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Jose Antonio Iglesias Date

An Investigation into The Epidemiologic Landscape of Drug Overdose Mortality, Georgia, 2000 to 2020

By

Jose Antonio Iglesias
Degree to be awarded: MPH

Epidemiology

_____ [Chair's signature]
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By

Jose Antonio Iglesias

B.S.
The University of South Florida
2022

Thesis Committee Chair: Michael Kramer, PhD, MMSc

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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2024

Abstract

An Investigation into The Epidemiologic Landscape of Drug Overdose Mortality, Georgia, 2000 to 2020

By Jose Antonio Iglesias

This study examines the escalating Georgia drug overdose health crisis, which has been steadily worsening over time, affecting communities statewide. Opioids and substance misuse increased in the late '90s and early 2000s but skyrocketed in 2010 and 2013 with the influx of heroin and fentanyl. In 2017, the Department of Health and Human Services declared the opioid crisis a national public health emergency. Despite ongoing national recognition of the crisis, overdose fatalities continue to rise. Using Georgia Department of Public Health (DPH) data, containing multiple cause of death information, the study utilized statistical and spatial analysis to identify demographic and geographic variation in Georgia fatal drug overdoses from 2000 to 2020. Analyzing the relationship between Social Determinants of Health (SDOH) and 2015 to 2020 drug overdose mortality data using aspatial and spatial error models and Moran's I and Hausman statistical test, revealed associations between SDOH and mortality. Overdose mortality rates were at their lowest in 2000 and peaked in 2020, shifting from 4.68 deaths to 18.13 per 100,000 individuals in this period. Unintentional drug overdose was the leading cause of overdose death in Georgia, making up 86.8% of all overdose deaths, followed by suicides making up 9.7%. The north and southeast regions of Georgia were of particular concern, containing the majority of counties at high risk of overdose fatalities. The analysis revealed that several SDOH themes, such as housing composition, minority status & language, and housing & transportation, were positively associated with overdose mortality, indicating that as these factors increase overdose fatalities increase. The socioeconomic theme was the only SDOH theme that was negatively associated with overdose mortality, indicating a decrease in deaths as socioeconomic conditions improve. This study contributed to a deeper understanding of the drug overdose landscape in Georgia, offering insight into demographic, geographic, and socioeconomic implications on overdose mortality. The results emphasize the need for targeted public health interventions and policy approaches that address the shifting overdose landscape.

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Introduction

Georgia, like many parts of the United States, has been consistently affected by the growing drug overdose public health epidemic.[1] Drug overdose mortality includes poisoning by drugs and biological substances that result in death, including all manners of intent, such as unintentional, suicide, homicide, and undetermined intent.[2] Rooted in complex social and economic disparities, this issue disproportionately burdens the most vulnerable individuals and segments of society, influencing overdose deaths and demanding a better understanding of their causes and consequences.[3] Understanding the root cause of this epidemic allows us to develop targeted public health interventions and policies that help those most affected, building toward an equitable future.

This thesis examines Georgia's drug overdose mortality through the epidemiologic landscape of the Georgia public health crisis between 2000 and 2020, a period marked by significant demographic shifts and evolving public health infrastructure.[4] In this two-decade span, Georgia's population grew yearly, increasing 30.4% from the 8.2 million Georgia residents who lived there in 2000. In the same period, the Black, non-Hispanic, population saw the most growth, increasing from 2.4 million in 2000 to 3.4 million in 2020. Hispanics saw the second highest growth, increasing from 441,576 in 2000 to 1,079,422 in 2020.[4]

This study focuses on distinct trends and demographic shifts associated with Georgia drug overdose mortality. Recognizing that health outcomes are not uniformly distributed across geographical areas, this thesis will examine mortality data across the state's urban, suburban, and rural communities. This spatial analysis will expose potential variations in mortality, highlighting the unique challenges each individual and county faces. Disaggregating the data by

demographics and analyzing demographic trends and geographic variation will further expose potential differences and point out the most burdened communities.

While trends and shifts may show who and where these tragedies occur, a better understanding is necessary. Beyond demographic and spatial trends lie deeper contributing forces that affect Georgia's public health landscape. We must look beyond the surface and examine the underlying Social Determinants of Health (SDOH) that shape vulnerability, violence, and harm. Social determinants like poverty, unemployment, education, and social support all contribute to this public health crisis. By understanding these interconnected factors, we can move beyond identifying who is affected to tackling the forces that create vulnerability. By doing so, the study aims to shed light on the invisible strings fueling the overdose crisis, informing future prevention and intervention strategies in Georgia.

Social Determinants of Health

The Centers for Disease Control and Prevention (CDC) defines SDOH as "nonmedical factors that influence health outcomes," or "conditions in which people are born, grow, work, live and age," as well as "the wider set of forces and systems shaping the conditions of daily life." [5] This includes the socioeconomic constraints that limit access to quality health and mental health services and the racial and ethnic disparities that perpetuate systemic inequities.[5] These forces manage to entangle individuals and communities in a dangerous cycle, potentially contributing to drug overdose mortality in Georgia.

