Spatial Heterogeneity in Fatal Overdose Rate Trends in Mexican Cities: 2005–2021

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Objectives. To describe national and city-level fatal drug overdose trends between 2005 and 2021 in Mexico.

Methods. We calculated fatal overdose rates at the city level in 3-year periods from 2005 to 2021 and annually at the national level for people aged 15 to 64 years in Mexico. We calculated rate differences and rate ratios for each city between periods.

Results. The national fatal overdose rate was 0.53 overdose deaths per 100 000 population and was almost twice as high in urban than in nonurban areas. The national fatal overdose rate was stable over the period 2005 to 2014 and increased monotonically to a peak in 2021. Fatal overdose rates varied across cities. Cities with the 8 highest fatal overdose rates in the period were all in states along the US–Mexico border.

Conclusions. Fatal overdoses have doubled over the past 15 years in Mexico. Overdose rates are particularly high and increasing in cities close to the US–Mexico border.

Public Health Implications. There is a need for enhanced overdose surveillance data and coordinated harm reduction strategies, particularly in the northern border region of Mexico. (*Am J Public Health*. 2024;114(7):705–713. https://doi.org/10.2105/AJPH.2024.307650)

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National estimates of drug use and harms in Mexico are limited, but available data indicate increases in use, decreases in age at initiation, and increases in prescription and illicit opioid availability. The National Survey on the Consumption of Drugs, most recently administered in 2016, reports that national drug use rates doubled between 2002 and 2016: past year use increased from 1.3% to 2.9% and lifetime use from 5% to 10.3%.[1] The median age of drug use initiation has been trending younger in Mexico: from 20.6 years in 2002 to 17.8 years in 2016.[1] Compared with national rates of drug use and related harms, those in the US–Mexico border region, particularly northwest Mexico, have long been significantly higher.[2]

Fatal drug overdose encompasses mortality from the misuse of any type of drug, typically psychoactive substances,[3] and often from a lack of overdose reversal intervention.[4] Fatal drug overdose rates have increased in several countries over recent decades,[5] but trends have not been described for most countries, including Mexico. A 2022 report, using 2016 survey data from people who inject drugs aged 15 to 64 years, estimated the national fatal drug overdose rate in Mexico as between 0.20 and 1.54 deaths per 100 000 population.[6]

Historically, Mexico has been a country of low-level opioid use. However, multiple factors have emerged and converged since 2015, increasing opioid use and overdose risk.[7] These factors are concentrated in the northern border region and include greater availability of psychoactive drugs from US-bound cocaine and synthetic opioid trafficking, regional methamphetamine production and cross-border pharmaceutical opioid access,[8–10] high levels of policing,[11] and strong social and economic ties to the United States during its opioid epidemic.[12,13]

The severity of drug use harms has escalated in recent years, owing in part to the increased presence of, and unknowing exposure to, fentanyl in the local drug supply.[11,14–17] In 2019, fentanyl checking found that 93% of white powder heroin samples in Tijuana contained fentanyl,[14] and a harm reduction program in Mexicali observed a 30% increase in overdoses between 2019 and 2021.[17] Fentanyl seizures also increased significantly in this period. In 2016, Mexican officials seized 15 kilograms (kg) of fentanyl.[18] Between 2017 and 2019 growth was significant, and in the period 2020 to 2022, fentanyl seizures increased exponentially to 1851 kg.[18] In 2023, more fentanyl was seized in 1 operation than in the entire period 2016 to 2019.[18]

Implementation of a national harm reduction strategy in Mexico is still pending.[19,20] In 2020, the federal government issued guidance on the integration of harm reduction into systems of care,[21] but a legal framework for harm reduction did not emerge until reform of the General Law on Mental Health in 2022.[22] This reform made explicit that harm reduction must be integrated into the provision of services for people who use drugs.[22] In 2023, the National Commission for Mental Health and Addictions (Comisión Nacional de Salud Mental y Adicciones [CONASAMA]; https://bit.ly/3Ju5lf5) was created as a result of reconfiguration in the Ministry of Health and empowered to develop a national strategy in the field of mental health and addiction, including the provision of harm reduction services.[23] To date, however, no concrete policy has been operationalized.

The increased public health risks associated with fentanyl require a systematic and evidence-based response to prevent overdose deaths in Mexican cities. Epidemiological data on fatal drug overdose allows us to understand overdose risk factors, including how they are patterned geographically and socially, and is necessary to inform opioid overdose prevention, harm reduction, and treatment strategies in Mexico.

