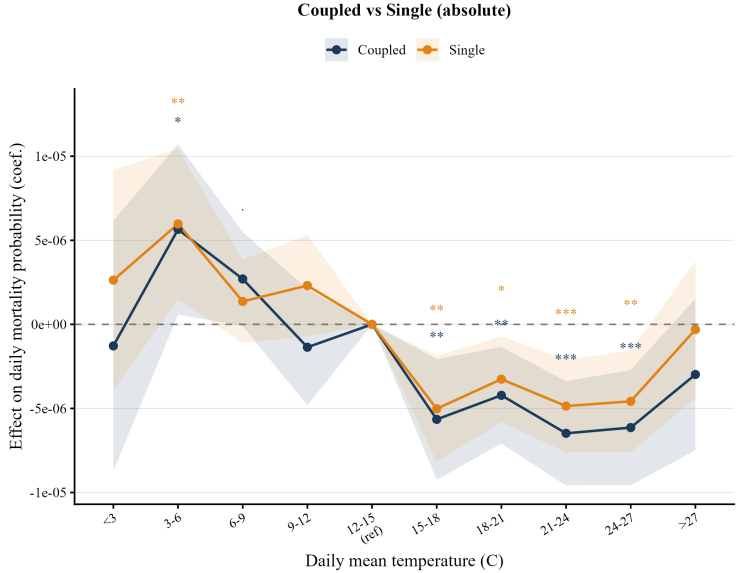
    Fig.
  - **Q4 (low)**: **Males** show **higher mortality** at cold and stronger protective effects at moderately heat temperatures. No meaningful temperature effects are observed for females.

    Fig.

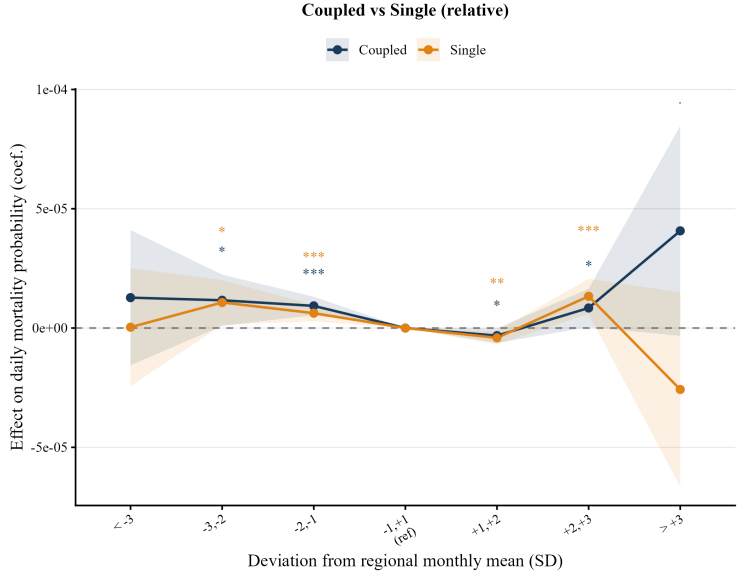
Heterogeneity by marital status

- **Coupled** (mostly married) vs **single** (incl. widowed): no differences in the temperature–mortality curve; this holds **for males and females separately**. Fig.
- **Sex gap within each group:** only one isolated significant bin (**coupled**, moderate rel. cold -higher for males); **no systematic sex gap** in either group. Fig.

Absolute temperature bins



Relative temperature bins



Discussion

1. **Effect of temperatures.** Cold effects are stronger and more consistent, while heat emerges when measured in relative (SD) terms; moderate warm temperatures are protective.

2. While relatively small, **sex differences are concentrated under cold exposure.** Males experience larger increases in mortality at low temperatures, whereas females show no clear increase in mortality under heat.

3. **The male disadvantage is concentrated among low-income individuals.** The gap is largely absent among higher-income groups and does not vary systematically by marital status.

4. By conditioning on **individually observed** frailty, LTC grade and diagnoses, we isolate sex as a modifier more cleanly than most studies, focusing on a particularly **vulnerable population** (individuals with LTC needs).

Policy implications & next steps

Policy. Among frail older adults in LTC, **sex-differences in temperature-related mortality exist but are small**. Prevention efforts should therefore focus on **frailty and socioeconomic disadvantage**, particularly among low-income males.