We must consider how factors, such as limited access to education and economic opportunities, can contribute to feelings of mental anguish, affecting mental health and increasing the risk of substance abuse. Unequal access to employment opportunities and quality education can contribute to poverty, potentially affecting substance use.[6] Fear of stigma related

to substance use can deter individuals from seeking care or receiving adequate treatment, potentially leading to delayed reporting of drug overdose and subsequent death.[7] Furthermore, racism and discrimination can lead to chronic stress and isolation, all of which contribute to increased vulnerability and drug use.[8]

By examining these underlying social determinants of health, we can gain a better understanding of Georgia's overdose mortality landscape. This knowledge is crucial for developing effective interventions that target the root cause of disparity.

Understanding Drug Overdose Mortality

Socioeconomic factors can often burden vulnerable individuals, disproportionately impacting their well-being and potentially influencing drug overdose deaths. This connection emphasizes the need to better understand the root cause of overdose fatalities. To highlight these issues, this study explores the shifting landscape of drug overdose fatalities, focusing on the rise of opioids, like heroin and fentanyl, and their impact on unintentional versus intentional overdoses.

Opioids, the leading cause of overdose-related death, have had a detrimental impact on Georgia and its residents, mirroring ongoing national trends.[1,10] The opioid epidemic was sparked by the significant increase in opioid prescriptions, opioid use, and, subsequently, rising overdose deaths in the 1990s and early 2000s. Pain medications were increasingly and widely prescribed, resulting in large-scale drug dependence and addiction.[10] This widespread dependence and addiction resulted in a rise in drug overdose deaths. The opioid overdose crisis gained momentum again around 2010 with an influx of heroin and again in 2013 with a rise in synthetic opioids like fentanyl infiltrating the drug supply.[10]

In the U.S., over one million individuals have died of drug overdose since 1999.[11] During the study period of 2000-2020, Georgia, like much of the U.S., witnessed a staggering increase in overdose deaths, accumulating over 20,000 deaths. Between 2010 and 2020, the total number of opioid-related overdose deaths in Georgia increased by 207%. Opioid-related overdose deaths reached a critical point in October 2017, prompting the Department of Health and Human Services to declare the opioid crisis a national public health emergency.[1]

Ultimately, Georgia's drug overdose public health crisis demands a better understanding to allow for targeted interventions, focused resource allocations, and reduction of deaths. Through a rigorous analysis of demographic patterns, spatial distributions, and the interplay of SDOH, the study looks into these complex issues in the hope of better understanding the overdose mortality landscape, as well as identify populations and geographic areas disproportionately impacted and identify potential contributing forces that affect drug overdose mortality.

Finally, uncovering these patterns and disparities and addressing social injustices and inequities that contribute to drug overdose deaths serves as a crucial step toward generating knowledge that empowers impactful overdose prevention and intervention strategies.

Methods

Data sources

The study utilized Georgia mortality data acquired from the Georgia Department of Public Health (GDPH). This restricted access dataset was provided by the Office of Health Indicators for Planning (OHIP) and made available with permission through the Public Health Information Portal (PHIP) of GDPH. The data included all drug overdose fatality data from 2000 to 2020, encompassing both overall state death cases and individual-level cause-of-death data

extracted from death certificates. Death certificates, an official public record that document and verify death, provided information such as demographics, manner of death, and specific cause of death, enabling a comprehensive analysis of mortality trends and patterns over the years. State and county population data for the years 2000-2009 were sourced from the 2000 decennial census counts, while data from 2010–2019 were derived from the 2010 American Community Survey (ACS) 5-year estimates. Population estimates for 2020 were derived from the 2020 ACS 5-year survey. The Social Vulnerability Index (SVI) is a spatial analytic tool developed by CDCs Agency for Toxic and Substances and Disease Registry (CDC/ATSDR) used to identify communities requiring support and specific needs. The integration of SVI SDOH variables such as poverty, unemployment, education, single parent families, and minority status, the study aims to investigate the relationship between drug overdose mortality from 2015 to 2020 and SDOH variables.

Study population

The study population consists of all residents of Georgia from 2000 to 2020, encompassing a total of 20,781 drug overdose fatalities during the study period. All age and race/ethnic groups were included in the analysis to better understand overdose mortality across multiple demographics. The study focused exclusively on individuals residing in Georgia to reflect the landscape of drug overdose mortality within Georgia.

Variables and definitions

Drug overdose deaths were defined by *International Classification of Disease, 10th Revision* (ICD-10) underlying cause of death codes: X40-X44 (unintentional poisoning by drugs), X60-X64 (suicide by drugs), X85 (homicide by drug poisoning), or Y10-Y14 (drug poisoning of undetermined intent). The type of drugs involved in overdose death are indicated by

ICD-10 multiple cause of death codes: T40.0 (opium), T40.1 (heroin), T40.2 (natural, semi-synthetic, and synthetic opioids), T40.3 (methadone), T40.4 (synthetic opioids other than methadone), T40.5 (cocaine), T43.6 (psychostimulants with abuse potential), and T50.9 (unspecified).