OBJECTIVES

We sought to fill knowledge gaps about fatal drug overdose trends in Mexico, including by providing estimates of fatal overdose rates and trends at the city level using mortality records. This information can aid in the development and implementation of targeted, evidence-based practices that prevent fatal and nonfatal overdose and link high-risk populations to harm reduction and treatment services at multiple ecological levels. Our objective was to describe the geographic and temporal variability in overdose mortality rates in Mexico from 2005 to 2021.

METHODS

We used data (Appendix Table A, available as a supplement to the online version of this article at http://www.ajph.org) compiled and harmonized by the SALURBAL (Salud Urbana en America Latina, or Urban Health in Latin America) project.[24] SALURBAL is a research project with teams across Latin America and the United States that study the effects of urban environments on population health.[25] Specifically, SALURBAL obtained mortality data for all deaths in Mexico from 2005 to 2021 from the Instituto Nacional de Estadística, Geografia e Informatica (INEGI). These data include age at death (in 5-year age groups), sex (male or female), underlying cause of death, and municipality where the decedent lived.

Underlying cause of death is recorded using *International Classification of Diseases, 10th Revision* (*ICD-10*; Geneva, Switzerland: World Health Organization; 1992) codes. We excluded records without decedents' place of residence (0.83% of records during the study period).[26] We obtained population projections and intercensal estimates for Mexico from INEGI and the Consejo Nacional de Población, including population counts by 5-year age groups, sex (male or female), and municipality of residence for individuals aged 0 to 65 years for the period 2005 to 2021.

Fatal Drug Overdose

We defined fatal drug overdose based on *ICD-10* codes for drug-involved causes of death. To determine which set of *ICD-10* codes to include in the definition of fatal overdose, we conducted a search of the literature on drug-involved or overdose mortality and hospitalization to determine best practice (Appendix Table B, available as a supplement to the online version of this article at http://www.ajph.org). *ICD-10* codes for injuries have an underlying cause (X and Y codes, indicating mechanism [e.g., drug or firearms] and intent [e.g., accidental or self-harm]) and a contributing cause (T and S codes, e.g., agent [e.g., opiates or stimulants]). *ICD-10* codes for drug use disorders (F codes) are categorized as "mental and behavioral disorders" but are often also included in measures of drug-involved poisoning or overdose. Additional *ICD-10* codes describing drug-involved outcomes are less commonly included in measures of drug-involved overdose and include an array of what are categorized as "other drug-induced causes or adverse effects" (Appendix Table B provides codes included in this category).

Because of major limitations in the coding of drug-involved deaths in Mexico, including a lack of formal testing for potential illicit drug presence,[27,28] the measure of overdose used in this study includes all drug-involved *ICD-10* codes within the categories of "overdose," "mental and behavioral disorders," and "other drug-induced causes or adverse effects" to account for potential coding of these deaths to a wider range of *ICD-10* codes. We redistributed ill-defined injury codes (X59, X84, Y09, and Y34) to other injury codes proportionally based on age and sex.[29] Still, these data likely underestimated drug-involved deaths in Mexico. Alcohol-related causes of death are described in Appendix Table B to provide a complete description of substance use codes but are excluded from this analysis because of the meaningful difference in rates of alcohol use in Mexico compared with drug use, as well as our focus on addressing a gap in knowledge about drug misuse and overdose trends in Mexico.

Analysis

This study is an ecological analysis. We aggregated death-level microdata for fatal overdoses to the municipality level as counts of fatal drug overdose events per municipality, restricting deaths to those aged 15 to 64 years, as this is the age group most likely to experience a drug-involved poisoning.[3] We linked these data to population count data per municipality, also restricted to those aged 15 to 64 years.

We conducted this analysis at 3 geographical scales: national, urban versus nonurban, and specific cities. First, we aggregated counts of drug-involved deaths and population counts across all municipalities in Mexico to compute national fatal overdose rates. These rates were calculated annually, and we calculated 95% confidence intervals (CIs) using a Poisson SE.

Second, we classified municipalities as urban or nonurban based on whether the municipality was part of the SALURBAL study.[24] Briefly, SALURBAL defined urban areas as aggregations of municipalities that overlap with the urban extent, as observed in 2010 satellite imagery of cities with 100 000 residents or more.[24] We then aggregated yearly counts of drug-involved deaths and population counts by urban versus nonurban status and computed fatal overdose rates and 95% CIs.

