

The Psychological Toll of Heat: The Effects of Temperature on Mental Health in Mexico^{*}

Yumin Hong[†]

Job Market Paper

Antonia Vazquez[‡]

October, 2025

[Click *here* for the latest version](#)

Abstract

Rising temperatures threaten mental health, yet causal evidence from middle-income countries is limited. Using weekly nationwide administrative data covering the entire population and a survey representative of Mexico's urban population, we estimate heat effects on self-reported well-being, emergency-department visits for mental illness, and suicide using a unified empirical design. Comparing hotter and cooler weeks within locations in the same calendar week of the year, we find that one extra day above 30°C increases suicides by 3.2% and emergency department visits for mental illness by 2.4%, and lowers reported mental well-being. While effects exceed comparable U.S. estimates, they are attenuated in municipalities with psychiatrist availability, suggesting protection through access to care, but show no consistent gradient with air-conditioning or urbanicity. Gender patterns differ from U.S. studies: women experience larger emergency department visit increases, while suicide effects are concentrated among men. Our results indicate that heat imposes mental health burdens from subclinical distress to clinical demand and mortality, highlighting mental health as a material component of climate damages and a priority for adaptation investments in health systems.

Keywords: temperature, mental health, suicide, Mexico

JEL Codes: I31, I12, Q54

*We thank Manuela Angelucci, Mary Evans, and Raissa Fabregas for their unconditional support. We also thank Jori Barash, Scott Carrel, Eric Chyn, Francisco Pardo, participants at the poster session at the AERE 2025 Summer Conference, AERE session at the 2024 EEA Conference, AERE session at the 2024 WEAI Conference, Development Economics Workshop poster session, seminars in the Department of Economics and LBJ Sack Lunch Seminar at the University of Texas at Austin for helpful comments and suggestions. All errors and omissions remain our own.

[†]Department of Economics, University of Texas at Austin. Email: ymhong@utexas.edu.

[‡]LBJ School of Public Affairs, University of Texas at Austin. Email: antonia.vazquez@utexas.edu.

1 Introduction

Globally, one in seven people live with a mental disorder,¹ making mental illness one of the leading causes of suffering and lost productivity worldwide. Emerging research suggests that environmental conditions such as temperature extremes can shape mental well-being, yet evidence on short-run responses to heat exposure remains limited, particularly outside high-income settings.² As global temperatures continue to rise, exposure to extreme heat is increasing worldwide (Lee et al., 2023; Arias et al., 2021), while the capacity to adapt remains especially constrained in low- and middle-income countries (Bianco et al., 2024; Hallegatte, 2016). These settings thus face a dual challenge: heightened exposure to heat and limited resources to mitigate its psychological toll.

The stakes are also high, as lower-income people face a 1.5-3 times higher risk of depression or anxiety (Ridley et al., 2020), and over 80% of the world’s 970 million people with a mental disorder reside in low- and middle-income countries.³ Despite this large burden, empirical evidence in these contexts remains limited and typically examines a single outcome – suicide, emergency visits, or depressive symptoms – often in different countries and using heterogeneous research designs. This fragmentation makes it difficult to form an integrated understanding of how temperature affects mental health across outcomes of differing severity in low- and middle-income countries.

We address this gap by estimating short-run causal responses to temperature across multiple mental health outcomes within a unified empirical framework in Mexico. Mexico provides a relevant setting given its large climatic variability, constrained psychiatric capacity,⁴ and heterogeneity in local infrastructure.⁵ We estimate short-run heat effects on mental health across the spectrum, from everyday psychological distress to clinical crises in emergency visits and suicide, and examine how they vary by gender, the availability of local mental health professionals, and cooling infrastructure.

We use multiple data sources collected from 2008 to 2019. We combine self-reported well-being, emergency-department visits for mental illness, and suicides with weekly municipality-

¹World Health Organization (2025).

²Sharpe and Davison (2021) show that low- and middle-income countries’ research to date has focused largely on disaster-related PTSD and depression, with far fewer studies on indirect climate exposures.

³Dinarte-Diaz, Lelys. “An Overlooked Priority: Mental Health.” World Bank Blogs, 2 May 2023, <https://blogs.worldbank.org/en/impactevaluations/overlooked-priority-mental-health>.

⁴In 2016, Mexico had approximately 2.1 psychiatrists per million residents, compared with 105 per million in the United States (WHO Global Health Observatory).

⁵In the United States, most states report household air-conditioning penetration above 80% (U.S. Energy Information Administration (EIA), 2020), whereas in Mexico only three states – Sonora, Sinaloa, and Tamaulipas – exceed 50% (National Survey of Household Income and Expenditure (ENIGH), 2018).

level temperature measures derived from high-resolution National Oceanic and Atmospheric Administration (NOAA) reanalysis data. Information on emergency department visits and suicides comes from administrative records (2008-2019), which we aggregate to the municipality-week level and adjust for population size to ensure comparability across regions. We also draw self-reported mental well-being from government surveys that are representative of urban populations (2013-2019). By combining administrative (suicide and emergency department visits) and subjective well-being measures with spatially consistent temperature and humidity exposures interpolated to municipality centroids, we provide a comprehensive story about how temperature affects mental health in one country, Mexico.

Our empirical strategy compares hotter and cooler weeks within the same location and calendar week of the year, aligning identification across all three outcomes. This design isolates short-run deviations from local seasonal norms and yields internally comparable evidence across the three outcomes, reducing bias from cross-sectional differences that may reflect location-specific selection or seasonality in mental health rather than temperature effects.

We find that one additional day above 30°C in a week increases suicides by 3.2% and emergency department visits for mental illness by 2.4%, relative to weekly means. These magnitudes exceed comparable U.S. benchmarks, with effects about 5.5 times larger for suicides and 1.3 times larger for mental illness emergency department visits. Results are robust to falsification tests using future temperatures, and to placebo tests of emergency department visits for cancers, congenital conditions, and appendicitis, which show no systematic response to heat. Survey outcomes move in the same direction: hotter weeks feature lower life satisfaction and higher psychological distress, with modest declines in perceived agency and meaning, providing a subjective counterpart to patterns observed in healthcare utilization and mortality records.

Guided by evidence that heat can reshape daily routines relevant for mental health, we study three behavioral pathways in a survey dataset: exercise, indoor solitary leisure, and sleep duration. On hotter weeks, both participation and intensity of exercise decline, consistent with reduced engagement in a protective activity linked to lower stress and anxiety (Soini et al., 2024; Xie et al., 2021). We also examine solitary indoor leisure, proxied by watching TV, given evidence that social isolation is associated with worse mental health (Holt-Lunstad, 2022). Consistent with this hypothesis, we find that people spend 5% more time watching TV as temperatures rise. Finally, we investigate sleep duration, as higher temperatures may disrupt sleep, which is essential for emotional regulation (Lõhmus, 2018; Buguet, 2007; Bessone et al., 2021). We do not find significant changes in sleep duration.

To understand who is most affected and how impacts manifest, we go beyond aggregate

effects and analyze how different populations respond to heat and what adaptive measures help mitigate the effects. While both women and men report worse mental well-being during hotter weeks, emergency department visits rise more among women, whereas suicide increases are driven by men and are concentrated among adults aged 60 and older. These contrasts with U.S. patterns are consistent with the idea that the mental-health impacts of heat are context-dependent, potentially shaped by differences in care access, stigma, and institutional capacity. Although disentangling these mechanisms is beyond the scope of this paper, two literatures on thermoregulation and gendered patterns of care-seeking motivate why such heterogeneity might arise.⁶

We then examine heterogeneity by adaptation capacity to assess which margins are associated with buffering heat-related mental health burdens. We find that municipalities served by psychiatrists show smaller increases in emergency department visits during hotter weeks, consistent with prescriptive and rapid triage capacity easing acute crises that would otherwise present to emergency care. By contrast, we detect no robust differences by state-level air-conditioning (A/C) prevalence or by an urban–rural municipality classification. For the A/C analyses, these null patterns should be interpreted cautiously, as A/C penetration is measured at the state level which obscures within-state variation, and overall adoption is relatively low in Mexico. These patterns focus attention on provider access as a plausible adaptation margin, while coarse measures of physical cooling show no consistent differences in this setting.

This paper builds on a growing literature on the causal link between temperature and mental health, which mostly focuses on high-income countries and single outcomes (Mullins and White, 2019; Burke et al., 2018; Obradovich et al., 2018). We contribute by unifying this fragmented evidence within a single empirical framework, broadening the range of outcomes, and situating results in a middle-income context with limited adaptive capacity. First, we provide internally comparable evidence on short-run causal responses across the spectrum of mental health outcomes – self-reported subjective well-being, emergency department visits for mental illness, and suicide – within a single country and a unified empirical design. Prior studies typically examine one outcome in isolation and across different countries or model structures, making cross-study comparisons difficult. Our research design allows comparisons across outcomes on the spectrum of mental health, yielding a cohesive understanding of how heat affects mental health.

Second, we extend the evidence base to a middle-income country and show that magnitudes exceed those in the United States when estimated under a comparable specification. This

⁶Physiological research documents sex-based variation in thermoregulation and heat sensitivity (e.g., Debray et al., 2025), while sociological and public-health studies highlight gendered barriers to mental-health help-seeking in Mexico, including stigma (Gearing et al., 2024; Domínguez et al., 2024).

finding underscores that the psychological burden of heat can be larger where treatment access and adaptive capacity are constrained. Replicating the specification from [Mullins and White \(2019\)](#) with our data from Mexico, we find larger responses in Mexico than in the U.S., highlighting that the mental health burden of heat can be greater where adaptation capacity is more constrained and results from high-income contexts may not generalize one-for-one to lower-resource settings.

Third, we contribute new evidence on distributional and adaptive dimensions of heat–mental health relationships, complementing mixed findings from high-income settings ([Lavigne et al., 2023](#); [Liu et al., 2021](#); [Nori-Sarma et al., 2022](#); [Wang et al., 2014](#); [Mullins and White, 2019](#)). We document gender differences that diverge from patterns observed in the United States. While identifying mechanisms is beyond the scope of this paper, these contrasts motivate future research on physiological differences in thermoregulation and gendered stigma with help-seeking behavior in middle-income contexts characterized by machismo cultural norms similar to those of Mexico. For adaptation capacity, we find that municipalities served by psychiatrists show smaller heat-related increases in emergency department demand, consistent with provider access buffering psychological stress. This result highlights mental-health provider availability as a potentially salient adaptation margin in this setting.

Our findings carry several policy implications. First, the burden of heat on mental health is not evenly distributed: older adults, men, and women are affected through distinct pathways—men via elevated suicide risk and women through greater reliance on emergency care—highlighting the need for targeted adaptation strategies in low- and middle-income settings. Second, strengthening mental-health systems can serve as an adaptation instrument ([World Health Organization, 2022](#)). The attenuation of emergency department visits in municipalities with psychiatrist availability suggests that expanding access to mental-health professionals, particularly in underserved areas, can stabilize crises before they escalate into clinical emergencies ([Bruckner et al., 2019](#); [Nesper et al., 2016](#)). Finally, the costs of climate change extend beyond physical illness or mortality. The mental-health consequences of heat remain largely invisible in climate adaptation planning, especially where resources are constrained ([World Health Organization, 2022](#)). Explicitly incorporating these often overlooked but substantial costs into climate and health policy is essential to designing systems that safeguard not only survival but also psychological well-being in a warming world ([Romanello et al., 2024](#)).

The remainder of the paper proceeds as follows. Section 2 provides conceptual background on why temperature may influence mental health and presents relevant institutional details about mental healthcare in Mexico. Section 3 details the empirical strategy and data. Section 4 presents the main results, and Section 5 examines behavioral and institutional adaptation

mechanisms. Section 6 offers robustness checks of the core findings, and Section 7 concludes by summarizing the key insights and policy implications.

2 Background

2.1 Heat and mental health

A large literature establishes that elevated temperatures increase physical morbidity and mortality across a wide range of settings (Deschênes and Greenstone, 2011; Barreca et al., 2016; Heutel et al., 2021; Carleton et al., 2022; Gasparrini et al., 2015). Evidence on the effect of high temperatures on mental health outcomes, however, remains more limited and uneven. Causal analyses are largely concentrated on high-income settings (Mullins and White, 2019; Noelke et al., 2016; Janzen, 2025), while findings from low- and middle-income countries (LMICs) are still emerging (Hua et al., 2023; Burke et al., 2018; Trang et al., 2016).

Although direct causal evidence is limited, several lines of research point to plausible mechanisms through which temperature may affect mental health. Literature suggests that short-run exposure to high temperatures can disrupt mental well-being through physiological, behavioral, and contextual pathways. Physiologically, elevated temperatures alter cerebral blood flow and serotonin activity and impair thermoregulation (McMorris et al., 2006; Chauhan et al., 2017; Löhmus, 2018), thereby affecting brain function and stress regulation (Gaoua, 2010; Tan et al., 2024). Related evidence from violent-crime contexts shows that heat increases aggression even when opportunities for social interaction remain constant, consistent with physiological and psychological stress mechanisms rather than purely behavioral exposure channels (Cohen and Gonzalez, 2024; Colmer and Doleac, 2023). These acute physiological strains narrow affective control and heighten autonomic arousal (Tang et al., 2021; Carrillo et al., 2016), increasing the likelihood of anxiety and stress responses, particularly among individuals with pre-existing mental health conditions. In clinical settings, such episodes often manifest as acute anxiety or stress reactions and, among vulnerable populations, as crises associated with elevated suicide risk (Sun et al., 2021; Yoo et al., 2021; Nori-Sarma et al., 2022; Burke et al., 2018; Zhou et al., 2023).

Heat also shifts time use and coping behaviors. On hotter days, individuals reduce outdoor activity and physical exertion, substituting toward indoor and sedentary behaviors that may reinforce dysphoria (Cheong and Gaynanova, 2024; Ho et al., 2023, 2022; Huang et al., 2020; Schuch et al., 2018; Zhai et al., 2015). In our data, we also find that people reduced their time spent on physical exercises in hotter weeks. Hot nights disrupt sleep, and sleep loss diminishes

emotional regulation and perceived control (Pailler and Tsaneva, 2018; Obradovich et al., 2017; Yoo et al., 2007).

A more concerning scenario arises when sleep disruption coincides with reduced physical activity, as coping responses may shift toward short-term relief strategies, such as alcohol or sedative use, which can exacerbate symptoms and increase the likelihood of emergency care (Li et al., 2025; Nori-Sarma et al., 2022; Sun et al., 2021). These behavioral adjustments are not evenly distributed: men and older adults may see larger rises in lethality risk when coping mixes with social isolation or substance use, while women more often seek acute care for anxiety and stress symptoms (Okafor et al., 2024; Ramadan et al., 2022; McLean et al., 2011). At the population margin, we therefore expect short periods of elevated temperature to register as broad, modest declines in self-reported well-being and to increase emergency department presentations for stress and anxiety.

Beyond individual physiology and behavior, the mental health consequences of heat may depend on the capacity of local institutions to manage distress and on the resources households can use to reduce exposure. Institutional capacity—such as outpatient triage, medication availability, and referral systems—shapes whether acute symptoms can be stabilized early or escalate into emergencies (Gilbert et al., 2025; Gliske et al., 2023). At the same time, physical adaptation through cooling and adequate housing can mitigate exposure (Hong, 2025; Sera et al., 2020; Barreca et al., 2016; O’Neill et al., 2005), but its reach may remain limited by income (Doremus et al., 2022; Barreca et al., 2022) and infrastructure in developing countries’ contexts. Together, these contextual factors determine both how heat-related distress manifests and how individuals enter the care system. This heterogeneity provides the foundation for understanding Mexico’s institutional landscape in mental healthcare, discussed next.

2.2 Mexico’s institutional context for mental healthcare

Mental healthcare in Mexico is delivered across a mixed public–social security–private platform, with specialist scarcity and urban concentration. Public counts indicate there were 1.1 psychiatrists per 100,000 and 6.9 psychologists per 100,000 working in Mexico in 2023, heavily concentrated in hospitals and in Mexico City (Barrón-Velázquez et al., 2024). World Health Organization (WHO)’s all-sector figures also report overall scarcity, with 1.56 psychiatrists and 5.85 psychologists per 100,000 (World Health Organization, 2021). Community-based capacity exists through public and NGO initiatives but remains thin and uneven outside large cities (Cordero-Oropeza et al., 2021; Berenzon et al., 2009).

Within the Ministry of Health (MoH) network, administrative encounters are recorded in

two national subsystems with ICD-10 primary plus up to six secondary diagnoses entered by trained coders: an Emergency Department (ED) registry and a Hospital Discharge (Inpatient) registry. In 2019 these subsystems covered 916 EDs and 857 hospitals, serving roughly 57% of the national population, with ICD-10 diagnoses coded by trained coders (Aguilar-Gomez et al., 2025). Importantly, ED access is not restricted by insurance: patients can present at any MoH EDs regardless of coverage status. MoH EDs serve the uninsured and those who were covered by Seguro Popular, but walk-in access means patients can present regardless of insurance status (Aguilar-Gomez et al., 2025). Landa-Ramírez et al. (2024) documented in a Mexico City hospital, mean ED length of stay was 70 hours⁷ and worse mental-health indicators predicted more re-admissions and longer stays.

National surveys report a 12-month prevalence of mental disorder about 12% and lifetime about 26%, with anxiety and mood disorders common and early ages of onset (Medina-Mora et al., 2007, 2005). Yet treatment contact is low and delayed. Only about a quarter of those with very severe 12-month disorders used any services, and initiation of first treatment often lags for years after onset (Medina-Mora et al., 2005).

Financing patterns help explain these gaps. Government spending on mental health is less than 2% of total health expenditure, with over 60% of that mental-health budget directed to mental hospitals, leaving relatively limited resources for community-based and outpatient care (World Health Organization, 2021). Households face high out-of-pocket exposure, especially for pharmaceuticals, which account for over 60% of the out-of-pocket health spending in Mexico (OECD, 2023). Catastrophic health expenditure is also common among households caring for a person with a mental disorder, particularly where medication purchases and low income coincide (Diaz-Castro et al., 2021). For schizophrenia, Cabello-Rangel et al. (2021) document median annual out-of-pocket costs of approximately USD \$510,⁸ along with substantial rates of catastrophic health expenditure among individuals without social security coverage.

3 Empirical Strategy and Data

3.1 Empirical strategy

We follow previous literature that used the high-dimensional fixed effects model to estimate the causal impact of temperature on mental health outcomes, which serves as our baseline specification (Burgess et al., 2011; Deryugina and Hsiang, 2014; Hsiang, 2016; Mullins and

⁷With standard deviation 65.7.

⁸This amount represents about 5% of Mexico's GDP per capita in 2019.

White, 2019; Dillender, 2021; Park et al., 2021; Kuruc et al., 2025). We estimate the following model at the municipality-week level:⁹

$$MH_{jswy} = \theta_0 + \sum_{b=1, b \neq 5}^{10} \{\theta^b Temp_{jswy}^b\} + \gamma Hum_{jswy} + \delta Prec_{jswy} + \eta_{jw} + \lambda_{sy} + \varepsilon_{jswy}. \quad (1)$$

where MH_{jswy} denotes mental health outcomes in municipality j of state s in week w of year y . In the case of emergency department visits and suicides, we observe them at the weekly level¹⁰ and divide them by a million residents within each municipality j . $Temp_{jswy}^b$ represents the number of days falling into temperature bin b during the week. We omit the 20–22°C bin ($b=5$) as the reference category so that all coefficients are interpreted relative to this temperature range. θ^b 's are our coefficients of interest, which capture the temperature's effect on the mental health outcomes.

$Temp_{jswy}^b$ indicates the number of days in the given week w falling into each of the ten temperature range bins based on daily average temperatures: <14°C, 14–16°C, ..., 28–30°C, and 30°C+. The highest temperature bin ($b=10$), $Temp_{jswy}^{30^\circ C+}$, for example, represents the number of days with an average temperature equivalent to 30°C or above within the municipality-week. The ten temperature bins are determined based on the actual distribution of temperatures in Mexico, ensuring they reflect the observed range and frequency of temperatures rather than arbitrary cutoffs.¹¹ Equation 1 also includes weekly average relative humidity (Hum_{jswy}) and rainfall exposure ($Prec_{jswy}$) controls. Our omitted temperature bin captures the weekly number of days between 20°C and 22°C ($b=5$) such that θ^b can be interpreted as the effect of the corresponding temperatures relative to this reference temperature category.

3.1.1 Identification

The model includes municipality by the week-of-the-year fixed effects (η_{jw}) and state by year fixed effects (λ_{sy}). The municipality by week-of-the-year fixed effects (η_{jw}) control for each municipality's typical seasonal pattern, thereby capturing heterogeneous baseline responses to

⁹In Mexico, a municipality is a sub-administrative region under the state-level government, similar to a county in the United States.

¹⁰Our administrative mental health data showed timing inconsistencies at the daily level, showing unusual patterns of data accumulation at midnight. The weather data exhibited some irregularities in daily temperature readings, such as the maximum temperature occasionally being recorded late at night. Aggregating to weekly measures minimizes these errors and provides more reliable inputs for analysis. For details, please see Appendix C.

¹¹See Figure 1 for the distribution of average temperatures across Mexico, which forms the basis for defining the ten temperature bins. For the additional illustrations of temperature variations in Mexico, please refer to Appendix Figures F.1–F.3.

temperatures.¹² For example, in Hermosillo in Sonora state, where summers are persistently hot, a week at 35°C may be perceived as normal in a summer week, whereas the same temperature in Mexico City, located at high altitude and rarely experiencing hot summers, could represent an unusual shock. Conversely, in chronically hot Hermosillo, a single, marginally hotter day may impose meaningful stress, whereas in cooler Mexico City an unusually warm day is more likely to be experienced as pleasant than harmful. By including η_{jw} , we remove these baseline seasonal differences and identify the impact of deviations from the usual local climate profile. This ensures that the estimated temperature effects are identified from short-run deviations from each municipality’s expected seasonal climate, rather than inherent climatic differences between hot and cool regions. State-by-year fixed effects (λ_{sy}) further absorb time-varying state-level policies and trends that may influence mental health, including economic policy changes or trends at the state level.