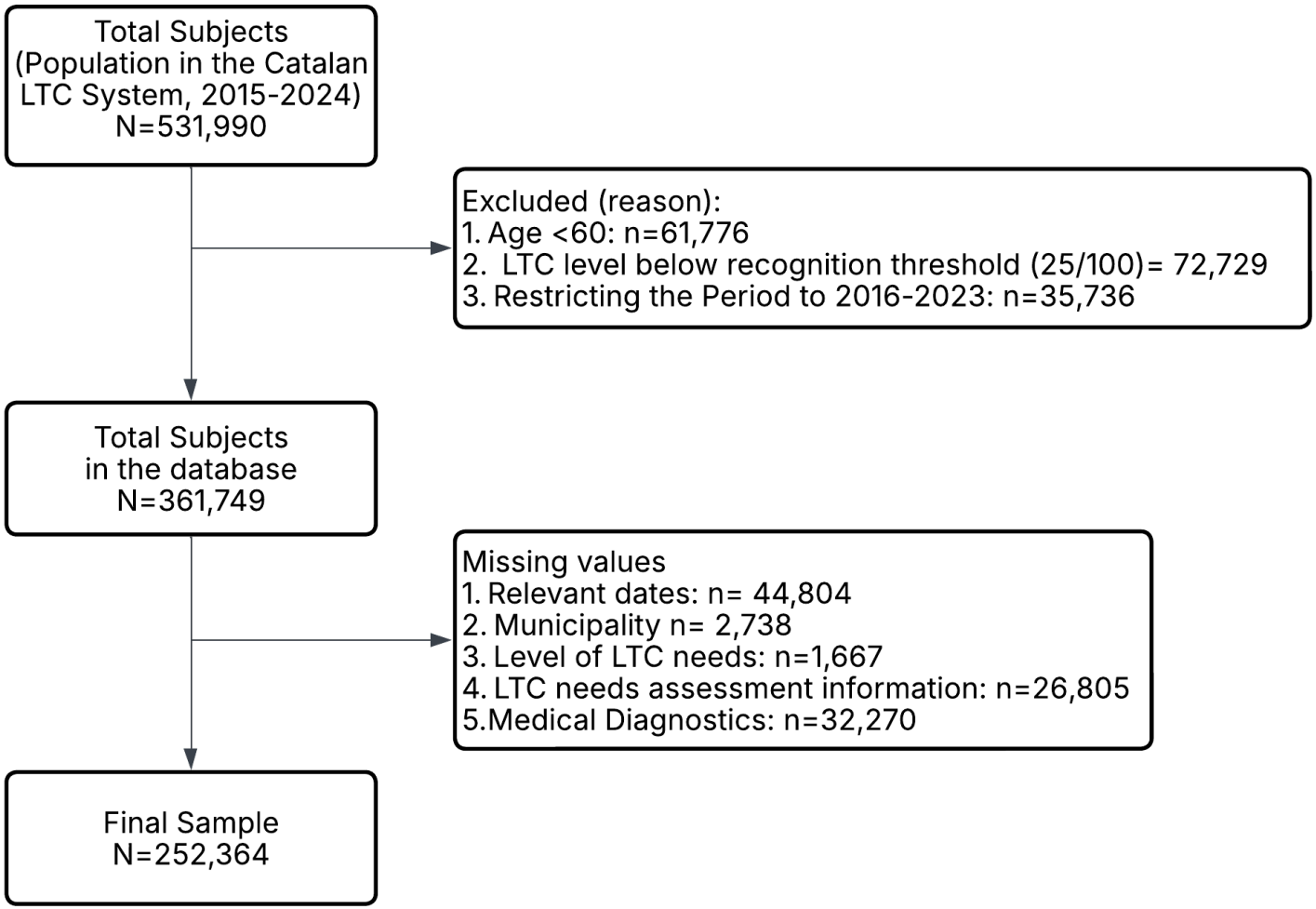
- **Role of the LTC System**: Effect of grades/benefits?
- Extreme events: **heatwaves** (*in progress*) and **cold spells**.
- Robustness: excluding COVID, adding pollution, alternative windows (7/14-day) and bins, stratification by LTC grade/ certain diagnoses.

Thank you!