Age groups for all death types included <15 years, 15 – 24, 25 – 34, 35 – 44, 45 – 54, 55 – 64, and 65+ years. Sex was characterized as either Male or Female. Race variables were categorized as White, Black, Native Hawaiian or other Pacific Islander, American Indian or Alaska Native, Asian, or Multiracial. Ethnicity variables were categorized as non-Hispanic or Hispanic. Racial/ethnic groupings were then combined together and labeled as White, White - Hispanic, Black, Native Hawaiian or other Pacific Islander, American Indian or Alaska Native, Asian, or Multiracial. Hispanics predominantly constituted the White category, prompting its separation as a distinct group. On the other hand, little to no Hispanic ethnicity was observed among other racial categories, prompting them to be kept together and not separated as distinct groups.

Statistical analysis

This study employed a multi-step data analysis using R software to investigate demographics, spatial heterogeneity, and socioeconomic factors impacting overdose mortality. Following data cleaning and merging, sex, race, and age distributions were examined based on the underlying cause of death to investigate patterns associated with overdose mortality. Mortality rates, including case-specific, drug-specific, and overall overdose rates were calculated by dividing the number of deaths by the relevant population size of their corresponding death year and multiplying by 100,000 to adjust for a standard population of 100,000 individuals.

To explore geographic variation in overdose mortality rates, deaths were further stratified by county and grouped in 4 time periods: 2000-2004, 2005-2009, 2010-2014, and 2015-2020. County-specific mortality rates were then calculated by dividing the number of deaths in the specific county by the county population size and multiplying by 100,000.

An aspatial linear regression and spatial error model (a spatial autoregressive linear model) were then utilized to investigate the association between county-level overdose mortality rates from 2015 to 2020 and social determinants of health (SDOH) variables acquired from the 2014 Social Vulnerability Index. Global Moran's I was used to assess for spatial autocorrelation in the residuals from aspatial linear regression of mortality on SDOH, providing insight into how these forces influence the spatial distribution of overdose mortality rates across the state. To adjust for spatial autocorrelation of overdose mortality patterns, a spatial weights matrix using queen contiguity, which defines neighbors as sharing a side or an edge, was used to fit the Spatial Error Model. The Hausman test of coefficients was then used to test the consistency of the regression coefficients in a spatial error model compared to the aspatial model.

Results

Drug Overdose Deaths, Georgia, 2000 to 2020										
	Total		Homicide		Suicide		Undetermined intent		Unintentional	
	Female (N=8,359)	Male (N=12,422)	Female (N=14)	Male (N=31)	Female (N=1,125)	Male (N=893)	Female (N=363)	Male (N=313)	Female (N=6,857)	Male (N=11,185)
Age (Years)										
Mean (SD)	45.4 (13.7)	41.2 (13.5)	22.9 (28.2)	26.1 (27.9)	47.3 (14.3)	45.6 (14.2)	46.1 (15.4)	41.7 (15.8)	45.1 (13.4)	40.9 (13.3)
Median [Min, Max]	46 [0, 98]	41 [0, 101]	5 [0, 84]	29 [0, 82]	48 [12, 89]	46 [15, 87]	47 [1, 92]	42 [0, 89]	45 [0, 98]	41 [0, 101]
Age group										
<15	54 (0.6%)	64 (0.5%)	8 (57.1%)	15 (48.4%)	11 (1.0%)	0 (0%)	8 (2.2%)	16 (5.1%)	27 (0.4%)	33 (0.3%)
15-24	454 (5.4%)	1,290 (10.4%)	0 (0%)	0 (0%)	56 (5.0%)	73 (8.2%)	20 (5.5%)	22 (7.0%)	378 (5.5%)	1,195 (10.7%)
25-34	1,271 (15.2%)	2,944 (23.7%)	2 (14.3%)	4 (12.9%)	138 (12.3%)	136 (15.2%)	47 (12.9%)	51 (16.3%)	1,084 (15.8%)	2,753 (24.6%)
35-44	2,165 (25.9%)	3,034 (24.4%)	0 (0%)	4 (12.9%)	263 (23.4%)	203 (22.7%)	87 (24.0%)	89 (28.4%)	1,815 (26.5%)	2,738 (24.5%)
45-54	2,449 (29.3%)	2,977 (24.0%)	2 (14.3%)	3 (9.7%)	318 (28.3%)	245 (27.4%)	107 (29.5%)	69 (22.0%)	2,022 (29.5%)	2,660 (23.8%)
55-64	1,360 (16.3%)	1,592 (12.8%)	1 (7.1%)	1 (3.2%)	221 (19.6%)	158 (17.7%)	59 (16.3%)	48 (15.3%)	1,079 (15.7%)	1,385 (12.4%)
65+	606 (7.2%)	521 (4.2%)	1 (7.1%)	4 (12.9%)	118 (10.5%)	78 (8.7%)	35 (9.6%)	18 (5.8%)	452 (6.6%)	421 (3.8%)