Third, we aggregated counts of drug-involved deaths and population counts to the city level and calculated city-level fatal overdose rates and 95% CIs. We computed an overall rate for the 2005 to 2021 period and for six 3-year periods (2-year for the final period): 2005 to 2007, 2008 to 2010, 2011 to 2013, 2014 to 2016, 2017 to 2019, and 2020 to 2021. These periods align with trends observed in changes in US overdose rates over the entire period, helping to smooth year-to-year variability given the rarity of events, particularly at the city level. To measure absolute and relative changes in city-level fatal overdose rates, we computed rate differences and rate ratios (RRs) between 2 sets of periods: between 2005 to 2007 and 2017 to 2019 and between 2017 to 2019 and 2020 to 2021. We chose these periods to separate overall secular trends (2005–2007 to 2017–2019) from changes during the COVID-19 pandemic (2017–2019 to 2020–2021). We used longitudinal mixed models with a random intercept for city and robust SEs to test whether changes in fatal overdose rates between these periods were statistically significant. We conducted the statistical analyses using STATA version 15 (StataCorp, College Station, TX).

RESULTS

The national fatal overdose rate among people aged 15 to 64 years was 0.53 overdose deaths per 100 000 inhabitants over the period 2005 to 2021 (Figure 1). National rates were stable from 2005 to 2014, when a monotonic increase started: from 0.44 to 0.79 fatal overdoses per 100 000 from 2014 to 2021 (a 79% increase over 8 years). There was a much higher rate in urban (0.60 per 100 000) than in nonurban (0.37 per 100 000) areas. Although the recent increases occurred in both urban (84% increase from 2014 to 2021) and nonurban (65% increase) areas, increases over the whole period were steeper in urban areas, as rates were similar during the 2000s and started separating in the early 2010s.

City-Level Fatal Overdose Rates

Fatal overdose rates varied widely across cities over the period 2005 to 2021, ranging from a high of 9.84 overdose deaths per 100 000 population in San Luis Rio Colorado (Sonora) to 0.05 in San Juan Bautista Tuxtepec (Oaxaca; Appendix Table C, available as a supplement to the online version of this article at http://www.ajph.org). Geographically, there is a trend of higher overdose fatality rates in northwestern cities, which decreases progressively moving southeast across the country (Figure 2; Appendix Figure A, available as a supplement to the online version of this article at http://www.ajph.org). Of the 15 cities with the highest overdose rates in