We cluster standard errors at the municipality level. Because temperature shocks are defined at the municipality level, all observations within a municipality in a given week are exposed to the same weather shock. Although our outcome variables are also aggregated at the municipality level (e.g., emergency department visits per 1,000,000 residents), clustering at the municipality level remains necessary. It is because unobserved shocks such as hospital administrative capacity, emergency care infrastructure, or cultural factors may generate correlation in residuals across weeks within the same municipality. Clustering allows for arbitrary correlation of residuals within municipalities, while maintaining independence across municipalities. Given that our data cover 2,457 municipalities in Mexico, the number of clusters is sufficiently large for asymptotic approximations to be reliable.¹³

Our identifying assumption is that, conditional on municipality-by-week-of-the-year and state-by-year fixed effects, along with humidity and rainfall exposures, remaining within-municipality deviations in temperature are as good as random with respect to other unobserved determinants of mental health. This implies that unusual weekly temperature fluctuations in a municipality, beyond its typical seasonal patterns, are not systematically related to other factors influencing mental health outcomes except through their direct effect on temperature-sensitive mechanisms. For instance, our assumption would not be violated by persistent cultural or institutional differences across municipalities (e.g., baseline healthcare seeking behavior), since these are absorbed by η_{jw} . It would also not be violated by recurring seasonal patterns such as annual holidays, festivals, or school schedules that coincide with specific calendar weeks, since these are also captured by η_{jw} . This strategy enables us to interpret estimated coefficients on

¹²Note that it is week-of-the-year, not week-of-the-sample. It refers to calendar weeks 1 through 52.

¹³When the unit of analysis is at the city level, instead of municipality, errors are clustered at the city level.

temperature bins as causal effects of unexpected temperature shocks.

3.1.2 Specification for survey outcomes

We also include self-reported mental health outcomes. While we use a similar specification as equation 1, we make adjustments to account for the different structure of the survey data. The survey covers the largest city in each of Mexico’s 32 states, and collects individual-level responses but is designed to be representative at the city level. Therefore, we aggregate the data to cities rather than municipalities for our analysis. Similar to the clinical data outcomes, we measure these self-reported outcomes at the weekly level and construct weather variables using weighted averages from four surrounding weather grid points. The city by week-of-the-year fixed effects (η_{cw}) controls for city-specific seasonality, and standard errors are clustered at the city level in equation 2. All survey outcome regressions are weighted using survey-provided personal weights to ensure either national or statewide representativeness.

$$MH_{icswy} = \beta_0 + \sum_{b=1, b \neq 5}^{10} \{\beta^b Temp_{cswy}^b\} + \gamma Humidity_{cswy} + \delta Prec_{cswy} + X_i + \eta_{cw} + \lambda_{sy} + \varepsilon_{cswy}. \quad (2)$$

Most of our survey outcomes analyses are based on this specification. The covariate vector X_i includes individual-level characteristics – education and age group, and gender – to capture observable heterogeneity. It is worth noting that the unit of analysis for these outcomes is at the individual level.

3.2 Mental health and weather data

Our analysis draws on multiple administrative and survey data sources from Mexico, which we describe in the following sections.

3.2.1 Emergency department (ED) visits and suicides

We use publicly available administrative data on all medical emergency visits reported by the Ministry of Health in Mexico (Secretaría de Salud) between 2008 and 2019. We select this time frame because 2008 is the first year of publicly available data, and 2019 is the last pre-COVID-19 year.¹⁴

¹⁴We do not include the COVID-19 years, as the pandemic caused disruptions to both mental health care demand and supply that are beyond the scope of our controls.

These data provide key details critical for our analysis, including the purpose of the emergency department visit (henceforth, ED visit) measured by ICD-10 codes, date of the visit, geographic location of the ED (state and municipality), and patient demographics such as age and sex. Among these, the ICD-10 codes are central to our study as we focus exclusively on mental illness emergency department visits. Using the ICD-10 codes, we identify one of our main outcomes: mental illness emergency department visits with the primary ICD-10 code falling under “Mental, Behavioral and Neurodevelopmental disorders (F00-F99)” or “Symptoms and signs involving cognition, perception, emotional state, and behavior (R40-R46).” The primary ICD-10 code reflects the key condition requiring emergency care, as determined by the treating physician following standardized coding protocols.¹⁵ Furthermore, we use subcategories of the ICD-10 codes within the mental health spectrum to explore specific mechanisms, such as neurotic disorders and substance use disorders.

The geographic and temporal information – where and when a patient visited the ED – allows us to link the dataset with historical weather data, enabling identification of the temperature and humidity conditions experienced by the patient at the week and location of their visit. We use patient demographic information, age and sex, in heterogeneity analyses.

We also use administrative mortality data covering all registered deaths in Mexico from 2008 to 2019, from which we extract information on suicides. Suicides are pre-identified in the mortality data according to the cause-of-death codes determined by medical examiners at the time of certification, and each record includes the municipality and date of death.

We create rates of mental health emergency department visits and suicides per million residents within each municipality using population data from the Mexican Census 2010 data. This adjustment allows us to standardize the outcomes, ensuring that the rates of emergency department visits and suicides are comparable across municipalities with different population sizes. Table 1 shows descriptive statistics for mental health-related outcomes. The mean weekly rate of mental health emergency department visits and suicide per million residents are at 51.35 and 0.09 per million residents, respectively.

3.2.2 Self-reported mental well-being

We use data on self-reported well-being from the Self-Reported Well-being Survey (Módulo de Bienestar Autorreportado) conducted quarterly (January, April, July, October) since July 2013 by Instituto Nacional de Estadística y Geografía (henceforth, INEGI).¹⁶ The survey captures

¹⁵See Appendix D for detailed coding procedures and examples.

¹⁶This module is part of the National Survey on Consumer Confidence (Encuesta Nacional sobre Confianza del Consumidor, ENCO).

Table 1: Descriptive Statistics for Mental Health Outcomes

	Mean	SD	Min	p25	p50	p75	p90	p99	Max
Panel A. Administrative outcomes									
Suicide	0.09	1.44	0	0	0	0	0	2	299
Mental Health ED Visit	51.35	97.18	0	0	16	63	139	472	3,378
Panel B. Self-reported mental well-being									
Life Dissatisfaction	1.89	1.60	0	1	2	3	4	8	10
Composite Dissatisfaction	2.30	1.14	0	2	2	3	4	6	10
Languishing Score	1.36	1.11	0	1	1	2	3	5	10
Pseudo PHQ-2	1.47	1.53	0	0	1	2	4	6	10
Anxiety	1.78	1.89	0	0	1	3	5	8	10
Negative Feelings	1.55	1.48	0	0	1	2	4	6	10
Lack of Control	1.28	1.34	0	0	1	2	3	6	10
Psychological Distress	1.32	1.18	0	0	1	2	3	5	10

Notes: Mental Health ED (emergency department) Visits and Suicides are measured per million residents within each municipality per week, spanning the period from 2008 to 2019. Mental Health ED Visit data are sourced from the Emergency Department Visits dataset, which compiles administrative records of all public ED visits across Mexico. Mental Health ED Visits include all visits with a primary diagnosis coded under ICD-10 F (Mental and Behavioral Disorders) and ICD-10 R 40–46 (Symptoms and Signs Involving Cognition, Perception, Emotional State, and Behavior). Suicides are sourced from the Ministry of Health’s official mortality records. Self-reported outcomes, such as Life Dissatisfaction, Composite Dissatisfaction, Languishing Scale, and Psychological Distress, are measured on an individual basis and surveyed every January, April, July, and October from 2013 to 2019. These self-reported measures are derived from the Self-Reported Well-being Survey (Módulo de Bienestar Autor-reportado) conducted by the National Institute of Statistics and Geography (INEGI) with individuals living in 32 urban cities across Mexico. Each self-reported measure is scaled to be from 0 to 10, where higher scores indicate worsened mental health. P25, P50, P75, P90, and P99 represent the 25th, 50th (median), 75th, 90th, and 99th percentiles, respectively.

several dimensions of mental health, focusing on everyday emotional states rather than severe outcomes that only manifest when individuals interact with the healthcare system, such as emergency department visits or suicides. All measures are rescaled to range from 0 to 10, with higher scores reflecting worse mental health.¹⁷

The first measure, *Life Dissatisfaction*, reflects individuals’ overall dissatisfaction with life, offering a general perspective on subjective well-being. A related measure (*Composite Dissatisfaction*) averages dissatisfaction across 10 specific dimensions, such as health, relationships, time use, and neighborhood conditions, to provide a multidimensional view of perceived life quality. For emotional states, we include *Negative Feelings*, which captures the prevalence of emotions like bad mood, stress, fatigue, boredom, and sadness. This measure complements *Anxiety*, which directly assesses acute emotional distress based on feelings of worry or stress,

¹⁷For the exact wording of survey questions in English, see Appendix Table F.1.

and *Pseudo PHQ-2*, constructed using items that align with depression symptoms, such as fatigue, anhedonia, and depressed mood.

To assess broader psychological well-being, we include *Languishing*, adapted from Diener (2009)’s Flourishing scale, which focuses on optimism, purpose, and meaningfulness of overall life. A higher score of *Languishing* indicates diminished perceptions of flourishing. *Psychological Distress*, adapted from Diener (2009)’s psychological well-being scale, synthesizes items related to adversity, self-worth, and purpose, offering a more comprehensive view of mental strain. Finally, *Lack of Control* captures perceptions of autonomy and agency by aggregating responses on freedom of decision-making and self-determination, reflecting how individuals feel in control of their lives.

These measures emphasize everyday experiences relating to mental health rather than clinical outcomes. Key summary statistics in Table 1 show that our sample has an average life dissatisfaction score of 1.89, composite dissatisfaction at 2.3, and an average pseudo PHQ-2 score of 1.47. For context, Reed et al. (2024) report an average PHQ-2 score of 0.7 among U.S. veterans based on their electronic health records, suggesting that the urban population in Mexico reports higher levels of depression. Reed et al. (2024) documents a mean score of 6.37 on a 0-10 satisfaction scale for U.S. veterans, translating to a dissatisfaction score of 3.63 when rescaled to match the metric in our study.¹⁸ Measures of anxiety, negative feelings, and psychological distress average 1.78, 1.55, and 1.32, respectively. These metrics provide a comprehensive snapshot of mental well-being in Mexico, complementing the clinical data.

We’d like to note that these self-reported well-being responses can be sensitive to context and demand effects, raising the possibility that respondents may report their mental well-being in ways that align with perceived expectations of the experimenter (Heffetz and Caspi, 2025).¹⁹ Thus, our measures in general follow the approach recommended by Heffetz and Caspi (2025), combining multiple components into a composite index.

3.2.3 Historical weather

We combine mental health outcomes with historical climate data from the North American Regional Reanalysis (NARR) model at the U.S. National Oceanic and Atmospheric Administration (NOAA). The NOAA-NARR dataset provides continuous and complete weather records for Mexico throughout our sample period. Our primary temperature metric is the conventional

¹⁸The PHQ-2 and dissatisfaction scores are rescaled to a 0-10 range for direct comparison with our measures.

¹⁹For instance, Heffetz and Caspi (2025) noted that discrepancies between physiological stress indicators (such as cortisol level that can rise when people feel stressed) and self-reported stress suggest that psychological self-reported measure may at times be noisy or influenced by external cues.

dry-bulb temperature, which we use in most of our specifications alongside relative humidity and rainfall as control variables. In parallel, we also conduct core analyses using *wet-bulb* temperature, a composite measure of heat and humidity altogether, to capture the physiological burden of thermal stress more directly. We construct wet-bulb temperature using the Stull method, as detailed in Appendix A.

Mexico’s national meteorological agency, the Comisión Nacional del Agua (CONAGUA), provides observational weather data from ground monitoring stations. While CONAGUA is the primary public institution responsible for meteorological monitoring, we do not rely on these records due to their non-trivial and irregular patterns of missingness and errors. Many stations experience frequent interruptions, and the absence of metadata makes it unclear whether these gaps arise from equipment failure, power outages, or extreme weather events themselves. The missing values are non-random across time and location, limiting their reliability for consistent exposure measurement.

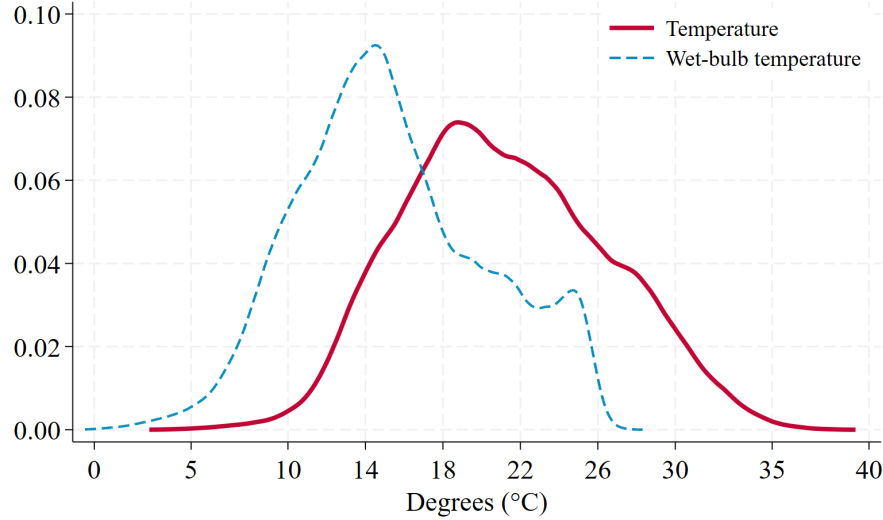
Instead, we rely on the NOAA-NARR dataset, which synthesizes multiple observational inputs, including those from CONAGUA, into a scientifically validated atmospheric reanalysis model. We selected NARR for its high spatial resolution at approximately 0.3 degrees (32km) resolution at the equator and demonstrated performance in Mexico. Despite being a modeled source, NARR offers full geographic and temporal coverage that is critical in data-scarce settings (Behrer, 2025). While the correlation between NARR and CONAGUA dry-bulb temperatures in our sample period is moderate ($r=0.577$), this likely reflects measurement noise in CONAGUA rather than inaccuracy in NARR.²⁰ Furthermore, our empirical strategy does not rely on precise temperature levels but on non-parametric bins defined at the 2°C level variation, making our estimates robust to small level shifts across sources. Appendix B presents descriptive comparisons between NARR and CONAGUA temperatures, including the observed correlation and the distribution of daily differences at the municipality level.

Figure 1 illustrates the distribution of average dry-bulb and wet-bulb temperatures across municipalities in Mexico based on weekly observations. The dry-bulb temperature, shown by the solid red line, represents conventional temperature, while the *wet-bulb* temperature, represented by the dashed blue line, accounts for both temperature and humidity. The distributions indicate that temperature mostly falls between 14°C and 30°C, with a peak around 19°C, which aligns with the omitted reference temperature bin (20-22°C) in our analysis in equation 1. The ten temperature bins, <14°C, 14-16°C, ..., 28-30°C, are determined based on the empirical distribution of dry-bulb temperatures in Mexico, as Figure 1 depicts, rather than being arbitrarily

²⁰When manually cross-checking high-discrepancy days against publicly archived weather records from The Weather Channel (<https://weather.com/weather>), we consistently find that our NARR temperature estimates are closer to the recorded reality, whereas CONAGUA values often appear erroneous.

assigned. We present summary statistics of all weather variables in Appendix Table F.2.

Figure 1: Distribution of Temperatures in Mexico



Notes: Observations depicted are the average dry-bulb and wet-bulb temperatures, calculated weekly in each year for each municipality in Mexico, covering a period from 2007 to 2021.

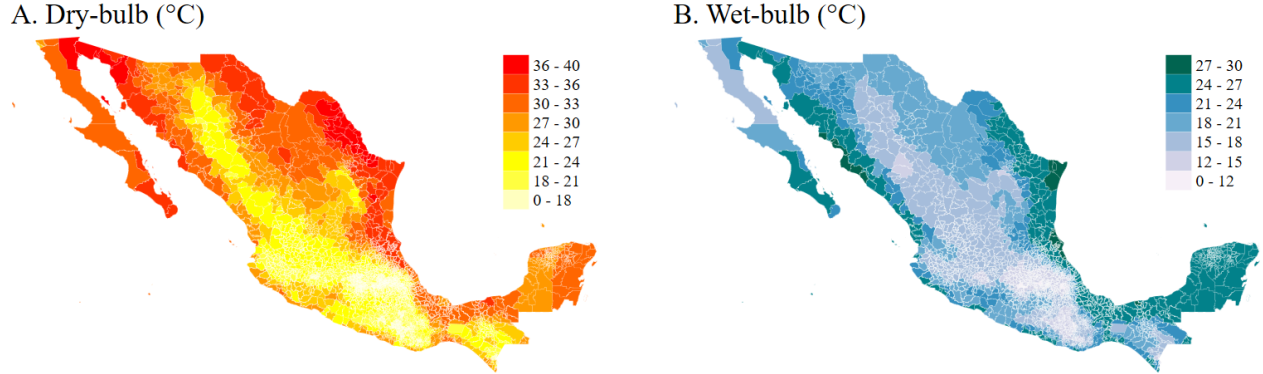
The relationship between temperature, humidity, and human thermal comfort is complex. While we focus on dry-bulb temperature for our main analyses, relative humidity plays a crucial role in how humans experience heat at different levels of humidity. For instance, a dry-bulb temperature of 30°C can feel substantially more oppressive at 80% relative humidity compared to 20% humidity, as high humidity impairs the body’s natural cooling mechanism through sweat evaporation. To account for this important interaction, we include relative humidity and rainfall as control variables in all our specifications.

To comprehensively address the role of humidity in heat exposure, we supplement our main findings with parallel analyses using wet-bulb temperature. The *wet-bulb* temperature metric, which combines temperature and humidity into a single measure, is particularly significant for understanding how humidity affects human cooling mechanisms (Vecellio et al., 2022).²¹ The relationship between wet-bulb and dry-bulb temperatures is non-linear, as detailed in equation 3 in the appendix. For example, a 25°C temperature with 95% relative humidity feels like a dry 40°C with lower humidity. As a reference, in Figure 2, we show the distribution of dry-bulb and wet-bulb temperature for Mexico in August 2019.

To link weather data with our municipality- or city-level mental health outcomes, we use

²¹Following established practice in the economics literature (Adhvaryu et al., 2020; Geruso and Spears, 2018; LoPalo, 2023), we construct wet-bulb temperatures using the Stull calculation method.

Figure 2: Geographic Variations of Temperature and Humidity in Mexico



Notes: This figure presents three key climatological parameters mapped across Mexico, showing monthly average values for August 2019. Panel A shows the spatial distribution of the conventional temperature metric, dry-bulb temperature (°C). Panel B displays wet-bulb temperature (°C). Wet-bulb temperatures are calculated using the Stull formula, which is presented in equation 3 in the appendix.

a two-step spatial linkage procedure. First, we generate the geographic centroids of each municipality (or city) using official shapefiles from Mexico government in a geographic information system (GIS), extracting their latitude and longitude in a standardized coordinate system. Second, for each centroid, we identify the four nearest NARR grid nodes²² and compute inverse-distance weighted averages of daily weather variables from these surrounding nodes. We follow established practices in the literature (Carrillo, 2020; Zhang et al., 2018; Geruso and Spears, 2018; Rocha and Soares, 2015; ?), ensuring a smooth interpolation from gridded weather surfaces to population-relevant geographic units, municipality. We then merge these weather data with our mental health outcomes at the municipality-week level. Finally, to construct our weekly temperature exposure measures, we count the number of days within the week where the daily average temperature falls into each temperature bin.

4 Main Results

4.1 Suicides and mental illness emergency department visits

We begin by presenting our results for outcomes that measure more severe mental distress. Figure 3 summarizes the results for suicides (Panel A) and mental illness emergency departments visits (Panel B). Although suicides appear first in the figure, we start by discussing Panel

²²Each grid is spaced approximately 32km apart in the NCEP Eta model. See <https://www.ncei.noaa.gov/products/weather-climate-models/north-american-regional> for details.

B, where the relationship with temperature is more precisely estimated. We find a statistically significant relationship between temperatures and mental illness emergency department visits, higher temperatures result in more visits, while lower temperatures lead to fewer visits. For example, we find that an additional day above 30°C ($\approx 86^\circ\text{F}$) in a week leads to 1.21 more mental illness emergency department visits per million residents, which is a 2.4% increase relative to the weekly average of 51.4 visits per million in our sample.

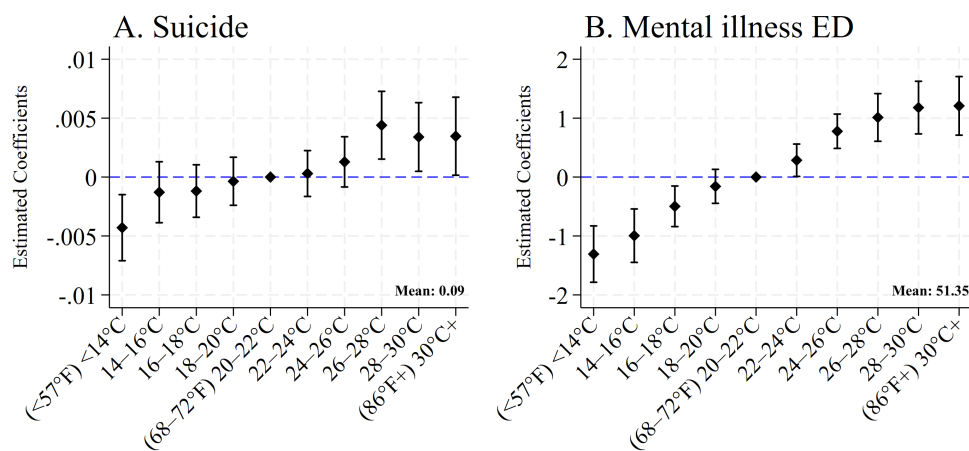
This quasi-linear pattern for mental illness ED visits is consistent with prior evidence. [Mullins and White \(2019\)](#) documented quasi-linear relationships between temperature and mental-health outcomes in California, showing that higher temperatures increased both ED visits and suicides. Similarly, [Lavigne et al. \(2023\)](#) found a comparable quasi-linear relationship in Canada, where short-term exposure to extreme heat was associated with higher risks of emergency visits for mental and behavioral disorders, while risks declined during extreme cold temperatures—consistent with previous evidence ([Yoo et al., 2021](#); [Lee et al., 2018](#); [Wang et al., 2014](#); [Hansen et al., 2008](#)). In the Mexican setting, [Cohen and Gonzalez \(2024\)](#) similarly documented linear associations between daily temperature and crime rates, underscoring that temperature influences a broad range of behavioral and mental health outcomes.