Race and Ethnicity										
American Indian or Alaska Native	7 (0.1%)	15 (0.1%)	0 (0%)	0 (0%)	0 (0%)	2 (0.2%)	1 (0.3%)	0 (0%)	6 (0.1%)	13 (0.1%)
Asian	44 (0.5%)	69 (0.6%)	0 (0%)	0 (0%)	20 (1.8%)	13 (1.5%)	2 (0.6%)	1 (0.3%)	22 (0.3%)	55 (0.5%)
Black	1,296 (15.5%)	2,250 (18.1%)	9 (64.3%)	14 (45.2%)	110 (9.8%)	94 (10.5%)	60 (16.5%)	51 (16.3%)	1,117 (16.3%)	2,091 (18.7%)
Multiracial	20 (0.2%)	24 (0.2%)	0 (0%)	0 (0%)	5 (0.4%)	3 (0.3%)	0 (0%)	2 (0.6%)	15 (0.2%)	19 (0.2%)
Native Hawaiian or Other Pacific Islander	1 (0%)	2 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	2 (0%)
White - Hispanic	53 (0.6%)	187 (1.5%)	0 (0%)	1 (3.2%)	14 (1.2%)	16 (1.8%)	3 (0.8%)	7 (2.2%)	36 (0.5%)	163 (1.5%)
White, non-Hispanic	6,938 (83.0%)	9,875 (79.5%)	5 (35.7%)	16 (51.6%)	976 (86.8%)	765 (85.7%)	297 (81.8%)	252 (80.5%)	5,660 (82.5%)	8,842 (79.1%)

Table 1. Demographic characteristics of Georgia drug overdose deaths, by case type.

As Table 1 shows, a total of 20,781 drug overdose fatalities were reported in Georgia between 2000 and 2020. Unintentional drug overdose deaths accounted for the majority, comprising 86.8% (18,042) of overdose deaths, followed by suicides with 9.7% (2,018). Overall, males accounted for 59.8% of overdose deaths, with a mean age of 41.2 (SD: 13.5), while females comprised 40.2%, with a mean age of 45.4 (SD: 13.7). Race played a significant role, with White, non-Hispanic individuals disproportionately affected by overdose deaths, accounting for 80.9%, followed by Black individuals at 17.1%, collectively representing 98% of drug overdose deaths. White individuals had the highest number of overdose deaths in 3 of 4 ICD-10 overdose codes: undetermined intent, suicide, and unintentional drug overdose. Black individuals had the highest number of overdose deaths in 1 of 4 categories: homicide.

Over the study period, the drug overdose mortality rate in Georgia showed a gradual yet relatively consistent increase, shifting from 4.7 deaths per 100,000 individuals in 2000 to its peak of 18.1 deaths per 100,000 in 2020 (Figure 1A).

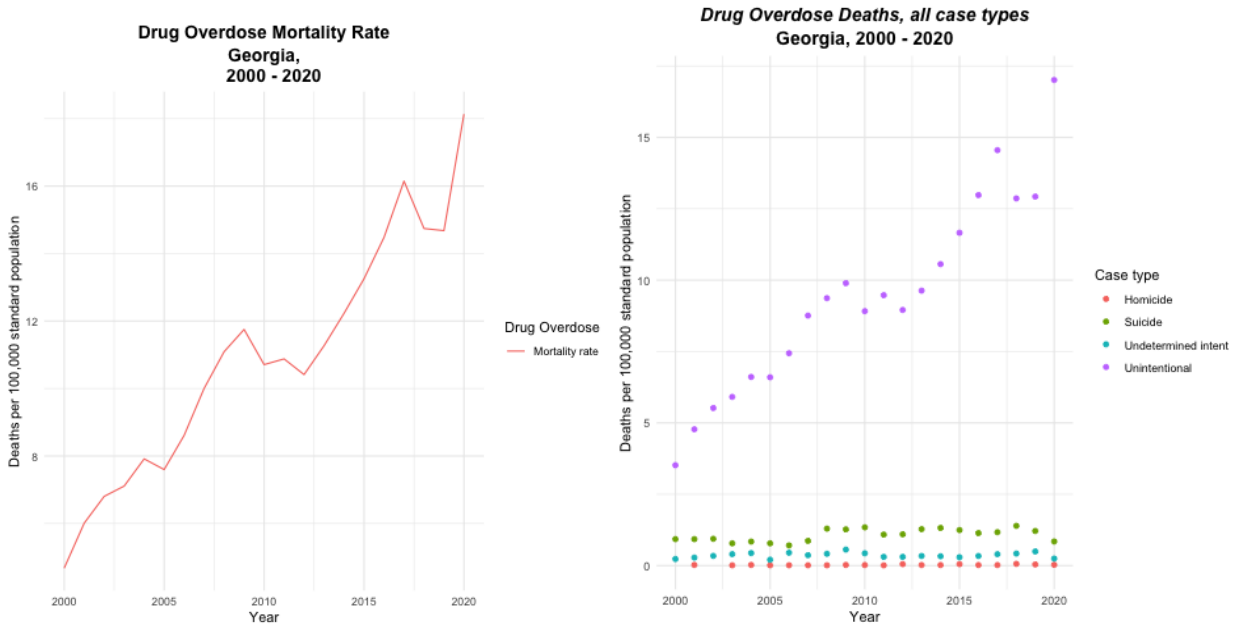

Figure 1. (A) Georgia overall drug overdose mortality rate, 2000 to 2020. (B) Georgia mortality rate, by case type, 2000 to 2020.