Albert Prades-Colomé & H.M. Hernández-Pizarro

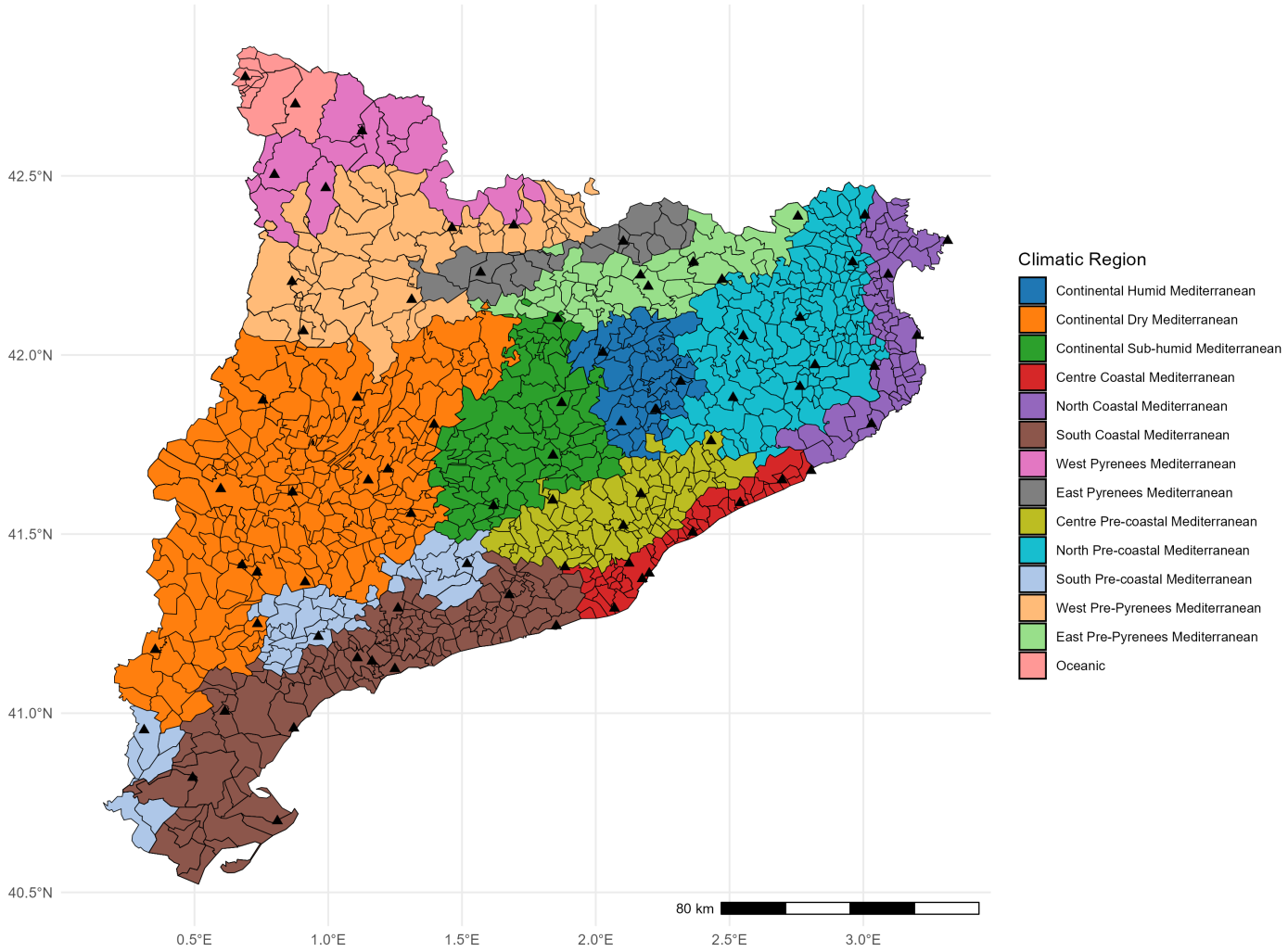
albert.pradesi@upf.edu

Data Cleaning Process



Back

Climatic Regions of Catalonia



Back

Diagnostic groups by sex

Diagnostic group	Total	Males	Females
Neurological	66.7%	70.1%	64.6%
Circulatory	51.3%	55.2%	48.9%
Digestive	4.5%	5.2%	4.1%
Osteoarticular	65.3%	51.2%	74.1%
Endocrine-metabolic	23.5%	24.0%	23.1%
Eye	18.7%	18.1%	19.0%
Ear	11.6%	11.1%	11.9%
Respiratory	18.8%	26.2%	14.1%
Genitourinary	26.6%	29.3%	24.9%
Mental	23.9%	18.3%	27.4%
Neoplasms	0.4%	0.5%	0.3%
Development	0.1%	0.1%	0.1%
Haematological	13.6%	18.8%	10.5%
Infectious	4.6%	4.7%	4.6%
Dermatological	1.0%	1.2%	0.9%