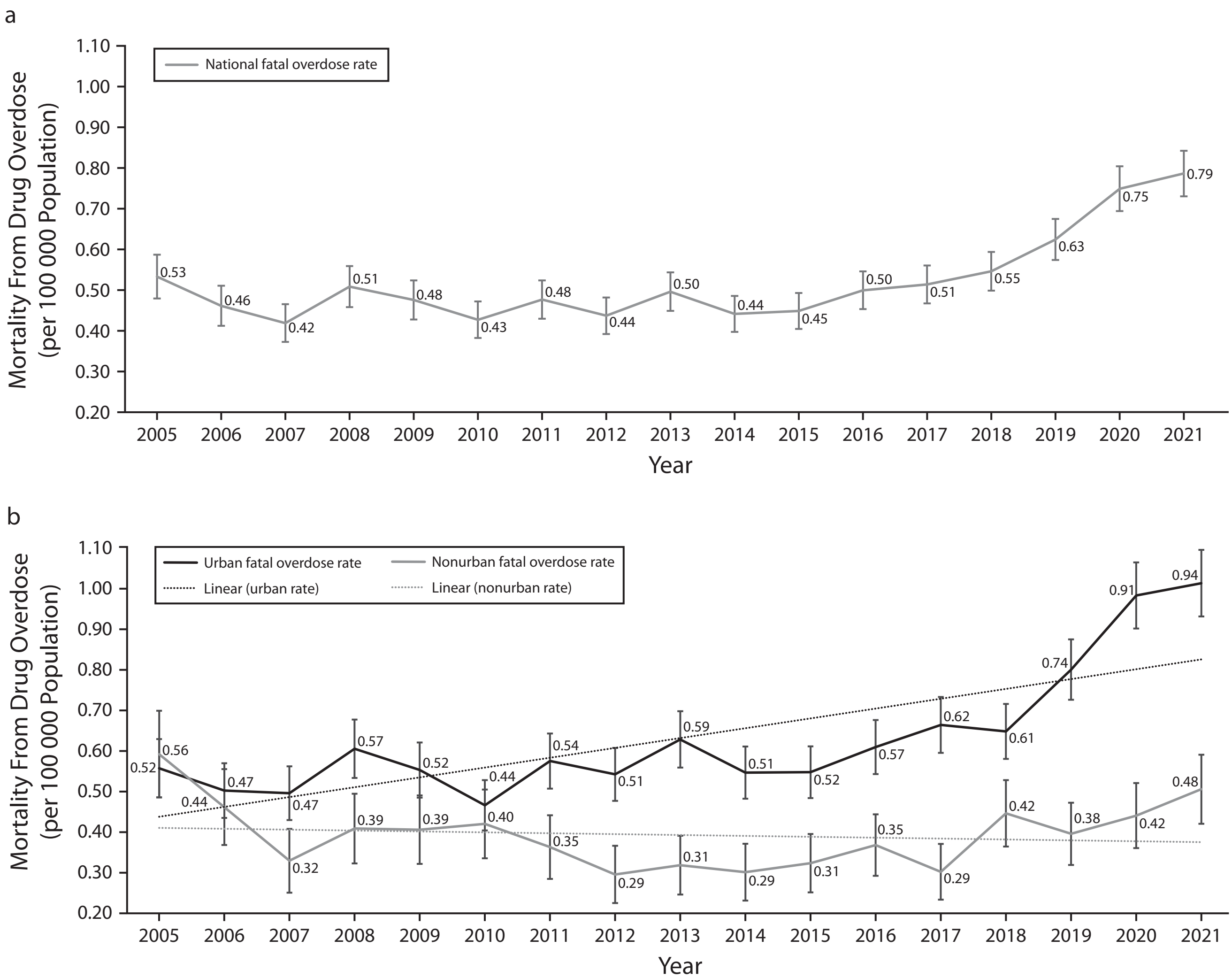

FIGURE 1— **Fatal Drug Overdose Rate Trends in Mexico Among People Aged 15–64 Years (a) Nationally and (b) Stratified by Urbanicity: 2005–2021**

Note. Whiskers represent 95% confidence intervals. Dotted lines are linear fits representing the slope over the 2005–2021 period.

the period, 11 are in the 4 westernmost states bordering the United States (Sonora, Chihuahua, Baja California, and Coahuila; Table 1) and 5 of these cities are located on the border.

Temporal Trends

We also found wide variation in fatal overdose rates over time (Figure 3; Appendix Figure B, available as a supplement to the online version of this article at http://www.ajph.org). In urban areas, fatal overdose rates increased by 0.17 deaths per 100 000 inhabitants between the first (2005–2007) and the fifth (2017–2019) period of observation and further increased by 0.27 deaths per 100 000 population between the fifth (2017–2019) and the final (2020–2021) period (Appendix Table D, available as a supplement to the online version of this article at http://www.ajph.org).

These changes represented a 35% (RR = 1.35; 95% CI = 1.23, 1.48) and 40% (RR = 1.40; 95% CI = 1.29, 1.52) relative increase from 2005 to 2007 to 2017 to 2019 and from 2017 to 2019 to 2020 to 2021, respectively. These changes followed a similar spatial patterning as overall rates, with larger absolute and relative increases in cities in the northwestern parts of Mexico, especially those bordering the United States (Appendix Table E, available as a supplement to the online version of this article at http://www.ajph.org). Increases in fatal drug overdose rates were significant between the periods 2005 to 2007 and 2017 to 2019 ($P = .02$) and between the periods 2017 to 2019 and 2020 to 2021 ($P = .05$).