As Figure 1B shows, unintentional drug overdose was the leading cause of overdose death in Georgia. This specific drug type made up 86.8% of all overdose death, with ages 35–54 making up more than half of all unintentional deaths (Table 1). White non-Hispanic individuals accounted for 80.4% (14,502/18,042) of unintentional deaths, with White non-Hispanic males and females alone accounting for 79.1% (8,842/11,185) and 82.5% (5,660/6,857) of all unintentional male and female unintentional overdose deaths, respectively. Black individuals made up 17.8% (3,208/18,042) of unintentional overdose deaths; overall, White, non-Hispanic, and Black individuals accounted for 98.2% (17,710/18,042) of all unintentional overdose deaths (Table 1). The unintentional overdose mortality rate increased from 3.5 in 2000 to 14.6 in 2017, reaching its peak of 17 deaths per 100,000 individuals in 2020 (Figure 1B).

Suicides ranked as the second leading cause of drug overdose death in Georgia, accounting for 9.7% of drug overdose deaths (Table 1). Drug-related suicides predominantly affected individuals ages 35-54 and women, with women making up 55.7% of all drug-related suicide deaths. White individuals accounted for 87.8% of suicide deaths, with white males and females making up 85.7% and 86.8% of all male and female drug-related suicide deaths, respectively (Table 1). The suicide mortality rates were relatively stable in the early 2000s, ranging between 0.7 – 0.9 deaths 100,000. Georgia's drug-related suicide rate reached its peak of 1.3 in 2008 and 2010. After this high point, the rate remained stable and slowly decreased until it reached 0.9 in 2020 (Figure 1B).

As Table 1 shows, undetermined intent and homicide contributed to overdose deaths but to a lesser extent, causing 676 (3.3%) and 45 (0.2%) overdose deaths, respectively. White, non-Hispanic males and females made up 80.5% and 81.8% of all male and female undetermined intent deaths. In addition, undetermined intent overdose deaths were highest in ages 35–44 and

45-54, making up more than half of all deaths. Undetermined intent drug overdose mortality increased from 0.2 in 2000 to 0.6 in 2009, before stabilizing and decreasing to 0.3 per 100,000 in 2020 (Figure 1B). Homicide deaths were the only category where Black individuals, specifically Black female individuals, had a higher proportion of deaths than White female individuals. However, White men still made up the majority of male overdose homicide deaths (Table 1). The homicide mortality rate remained relatively stable between 0.01 – 0.02 deaths per 100,000, peaking at 0.05 in 2012 and 2015 (Figure 1B).