Turning to suicides, Figure 3 Panel A shows a noisier relationship with wider confidence intervals and a less clearly linear pattern, though the direction is consistent with the aggregate effect. Suicides decline significantly only at the coldest temperatures, while the three hottest bins drive modest increases. Our estimates imply that having one additional day above 30°C a week leads to a 3.2 percent increase in suicides (0.003 additional suicides per million residents weekly) relative to the mean of 0.093 suicides.

To compare our estimates with those of [Mullins and White \(2019\)](#), we adjust our estimates to match the unit used in their study: per 100,000 residents a month. We mimic their specification by aggregating our weekly data to the monthly level, using six temperature bins in Fahrenheit, and excluding humidity as a control. [Mullins and White \(2019\)](#) report that an additional day above 80°F increased mental health emergency department visits by 0.3% and suicides by 0.24% relative to their sample mean. Under this approach, we estimate a 0.4% increase in emergency department visits and 1.1% more suicides in Mexico.²³ These estimates correspond to effects roughly 1.3 times larger for emergency department visits and about 5 times larger for suicides compared to those found in the U.S. These slightly larger effects in Mexico may be due to differences in climate itself, climate adaptation, healthcare infrastructure, or social resilience when compared to the U.S.

²³The effect on emergency department visits is statistically significant, whereas the effect on suicide is not. The latter should be interpreted with caution.

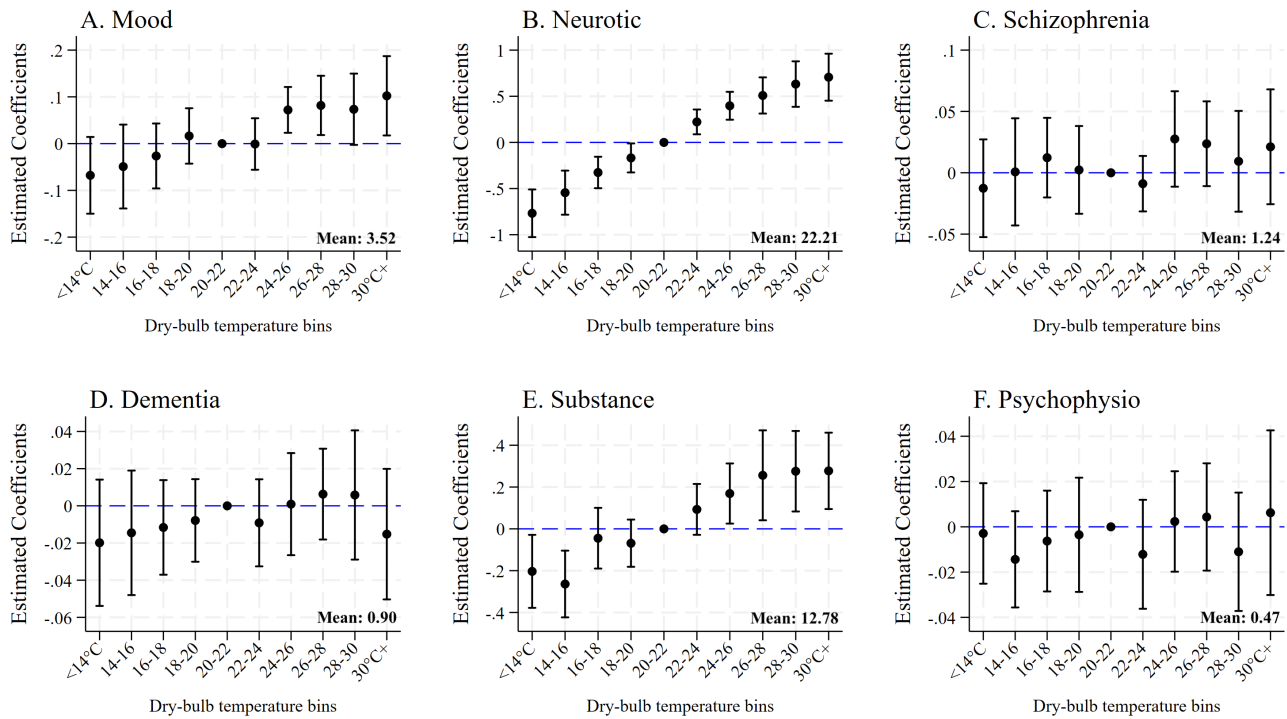
Figure 3: Relationship between Temperature and Extreme Mental Health Outcomes



Notes: The estimated coefficients and the 95 percent confidence intervals using standard errors clustered at the municipality level are depicted in this figure. The 20-22°C temperature bin is omitted as the reference category. All dependent variables are presented as rates per million residents within each municipality. For example, the dependent variable in Panel B represents all mental illness ED visits per million residents within each municipality a week, including all ED visits with the primary diagnosis of ICD-10 F: Mental and behavioral disorders and ICD-10 R 40-46: Symptoms and signs involving cognition, perception, emotional state and behavior. Each suicide is matched to the temperature of the municipality where it occurred. All specifications control for the municipality by week-of-the-year fixed effects and state by year fixed effects, as well as weekly humidity and rainfall exposure.

To identify which mental health disorders are driving our results, we examine subcategories of emergency department visits by primary diagnoses in Figure 4. These categories encompass the major domains of mental health: mood disorders (primarily depression and similar emotional conditions), neurotic disorders (anxiety and stress-related symptoms), schizophrenia (disorders involving altered perception of reality), dementia (cognitive decline conditions), substance use disorders (involving alcohol, opioid, and other psychoactive substances), and psychophysiological disorders (physical manifestations of psychological distress).

Figure 4: Temperature and Mental Health ED by Visit Type



Notes: The estimated coefficients and the 95 percent confidence intervals using standard errors clustered at the municipality level are depicted in this figure. The 20-22°C temperature bin is omitted as the reference category. All dependent variables are presented as rates per million residents within each municipality. Mood disorders in column (1) include ED visits with the primary diagnosis of ICD-10 F 30-39: Mood [affective] disorders (depression); Neurotic disorders in (2) include F 40-48: Neurotic, stress-related and somatoform disorders; Schizophrenia in (3) includes F 20-29: Schizophrenia, schizotypal and delusional disorders; Dementia in (4) includes F 00-09 Organic, including symptomatic, mental disorders; Substance in (5) includes F 10-19: Mental and behavioral disorders due to psychoactive substance use; and Psychophysio in (6) includes F 50-59: Behavioral syndromes associated with physiological disturbances and physical factors. All specifications control for the municipality by week-of-the-year fixed effects and state by year fixed effects, as well as weekly humidity and rainfall exposure.

We observe varying temperature sensitivities across conditions, with statistical precision largely reflecting their prevalence. Mood disorder visits (Panel A) rise significantly above 24°C,

with one additional day above 30°C a week leading to an increase of 0.1 visits per million residents (2.8% relative to the mean of 3.52). This pattern aligns with prior literature showing that mood-related disorders are particularly sensitive to heat exposure, likely through pathways involving stress regulation and mood instability.²⁴

Neurotic disorders (Panel B), with the highest baseline rate of 22.2 visits per million residents on average, show the most significant effect with a rise at all high temperature bins. This result highlights stress as a potential mechanism. Neurotic disorder visits increase by 0.71 on average with an additional day above 30°C a week (3.2% relative to the mean of 22.21). This pattern may reflect how heat stress can amplify anxiety and psychological tension (Soini et al., 2024; Xie et al., 2021), potentially through both direct physiological effects on the nervous system and indirect effects on sleep and daily activities (Buguet, 2007; Löhms, 2018; Irwin, 2023). We explore potential mechanisms in a later section by examining changes in sleep patterns and time people spend on leisure activities.

Substance use disorders (Panel E) also show increased emergency department visits at higher temperatures, consistent with findings linking heat to worsened alcohol and drug-related health outcomes. Dementia-related and schizophrenia visits (Panel C and D) exhibit no significant relationship with temperature, diverging from prior studies suggesting vulnerability during heatwaves.²⁵ Psychophysiological disorders (Panel F) also display no clear pattern along the temperature bins.

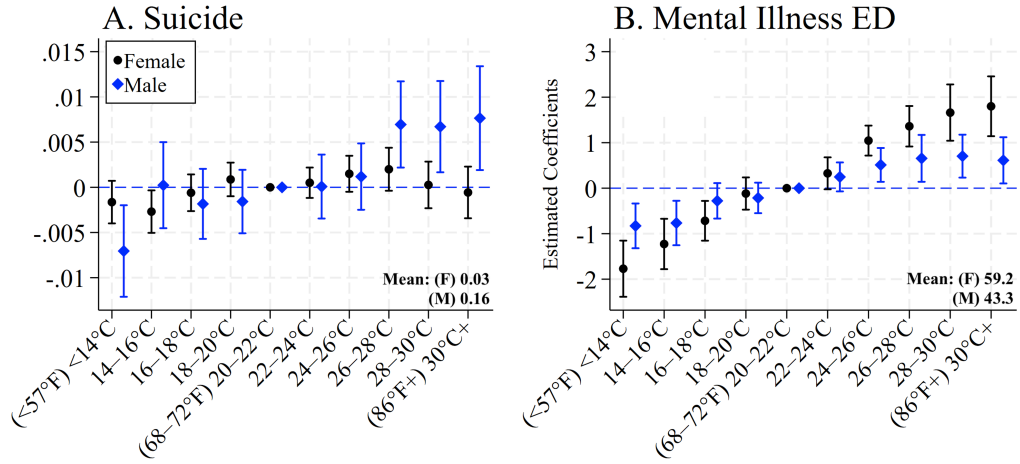
The effects of temperature may differ across population groups. For example, anxiety, depression, and stress are up to twice as prevalent among women as among men (Altemus et al., 2014), suggesting that heat-related mental health responses may also vary by gender. Our findings in Figure 5 illustrates clear gender differences in the temperature–mental health relationship. All outcome measures are normalized per million residents of the same gender within each municipality, rather than by the total population. For example, the weekly number of female suicides in a municipality is adjusted by the corresponding female population.

Panel A in Figure 5 shows that women are more sensitive to heat. An additional day above 30°C increasing emergency department visits by 1.8 per million women (3% relative to the sample mean), compared to 0.6 per million men (1.4%). Cold temperatures modestly reduced emergency department visits for both genders. In contrast, men’s suicide rates are more responsive to heat than those of women, with extreme heat disproportionately affecting men. While women’s rates remain unaffected, each additional day above 30°C increases male suicides by

²⁴See Rony and Alamgir (2023); Cianconi et al. (2020); Saldaris et al. (2020); Hansen et al. (2008); Trang et al. (2015).

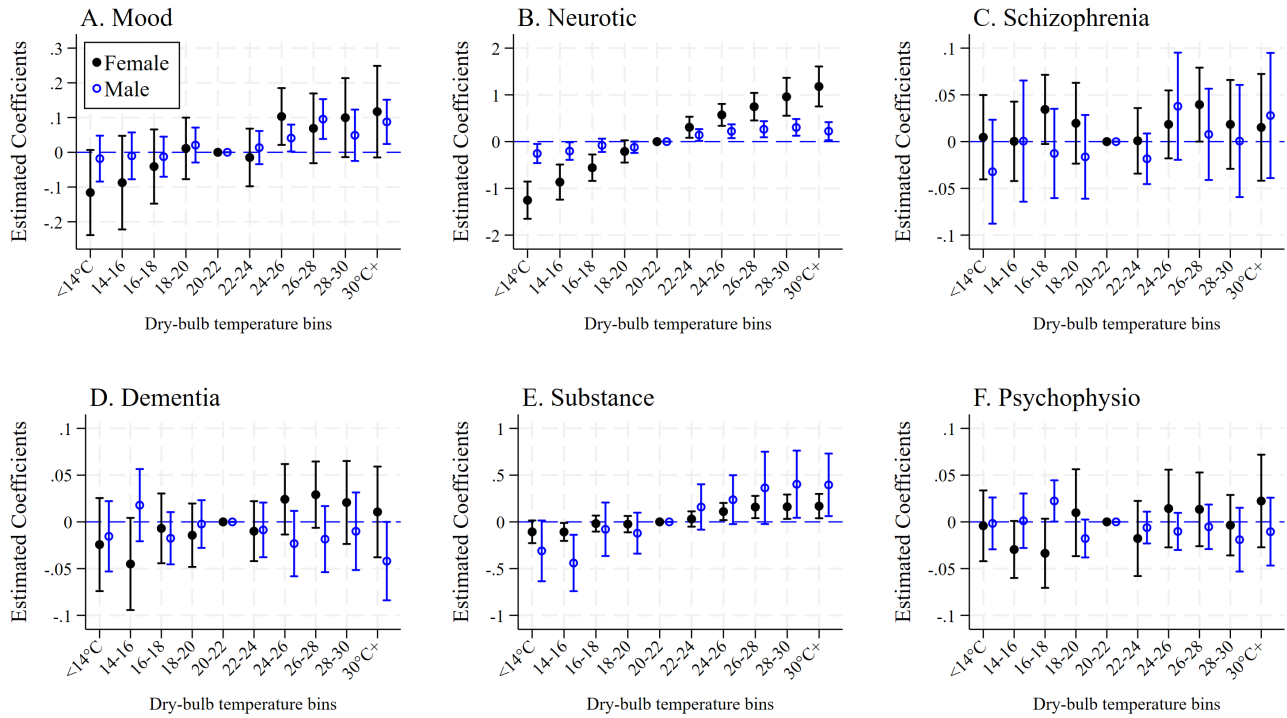
²⁵See Cornwall (2023); Lee et al. (2023); Zhao et al. (2016); Sung et al. (2011) for schizophrenia, and Hansen et al. (2008); Conti et al. (2007); Linares et al. (2017) for dementia.

Figure 5: Temperature and Mental Health by Gender



Notes: All dependent variables are presented as rates per million residents within each municipality's corresponding gendered population. All specifications control for the municipality by week-of-the-year fixed effects and state by year fixed effects, as well as weekly humidity and rainfall exposure. For additional details, please refer to the notes for Figure 3.

Figure 6: Mental Health ED by Visit Type and Gender



Notes: See notes for Figure 4.

0.008 per million men – a 5% increase relative to the male sample mean of 0.159 suicides per million per week. Even after accounting for the fact that men already exhibit higher baseline suicide rates, our results indicate that male suicides primarily drive the temperature–suicide relationship. These findings highlight distinct gender patterns in mental health risks. Women are more likely to seek emergency care for mental illness when temperatures are high; whereas men bear a heavier burden at the most severe end of mental health outcomes, suicide.

The heterogeneity analysis by visit type in Figure 6 also reveals distinct gender-specific patterns. Neurotic and substance use disorders (Panels B and E) showing the most pronounced contrasts between women and men. Emergency department visits for neurotic disorders (Panel B) increase significantly at higher temperatures, with women showing a consistently bigger magnitude of effects than men. In contrast, substance use disorder visits (Panel E) also rise with temperature, but disproportionately among men.

Mood disorders (Panel A) show similar responses across genders, with both men and women experiencing increased emergency department visits at higher temperatures. Schizophrenia (Panel C), dementia (Panel D), and psychophysiological disorders (Panel F) do not display clear or statistically significant temperature effects for either gender, likely reflecting the rarity of these emergency visits in the data. These patterns suggest that anxiety and stress cases drive the increase in emergency department visits, especially among women, and substance use-related emergency department visits also rise with heat, but disproportionately among men. Taken together, this evidence is consistent with heat amplifying acute stress and prompting maladaptive coping (Vergunst et al., 2023).

We also examine heterogeneity by age to understand how heat sensitivity varies across life stages. Panels A.1-A.6 in Appendix Figure F.7 show that emergency department visits increase significantly with heat for most age groups, except young children (0-5 years) and adults aged 60 and over. In contrast, suicide responses to heat are concentrated among older adults: Panels B.1-B.6 in Appendix Figure F.7 indicate that only individuals aged 60 and above experience a statistically significant increase in suicides on hotter weeks. While some younger age groups show suggestive upward patterns, these estimates are less powered. These results suggest evidence that age conditions both exposure and vulnerability – older adults face elevated risks at the most severe endpoints, whereas working-age populations more often experience non-fatal distress leading to emergency visits.

4.2 Self-reported mental well-being

To provide a more comprehensive understanding of temperature effects on mental health, we examine various self-reported mental health and well-being measures. Figure 7 presents results from our main specification, which controls for weekly relative humidity and rainfall exposure, city-week and state-year fixed effects, and clusters errors at the city level. It should be noted that all measures are rescaled so that higher measures indicate worse mental health. We provide parallel analyses using wet-bulb temperature in Appendix Figure F.5.

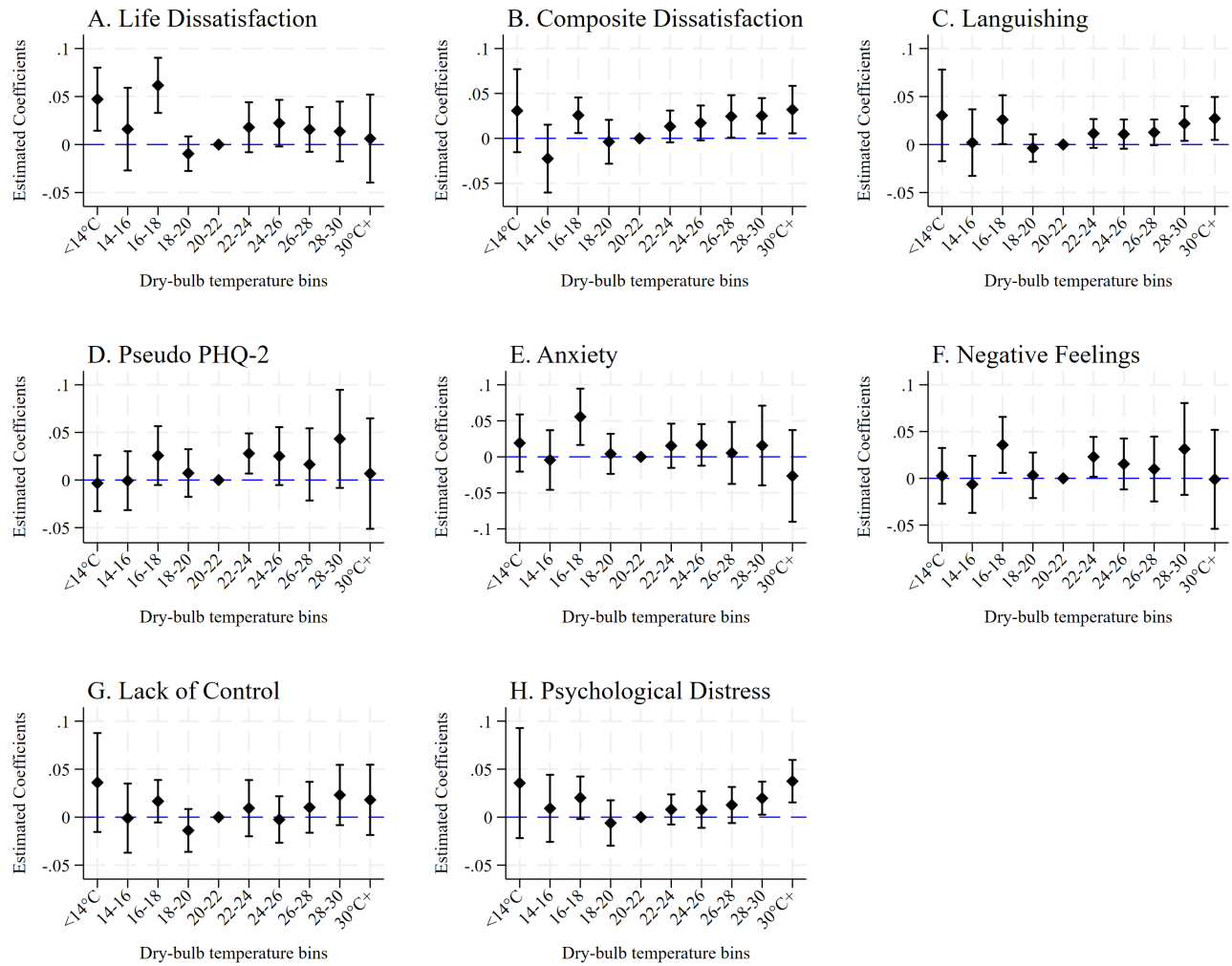
Our findings reveal consistent patterns in how temperature affects various dimensions of mental well-being, particularly at extreme temperatures. Life dissatisfaction (Panel A, 7) is positively correlated with low temperatures. The composite dissatisfaction measure in Panel B displays a similar pattern at lower temperatures, but with significantly positive correlation with high temperatures as well. The divergent patterns at higher temperatures between life dissatisfaction and composite dissatisfaction may reflect how heat exposure differently affects overall (Life Dissatisfaction) versus specific domains of (Composite Dissatisfaction) well-being. While people may adapt their behaviors during hot weeks to maintain overall life satisfaction, the composite measure captures specific domains like health, daily activities, relationships, housing, and community domains – that remain disrupted despite their adaptations. The aspects captured by the composite dissatisfaction measure may be more systematically affected by a week of high temperatures through sleep disruption, reduced outdoor activities, and constrained social interactions.