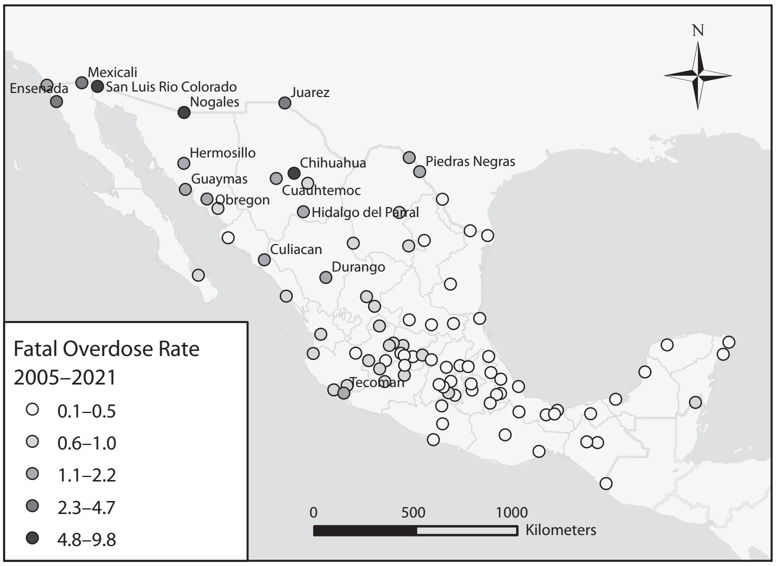

FIGURE 2— Fatal Overdose Rates in Mexican Cities per 100 000 Population: 2005–2021

Note. The sample size was 92 cities. For a full-color version of this map, please see Figure A of the Appendix (available as a supplement to the online version of this article at http://www.ajph.org).

DISCUSSION

In our examination of spatial and temporal heterogeneity of fatal overdose rates in Mexico, we observed 3 key findings. First, national fatal overdose rates in Mexico have increased significantly since 2005, peaking in 2021 so far, with a steep increase from 2014 onward. Second, these increases have been especially steep in urban areas, which had rates similar to those of nonurban areas at the beginning of the study period but almost double by 2021. Third, cities in northwest Mexico had much higher fatal overdose rates and much more steep increases over time.

In Mexico, the national fatal overdose rate was stable over the period 2005 to 2014 and then increased from 0.44 deaths per 100 000 population in 2014 to 0.79 in 2021 (a 79% increase). In the United States, fatal overdose trends remained relatively stable between 2006 and 2013 and then increased from 13.8 deaths per 100 000 in 2013 to 32.4 deaths per 100 000 in 2021 (a 134% increase).[3] Although fatal overdose rates in Mexico are much lower than those in the United States over the same period, the trends are similar.

Urban areas drove increases in national fatal overdose rates, with fatal overdose rate trends in urban areas stable over the period 2005 to 2018 and then increasing to 0.74 in 2019, 0.91 in 2020, and 0.94 in 2021. This represented a 40% increase in fatal overdose rates between the periods 2017 to 2019 and 2020 to 2021 in urban areas. These findings that overdose rates have increased are consistent with findings from an opioid overdose reversal program in Mexicali, which reported a 30% increase in drug overdoses between 2019 and 2021.[17]

Fatal overdose rates were higher in cities in border states and highest in border cities compared with cities in nonborder states. This finding is aligned with historically higher rates of opioid use[2,13] and recently described fentanyl use on the US–Mexico border.[14,15] The observed geographic variation in fatal overdose rates across the country also aligns with the geographic distribution of governmental fentanyl seizures between 2018 and 2023, which occurred in the northwestern states of Baja California (Ensenada, Mexicali, Tecate, Tijuana), Sonora (Opodepe, San Luis Rio Colorado), and Sinaloa (Culiacan, Ahome).[30] These trends suggest that geographic proximity to the United States during its opioid overdose crisis is a risk factor for fatal overdose in Mexico.[7,12,13,18]

Despite these alarming trends, the infrastructure necessary to monitor overdose rates, identify real-time shifts in drug markets, and reduce opioid-related harms in Mexico is insufficient. There is no nationwide overdose surveillance system,[31] and few hospitals and forensic services have the equipment and training necessary to determine drug-related causes of death.[27,28] Evidence-based harm reduction interventions, including community distribution of naloxone, remain criminalized and uncoordinated.[11,17,31] For those seeking treatment, access to evidence-based medications is extremely limited.[31] Our analysis supports local harm reduction practitioners' and epidemiologists' call for a comprehensive, decentralized, and evidence-based policy strategy in response to the emerging overdose crisis along the US–Mexico border.[11,15,17,31]

Limitations

The main limitations of this study are related to the use of vital registration data. Although SALURBAL has imputed missing variables (age, sex) and redistributed ill-defined causes of death,[26,29] there is still the possibility of differential measurement error.