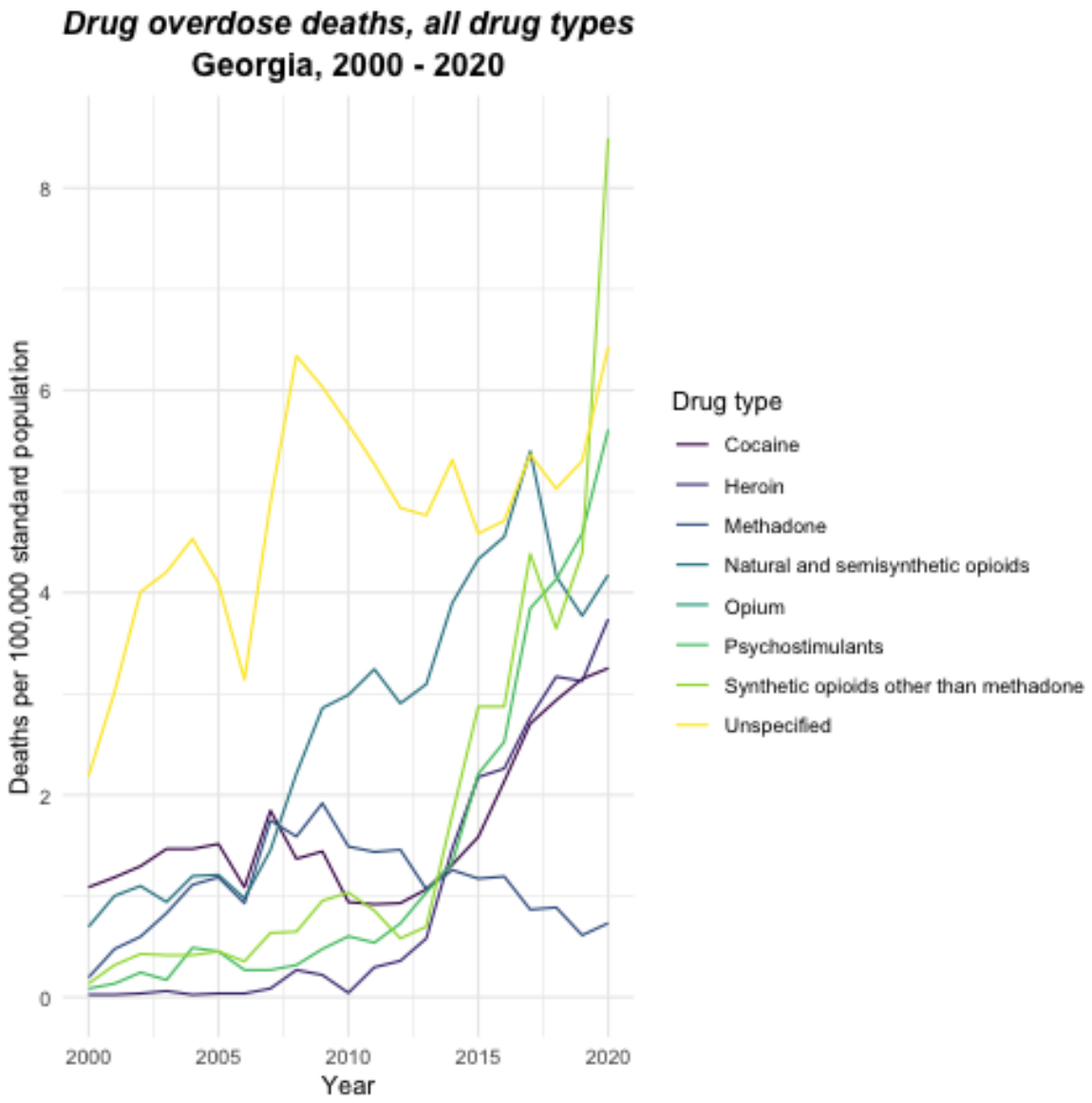

Figure 2. Georgia drug overdose mortality, by drug type, 2000 to 2020.

From 2000 to 2020, Georgia experienced various shifts in drug-specific overdose mortality rates, particularly evident in the significant rates of change observed after 2010 and in 2020. While drug-overdose categories are not mutually exclusive, there were general trends of increase across unspecified drugs, heroin, natural and semisynthetic opioids, synthetic opioids other than methadone, cocaine, and psychostimulants (Figure 2).

Unspecified drug types consistently held the highest overdose mortality rates, except in 2017 and 2020, when natural and semisynthetic opioids, followed by synthetic opioids other than

methadone, surpassed them, respectively. Synthetic opioids other than methadone, including drugs like tramadol and fentanyl, experienced a 65-fold increase in mortality rates over the two decades. The mortality rate increased from 0.1 deaths per 100,000 in 2000 to 4.4 by 2019. Between 2019 and 2020, the rate nearly doubled, increasing from 4.4 to 8.5, surpassing all other drug types and becoming the leading cause of drug overdose deaths (Figure 2).

Drug overdose mortality involving stimulants exhibited fluctuations over time but displayed an increasing trend after 2012. Cocaine-related mortality rates increased steadily from 1.1 in 2000 to its peak in 2020 at 3.3 per 100,000 individuals. Psychostimulant-related mortality increased from 0.9 in 2000 to its peak of 5.6 in 2020. Lastly, methadone exhibited fluctuations in mortality over time but was the only drug type to have a general trend of decline over the 20 years. Its mortality rate peaked at 1.9 in 2009 and decreased to 0.7 in 2020, ultimately becoming the least common cause of drug overdose death by the end of the study period (Figure 2).