The languishing scale (Panel C), which measures seven components of eudaimonic well-being from self-acceptance to daily accomplishment, shows adverse effects at higher temperatures. Heat exposure may be correlated with undermining fundamental aspects of psychological thriving and personal development, as the languishing scale measures deeper psychological resources like autonomy, self-acceptance, optimism, and resilience.

Looking at emotional and depressive metrics in Panels D-F, we do not observe statistically significant patterns. Lack of control (Panel G), which reflects individuals' sense of agency over their lives, autonomy in decision-making, and self-determination of life outcomes, shows weak deterioration at higher temperatures, suggesting heat exposure may diminish people's perceived control over their circumstances. Psychological Distress in the last panel (Panel H) shows a weakly U-shaped pattern, with precisely negative correlations at higher temperatures. This result is concerning for long-term mental health and resilience, because what this psychological distress measure captures (optimism, sense of purpose, feeling that life is worthwhile) are core aspects of psychological functioning rather than just temporary mood states.

Across the self-reported measures, we find mixed evidence regarding the effects of tem-

Figure 7: Nonlinear Temperature Effects on Self-Reported Mental Well-being



Notes: This figure presents the relationship between dry-bulb temperature exposure and various well-being outcomes: (A) General life satisfaction, (B) Composite dissatisfaction index averaging twelve domains spanning personal, social, and environmental aspects, (C) Languishing scale adapted from Diener (2009) measuring eudaimonic well-being, (D) Pseudo PHQ-2 depression screening capturing fatigue, anhedonia, and depressed mood, (E) Anxiety, (F) Psychological distress adapted from the psychological well-being scale measuring optimism, purpose and daily meaningfulness in Diener (2009), (G) Lack of control measuring perceived agency and autonomy, and (H) Negative feelings from the SPANE measure in Diener (2009). All measures range from 0-10, with higher values indicating worse mental health outcomes. The estimated coefficients and the 95 percent confidence intervals using standard errors clustered at the city level are depicted in this figure. The reference temperature bin is 20-22°C, chosen as it represents the middle range of the temperature distribution in the sample. All specifications control for city by week-of-the-year effects and state by year fixed effects, weekly humidity and rainfall exposure, as well as individual gender, age group, and education. The data come from quarterly surveys (January, April, July, and October) conducted yearly from 2013 to 2019. Parallel analyses using wet-bulb temperature bins are presented in Appendix Figure F.5.

perature extremes on mental well-being. Some measures, such as composite dissatisfaction, languishing, and psychological distress, show significant associations at high temperatures. Composite dissatisfaction highlights how specific life domains, like health and social interactions, may be more vulnerable to heat-related disruptions despite overall life satisfaction remaining stable. Similarly, both the languishing scale and psychological distress reflect deeper psychological effects, such as reduced optimism, autonomy, and a sense of purpose, which may be undermined during heat exposure. However, other measures, such as pseudo PHQ-2 and anxiety, show imprecise estimates. This may reflect a genuine lack of association with temperature or insufficient statistical power in the survey data to detect subtle effects. Lack of control exhibits a weak correlation, indicating potential but not definitive links to temperature extremes. Overall, while some results suggest evidence of the vulnerability of certain dimensions of mental health to temperatures, the findings are noisier than those derived from clinical outcomes.²⁶

5 Adaptation

This section examines how individuals and local systems adapt to high temperatures in ways that may shape their mental health responses. We focus on both behavioral adjustments – such as changes in sleep, physical activity, and time spent indoors – and infrastructural forms of adaptive capacity, including access to mental health professionals, air conditioning, and urban infrastructure. Together, these analyses situate the temperature–mental health relationship within a broader framework of coping and resilience.

We first revisit behavioral channels that may mediate the effects of heat on mental well-being, using complementary time-use datasets to explore changes in sleep and leisure activities. Prior work has identified similar behavioral mechanisms in Mexico (e.g., [Cohen and Gonzalez, 2024](#)), and we assess whether these patterns are consistent in our data. We then extend the analysis to newly examined dimensions of adaptation – mental health service availability, air-conditioning penetration, and rural–urban context – to test how institutional and infrastructural capacity mitigates heat-related mental health risks.

²⁶In addition to the self-reported mental well-being measures, we also test secondary outcomes identified in the literature as potential manifestations of mental health strain, including psychological stress, blood pressure, and smoking behavior. We find no significant associations for these outcomes, which rely on either state-level aggregated data or survey measures. These analyses are presented in Appendix E for readers interested in the full results and methodological details.

5.1 Data

To analyze both behavioral and infrastructural forms of adaptation, we compile several complementary datasets that capture individual time use, local health resources, and environmental conditions across Mexican municipalities.

The Mexican Family Life Survey (MxFLS) provides individual-level information on sleep, sports activity, and TV watching, which we use to study behavioral adjustments under temperature stress. Although the MxFLS is longitudinal, we treat it as a repeated cross-section because of substantial panel attrition, pooling data from all three waves.²⁷ Each record includes the month and year of interview and the municipality of residence, which allows linkage with contemporaneous monthly weather data. The key variables of interest are average daily minutes spent sleeping, engaging in sports, and watching TV, which are the activities that together reflect rest, outdoor exercise, and indoor leisure. This setup enables us to evaluate how people adjust their daily routines in response to heat exposure, extending prior behavioral evidence for Mexico (e.g., [Cohen and Gonzalez, 2024](#)) to a longer temporal window and different survey population in Mexico.

We also complement the MxFLS with the Sports Practice and Physical Exercise Module, collected annually each November since 2013 across 32 major urban areas. This dataset offers an independent validation of temperature–exercise relationships observed in the MxFLS, providing a more recent urban sample with consistent activity definitions.

To examine institutional and infrastructural adaptability, we merge in three additional data sources. The Ministry of Health’s Medical Resources dataset records the annual presence of psychiatrists and psychologists by municipality, which we use to identify whether a locality is “served” by each type of professional. The National Household Income and Expenditure Survey (ENIGH) series (biannual, 2008–2020) reports household air-conditioning ownership, aggregated to the municipality level to construct A/C penetration rates. Finally, the 2010 Population Census provides the urban–rural classification used to distinguish municipalities by degree of urbanization.

All datasets are spatially merged with the corresponding weather exposure measures using the procedure described in Section 3.2.3. Whenever municipality-level identifiers are available, we match at that level; when data are reported only for larger urban areas, we use city-level matching.

²⁷Wave 1 (2002); Wave 2 (2005–2007); Wave 3 (2009–2013).

5.2 Changes in sleep and leisure activities

Behavioral responses such as changes in sleep, exercise, and indoor activity are among the direct ways individuals adapt to heat. Prior work in Mexico has shown that temperature influences time allocation, social behavior, and physical exertion (Cohen and Gonzalez, 2024). Using the MxFLS, we examine whether similar behavioral adjustments emerge in our broader sample and whether they plausibly contribute to the observed mental health patterns.

The analysis links individual time-use information to contemporaneous monthly weather data at the municipality level.²⁸ The three outcomes – minutes spent sleeping, engaging in sports, and watching TV – capture rest, outdoor exercise, and indoor leisure, respectively.

Figure 8 shows consistent behavioral adjustments with temperature. Panel A indicates slightly longer sleep duration at moderate temperatures (20–26°C), while extreme temperatures show no significant deviations. Panel B shows that heat discourages physical activity: each additional day above 30°C reduces sports time by about two minutes per day, equivalent to a 31% decline relative to the mean of 6.5 minutes. Regular exercise is known to buffer stress and improve mood (Soini et al., 2024; Xie et al., 2021), suggesting that reduced activity could be one pathway linking heat to worsened mental health.^{29 30}

In contrast, Panel C shows an increase in time spent on indoor activities such as watching TV during both cold and hot weeks, consistent with behavioral retreat into climate-controlled settings. These patterns align closely with prior evidence and provide suggestive confirmation that individuals modify daily routines to cope with thermal discomfort (Cheong and Gayanova, 2024; Ho et al., 2023, 2022; Huang et al., 2020; Schuch et al., 2018; Zhai et al., 2015). While such adjustments are adaptive in the short term, they may simultaneously reduce protective behaviors like exercise or social interaction. We next turn to institutional dimensions of adaptation that could mediate or buffer these behavioral effects.

5.3 Mental health professional accessibility

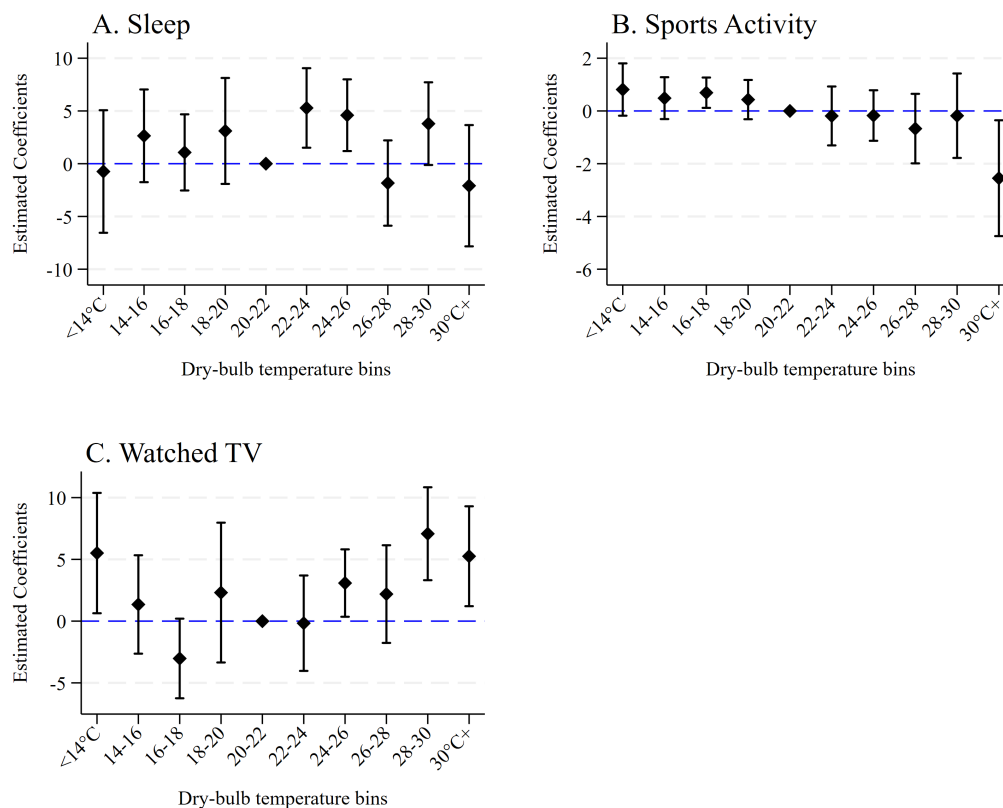
The capacity of local health systems to manage heat-related distress can be a key dimension of adaptation. We therefore examine how the availability of mental health professionals conditions the link between temperature and mental health outcomes. Using municipality-level data from the Ministry of Health’s Medical Resources dataset, we classify each municipality-

²⁸Although respondents report time use for the “past week,” the MxFLS provides only year–month interview dates. We therefore assume that reported activities reflect exposure to the average temperature of the interview month.

²⁹However, the magnitude of the effects suggests that it is likely not the only mechanism at play.

³⁰We also confirm the robustness of the results of Panel B in Figure 8, using an alternative dataset that surveyed sports practice and physical exercises among urban Mexicans in Appendix Figure F.6.³¹

Figure 8: Effects of Temperature on Sleep and Leisure using Mexican Family Life Survey



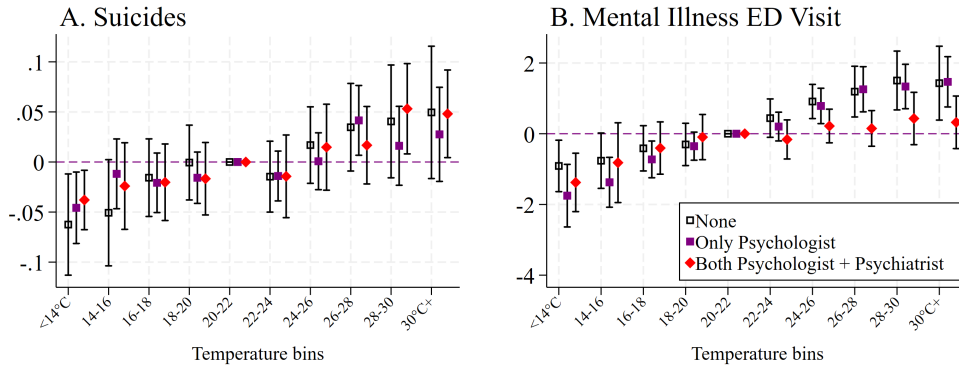
Notes: The estimated coefficients and the 95 percent confidence intervals using standard errors clustered at the municipality level. We chose the reference temperature bin to be 20-22°C, which represents the middle range of the temperature distribution in the sample. The dependent variables are daily average minutes spent on three activities during the previous week: Sleep (Panel A), Sports Activity (Panel B), and Watching TV (Panel C). All specifications control for municipality by month-of-the-year and state by year fixed effects, as well as average relative humidity and rainfall exposure at the municipality-month level. Survey weights from the Mexican Family Life Survey (MXFLS) Waves 1–3 are applied to account for the survey’s sampling design.

year into three categories based on the presence of psychiatrists and psychologists: (i) *None*, if the municipality has neither type of professional; (ii) *Psychologist only*, if it has at least one psychologist but no psychiatrist; and (iii) *Both*, if it has at least one psychiatrist and at least one psychologist. In 2019, about two-thirds of municipalities had no mental health professionals, one-fourth had only psychologists, and 6% had both. Only five municipalities had psychiatrists without psychologists, which we treat as missing values.

The contrast between psychiatrists and psychologists is relevant for interpreting these categories: psychiatrists, as medical doctors, can prescribe medication or authorize emergency

hospitalization during acute psychiatric crises, whereas psychologists focus on therapy and crisis assessment but lack prescriptive authority. Figure 9 presents estimated effects of temperature on suicides (Panel A) and mental illness emergency department (ED) visits (Panel B) across these categories.

Figure 9: Temperature and Mental Health by Health Professional Accessibility



Notes: Municipalities are classified according to the annual availability of mental health professionals using the Ministry of Health’s Medical Resources dataset: *None* indicates that a municipality-year has neither a psychiatrist nor a psychologist (1,593 municipalities in 2019); *Psychologist only* indicates at least one psychologist but no psychiatrist (678 municipalities in 2019); and *Both* indicates at least one psychiatrist and at least one psychologist (163 municipalities in 2019). Only five municipalities had psychiatrists without psychologists in 2019, which are dropped from the analysis. All regressions include municipality by week-of-year fixed effects, and state-by-year fixed effects, as well as weekly rainfall and humidity controls. Standard errors clustered at the municipality level.

Panel A shows that suicide responses to temperature do not vary meaningfully across categories of mental health professional availability. The estimated coefficients are similar in magnitude and precision across municipalities with no professionals, psychologists only, or both psychiatrists and psychologists. This pattern suggests that, within the available data, the relationship between temperature and suicide rates is largely invariant to the local presence of mental health providers. The result is consistent with the interpretation that suicide, as a rare and extreme outcome, reflects crises that unfold too acutely for outpatient service availability to play a moderating role.

In contrast, Panel B reveals heterogeneity in how temperature affects emergency department (ED) visits for mental illness. Municipalities with both psychiatrists and psychologists exhibit smaller increases in ED visits during high-temperature periods compared to those with limited or no professional coverage. Because the availability of professionals is highly correlated with socioeconomic and institutional characteristics, these differences should not be interpreted causally. Rather, they indicate that municipalities with stronger overall mental health infrastructure, which includes but is not limited to psychiatrist presence, experience

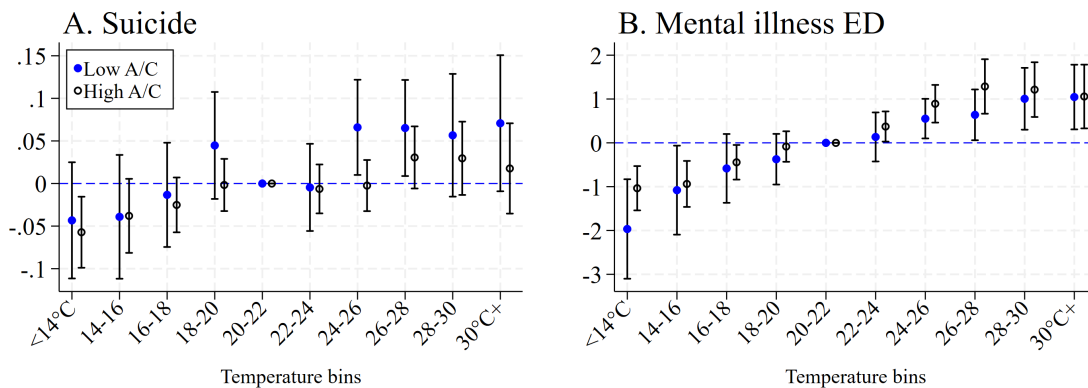
attenuated heat-related surges in emergency presentations.

The attenuated ED responses in areas with both psychiatrist and psychologist are consistent with greater clinical capacity for early stabilization or alternative care pathways outside the emergency setting. However, the absence of heterogeneity in suicide outcomes underscores the limits of such buffering: even where professional resources are available, the most severe crises remain largely unmitigated by local service presence.

5.4 Adaptability by air conditioning and rurality

We do not find clear heterogeneity in mental health outcomes by air-conditioning (A/C) penetration. The overlapping confidence intervals for municipalities with low and high A/C penetration in Figure 10 suggest that A/C adoption may not significantly alter the observed patterns. This aligns with findings by Mullins and White (2019), who report no notable heterogeneity in suicides in the U.S. Similarly, Cohen and Gonzalez (2024) find that the mitigating effect of A/C penetration on temperature-induced crime in Mexico is either minimal or not robust. These similarities suggest that A/C penetration alone may not explain variations in outcomes, especially in contexts with relatively low A/C adoption rates like Mexico.³²

Figure 10: Temperature and Mental Health by Air Conditioning Penetration



Notes: The air conditioning penetration rate is aggregated at the state level. Municipalities with rates above the national median state are classified as having higher penetration, while those below the median are categorized as having lower penetration.

Interpreting the heterogeneity results by A/C penetration requires caution. Limited variation in A/C penetration rates across Mexico, as seen in Appendix Figure F.8, and reliance on

³²See Appendix Figure F.8.

state-level aggregated data to define the A/C penetration may obscure differences across municipalities, limiting our ability to detect localized effects. Additionally, confounding variables could influence both A/C penetration and mental health outcomes. For example, wealthier municipalities with higher A/C adoption might also enjoy better access to healthcare services, confounding the relationship between temperature adaptation and mental health.

From a broader perspective, relying on A/C as a coping mechanism for extreme temperatures to protect mental health comes with a sustainability concern. Increased usage of A/C could drive higher energy demand and CO₂ emissions in the long term (Colelli et al., 2023) while rising energy costs from A/C usage might impose financial burdens on households (Barreca et al., 2022).

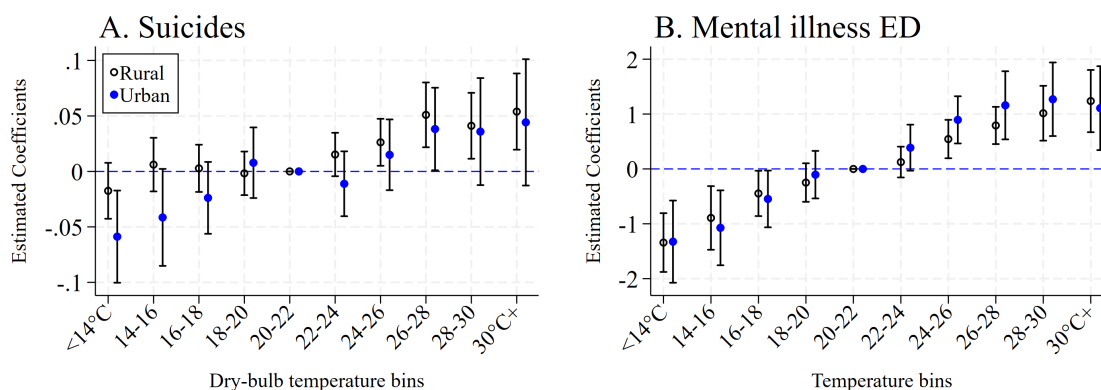
We also examine whether the temperature effects on mental health vary by rurality of each municipality, as urban areas typically have better infrastructure and healthcare access with cooling facilities that might provide greater resilience to temperature shocks. Figure 11 shows results comparing municipalities classified as urban (metropolitan, large urban, and medium urban areas) versus rural (rural, semi-urban, and mixed-urban areas). Similar to the air conditioning analysis in Figure 10 above, we find no clear heterogeneity in clinical outcomes across rural and urban settings. This finding indicates that the temperature-mental health relationship is robust across different levels of urbanization in Mexico, despite potential differences in adaptive capacity and infrastructure between urban and rural areas. Note that the BIARE survey itself targets only urban residents, meaning that our self-reported mental well-being outcomes in Figure 7 represent the relationship among urban populations.

6 Robustness

As the first robustness check, we conduct placebo tests using health outcomes that are unlikely to be affected by short-term temperature fluctuations. Figure 12 presents results for six conditions: malignant tumors, benign (non-cancerous) neoplasms, congenital disorders, appendicitis, acute cholecystitis, and bowel obstruction. These conditions represent either chronic diseases with long development periods (e.g., tumors and congenital anomalies) or acute internal pathologies with physiological causes unrelated to ambient temperature (e.g., appendicitis, cholecystitis, and bowel obstruction). Across all six outcomes, the estimated coefficients are statistically insignificant, indicating that our main results are not driven by spurious correlations that vary systematically with temperature.