TABLE 1— City-Level Fatal Overdose Rate Trends Over the Period 2005–2021 (Ordered by Highest Fatal Overdose Rate in the Overall Period) in the 15 Mexican Cities With the Highest Fatal Overdose Rates in the Overall Period

State	City	Fatal Overdose Rate per 100 000 Population						
		2005–2021, Overall Period	2005–2007, Period 1	2008–2010, Period 2	2011–2013, Period 3	2014–2016, Period 4	2017–2019, Period 5	2020–2021, Period 6
Sonora[a]	San Luis Rio Colorado[b]	9.84	4.53	6.28	3.32	7.74	10.97	29.51
Sonora[a]	Nogales[b]	7.55	9.54	4.76	2.76	3.85	9.19	17.59
Chihuahua[a]	Chihuahua	4.74	1.72	3.16	4.30	6.91	4.98	7.38
Baja California[a]	Mexicali[b]	3.46	2.16	1.64	1.97	2.69	4.39	8.69
Baja California[a]	Ensenada	2.90	4.61	2.44	2.78	3.04	3.03	1.35
Chihuahua[a]	Ciudad Juarez[b]	2.24	0.63	3.60	3.37	1.93	1.73	2.11
Chihuahua[a]	Hidalgo del Parral	1.87	1.35	1.27	2.46	0.40	2.69	3.32
Coahuila[a]	Piedras Negras[b]	1.51	0.87	2.17	0.51	0.73	0.92	4.67
Sinaloa	Culiacan	1.46	0.95	1.15	1.86	1.14	2.00	1.59
Colima	Tecoman	1.41	1.92	0.69	2.26	1.22	1.45	0.83
Sonora[a]	Guaymas	1.41	2.51	0.92	0.87	1.66	1.58	0.85
Chihuahua[a]	Cuauhtemoc	1.37	1.39	0.93	0.87	0.84	1.56	2.96
Sonora[a]	Hermosillo	1.23	1.19	0.90	1.06	1.09	1.32	1.95
Sonora[a]	Ciudad Obregon	1.22	0.85	0.67	0.74	1.41	1.24	2.61
Durango	Durango	1.17	0.72	0.82	1.30	1.29	1.22	1.65
All cities (n = 92)		0.60	0.49	0.51	0.55	0.53	0.66	0.92
Nonurban municipalities		0.37	0.43	0.39	0.31	0.32	0.37	0.45

Note. See Appendix Table C (available as a supplement to the online version of this article at http://www.ajph.org) for data on each of the 92 cities.
[a]a state that shares a border with the United States.
[b]a city on the US–Mexico border.

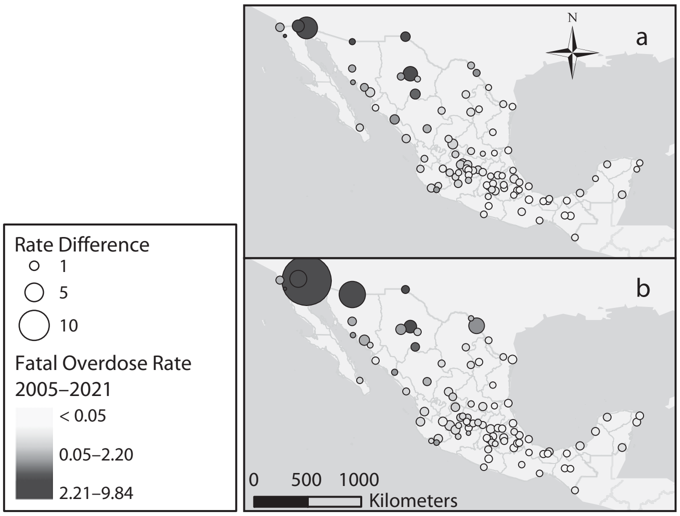

FIGURE 3— Absolute Changes in City Fatal Overdose Rates (a) Before and (b) After Declaration of the COVID-19 Pandemic: Mexico, 2005–2021

Note. Part a shows rate differences between 2005–2007 and 2017–2019. Part b shows rate differences between 2017–2019 and 2020–2021. For a full-color version of this map, please see Figure B of the Appendix (available as a supplement to the online version of this article at http://www.ajph.org).