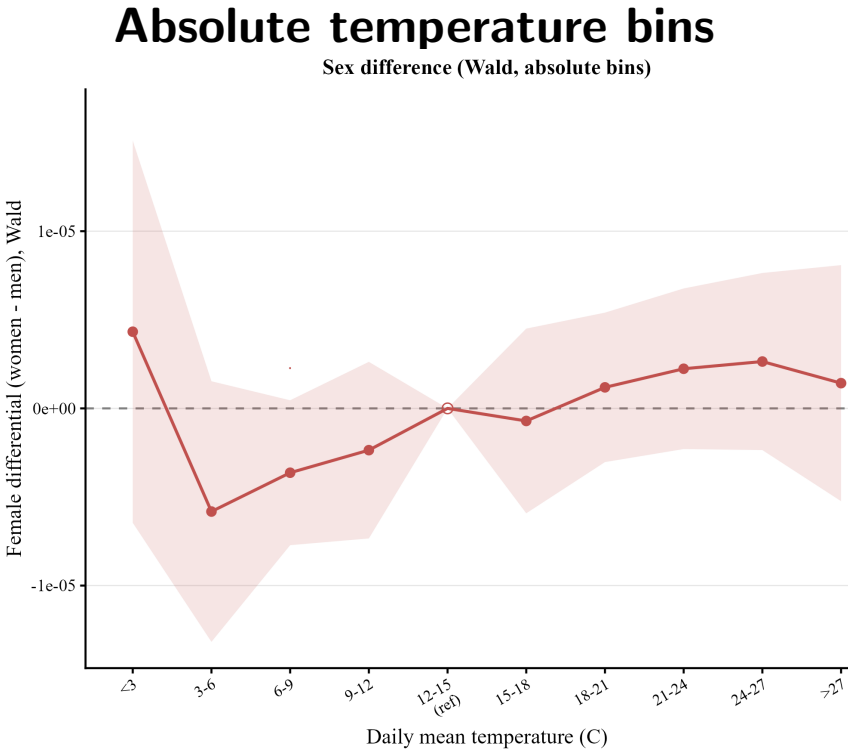
Back

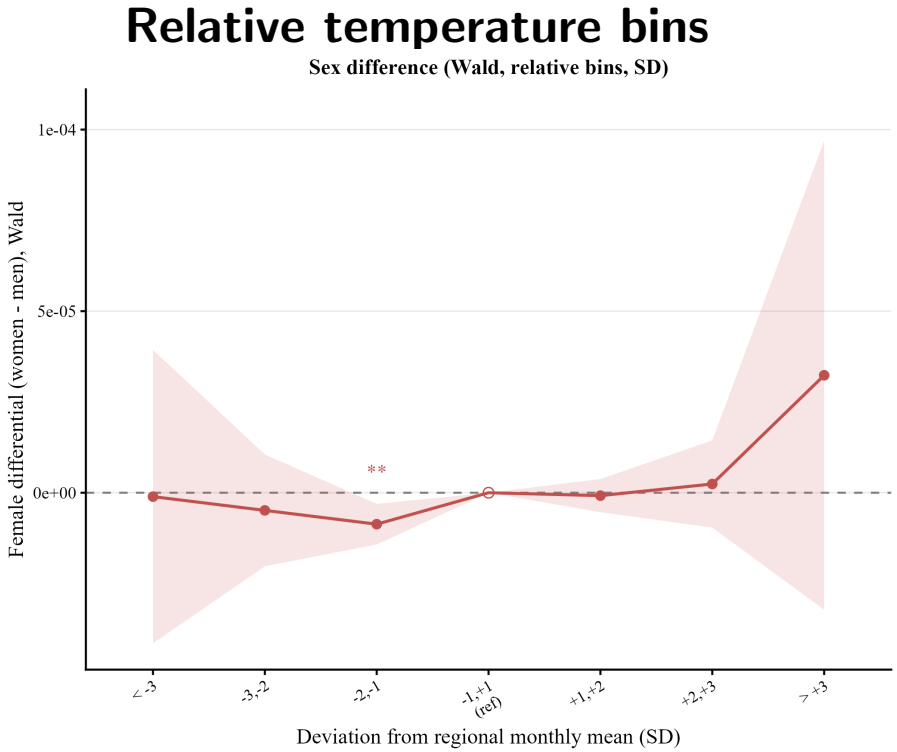
Climatic region of residence

Climatic region	Total	Males	Females
Centre Coastal Mediterranean	45.3%	44.5%	45.7%
Centre Pre-Coastal Mediterranean	18.2%	18.3%	18.1%
Continental Dry Mediterranean	6.9%	7.1%	6.7%
Continental Humid Mediterranean	2.1%	2.0%	2.1%
Continental Sub-Humid Mediterranean	4.7%	4.5%	4.7%
East Pre-Pyrenees Mediterranean	0.6%	0.6%	0.6%
East Pyrenees Mediterranean	0.1%	0.1%	0.1%
North Coastal Mediterranean	2.8%	2.8%	2.8%
North Pre-Coastal Mediterranean	5.7%	5.8%	5.6%
Oceanic	0.1%	0.1%	0.1%
South Coastal Mediterranean	11.7%	12.1%	11.5%
South Pre-Coastal Mediterranean	0.9%	1.0%	0.9%
West Pre-Pyrenees Mediterranean	0.9%	0.9%	0.9%
West Pyrenees Mediterranean	0.1%	0.1%	0.1%