Second, we implement falsification tests by including future temperature bins as regressors in addition to the contemporaneous bins in our main specifications. If our estimates reflect

Figure 11: Temperature and Mental Health by Rurality



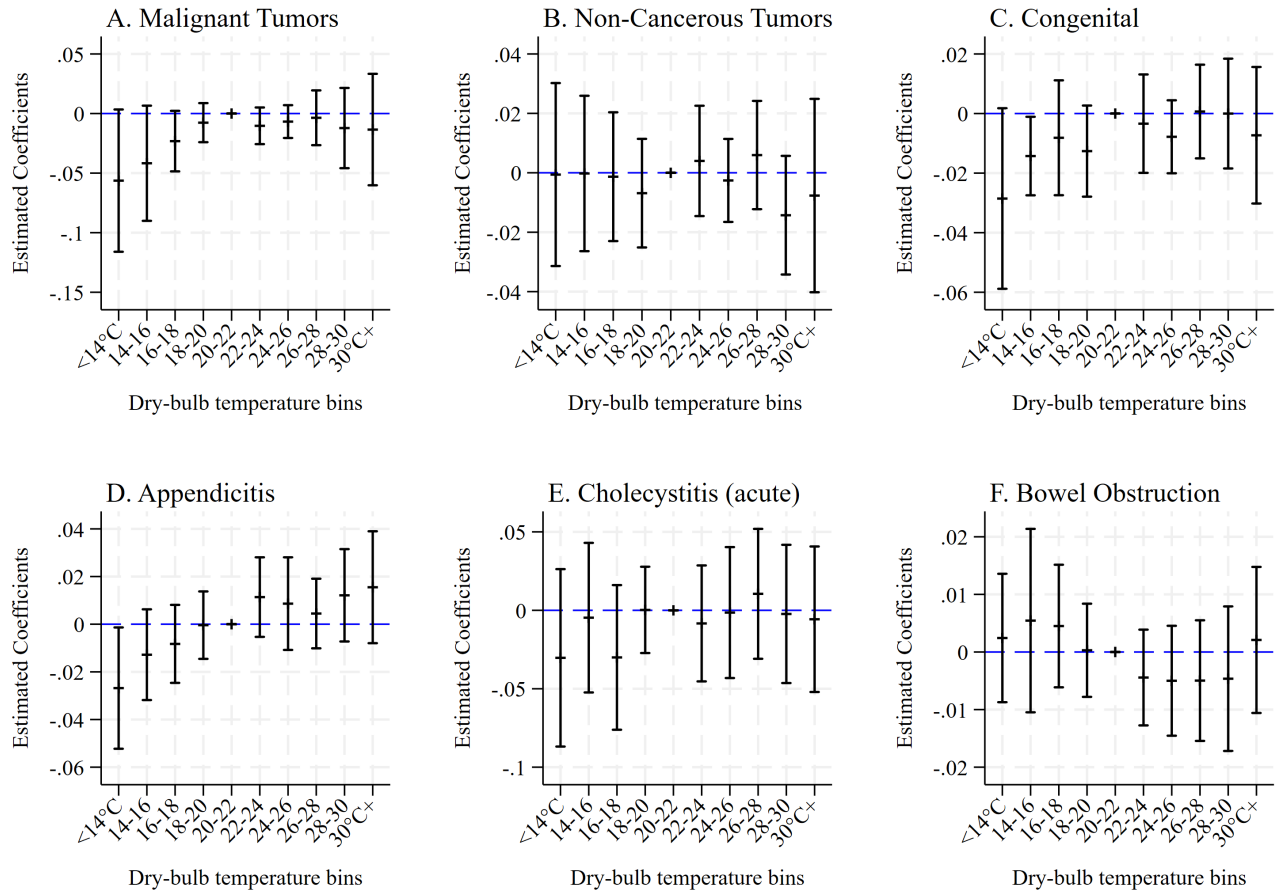
Notes: Rurality classification is based on the 2010 Census INEGI's municipality classification according to locality size. Municipalities are classified as Rural if more than 50% of their population lives in rural (localities with population < 2,500), semi-urban (with 2.5K-15K), or mixed (no single category exceeds 50%) areas. Municipalities are classified as Urban if more than 50% of their population lives in metropolitan (> 1 million), large urban (100K-1 million), or medium urban (15K-100K) areas.

causal temperature effect, future weeks' temperature conditions should not predict current health outcomes. Appendix Figure F.4 shows results when we include temperature bins from one and two weeks in the future alongside contemporaneous temperature measures. For the clinical outcomes in Panel A (left), we see clean falsification results, where the outcomes are objective and behavioral – actual emergency department visits, suicides, and deaths. Future weather can't cause someone to go to ED today.

But for the self-reported outcomes in Panel B (right), people are being asked to evaluate their current mental state or how they felt *yesterday*, and we see some significant future temperature effects. This likely reflects psychological anticipation effects, where anticipating uncomfortable weather conditions through forecasts makes respondents rate their current mental state more negatively; we cannot rule out systematic survey timing patterns that coincide with certain temperature forecasts. Recall that self-reported mental well-being surveys are conducted quarterly (January, April, July, and October) every year.

Third, we cluster standard errors by municipality interacted with week of the year and by municipality interacted with month of the year, and the main results remain robust.

Figure 12: Falsification Tests



Notes: All dependent variables are presented as rates per million residents within each municipality. Malignant Tumors in Panel A includes all ED visits with the primary diagnosis of ICD-10 C 00-97: Malignant neoplasms; Non-cancerous Tumors in Panel B includes D 10-36: Benign neoplasms; Congenital in Panel C includes Q 00-99: Congenital malformations, deformations and chromosomal abnormalities; Appendicitis in Panel D includes K 35-38: Diseases of appendix; Cholecystitis in Panel E includes K 81: Cholecystitis; and Bowel Obstruction in F includes K 56: Paralytic ileus and intestinal obstruction without hernia. All specifications control for the municipality by week-of-the-year fixed effects and state by year fixed effects, as well as weekly rainfall exposure. For additional details, please refer to the notes for Figure 3.

7 Conclusion with Discussion

We provide evidence that rising temperatures are linked to worsened mental health in Mexico. Using multiple administrative and survey data sources, we document that higher temperatures increase suicides and emergency department (ED) visits for mental illness, while reducing self-reported well-being. These effects are substantial: one additional hot day above 30°C per week raises suicides by 3.2 percent and mental illness ED visits by about 2.4 percent. Our findings show that heat affects a wide range of mental health outcomes, from subclinical distress to fatal crises.

Our analysis further shows that these impacts are not uniform across type of mental disorders or populations. Mood, neurotic, and substance use disorders display the largest increases in emergency visits. Women are more likely to seek care for heat-related psychological distress through ED visits, whereas men drive the rise in suicides under heat exposure. Older adults also experience disproportionate effects, pointing to the need for age- and gender-sensitive prevention and outreach.

We provide suggestive evidence that behavioral adjustments, such as reduced outdoor physical activity and greater time spent indoors, may accompany these mental health effects, while sleep disruption appears limited. These results are consistent with prior findings for Mexico and indicate that ordinary coping behaviors during hot periods, while adaptive in the short term, can also diminish protective routines like exercise and social interaction (Cohen and Gonzalez, 2024).

Institutional and infrastructural forms of adaptation appear limited. Municipalities that have both psychiatrists and psychologists experience smaller increases in mental health ED visits during hot weeks than those with little or no professional coverage. This pattern is consistent with greater local capacity for early stabilization or for providing alternatives to emergency care. However, these differences should not be interpreted causally, as the availability of professionals is strongly correlated with broader socioeconomic and institutional characteristics. Access to air conditioning (A/C) and urban infrastructure shows no consistent protective effect, suggesting that technological or environmental adaptation alone may not suffice to buffer mental health stressors when the overall A/C penetration is low. Our results suggest that Mexico's current adaptive landscape remains constrained in its ability to mitigate the immediate psychological impacts of heat exposure.

We can translate these estimates into approximate economic terms. Sustaining one additional day above 30°C per week across a twelve-week summer corresponds to an estimated

annual economic loss of roughly \$860,000, based on Mexico's value of a statistical life.³³ While modest in aggregate terms, this figure captures only the mortality cost from suicides. The total societal burden would be far larger once we account for heat-related emergency visits for mental illness, long-term mental illness, and productivity losses associated with reduced well-being (Chisholm et al., 2016; Evans-Lacko and Knapp, 2016). These costs are typically absent from climate damage assessments, yet they likely represent a meaningful share of the welfare losses induced by extreme heat.

The policy implications are twofold. First, the mental health burden of heat manifests differently across the population. While men experience higher suicide risks, women and individuals in school and working ages exhibit greater vulnerability through nonfatal distress and service use. Policymakers should therefore evaluate not only mortality but also multiple indicators of mental health burden when designing heat adaptation and preparedness strategies. Second, strengthening the mental health system itself may constitute an important form of climate adaptation. Expanding psychiatrist availability could help stabilize crises before they escalate into emergency care, particularly in underserved regions, although further research is needed to assess these effects causally.

More broadly, climate adaptation strategies should explicitly recognize the mental health consequences of extreme temperatures, which remain largely invisible in current climate-economy frameworks. Mental health is rarely included in estimates of climate damages or adaptation benefits, particularly in low- and middle-income countries.

³³Calculated using 0.003 additional suicides per million residents $\times$ 113 million residents $\times$ 12 weeks $\times$ \$210,880 per person (de Lima, 2020).

References

- Adhvaryu, A., N. Kala, and A. Nyshadham (2020) “The Light and the Heat: Productivity Co-Benefits of Energy-Saving Technology,” *The Review of Economics and Statistics*, 102 (4), 779–792.
- Aguilar-Gomez, S., J. S. G. Zivin, and M. J. Neidell (2025) “Killer congestion: Temperature, healthcare utilization and patient outcomes,” Technical report, National Bureau of Economic Research.
- Altemus, M., N. Sarvaiya, and C. Neill Epperson (2014) “Sex differences in anxiety and depression clinical perspectives,” *Frontiers in neuroendocrinology*, 35 (3), 320–330.
- Arias, P., N. Bellouin, E. Coppola, R. Jones, G. Krinner, J. Marotzke, V. Naik, M. Palmer, G.-K. Plattner, J. Rogelj et al. (2021) “Climate Change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; technical summary.”
- Barreca, A., K. Clay, O. Deschenes, M. Greenstone, and J. S. Shapiro (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.
- Barreca, A., R. J. Park, and P. Stainier (2022) “High temperatures and electricity disconnections for low-income homes in California,” *Nature Energy*, 7 (11), 1052–1064.
- Barrón-Velázquez, E., J. J. Mendoza-Velásquez, A. Mercado-Lara, J. M. Quijada-Gaytán, and J. F. Flores-Vázquez (2024) “The mental health provider shortage in the Mexican public sector: 2023 estimates of psychiatrists and psychologists,” *Salud mental*, 47 (4), 179–187.
- Baylis, P. (2020) “Temperature and temperament: Evidence from Twitter,” *Journal of public economics*.
- Behrer, P. (2025) “Mismeasured weather and the challenges of satellite data,” World Bank Blogs.
- Berenzon, S., H. Senties, and E. Medina-Mora (2009) “Mental health services in Mexico,” *International Psychiatry*, 6 (4), 93–95.
- Bessone, P., G. Rao, F. Schilbach, H. Schofield, and M. Toma (2021) “The Economic Consequences of Increasing Sleep Among the Urban Poor,” *The Quarterly Journal of Economics*, 136 (3), 1887–1941.
- Bianco, G., R. M. Espinoza-Chávez, P. G. Ashigbie, H. Junio, C. Borhani, S. Miles-Richardson, and J. Spector (2024) “Projected impact of climate change on human health in low-and middle-income countries: a systematic review,” *BMJ Global Health*, 8 (Suppl 3), e015550.
- Bruckner, T. A., P. Singh, B. Chakravarthy, L. Snowden, and J. Yoon (2019) “Psychiatric emergency department visits after regional expansion of community health centers,” *Psychiatric Services*, 70 (10), 901–906.
- Buguet, A. (2007) “Sleep under Extreme Environments: Effects of Heat and Cold Exposure, Altitude, Hyperbaric Pressure and Microgravity in Space,” *Journal of the Neurological Sciences*, 262 (1-2), 145–152.
- Burgess, R., O. Deschenes, D. Donaldson, and M. Greenstone (2011) “Weather and Death in India: Mechanisms and Implications for climate change,” *Cambridge, United States: Massachusetts Institute of Technology, Department of Economics. Mimeographed document*.
- Burke, M., F. González, P. Baylis, S. Heft-Neal, C. Baysan, S. Basu, and S. Hsiang (2018) “Higher Temperatures Increase Suicide Rates in the United States and Mexico,” *Nature Climate Change*, 8 (8), 723–729.
- Cabello-Rangel, H., H. Reyes-Morales, M. E. Medina-Mora, and A. Arredondo-López (2021) “Out-of-pocket and catastrophic expenses in households of patients with schizophrenia lacking social security,” *salud pública de méxico*, 63 (4), 547–553.
- Carleton, T. et al. (2022) “Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits*,” *The quarterly journal of economics*, 137 (4), 2037–2105.
- Carretero, O. A. and S. Oparil (2000) “Essential Hypertension: Part I: Definition and Etiology,” *Circulation*, 101 (3), 329–335.
- Carrillo, A. E., A. D. Flouris, C. L. Herry, M. P. Poirier, P. Boulay, S. Dervis, B. J. Friesen, J. Malcolm, R. J. Sigal, A. J. Seely et al. (2016) “Heart rate variability during high heat stress: a comparison between young and older adults with and without Type 2 diabetes,” *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 311 (4), R669–R675.
- Carrillo, B. (2020) “Early Rainfall Shocks and Later-Life Outcomes: Evidence from Colombia,” *The World*

- Bank economic review*, 34 (1), 179–209.
- Chauhan, N. R., M. Kapoor, L. P. Singh, R. K. Gupta, R. C. Meena, R. Tulsawani, S. Nanda, and S. B. Singh (2017) “Heat stress-induced neuroinflammation and aberration in monoamine levels in hypothalamus are associated with temperature dysregulation,” *Neuroscience*, 358, 79–92.
- Cheong, S.-M. and I. Gaynanova (2024) “Sensing the impact of extreme heat on physical activity and sleep,” *Digital Health*, 10, 20552076241241509.
- Chisholm, D., K. Sweeny, P. Sheehan, B. Rasmussen, F. Smit, P. Cuijpers, and S. Saxena (2016) “Scaling-up treatment of depression and anxiety: a global return on investment analysis,” *The Lancet Psychiatry*, 3 (5), 415–424.
- Cianconi, P., S. Betrò, and L. Janiri (2020) “The Impact of Climate Change on Mental Health: A Systematic Descriptive Review,” *Frontiers in Psychiatry*, 11, 74.
- Cohen, F. and F. Gonzalez (2024) “Understanding the Link between Temperature and Crime,” *American Economic Journal: Economic Policy*, 16 (2), 480–514.
- Colelli, F. P., I. S. Wing, and E. D. Cian (2023) “Air-conditioning adoption and electricity demand highlight climate change mitigation–adaptation tradeoffs,” *Scientific reports*, 13 (1), 1–12.
- Colmer, J. and J. L. Doleac (2023) “Access to guns in the heat of the moment: more restrictive gun laws mitigate the effect of temperature on violence,” *Review of Economics and Statistics*, 1–40.
- Conti, S., M. Masocco, P. Meli, G. Minelli, E. Palummeri, R. Solimini, V. Toccaceli, and M. Vichi (2007) “General and specific mortality among the elderly during the 2003 heat wave in Genoa (Italy),” *Environmental research*, 103 (2), 267–274.
- Cordero-Oropeza, M., S. Berenzon, R. Robles, T. Real, and M. E. Medina Mora (2021) “Community-Based Mental Health Services in Mexico,” *Consortium PSYCHIATRICUM*, 2 (3), 53–62.
- Cornwall, W. (2023) “Schizophrenia pinpointed as a key factor in heat deaths,” *Science*, 379 (6637), 1079.
- Debray, A., S. Sardar, T. A. Deshayes, A. Mornas, K. Oubouchou, Y. Ouazaa, and D. Gagnon (2025) “Sex-related differences in temperature regulation during heat stress from childhood to older age,” *Autonomic Neuroscience*, 103294.
- Deryugina, T. and S. M. Hsiang (2014) “Does the Environment Still Matter? Daily Temperature and Income in the United States,” *NBER Working Paper*.
- Deschênes, O. and M. Greenstone (2011) “Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather in the US,” *American Economic Journal: Applied Economics*, 3 (4), 152–185.
- Díaz-Castro, L., H. Cabello-Rangel, C. Pineda-Antúnez, and A. P. de León (2021) “Incidence of catastrophic healthcare expenditure and its main determinants in Mexican households caring for a person with a mental disorder,” *Global Mental Health*, 8, e2.
- Diener, E. ed. (2009) *Assessing well-being: The collected works of ed Diener*, Social Indicators Research Series, Dordrecht, Netherlands: Springer, 2009th edition.
- Dillender, M. (2021) “Climate Change and Occupational Health: Are There Limits to Our Ability to Adapt?” *Journal of Human Resources*, 56 (1), 184–224.
- Domínguez, T., D. P. Puebla, A. Fresán, T. Sheinbaum, L. Nieto, R. Robles, S. R. López, C. de la Fuente-Sandoval, M. D. C. L. Muñoz, N. Barrantes-Vidal et al. (2024) “Why do some Mexicans with psychosis risk symptoms seek mental health care and others do not?” *Psychiatry Research*, 342, 116199.
- Doremus, J. M., I. Jacqz, and S. Johnston (2022) “Sweating the energy bill: Extreme weather, poor households, and the energy spending gap,” *Journal of environmental economics and management*, 112, 102609.
- Evans-Lacko, S. and M. Knapp (2016) “Global patterns of workplace productivity for people with depression: absenteeism and presenteeism costs across eight diverse countries,” *Social psychiatry and psychiatric epidemiology*, 51 (11), 1525–1537.
- Friedman, A. S. (2020) “Smoking to Cope: Addictive Behavior as a Response to Mental Distress,” *Journal of Health Economics*, 72, 102323.
- Gaoua, N. (2010) “Cognitive function in hot environments: a question of methodology,” *Scandinavian journal of medicine & science in sports*, 20, 60–70.
- Gasparrini, A., Y. Guo, M. Hashizume, E. Lavigne, A. Zanobetti, J. Schwartz, A. Tobias, S. Tong, J. Rocklöv, B. Forsberg et al. (2015) “Mortality risk attributable to high and low ambient temperature: a

- multicountry observational study," *The lancet*, 386 (9991), 369–375.
- Gearing, R. E., K. B. Brewer, M. Washburn, M. Yu, P. I. de la Cruz, A. Garcia Andres, and L. R. Torres (2024) "Mental health help-seeking in Mexico," *Global health promotion*, 31 (1), 55–64.
- Geruso, M. and D. Spears (2018) "Heat, Humidity, and Infant Mortality in the Developing World."
- Gilbert, J. L., B. B. Nelson, J. Britz, B. Webel, E. French, J. H. Lee, E. R. Wolf, E. M. Brooks, R. T. Sabo, A. S. Wright et al. (2025) "Trends in Emergency Department, Primary Care, and Behavioral Health Use for Pediatric Mental Health Conditions in Virginia before and during the COVID-19 pandemic," *BMC Primary Care*, 26 (1), 1–8.
- Gliske, K., J. Ballard, K. R. Berry, M. Killian, E. Kroll, and C. Fenkel (2023) "Reduction of mental health-related emergency department admissions for youth and young adults following a remote intensive outpatient program: quality improvement analysis," *JMIR formative research*, 7, e47895.
- Hallegatte, S. (2016) *Shock waves: managing the impacts of climate change on poverty*: World Bank Publications.
- Hansen, A., P. Bi, M. Nitschke, P. Ryan, D. Pisaniello, and G. Tucker (2008) "The effect of heatwaves on mental health in a temperate Australian city," *Epidemiology*, 19 (6), S85.
- Heffetz, O. and Y. Caspi (2025) "Measuring Self-Reported Well-Being," *NBER Working Paper Series*, 33847.
- Heutel, G., N. H. Miller, and D. Molitor (2021) "Adaptation and the mortality effects of temperature across US climate regions," *Review of Economics and Statistics*, 103 (4), 740–753.
- Ho, J. Y., W. B. Goggins, P. K. Mo, and E. Y. Chan (2022) "The effect of temperature on physical activity: an aggregated timeseries analysis of smartphone users in five major Chinese cities," *International Journal of Behavioral Nutrition and Physical Activity*, 19 (1), 68.
- Ho, J. Y., H. Y. Lam, Z. Huang, S. Liu, W. B. Goggins, P. K. Mo, and E. Y. Chan (2023) "Factors affecting outdoor physical activity in extreme temperatures in a sub-tropical Chinese urban population: an exploratory telephone survey," *BMC Public Health*, 23 (1), 101.
- Holt-Lunstad, J. (2022) "Social connection as a public health issue: The evidence and a systemic framework for prioritizing the "social" in social determinants of health," *Annual Review of Public Health*, 43 (1), 193–213.
- Hong, Y. (2025) "Heat and humidity on early-life outcomes: Evidence from Mexico," *Journal of Environmental Economics and Management*, 129, 103082.
- Hsiang, S. (2016) "Climate Econometrics," *Annual Review of Resource Economics*.
- Hua, Y., Y. Qiu, and X. Tan (2023) "The Effects of Temperature on Mental Health: Evidence from China," *Journal of Population Economics*, 36 (3), 1293–1332.
- Huang, Y., L. Li, Y. Gan, C. Wang, H. Jiang, S. Cao, and Z. Lu (2020) "Sedentary behaviors and risk of depression: a meta-analysis of prospective studies," *Translational psychiatry*, 10 (1), 26.
- Irwin, M. R. (2023) "Sleep disruption induces activation of inflammation and heightens risk for infectious disease: Role of impairments in thermoregulation and elevated ambient temperature," *Temperature (Austin, Tex.)*, 10 (2), 198–234.
- Janzen, B. (2025) "Temperature and mental health: Evidence from helpline calls," *Journal of the Association of Environmental and Resource Economists*, 12 (6), 1431–1457.
- Johnson, H. M. (2019) "Anxiety and Hypertension: Is There a Link? A Literature Review of the Comorbidity Relationship Between Anxiety and Hypertension," *Current Hypertension Reports*, 21 (9), 66.
- Kuruc, K., M. LoPalo, and S. O'Connor (2025) "The willingness to pay for a cooler day: Evidence from 50 years of Major League Baseball games," *American Economic Journal. Applied Economics*, 17 (1), 126–159.
- Landa-Ramírez, E., L. P. Díaz-Vásquez, M. E. Hernández-Nuñez, J. Castillo-Cruz, G. X. Ortega-Ramírez, A. H. Guerrero-Martínez, N. A. Domínguez-Vieyra, and A. López-Gómez (2024) "Patients' Mental Health and Length of Stay in Emergency Departments in Mexico," *Salud mental*, 47 (4), 171–177.
- Lavigne, E., A. Maltby, J.-N. Côté, K. R. Weinberger, C. Hebborn, A. M. Vicedo-Cabrera, and P. Wilk (2023) "The effect modification of extreme temperatures on mental and behavior disorders by environmental factors and individual-level characteristics in Canada," *Environmental research*, 219 (114999), 114999.