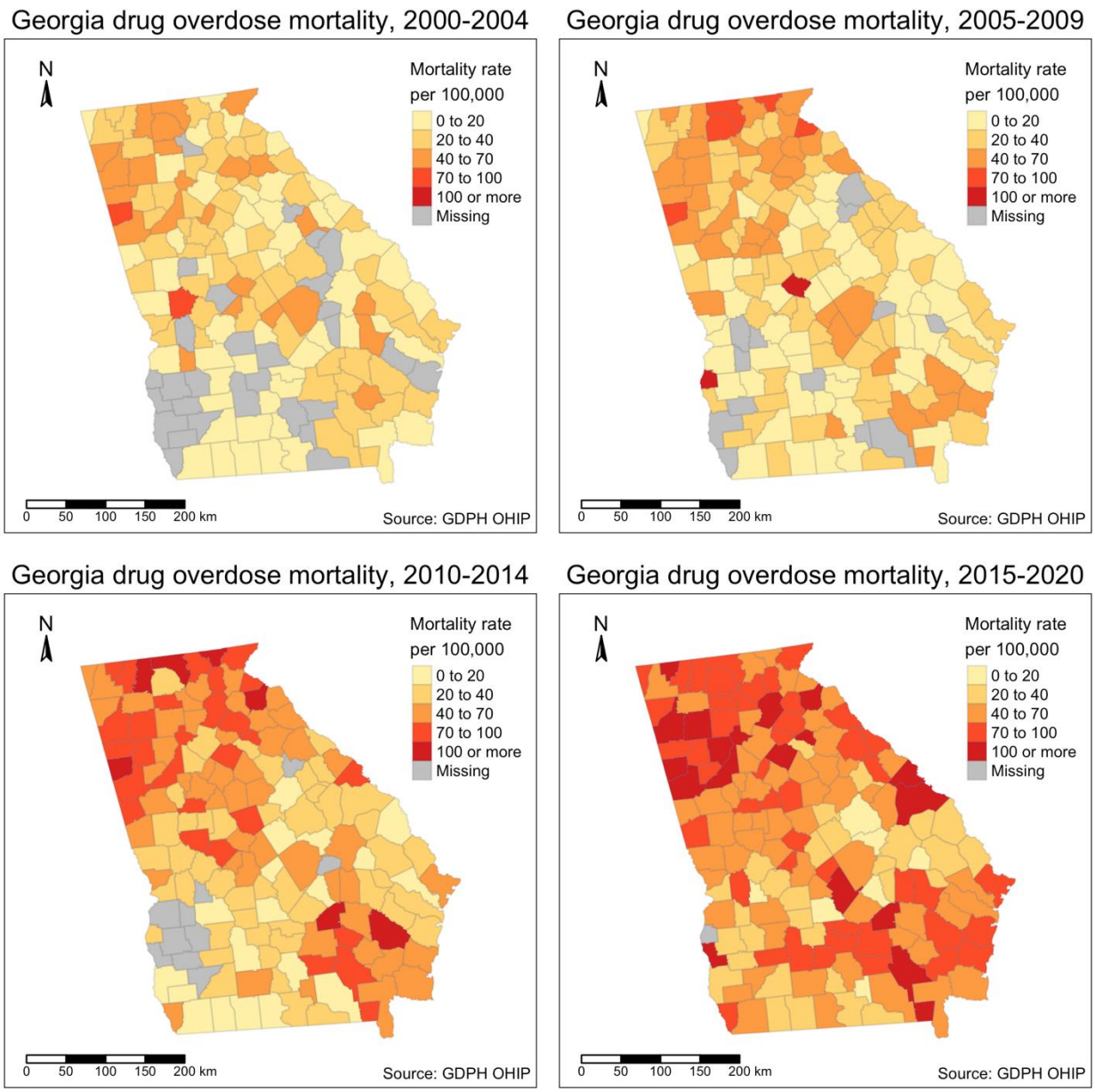

Figure 3. County drug overdose mortality, Georgia, 2000 to 2020.

Between 2000 and 2020, Georgia witnessed a tremendous rise in drug overdose mortality rates, experiencing a more than threefold increase from a median rate of 33.5 to 88.9 deaths per 100,000 individuals. Spatial analysis revealed consistent overdose mortality patterns throughout Georgia, particularly impacting the northern and southeastern regions, with sporadic clusters in central Georgia (Figure 3).

Specifically, from 2000 to 2004, two counties in west Georgia exhibited the highest drug overdose mortality rates, ranging between 70 to 100 deaths per 100,000 individuals, while the northwest region and Atlanta metropolitan area recorded rates between 20 to 70 per 100,000. Satellite clusters in central and southeastern Georgia experienced similar mortality rates as the northwest, ranging from 20 to 70 deaths per 100,000 individuals. Following similar spatial distributions, from 2005 to 2009, Georgia experienced a rise in overdose mortality rates, particularly in the northern and southeastern regions. In the north, mortality rates migrated east, with counties in the northeast reporting the highest mortality rates in the state and being of particular concern.

From 2010 to 2020, Georgia experienced a significant spike in overdose mortality rates statewide. From 2010 to 2014, the median mortality rate for this period was 67.2, with high mortality rates observed in the northern and southeastern regions. In the north, counties of particular concern were located along the state border with Tennessee, North Carolina, and Alabama. Counties in and around the Atlanta metropolitan area also saw increased rates of death, though to a lesser extent. The central and southeastern regions saw significant spikes in mortality, ranging from 20 to 100 deaths or more per 100,000. From 2015 to 2020, overdose mortality rates worsened, spreading across all regions of Georgia. The northwestern - Atlanta metropolitan area - and southeastern regions experienced the highest mortality rates. Rates of 100 deaths or more were also observed along Georgia's eastern border with South Carolina (Figure 3).

The Impact of Social vulnerability on 2015 - 2020 Overdose Mortality Rate									
	Unadjusted Aspatial Model			Mutually Adjusted Aspatial Model			Spatial Error Model		
(per 10%)	Model	2.5% CI	97.5% CI	Model	2.5% CI	97.5% CI	Model	2.5% CI	97.5% CI
Socioeconomic Theme	**-227.1**	**-387.6**	**-66.6**	**-286.5**	**-542.2**	**-30.8**	**-229.7**	**-462.8**	**3.3**
Poverty	-7.1	-13.8	-0.4	0.7	-9.5	10.8	11.4	1.2	21.5
Unemployment	0.1	-14.7	14.8	13	-3	29	8	-7.7	23.6
No HS Diploma	-8.1	-15.8	-0.5	-7.5	-17.3	2.4	-8.8	-17.8	0.3
Housing Composition Theme	**-93.5**	**-256.1**	**69**	**50.7**	**-143.8**	**245.1**	**106.3**	**-73.9**	**286.5**
Single parent household	-13.5	-31.3	4.2	4.7	-17.9	27.2	2.6	-18.9	24
Minority Status & Language Theme	**-30.3**	**-193.6**	**133**	**29.1**	**-150.3**	**208.5**	**44.2**	**-129.9**	**218.4**
Minority	-4.1	-6.8	-1.3	-5	-8.9	-1.2	-3.8	-8	0.3
Housing & Transportation Theme	**-137.5**	**-299.2**	**24.2**	**31.9**	**-212**	**275.8**	**182.6**	**-39.5**	**404.7**
Lambda									
log likelihood				**-757.7869**			**-750.039**		
Hausman test: p-value							**0.9509**		
Lambda							0.47249		
Log likelihood				-755.0657			-748.7462		
Hausman test: p-value							0.003582		

Table 2. Evaluating the Impact of Social Vulnerability on 2015-2020 Drug Overdose Mortality Rate.