Back

Figures of the differences

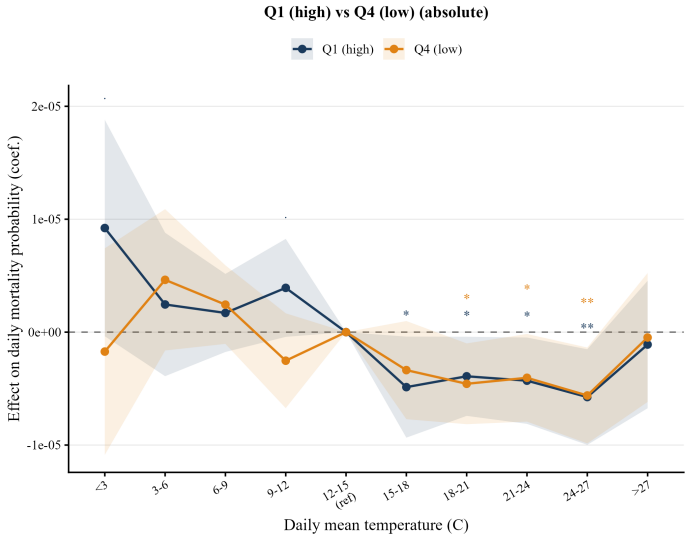




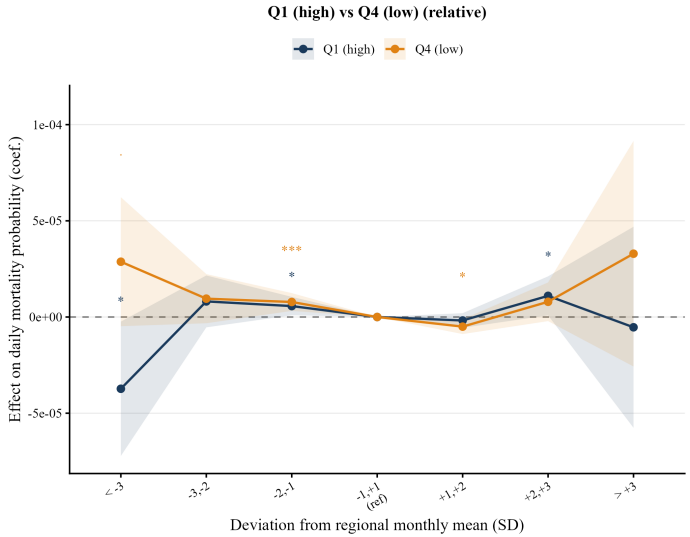
Back

Income groups: Full sample. Differences by income group

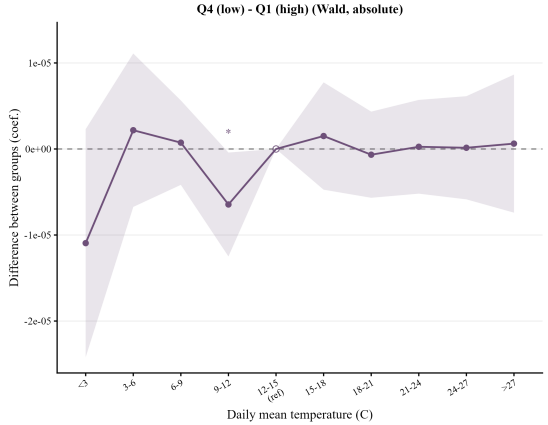
Full sample: absolute bins



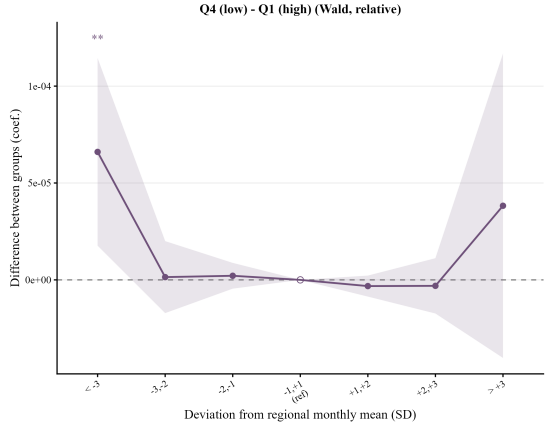
Full sample: relative bins



Wald differences: absolute bins



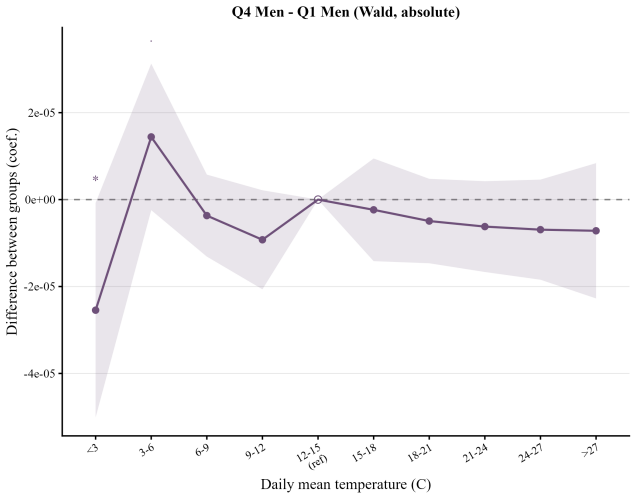
Wald differences: relative bins



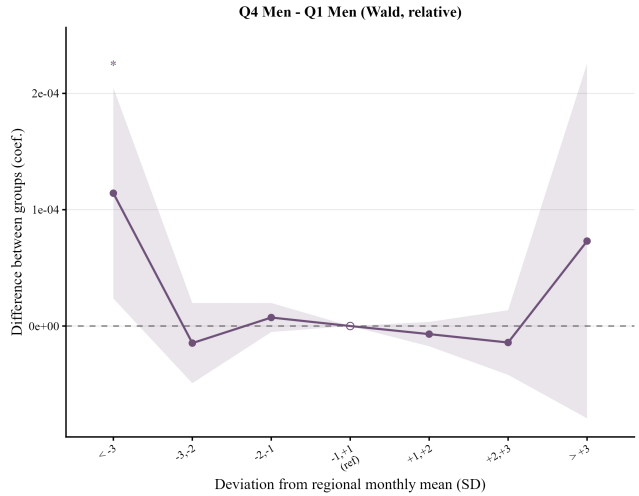
Back