- Lee, H., K. Calvin, D. Dasgupta, G. Krinner, A. Mukherji, P. Thorne, C. Trisos, J. Romero, P. Aldunce, K. Barret et al. (2023) "IPCC, 2023: Climate change 2023: Synthesis report, summary for policy-makers. Contribution of working groups I, II and III to the sixth assessment report of the intergovernmental panel on climate change [core writing team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland."
- Lee, M. J., K. E. McLean, M. Kuo, G. R. A. Richardson, and S. B. Henderson (2023) "Chronic Diseases Associated With Mortality in British Columbia, Canada During the 2021 Western North America Extreme Heat Event," *GeoHealth*, 7 (3), e2022GH000729.
- Lee, S., H. Lee, W. Myung, E. J. Kim, and H. Kim (2018) "Mental Disease-Related Emergency Admissions Attributable to Hot Temperatures," *Science of The Total Environment*, 616–617, 688–694.
- Li, K., S. B. Henderson, E. S. Coker, K. E. McLean, and M. J. Lee (2025) "The association between hot days and substance-related suicides: a time-stratified case-crossover analysis in British Columbia, Canada," *Environmental Health*, 24 (1), 25.
- de Lima, M. (2020) "The value of a statistical life in Mexico," *Journal of Environmental Economics and Policy*, 9 (2), 140–166.
- Linares, C., D. Culqui, R. Carmona, C. Ortiz, and J. Díaz (2017) "Short-term association between environmental factors and hospital admissions due to dementia in Madrid," *Environmental research*, 152, 214–220.
- Liu, J., B. M. Varghese, A. Hansen, J. Xiang, Y. Zhang, K. Dear, M. Gourley, T. Driscoll, G. Morgan, A. Capon et al. (2021) "Is there an association between hot weather and poor mental health outcomes? A systematic review and meta-analysis," *Environment international*, 153, 106533.
- Liu, M.-Y., N. Li, W. A. Li, and H. Khan (2017) "Association between Psychosocial Stress and Hypertension: A Systematic Review and Meta-Analysis," *Neurological Research*, 39 (6), 573–580.
- Löhmus, M. (2018) "Possible Biological Mechanisms Linking Mental Health and Heat—A Contemplative Review," *International Journal of Environmental Research and Public Health*, 15 (7), 1515.
- LoPalo, M. (2023) "Temperature, Worker Productivity, and Adaptation: Evidence from Survey Data Production," *American Economic Journal: Applied Economics*, 15 (1), 192–229.
- McLean, C. P., A. Asnaani, B. T. Litz, and S. G. Hofmann (2011) "Gender differences in anxiety disorders: prevalence, course of illness, comorbidity and burden of illness," *Journal of psychiatric research*, 45 (8), 1027–1035.
- McMorris, T., J. Swain, M. Smith, J. Corbett, S. Delves, C. Sale, R. C. Harris, and J. Potter (2006) "Heat stress, plasma concentrations of adrenaline, noradrenaline, 5-hydroxytryptamine and cortisol, mood state and cognitive performance," *International journal of psychophysiology*, 61 (2), 204–215.
- Medina-Mora, M. E., G. Borges, C. Lara, C. Benjet, J. Blanco, C. Fleiz, J. Villatoro, E. Rojas, and J. Zambrano (2005) "Prevalence, service use, and demographic correlates of 12-month DSM-IV psychiatric disorders in Mexico: results from the Mexican National Comorbidity Survey," *Psychological medicine*, 35 (12), 1773–1783.
- Medina-Mora, M. E., G. Borges, C. Benjet, C. Lara, and P. Berglund (2007) "Psychiatric disorders in Mexico: lifetime prevalence in a nationally representative sample," *The British Journal of Psychiatry*, 190 (6), 521–528.
- Mullins, J. T. and C. White (2019) "Temperature and Mental Health: Evidence from the Spectrum of Mental Health Outcomes," *Journal of Health Economics*, 68, 102240.
- Nesper, A. C., B. A. Morris, L. M. Scher, and J. F. Holmes (2016) "Effect of decreasing county mental health services on the emergency department," *Annals of emergency medicine*, 67 (4), 525–530.
- Noelke, C., M. McGovern, D. J. Corsi, M. P. Jimenez, A. Stern, I. S. Wing, and L. Berkman (2016) "Increasing ambient temperature reduces emotional well-being," *Environmental research*, 151, 124–129.
- Nori-Sarma, A., S. Sun, Y. Sun, K. R. Spangler, R. Oblath, S. Galea, J. L. Gradus, and G. A. Wellenius (2022) "Association Between Ambient Heat and Risk of Emergency Department Visits for Mental Health Among US Adults, 2010 to 2019," *JAMA psychiatry*, 79 (4), 341–349.
- Obradovich, N., R. Migliorini, S. C. Mednick, and J. H. Fowler (2017) "Nighttime temperature and human sleep loss in a changing climate," *Science advances*, 3 (5), e1601555.
- Obradovich, N., R. Migliorini, M. P. Paulus, and I. Rahwan (2018) "Empirical Evidence of Mental Health

- Risks Posed by Climate Change,” *Proceedings of the National Academy of Sciences*, 115 (43), 10953–10958.
- OECD (2023) “Financial hardship and out-of-pocket expenditure: Health at a Glance 2023,” Accessed: 2025-10-13.
- Okafor, N., E. Okoro, M. M. Bojerenu, N. Umeani, D. C. Udegbe, C. K. Omeh, C. G. Nwume, T. D. Alabi, I. A. Fouhad, V. Okpujie et al. (2024) “National Case Volumes and Gender Disparities in Emergency Department Utilization for Psychiatric Emergencies: A Population-Based Claims Data Analysis,” *Cureus*, 16 (8).
- O’Neill, M. S., A. Zanobetti, and J. Schwartz (2005) “Disparities by race in heat-related mortality in four US cities: the role of air conditioning prevalence,” *Journal of urban health*, 82 (2), 191–197.
- Pailler, S. and M. Tsaneva (2018) “The effects of climate variability on psychological well-being in India,” *World Development*, 106, 15–26.
- Park, R. J., A. P. Behrer, and J. Goodman (2021) “Learning is inhibited by heat exposure, both internationally and within the United States,” *Nature Human Behaviour*, 5 (1), 19–27.
- Ramadan, M., A. M. Fallatah, Y. F. Batwa, Z. Saifaddin, M. S. Mirza, M. Aldabbagh, and N. Alhusseini (2022) “Trends in emergency department visits for mental health disorder diagnoses before and during the COVID-19 pandemic: a retrospective cohort study 2018–2021,” *BMC psychiatry*, 22 (1), 378.
- Reed, D. E., 2nd, C. C. Engel, S. Coggeshall, M. Michel, B. Etingen, R. E. Bolton, K. Kroenke, B. G. Bokhour, and S. B. Zeliadt (2024) “Is the PHQ-2 a good measure to inform providers about patient well-being and functioning? Data from the Veterans health and life survey,” *Medical care*, 62 (12 Suppl 1), S76–S83.
- Ridley, M., G. Rao, F. Schilbach, and V. Patel (2020) “Poverty, Depression, and Anxiety: Causal Evidence and Mechanisms,” *Science*, 370 (6522), eaay0214.
- Rocha, R. and R. R. Soares (2015) “Water scarcity and birth outcomes in the Brazilian semiarid,” *Journal of development economics*, 112, 72–91.
- Romanello, M., M. Walawender, S.-C. Hsu, A. Moskeland, Y. Palmeiro-Silva, D. Scamman, Z. Ali, N. Ameli, D. Angelova, S. Ayeb-Karlsson et al. (2024) “The 2024 report of the Lancet Countdown on health and climate change: facing record-breaking threats from delayed action,” *The Lancet*, 404 (10465), 1847–1896.
- Rony, M. K. K. and H. M. Alamgir (2023) “High temperatures on mental health: Recognizing the association and the need for proactive strategies-A perspective,” *Health science reports*, 6 (12), e1729.
- Saldaris, J. M., G. J. Landers, and B. S. Lay (2020) “Physical and perceptual cooling: Improving cognitive function, mood disturbance and time to fatigue in the heat,” *Scandinavian journal of medicine & science in sports*, 30 (4), 801–811.
- Schuch, F. B., D. Vancampfort, J. Firth, S. Rosenbaum, P. B. Ward, E. S. Silva, M. Hallgren, A. Ponce De Leon, A. L. Dunn, A. C. Deslandes et al. (2018) “Physical activity and incident depression: a meta-analysis of prospective cohort studies,” *American journal of psychiatry*, 175 (7), 631–648.
- Secretaría de Salud (2023) *Instructivo de llenado de la hoja diaria del servicio de urgencias (SINBA-SEUL-16-P DGIS) – Versión 2024*, Sistema Nacional de Información Básica en Materia de Salud (SINBA), Ciudad de México, México, Fecha del documento: Diciembre, 2023.
- Sera, F., M. Hashizume, Y. Honda, E. Lavigne, J. Schwartz, A. Zanobetti, A. Tobias, C. Iñiguez, A. M. Vicedo-Cabrera, M. Blangiardo et al. (2020) “Air conditioning and heat-related mortality: a multi-country longitudinal study,” *Epidemiology*, 31 (6), 779–787.
- Sharpe, I. and C. M. Davison (2021) “Climate change, climate-related disasters and mental disorder in low-and middle-income countries: a scoping review,” *BMJ open*, 11 (10), e051908.
- Soini, E., T. Rosenström, I. Määttänen, and M. Jokela (2024) “Physical activity and specific symptoms of depression: A pooled analysis of six cohort studies,” *Journal of affective disorders*, 348, 44–53.
- Sun, S., K. R. Weinberger, A. Nori-Sarma, K. R. Spangler, Y. Sun, F. Dominici, and G. A. Wellenius (2021) “Ambient heat and risks of emergency department visits among adults in the United States: time stratified case crossover study,” *Bmj*, 375.
- Sung, T.-I., M.-J. Chen, C.-Y. Lin, S.-C. Lung, and H.-J. Su (2011) “Relationship between mean daily ambient temperature range and hospital admissions for schizophrenia: Results from a national cohort

- of psychiatric inpatients," *The Science of the total environment*, 410-411, 41–46.
- Tan, X. R., M. C. Stephenson, S. B. Alhadad, K. W. Loh, T. W. Soong, J. K. Lee, and I. C. Low (2024) "Elevated brain temperature under severe heat exposure impairs cortical motor activity and executive function," *Journal of Sport and Health Science*, 13 (2), 233–244.
- Tang, M., Y. He, X. Zhang, H. Li, C. Huang, C. Wang, Y. Gao, Y. Li, H. Kan, J. Hu et al. (2021) "The acute effects of temperature variability on heart rate variability: a repeated-measure study," *Environmental research*, 194, 110655.
- Trang, P. M., J. Rocklöv, K. B. Giang, H. Minh, L. T. Tinh, and M. Nilsson (2015) "Weather variations and hospital admissions for depressive disorders : A case study in Hanoi," *Annals of Psychiatry and Mental Health*, 3 (1).
- Trang, P. M., J. Rocklöv, K. B. Giang, and M. Nilsson (2016) "Seasonality of hospital admissions for mental disorders in Hanoi, Vietnam," *Global health action*, 9, 32116.
- Vecellio, D. J., S. T. Wolf, R. M. Cottle, and W. L. Kenney (2022) "Evaluating the 35°C wet-bulb temperature adaptability threshold for young, healthy subjects (PSU HEAT Project)," *Journal of applied physiology*, 132 (2), 340–345.
- Vergunst, F., H. L. Berry, K. Minor, and N. Chadi (2023) "Climate change and substance-use behaviors: a risk-pathways framework," *Perspectives on Psychological Science*, 18 (4), 936–954.
- Wang, X., E. Lavigne, H. Ouellette-kuntz, and B. E. Chen (2014) "Acute Impacts of Extreme Temperature Exposure on Emergency Room Admissions Related to Mental and Behavior Disorders in Toronto, Canada," *Journal of Affective Disorders*, 155, 154–161.
- World Health Organization (2021) "Mental Health Atlas 2020: Member State Profile — Mexico," https://cdn.who.int/media/docs/default-source/mental-health/mental-health-atlas-2020-country-profiles/mex.pdf?download=true&sfvrsn=c3c55383_5, Accessed: 2025-10-13.
- (2022) "Mental health and climate change: Policy brief," policy brief, World Health Organization.
- (2025) "Mental disorders," <https://www.who.int/news-room/fact-sheets/detail/mental-disorders>, Accessed: 2025-10-15.
- Xie, Y., Z. Wu, L. Sun, L. Zhou, G. Wang, L. Xiao, and H. Wang (2021) "The effects and mechanisms of exercise on the treatment of depression," *Frontiers in psychiatry*, 12, 705559.
- Yoo, E.-h., Y. Eum, Q. Gao, and K. Chen (2021) "Effect of Extreme Temperatures on Daily Emergency Room Visits for Mental Disorders," *Environmental Science and Pollution Research*, 28 (29), 39243–39256.
- Yoo, S.-S., N. Gujar, P. Hu, F. A. Jolesz, and M. P. Walker (2007) "The human emotional brain without sleep—a prefrontal amygdala disconnect," *Current biology: CB*, 17 (20), R877–8.
- Zhai, L., Y. Zhang, and D. Zhang (2015) "Sedentary behaviour and the risk of depression: a meta-analysis," *British journal of sports medicine*, 49 (11), 705–709.
- Zhang, P., O. Deschenes, K. Meng, and J. Zhang (2018) "Temperature effects on productivity and factor reallocation: Evidence from a half million chinese manufacturing plants," *Journal of environmental economics and management*, 88, 1–17.
- Zhao, D., X. Zhang, M. Xie, J. Cheng, H. Zhang, S. Wang, K. Li, H. Yang, L. Wen, X. Wang, and H. Su (2016) "Is greater temperature change within a day associated with increased emergency admissions for schizophrenia?" *The Science of the total environment*, 566-567, 1545–1551.
- Zhou, Y., Y. Gao, P. Yin, C. He, W. Liu, H. Kan, M. Zhou, and R. Chen (2023) "Assessing the burden of suicide death associated with nonoptimum temperature in a changing climate," *JAMA psychiatry*, 80 (5), 488–497.

The Psychological Toll of Heat: The Effects of Temperature on Mental Health in Mexico

- Appendix -

Yumin Hong & Antonia Vazquez

A	The Stull Method for Wet-bulb Temperatures	A2
B	Weather datasets: NOAA-NARR and CONAGUA	A2
C	Linking Mental Health Data and Weather Data at the Weekly Level	A3
D	Primary ICD-10 Code Assignment for Emergency Department Visits	A5
E	Secondary Outcomes: Stress, Blood Pressure, and Smoking Behavior	A6
F	Appendix Figures and Tables	A10

A The Stull Method for Wet-bulb Temperatures

We use the Stull method formula to calculate wet-bulb temperature as in the following equation:

$$T_{wb} = T_{db} * \operatorname{atan}\{0.151977 * (RH + 8.313658)^{\frac{1}{2}}\} + \operatorname{atan}(T_{db} + RH) - \operatorname{atan}(RH - 1.676331) + 0.00391838 * RH^{\frac{3}{2}} * \operatorname{atan}(0.023101 * RH) - 4.686035 \quad (3)$$

where relative humidity (RH) is defined as

$$RH = 0.263 * PRES * SH * \{ \exp(\frac{17.67 * (T_{db} - 0.01)}{T_{db} - 243.5}) \}^{-1} \quad (4)$$

and wet-bulb (T_{wb}) and dry-bulb (T_{db}) temperatures are in degrees in Celsius ($^{\circ}\text{C}$), RH is in %, and air pressure ($PRES$) is in Pacals (Pa).

Within the framework of the Stull formula for constructing the wet-bulb temperature, two principal insights emerge. Firstly, the wet-bulb temperature, by definition, is the lowest temperature that can be reached through the process of evaporative cooling and is, therefore, always lower than the corresponding dry-bulb temperature. This characteristic reflects the wet-bulb temperature's role as a measure of the cooling potential of the air. Secondly, the relationship between wet-bulb and dry-bulb temperatures is not a straightforward linear one. This non-linearity means that a simple one-to-one comparison between the two temperature readings is not possible. Instead, this relationship is influenced by a complex set of atmospheric conditions including relative humidity, air pressure, and the thermal properties of water vapor, all of which affect the rate of evaporation and the consequent cooling effect.

B Weather datasets: NOAA-NARR and CONAGUA

Table B.1: Correlation Between NARR (NOAA) and CONAGUA Dry-bulb Temperatures

	NARR	CONAGUA
NARR	1.000	
CONAGUA	0.577*	1.000

Notes: Pairwise correlation computed across municipality-day observations between modeled dry-bulb temperature from NARR and observed temperature from CONAGUA. * indicates significance at the 5% level.

C Linking Mental Health Data and Weather Data at the Weekly Level

In this section, we describe the process of linking weather data and mental health data at the weekly level. Although both datasets are initially provided at the daily level, we aggregate them to a weekly level due to concerns about potential measurement errors in the daily data.

The mental health data presented measurement concerns at the daily level, showing unusual patterns of data accumulation at the midnight (00:00), specifically. We were not able to identify if these records actually occurred on that day or were automatically registered from the previous day. To minimize potential measurement error from this timing uncertainty, we aggregate the data to weekly measures.

Similarly, the weather data exhibited some suspicious patterns at the daily level. For instance, some daily maximum temperatures were recorded at 9PM (although we do not utilize the maximum-minimum temperature information because of this reason), which is implausible in Mexico where maximum temperatures typically occur in the late afternoon (3-6PM). This further supported the decision to aggregate to weekly measures.

The weather variables in this study consist of ten temperature bins that count the number of days in each week falling into specific temperature ranges, as detailed in equation 1. Crucially, these variables require a consistent seven-day base for proper measurement. Each temperature bin variable ranges from 0 to 7, where 0 indicates no days in that temperature range during the week, and 7 indicates all seven days fell in that range. These bins are mutually exclusive – for instance, if the 10th temperature bin equals 7 (indicating all days were above 30°C), the other temperature bins must equal 0.

To link these datasets, we need to construct a unique week identifier. Stata's built-in date functions proved inadequate for this purpose. The *week* function generates values from 1-52, but this creates problems for partial weeks at year boundaries. For example, 2024/12/31 falls on a Tuesday, meaning the 52nd week of 2024 would only contain three days, and the 1st week of 2025 would have four days. This breaks the 7-day consistency required for defining the temperature bins variable in equation 1.

We also explored Stata's *yw* function, which generates weekly dates similar to Stata's daily date variable (counting from 1960/1/1). However, when examining our sample data, which is at the state-municipality-week level, this revealed instances of 8-9 day weeks, particularly around year-ends, making it unsuitable for our analysis which requires consistent 7-day periods.

To address these issues, we created a custom weekly variable using the following formula: $\text{myweek} = \text{floor}((\text{date}-1)/7)+1$, where *date* is Stata's built-in daily date variable (counting days

since 1960/1/1). The *floor* function returns the largest integer less than or equal to the given number. This formula ensures that each week spans exactly 7 days, satisfying the 7-day consistency requirement for defining our temperature bins. For example, 1960/1/1-1960/1/7 corresponds to myweek=1, 1960/1/8-1960/1/14 corresponds to myweek=2, ..., 2007/12/29-2008/1/4 corresponds to myweek=2505, 2008/1/5-2008/1/11 corresponds to myweek=2506, and so on. The subtraction of 1 from the date variable before division, combined with adding 1 after the floor operation, ensures that each week contains exactly seven days.

By constructing the week identifier in this manner, we ensure the integrity of the weekly measures while avoiding the limitations of irregular week lengths that would arise from using Stata's built-in week functions. The resulting dataset allows for consistent analyses of the relationship between weekly temperature patterns and mental health outcomes.

D Primary ICD-10 Code Assignment for Emergency Department Visits

Primary ICD-10 (International Classification of Diseases, 10th revision) codes in emergency department (ED) visit records capture the condition requiring the most significant medical intervention. These are determined through a systematic process implemented by the Ministry of Health (Secretaría de Salud) (Secretaría de Salud, 2023). The attending physician evaluates the patient's symptoms and records all relevant ICD-10 codes during the visit. After diagnosis and treatment, the physician designates the primary ICD-10 code among those to indicate the condition most responsible for the ED visit.