We corrected for the incomplete coverage of deaths using a city-specific correction factor,[26] but there is the possibility that the coverage of fatal overdose deaths differs from other deaths or that there is miscoding of the cause of death for drug overdose deaths. For example, because drug use is stigmatized, overdoses could occur in isolation and discovery of the decedent could occur after a long time with little indication of cause.[4] In these cases, it is challenging for medical examiners to classify the underlying cause of death as drug involved, particularly without the use of toxicology equipment and the legal and material infrastructure to further investigate the cause of death. This is evident in toxicology data from the Servicio Médico Forense, which in 2021 reported only 1 death from drugs in the states of Baja California, Sonora, Sinaloa, Zacatecas, Nayarit, Colima, Aguascalientes, and Zacatecas but 528 in Chihuahua, 199 in Mexico City, and 283 in Jalisco.[28] This inconsistency in reporting overdose fatalities may explain why the estimated fatal overdose rate for Tijuana, a city known for its high prevalence of drug use, ranked as 16th highest in Mexico between 2005 and 2021.

It is likely that our estimates are a serious underestimation of the true extent of overdose mortality in Mexico. To our knowledge, no data exist to assess whether the extent of undercounts of overdose mortality has changed over time or varies across geographic areas, which would affect our findings regarding secular changes and spatial distribution. This limitation of our study stems from the inadequacy of the current overdose surveillance system in Mexico.

Furthermore, drug-involved events are relatively rare. This limitation does not affect representativeness of the estimates of drug-involved mortality; however, it may affect reliability of the estimates at smaller geographic levels (e.g., municipality). To address this, we pooled 3-year (2-year for the last period) deaths and population. Last, we lacked information on contributing causes (T and S codes), which could have allowed us to explore specific drugs contributing to fatal overdoses, a major and important knowledge gap in Mexico. For example, recent testing for fentanyl in Mexicali found that close to 20% of deaths were fentanyl related.[32]

Public Health Implications

There are several implications of our findings. First, surveillance of drug-related deaths in Mexico is challenging, demonstrating an urgent need for investment in data infrastructure to assess the true magnitude of overdose mortality in Mexico and to monitor trends that indicate a looming overdose crisis. These investments include the use of standardized protocols for coding and reporting drug-related deaths, use of toxicology to identify specific drugs involved in fatal overdose, and the integration of contributory codes on death certificates.[31,33] To account for the gap between overdose events and reporting these events, real-time surveillance systems, including wastewater[34] and street-based[11] drug-checking studies, are necessary for rapid identification of shifts in local drug supply.

Second, the steep increases in fatal overdose we observed emphasize the need for CONASAMA, in partnership with civil society organizations, to coordinate a decentralized, national harm reduction strategy. One of the most effective interventions to prevent opioid overdose deaths is community distribution of harm reduction supplies (e.g., fentanyl test strips, naloxone) paired with education on how to use them for people most likely to witness an overdose.[4,31] In Mexico, however, naloxone is currently classified as a psychotropic drug that requires a prescription and is not available at most pharmacies.[17,31] Our study supports the need for the declassification of naloxone as psychotropic, particularly to address the concerning trend in overdose deaths in the northwest of the country.

Third, future studies should consider the city characteristics that drive fatal overdose rates in Mexican cities. This includes assessing the social, structural, and policy conditions contributing to overdose risk and how these conditions intersect for people in situations of vulnerability,[35] as well as evaluating context-specific interventions to prevent and reverse the occurrence of overdose. This research will be critical for the development of policies and infrastructure to prevent and mitigate overdose risk.

Conclusions

We aimed to understand the temporal and geographic variability in fatal overdose rates in Mexico. We observed an acceleration of fatal overdose rates, particularly in urban areas and in cities closer to the United States. Although the magnitude of the rates in Mexico seems smaller than in the United States, the similarity in temporal trends suggests that important changes in overdose risk are occurring in Mexico, particularly because of the presence and use of synthetic opioids. To prevent an overdose epidemic in Mexico, there is a need for stronger data on drug-related behaviors and harms, harm reduction services prioritizing cities and populations with higher risk, and the expansion of noncompulsory, evidence-based treatment of opioid use disorder. AJPH

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Note. The findings of this study and their interpretation are the responsibility of the authors and do not represent the views or interpretations of the institutions or groups that compiled, collected, or provided the data. The use of data from these institutions does not imply that they have participated in, approved, endorsed, or otherwise supported the development of this publication. They are not liable for any errors, omissions, or other defects or for any actions taken in reliance thereon. The funding agencies had no involvement in the study design; in the data collection, analyses, or interpretation of data; in the writing of this article; or in the decision to submit the article for publication.

CONFLICTS OF INTEREST

The authors report no potential or actual conflicts of interest.

HUMAN PARTICIPANT PROTECTION

This study is exempt from institutional review board review because it involves only de-identified publicly available data.

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