Income groups: Stratified by Sex

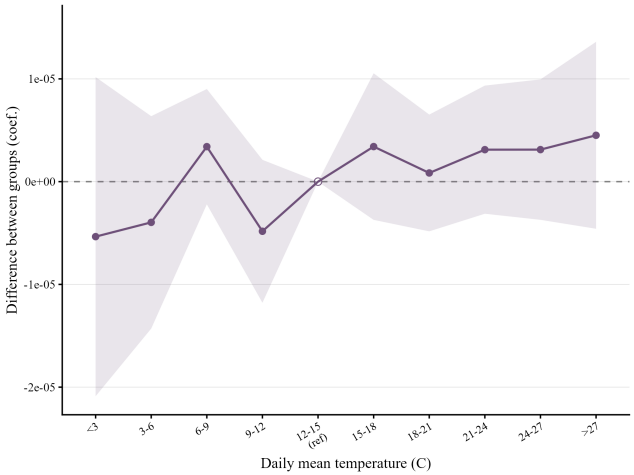
Males: absolute bins



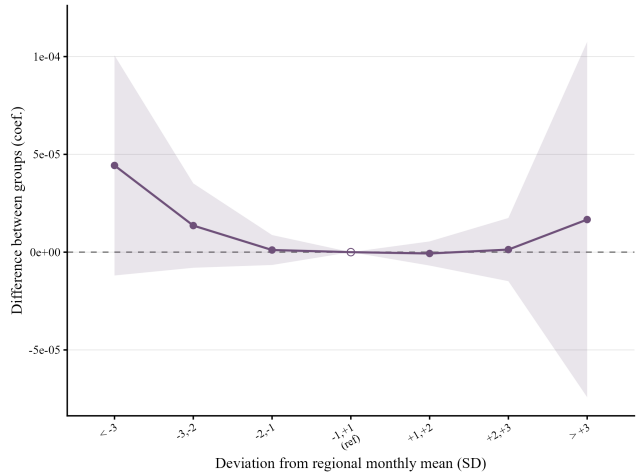
Males: relative bins



Females: absolute bins



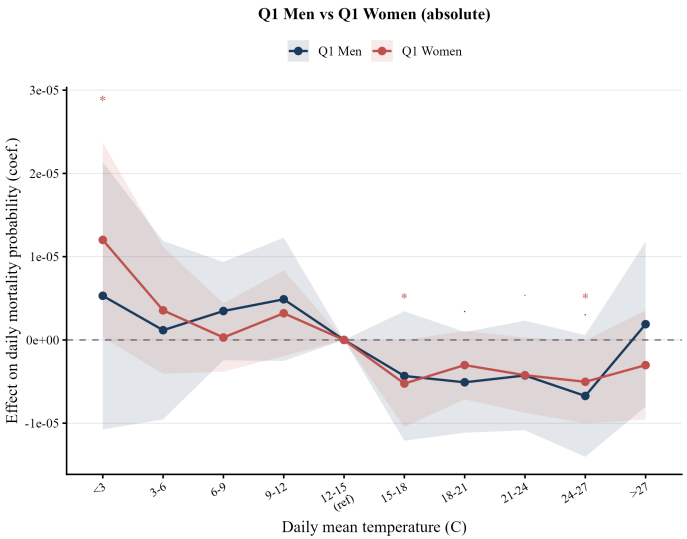
Females: relative bins



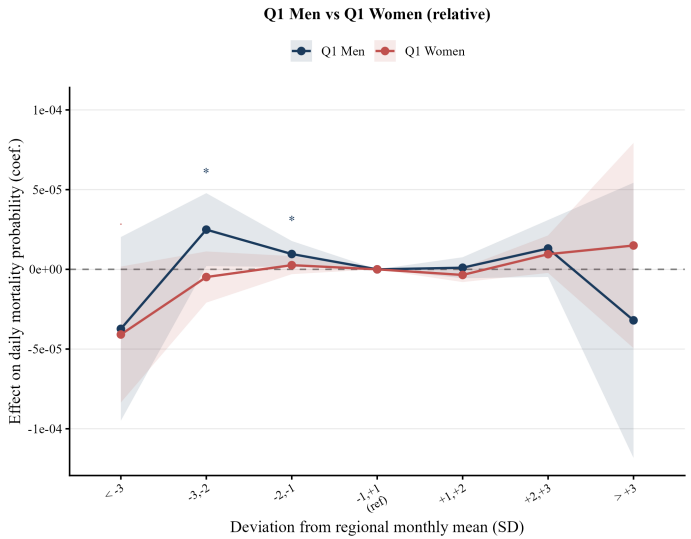
Back

Income groups: Q1. Differences by Sex

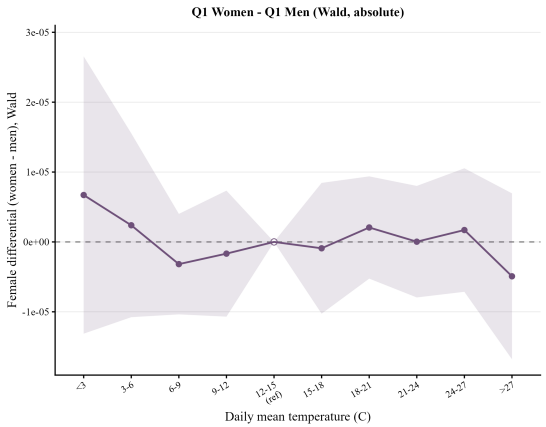
Q1 (high): absolute bins



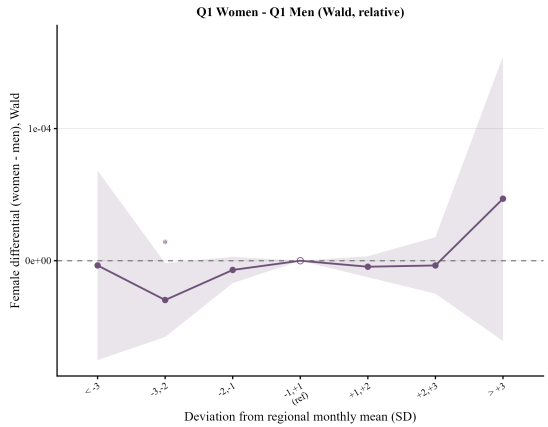
Q1 (high): relative bins



Wald diff.: absolute bins