For example, we observe a patient in our sample with depressive symptoms (F32.3) and benzodiazepine poisoning (T42.4) might have T42.4 recorded as the primary code if the poisoning was the critical issue. For another example, a patient presented with four ICD-10 codes: alcohol dependence syndrome (F10.2), volatile solvent dependence syndrome (F18.2), other disorders of the lung (J98.4), and residual and late-onset psychotic disorder due to multiple drug use (F19.7). Among these, the primary ICD-10 code was determined to be residual and late-onset psychotic disorder due to multiple drug use (F19.7), reflecting the most critical condition driving the need for emergency care.

Finally, the hospital's billing department verifies the selection to ensure alignment between diagnosis, treatment, and resource utilization.

E Secondary Outcomes: Stress, Blood Pressure, and Smoking Behavior

To further investigate the relationship between weather and mental health, we study secondary outcomes that may be influenced by mental health strain. We focus on psychological stress, blood pressure, and cigarette smoking.

E.1 Stress

To measure psychological stress, we utilize a sentiment score dataset provided by the National Institute of Statistics and Geography (INEGI) using data from X, formerly known as Twitter. In 2015, INEGI began collecting geo-referenced public tweets within the Mexican territory and in the southern part of the U.S. By employing various algorithms, they categorized each tweet by its emotional tone (positive or negative). This information was then used to calculate and publish a sentiment score, representing the ratio of positive tweets to negative ones. This score serves as our proxy for population-level stress. The index is available from January 2016 to June 2023 and is provided at daily, weekly, monthly, and annual levels for all states in Mexico. We use the sentiment score at the weekly level, which is consistent with our temporal aggregation strategy in our baseline specification. Our analysis builds on the framework established by Baylis (2020), who demonstrated a significant relationship between temperature and expressed sentiment using Twitter data in the U.S.³⁴ This method leverages social media sentiment as a high-frequency, real-time indicator of psychological stress and well-being. However, it is worth noting that this sentiment data are provided only at the state level, limiting our analysis's spatial granularity.

We explore whether elevated heat and humidity worsen temperament (measured by sentiment score using X data) and mental health outcomes. Since the sentiment score is only available at the state level, we aggregated the mental health outcomes to the state level as well. For this state-by-week analysis, we control for state-level rainfall exposure and incorporate the four sets of fixed effects: state, week-of-the-year, month-of-the-year, and year-fixed effects.

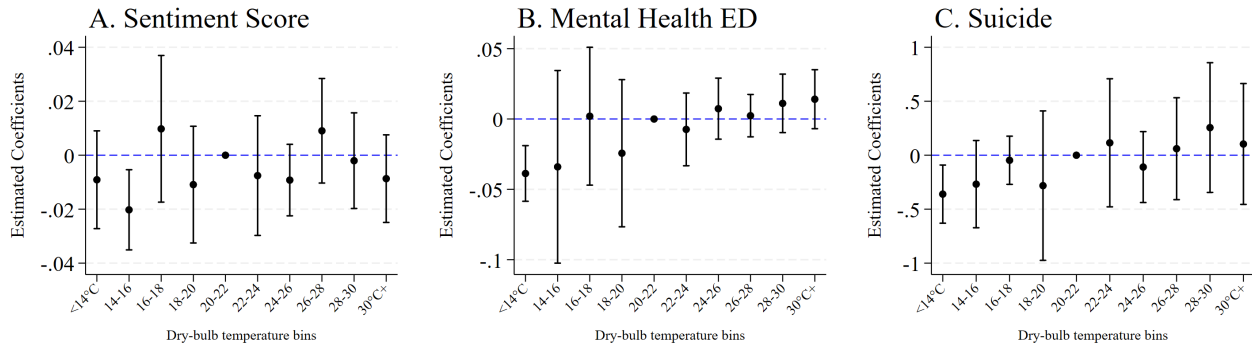
The coefficients estimated for the relationship between sentiment score and wet-bulb temperature in Panel A of Figure E.1 are mostly imprecise. Estimates for mental health emergency department visits (Panel B) and suicide rates (Panel C) are also less precise compared to those estimated at the municipality level in Figure 3. From the state-level analysis, we do not find

³⁴Baylis (2020) identified an inverted U-shaped relationship, with sentiment peaking at moderate temperatures and declining at extremely hot or cold temperatures.

clear evidence of a stress mechanism linking mental health outcomes to wet-bulb temperatures.

Our main specification, which uses municipality-by-week data from 2008–2019, benefits from greater temporal variation across 12 years, enabling more precise estimates. In contrast, the state-by-week analysis relies on data from 2016–2019, with only 4 years of variation, which likely contributes to the imprecision of the estimated coefficients for the main outcomes in Panel B and Panel C, E.1. This limited variation may explain why significant relationships observed at the municipality level are not evident in the state-level analysis, also showing imprecise estimates for the sentiment score in Panel A, E.1.

Figure E.1: Relationship between Temperature and Sentiment Score at the State Level



Notes: The estimated coefficients and the 95 percent confidence intervals using standard errors clustered at the state level. Note that our social media data is only available at the state level, not at the municipality level. The reference temperature bin is 20–22°C, chosen as it represents the middle range of the temperature distribution in the sample. All specifications control for state, month-of-the-year, and year fixed effects, as well as weekly humidity and rainfall exposure. The data was collected, processed, and maintained by INEGI from 2016–2019.

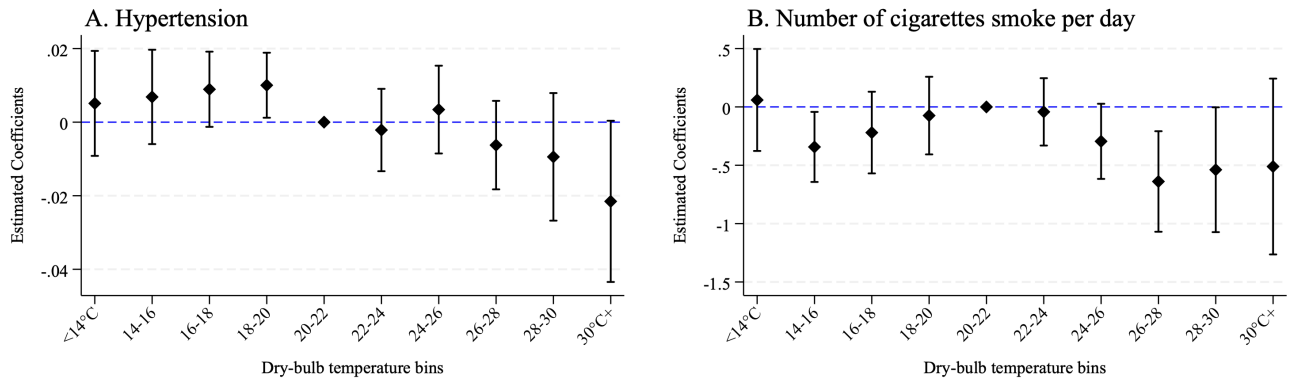
E.2 Blood pressure

We analyze blood pressure as a physical manifestation of mental health strain, given its known association with stress and anxiety (Liu et al., 2017; Johnson, 2019). Using the National Health and Nutrition Survey (Encuesta Nacional de Salud y Nutrición, ENSANUT) conducted by the Secretariat of Health in Mexico (Secretaría de Salud), we examine systolic and diastolic blood pressure data collected in 2006, 2012 and 2018 waves.³⁵ Consistent with the medical literature, we define hypertension as having a systolic blood pressure of 140 mmHg or above or a diastolic blood pressure of 90 mmHg or above (Carretero and Oparil, 2000).

³⁵The 2006 and 2012 waves publicly report the survey date, while the survey date for the 2018 wave is obtained from Cohen and Gonzalez (2024).

Our results in Figure E.2 indicate no significant deviations from the baseline at moderate temperatures. One possible explanation for this lack of effect is that we aggregate the measures at the weekly level, which may obscure short-term variations in blood pressure. We also interpret this result with caution, as we are not able to observe the baseline blood pressure for individuals.

Figure E.2: Temperature Exposure, hypertension, and Cigarette Smoking



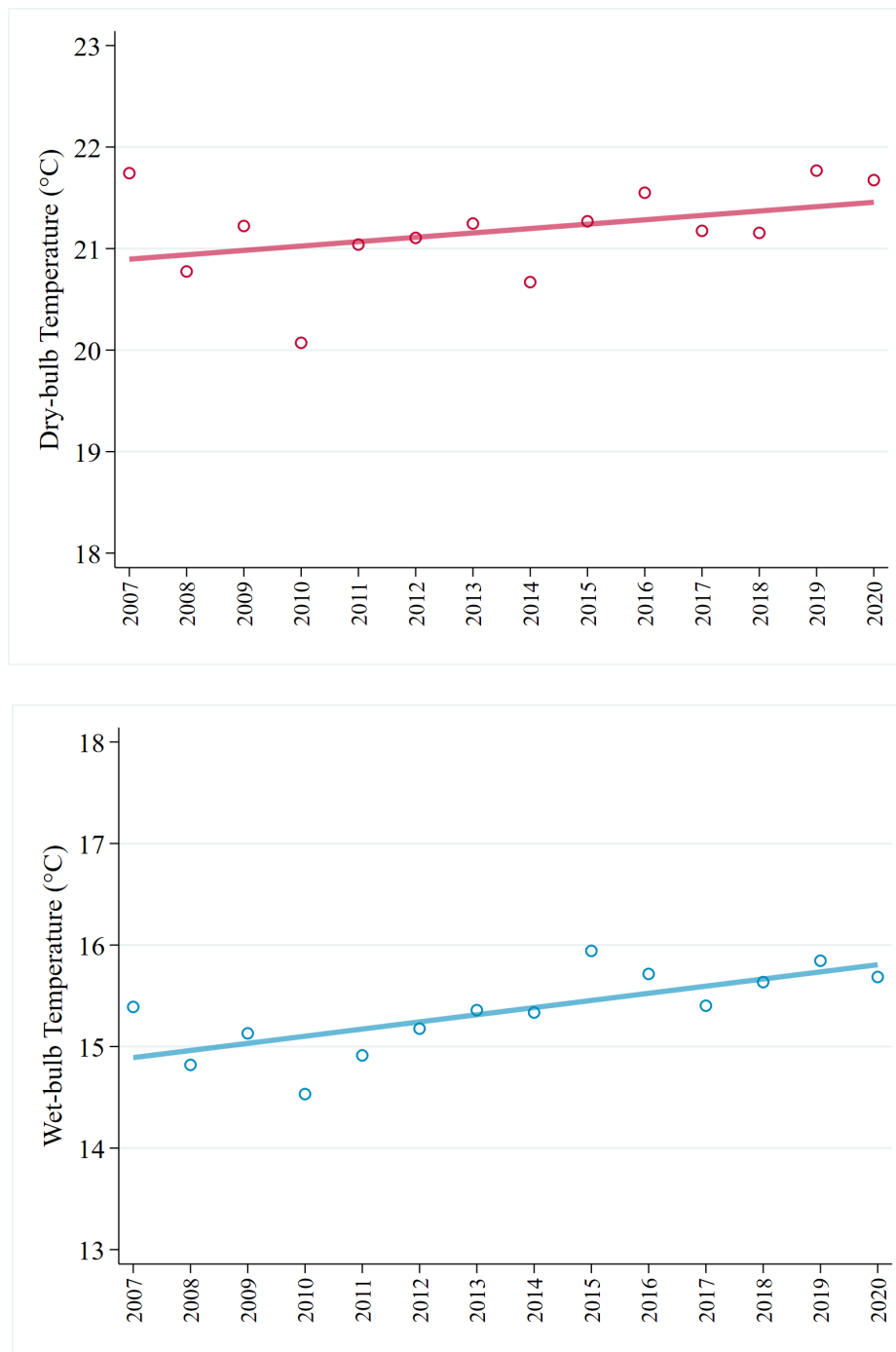
Notes: This figure presents the relationship between temperature exposure and hypertension (Panel A) and the number of cigarettes smoked per day (Panel B). We use dry-bulb temperature and control for relative humidity. We clustered the standard errors at the municipality level. The reference temperature bin is 20-22°C, chosen as it represents the middle range of the temperature distribution in the sample. We control for municipality by month-of-the-year effects and state-by-year fixed effects.

E.3 Smoking behavior

We analyze smoking behavior as a coping mechanism for mental distress, measured by the number of cigarettes a person reports smoking per day. Using the same ENSANUT dataset as for blood pressure, we hypothesize that extreme temperatures may heighten stress, leading to higher smoking intensity (Friedman, 2020). However, Panel B of Figure E.2 shows an inverted U-shaped relationship, where cigarette consumption decreases at temperature extremes. This pattern suggests that while extreme temperatures may induce mental distress, they might also simultaneously suppress smoking behavior. Possible explanations include reduced outdoor activity. Extreme weather likely discourages outdoor smoking, especially given restrictions on indoor smoking.

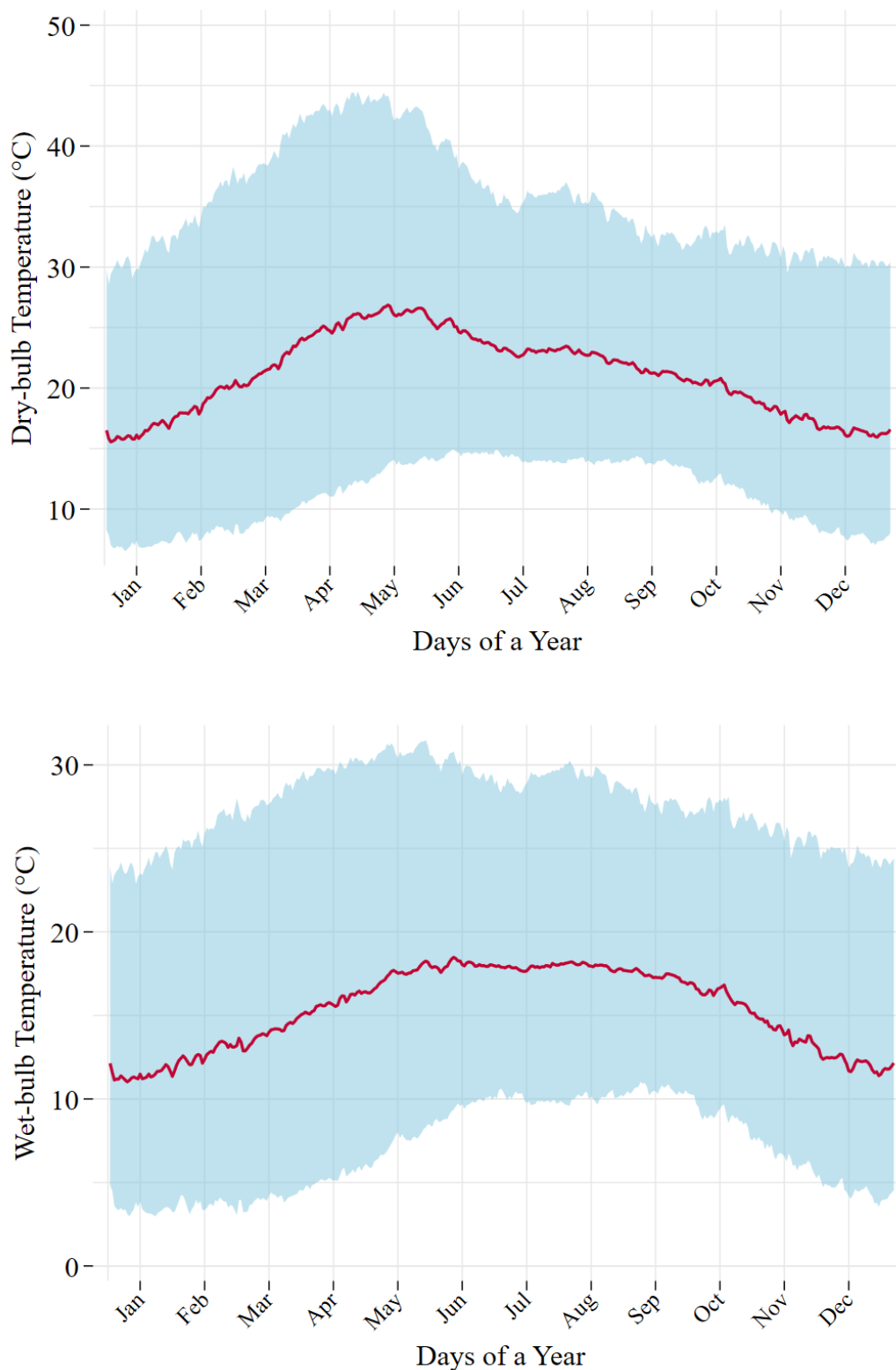
F Appendix Figures and Tables

Figure F.1: Annual Trend in Temperatures Dry-bulb (top) and Wet-bulb (bottom)



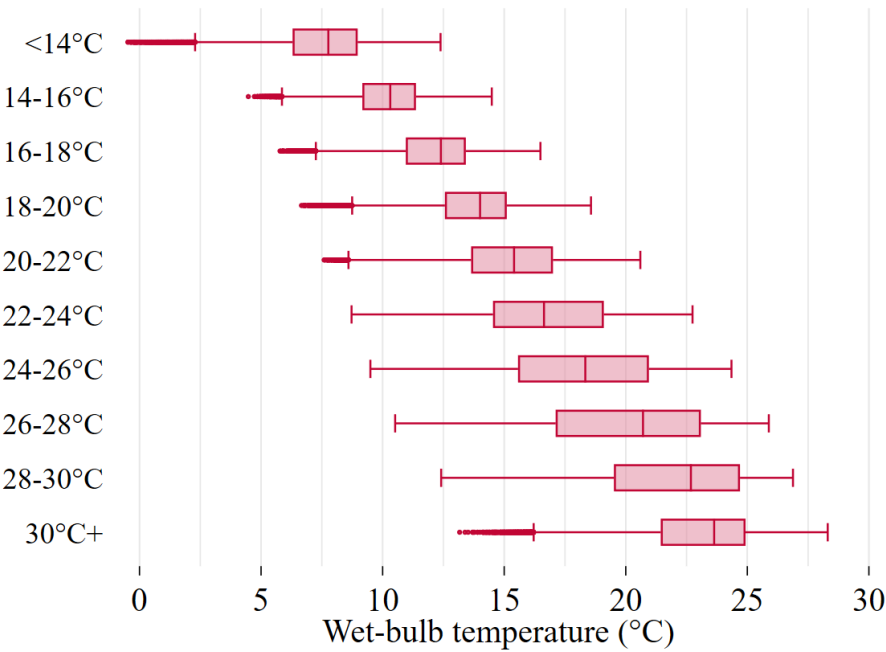
Notes: These figures present national average annual temperature trends in Mexico from 2007 to 2020 using the North American Regional Reanalysis (NARR) data from the U.S. National Oceanic and Atmospheric Administration (NOAA). Temperatures are aggregated at the annual level for the entire country. Dots represent annual average temperatures, while the solid line represents the fitted linear regression trend with a 95% confidence interval. Wet-bulb temperature is calculated using the SA110 method (See Appendix A).

Figure F.2: Inter-annual Temperature Variation: Dry-bulb (top) and Wet-bulb (bottom)



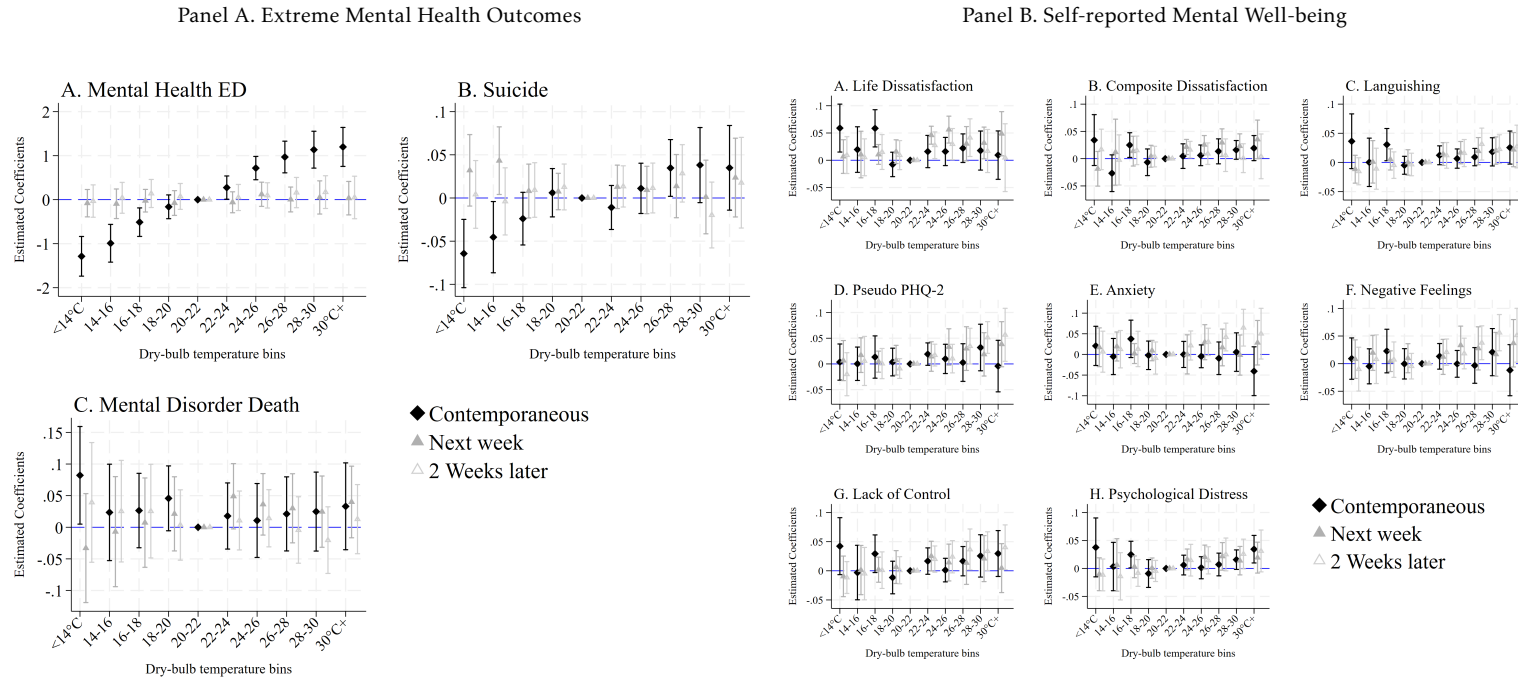
Notes: These figures present daily temperature patterns in Mexico using the NARR data from the NOAA. Data cover the period from 2007 to 2020 and are aggregated across years and municipalities for each day of the year (January 1 to December 31). The solid red line represents the average temperature for each day of the year, while the blue shaded area indicates the observed minimum and maximum temperatures for that day. Wet-bulb temperature is calculated using the Stull method (See Appendix A).