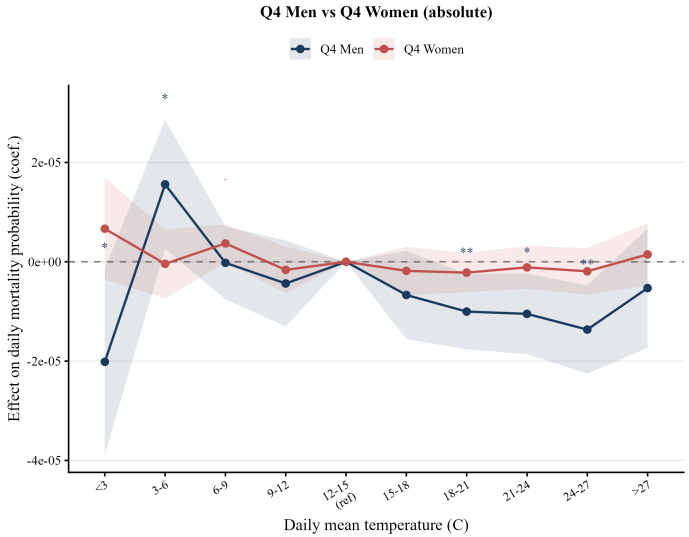
Wald: relative bins



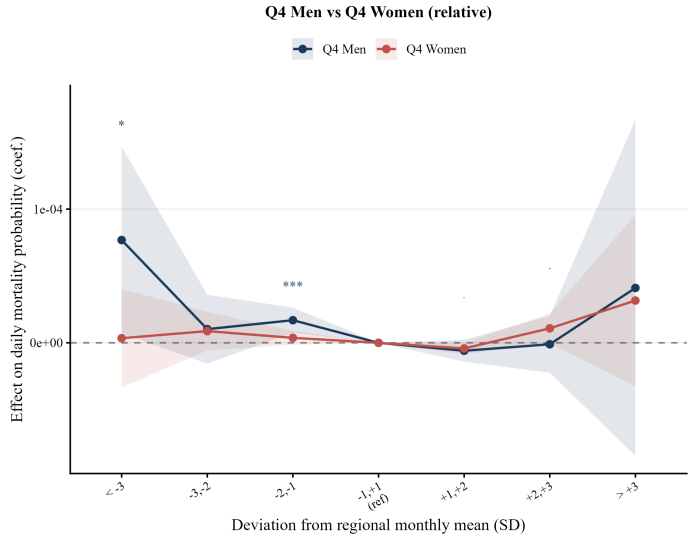
Back

Income groups: Q4. Differences by Sex

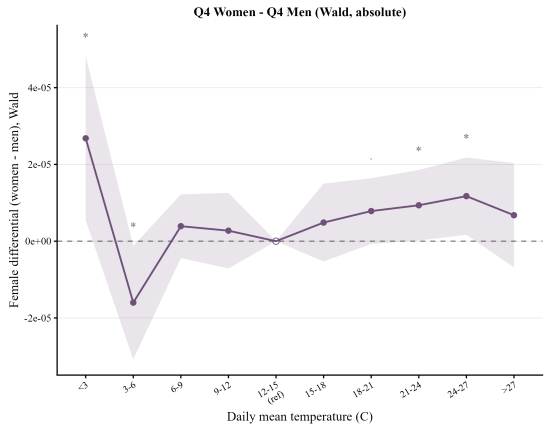
Q4 (low): absolute bins



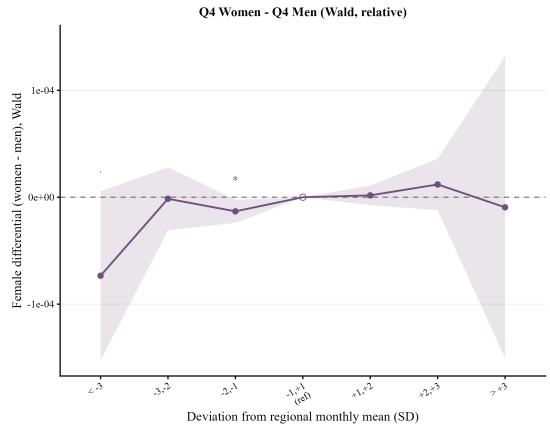
Q4 (low): relative bins



Wald diff.: absolute bins



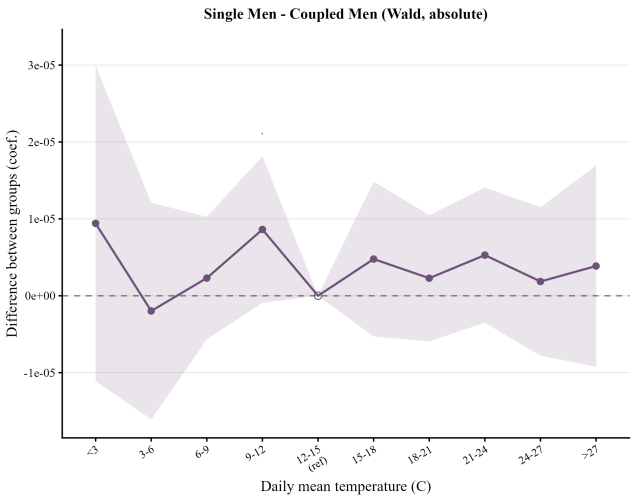
Wald: relative bins



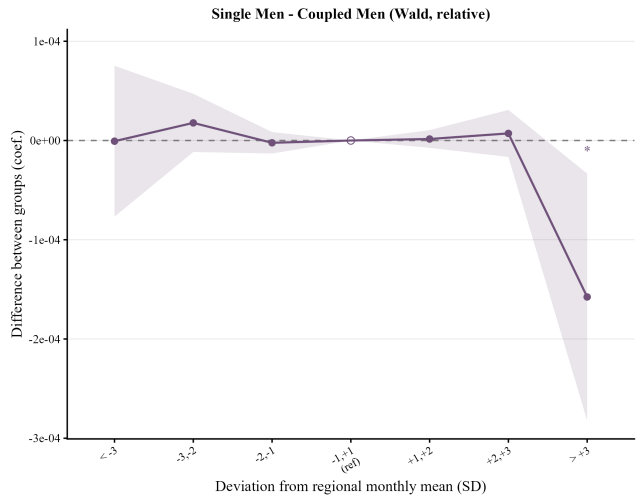
Back

Marital Status: by Sex. Differences by marital status

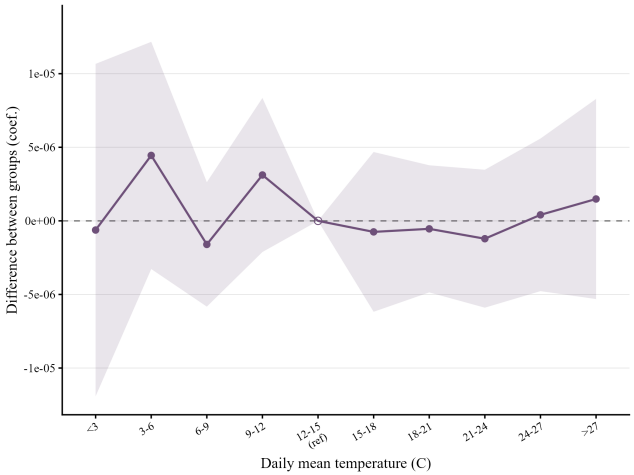
Males: absolute bins



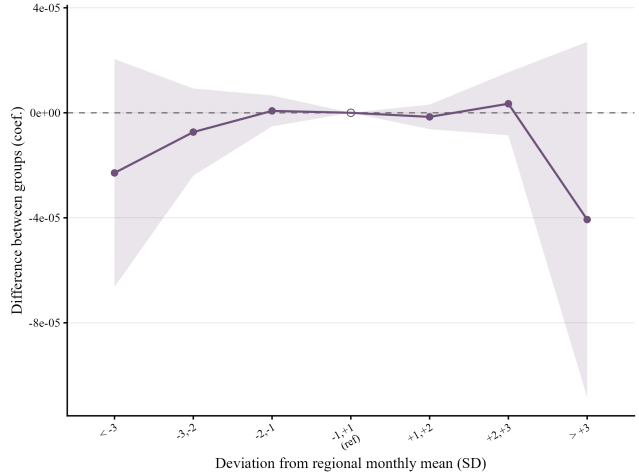
Males: relative bins



Females: absolute bins



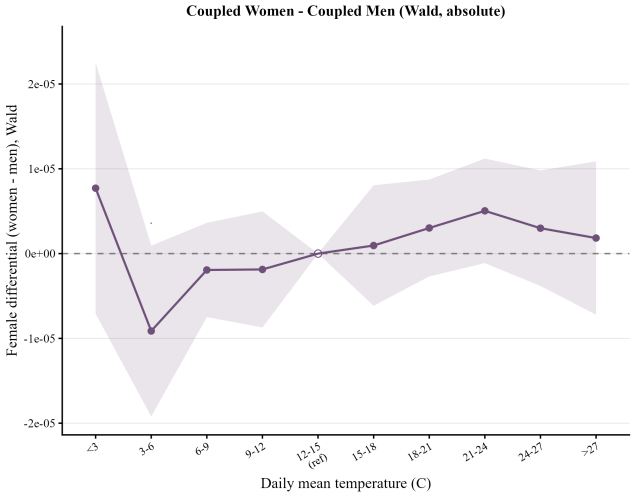
Females: relative bins



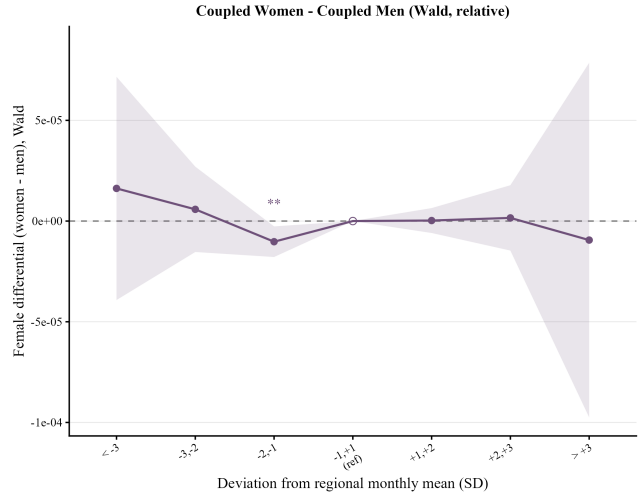
Back

Marital Status. Differences by Sex within status

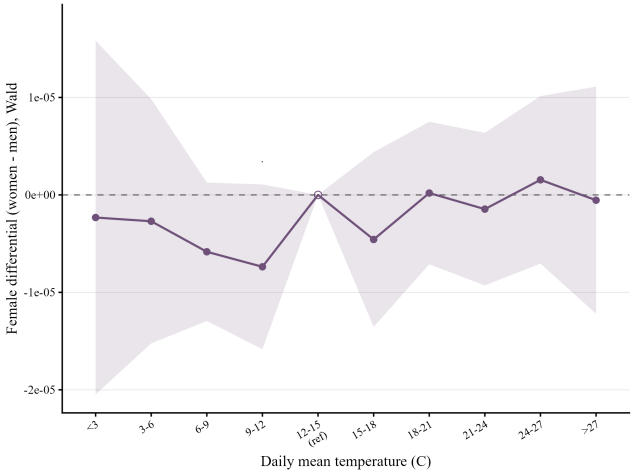
Coupled: absolute bins



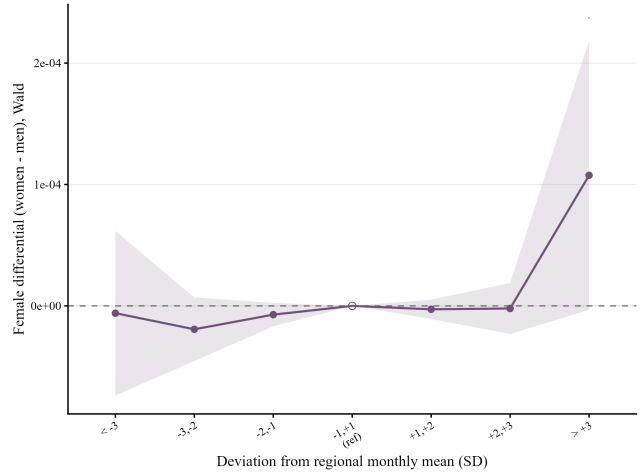
Coupled: relative bins



Single: absolute bins



Single: relative bins



Back