Figure F.3: Distribution of Wet-bulb Temperatures (horizontal) by Dry-bulb Temperature Bins (vertical)



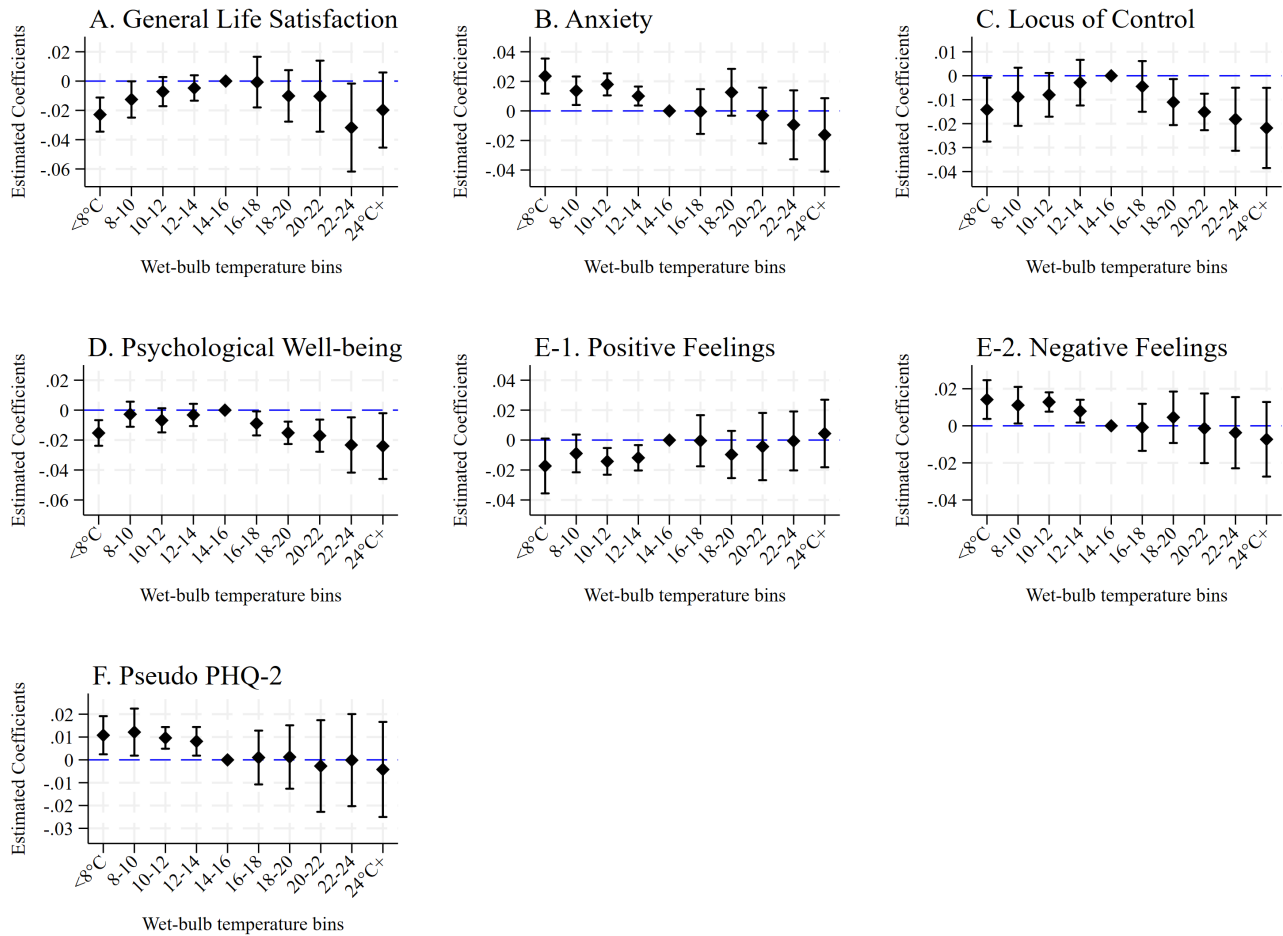
Notes: Observations depicted are the average dry-bulb and wet-bulb temperatures, calculated weekly in each year for each municipality in Mexico, covering a period from 2007 to 2021.

Figure F.4: Falsification Tests using Lead Weeks



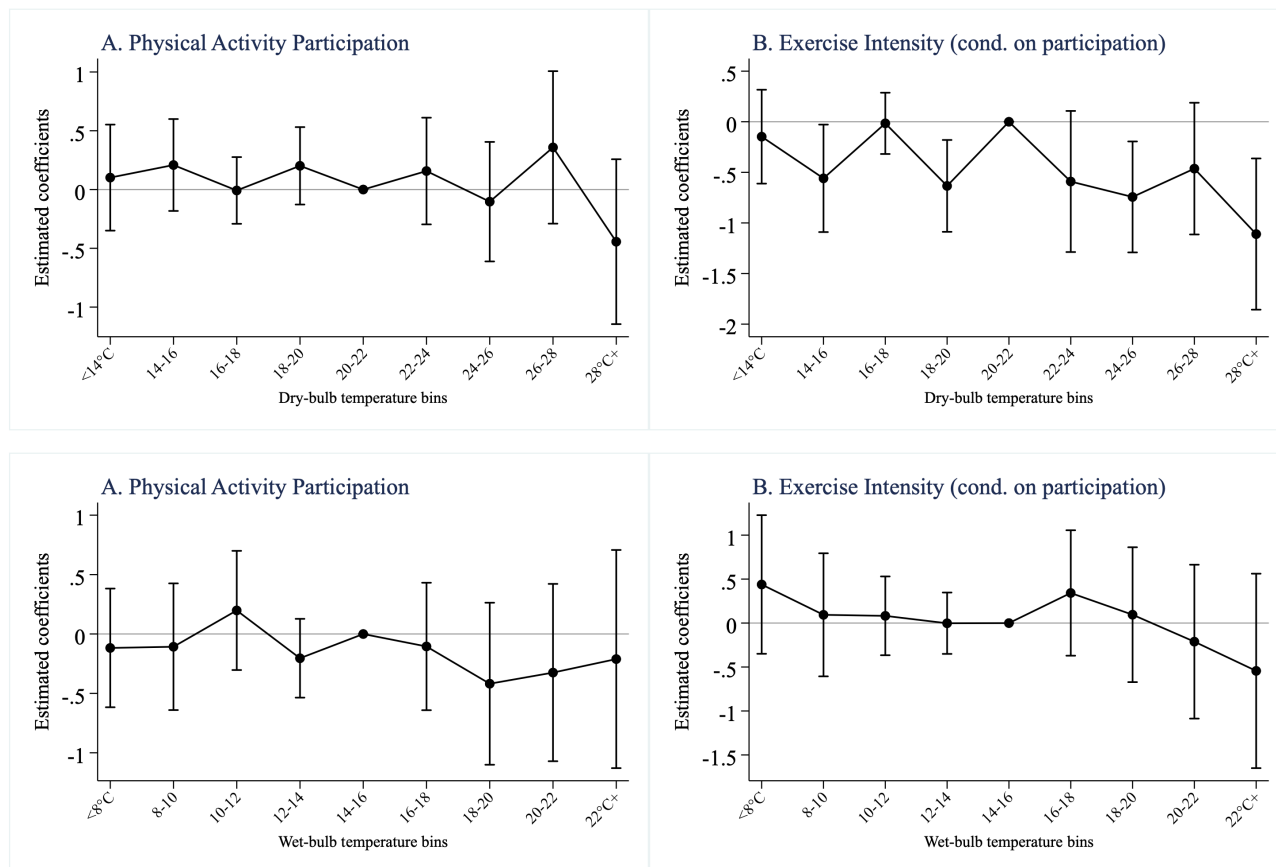
Notes: Panel A: All dependent variables are presented as rates per million residents within each municipality. All specifications control for the municipality by week-of-the-year fixed effects and state by year fixed effects, as well as weekly humidity and rainfall exposure. Standard errors are clustered at the municipality level. For additional details, please refer to the notes for Figure 3. Panel B: All measures range from 0-10, with higher values indicating worse mental health outcomes. All specifications control for city by week-of-the-year effects and state by year fixed effects, as well as weekly humidity and rainfall exposure. Standard errors are clustered at the city level. The data come from quarterly surveys (January, April, July, and October) conducted yearly from 2013 to 2019, and all specifications are weighted using survey-provided personal weights to ensure national representativeness. For additional details, please refer to the notes for Figure 7.

Figure F.5: Wet-bulb Temperature Effects on Self-Reported Mental Well-being



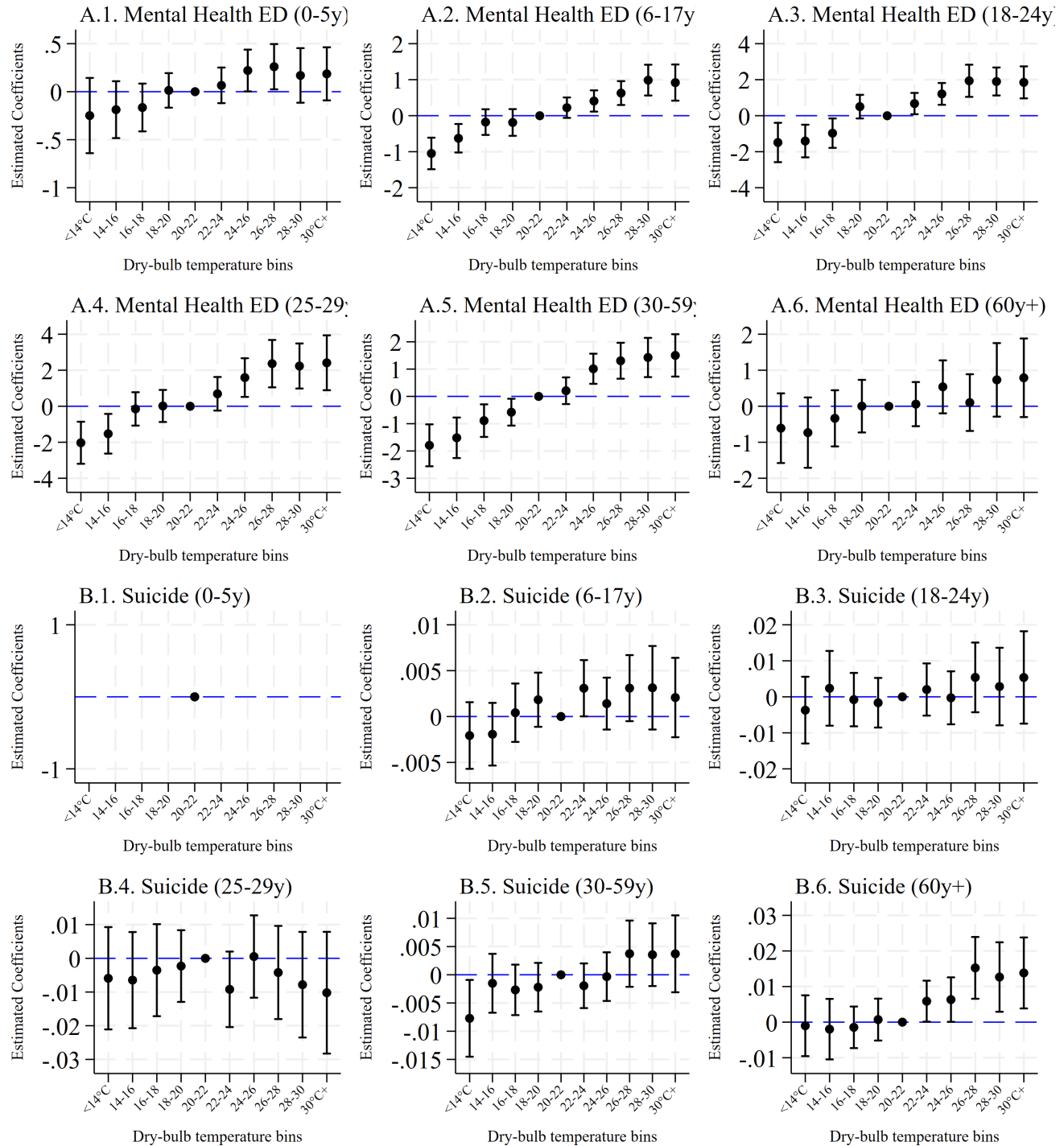
Notes: This figure presents the relationship between dry-bulb temperature exposure and various well-being outcomes. The reference temperature bin is 14-16°C in wet-bulb temperature, chosen as it represents the middle range of the temperature distribution in the sample. The outcomes are (A) General life satisfaction, (B) Composite dissatisfaction index averaging twelve domains spanning personal, social, and environmental aspects, (C) Languishing scale adapted from Diener (2009) measuring eudaimonic well-being, (D) Pseudo PHQ-2 depression screening capturing fatigue, anhedonia, and depressed mood, (E) Anxiety, (F) Psychological distress adapted from the psychological well-being scale measuring optimism, purpose and daily meaningfulness in Diener (2009), (G) Lack of control measuring perceived agency and autonomy, and (H) Negative feelings from the SPANE measure in Diener (2009). All measures range from 0-10, with higher values indicating worse mental health outcomes. The estimated coefficients and the 95 percent confidence intervals using standard errors clustered at the city level are depicted in this figure. The reference temperature bin is 20-22°C, chosen as it represents the middle range of the temperature distribution in the sample. All specifications control for city by week-of-the-year effects and state by year fixed effects, as well as weekly humidity and rainfall exposure. The data come from quarterly surveys (January, April, July, and October) conducted yearly from 2013-2019.

Figure F.6: Temperature Exposure and Physical Activity – Participation and Intensity



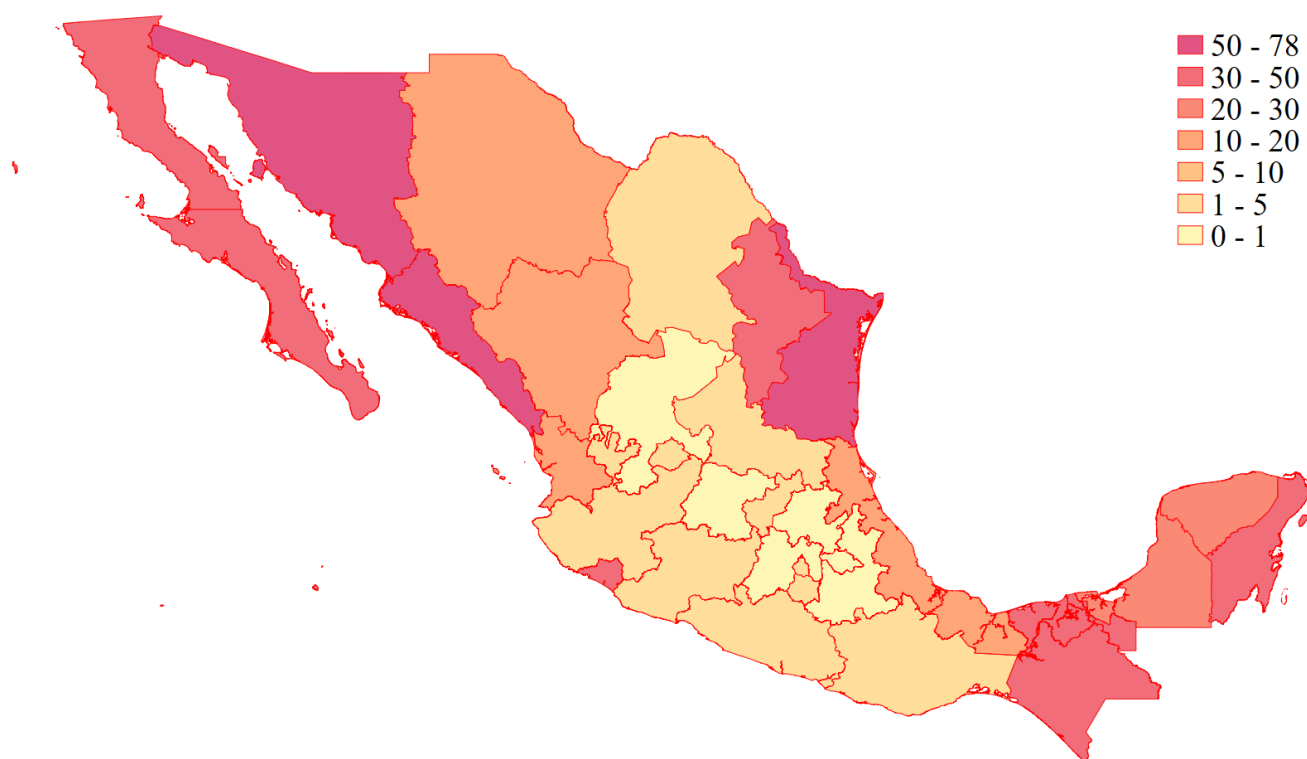
Notes: This figure presents the relationship between temperature exposure and physical activity outcomes: (A) Physical activity participation based on the survey question "In your leisure time, do you practice any sport or physical exercise, such as soccer, basketball, aerobics, cycling, walking or other?" coded as yes=100, no=0), and (B) Exercise intensity (conditional on participation in physical activity, coded as moderate=0, vigorous=100), conditional on participation (A). The survey data come from annual surveys conducted each November from 2013 to 2019 across 32 major cities in Mexico, using the Sports Practice and Physical Exercise Module (Módulo de Práctica Deportiva y Ejercicio Físico). The top panels represent the relationship between dry-bulb temperature and sports exercises, and the bottom panels represent the relationship between wet-bulb temperature sports exercises. The temperature bin in the middle for all the analyses is dropped as the reference. For dry-bulb temperature analyses (top), monthly relative humidity is additionally controlled for. The estimated coefficients and the 95 percent confidence intervals using standard errors clustered at the city level are depicted in this figure. The reference temperature bin is 20-22°C, chosen as it represents the middle range of the temperature distribution in the sample. All specifications control for city by month-of-the-year effects and state by year fixed effects, as well as monthly rainfall exposure.

Figure E.7: Temperature and Mental Health by Age Group



Notes: All dependent variables are presented as rates per million residents within each municipality's corresponding age group's population. All specifications control for the municipality by week-of-the-year fixed effects and state by year fixed effects, as well as weekly humidity and rainfall exposure. For additional details, please refer to the notes for Figure 3.

Figure F.8: Air-conditioned Households (%)



Notes: This figure presents the percentage of households with air-conditioning facilities in each municipality. Air-conditioning penetration rates are derived from the 2018 ENIGH, where households reported their possession of air-conditioning facilities.

Table F.1: Questions from Self-reported well-being survey (BIARE)

BIARE Code	Survey Question	Associated Measure(s)
p1	Could you tell me on a scale of 0 to 10 how satisfied you are currently with your life?	Life Dissatisfaction
On a scale of 0 to 10, how much do you agree or disagree with the statement ...		
p3_1	In general, I feel good about myself.	Languishing
p3_2	I am always optimistic regarding my future.	Languishing, PD
p3_3	I am free to decide my own life.	Languishing, LC
p3_4	I have strength in the face of adversities.	Languishing
p3_5	I usually feel that what I do in my life is worthwhile.	Languishing, PD
p3_6	I am a lucky person.	Languishing
p3_7	Whether things go well or badly for me depends fundamentally on me.	LC
p3_8	I feel like I have a purpose or a mission in life.	PD
p3_10	Most days, I feel like I have achieved something.	Languishing
The questions I am going to ask you next are about how much of yesterday you felt...		
p4_6	...in a bad mood?	Feeling
p4_7	...worried, anxious, or stressed?	Anxiety, Feeling
p4_8	...tired or lacking vitality?	Feeling, PHQ2
p4_9	...bored or uninterested in what you were doing?	Feeling, PHQ2
p4_10	...sad, depressed, or despondent?	Feeling, PHQ2
Here the questions refer to your satisfaction, no longer with your life in general, but with some specific aspects.		
p5_1	How satisfied are you with your standard of living?	CD
p5_2	How satisfied are you with your health?	CD
p5_3	How satisfied are you with your achievements in life?	CD
p5_4	How satisfied are you with your personal relationships?	CD
p5_5	How satisfied are you with your future prospects?	CD
p5_6	How satisfied are you with the time available to do what you like?	CD
p5_7	How satisfied are you with your citizen security?	CD
p5_8	How satisfied are you with the main activity that you perform (work, chores, study, or caring for a relative)?	CD
p5_9	How satisfied are you with your dwelling?	CD
p5_10	How satisfied are you with your neighborhood?	CD

Notes: PD stands for Psychological Distress, LC for Lack of Control, Feeling for Negative Feelings, PHQ2 for Pseudo PHQ-2, and CD for Composite Dissatisfaction.

Table E.2: Summary Statistics of Weather Variables

Variable	Mean	SD	Min	p25	p50	p75	Max
Dry-bulb temperature (°C)	21.18	5.44	-1.91	17.23	20.81	25.02	40.19
Relative humidity (%)	56.22	17.28	6.84	43.95	58.36	69.76	96.72
Wet-bulb temperature (°C)	15.37	5.01	-4.84	11.91	14.88	18.73	28.73
Precipitation (mm)	2.51	3.67	0.00	0.03	0.82	3.77	68.11

Notes: Weekly averages calculated from daily municipal-level measurements spanning 2007-2021. Precipitation measures rainfall in millimeters. P25, P50, and P75 represent the 25th, 50th (median), and 75th percentiles, respectively.