The regression coefficients suggest that the socioeconomic SVI theme is negatively associated with overdose mortality in both aspatial and spatial error models. For each 10% increase in socioeconomic percentile ranking, there are about 229.7 (CI: 462.8, 3.3) fewer deaths per 100,000. The regression coefficients also suggest that household composition, minority status & language, and housing & transportation SVI themes are positively associated with overdose mortality in the mutually adjusted and spatial error models. For each 10% increase in household composition, minority status & language, and housing and transportation themes, there are about 106.3, 44.2, and 182.6 more deaths per 100,000, respectively.

Individual variables within socioeconomic, household composition, and minority status and language SVI themes were also examined. Socioeconomic variables include poverty, unemployment, and no high school diploma. Poverty and unemployment were found to be positively associated with overdose mortality. For each 10% increase in poverty, there is an 11.4 (CI: 1.22, 21.52) increase in deaths per 100,000 individuals. In addition, for each 10% increase in unemployment, there are 8 (CI: -7.71, 23.64) more deaths per 100,000 individuals. No high school diploma was found to be negatively associated with overdose mortality. For each 10% increase in no high school diploma, there are about 8.8 (CI: -17.8, 0.3) fewer deaths per 100,000.

The household composition variable of interest included those in single parent households with children under 18. Regression coefficients suggest that for each 10% increase in single parent household composition, there are 2.6 more deaths per 100,000. The minority status & language variable of interest included that of community minority status (all persons except white, non-Hispanic). Regression coefficients suggest that for each 10% increase in minority status, there are 3.8 (CI: -7.99, 0.33) fewer deaths per 100,000.

The unadjusted aspatial model found all SVI themes to be negatively associated with drug overdose mortality. Similarly, variables of interest, such as poverty, no high school diploma, single-parent household, and minority status were also found to be negatively associated with overdose mortality. Unemployment status was the only variable positively associated with drug overdose mortality in the unadjusted aspatial model, though insignificant, with 0.1 more deaths per 100,000 for every 10% increase in unemployment status.

The Hausman statistical test is a tool used to evaluate the consistency between regression coefficients in the spatial error model compared to the aspatial model. When looking at overall SVI themes, based on the p-value > 0.05, the Hausman test suggests there is non-significant bias from spatial autocorrelation in the aspatial model, and thus we would prefer the aspatial model over the spatial error model. When looking at specific SVI variables, based on the p-value < 0.05, the Hausman test suggests significant bias in the aspatial model compared to the spatial error model, meaning we would prefer the spatial error model.

Discussion

The findings of this analysis shed light on the epidemiology of drug overdose mortality in Georgia between 2000 and 2020, a period marked by 20,781 fatal overdose deaths. The study discovered an increase in drug-related mortality rates over the two-decade period, from 4.7 deaths per 100,000 in 2000 to a peak of 18.1 in 2020, revealing distinct demographic and geographic trends and patterns that contribute to overdose fatalities, highlighting the severity of this public health issue in Georgia.

Demographic analysis revealed distinct burdens of the Georgia drug overdose crisis on different groups of people. Males were predominantly affected by drug overdose fatalities, making up 60% of all overdoses, though females made up the majority of overdose suicides and

undetermined intent. This finding is consistent with overall U.S. overdose fatality data from 2000 to 2020, which highlights that male mortality rates consistently exceeded female mortality rates.[12] In addition to sex differences, the study highlights the disproportionate impact on specific races, notably White, non-Hispanic, and Black individuals, paralleling Georgia and U.S. overdose research, which found that the overdose mortality rate is highest among whites compared to other racial/ethnic groups, while simultaneously emphasizing the sharp increase in mortality across the Black and Latino communities.[12]

In addition, the study also analyzed cause-specific overdose mortality trends over the two-decade span. Unintentional drug overdose deaths were the leading cause of drug-related death, accounting for the vast majority, 86.8%, of all overdose fatalities, followed by suicides with 9.7%. Recent 2022 U.S. national overdose data showed similar rates, finding that 92.3% of overdoses were unintentional and 4.5% were suicides, followed by undetermined intent and homicides, making up a small proportion of overdose deaths.[13] Despite ongoing efforts to address and curb substance misuse, it is evident that overdose mortality rates show the escalating burden and demand of drug use. For example, tracking and regulating opioid prescriptions may not be addressing the full extent of the overdose crisis. In addition, the availability of Narcan, which aims to reduce overdose fatalities, may be affected by inadequate distribution and outreach practices within communities. These ongoing and continuous cycle of elevated overdose mortality emphasizes the need for additional and new comprehensive prevention strategies targeting substance misuse and abuse as previous prevention efforts may not be keeping up with the escalating demand.

Furthermore, drug-specific mortality analysis was conducted and revealed increased rates of opioid and stimulant-involved overdose deaths in recent years. Although experiencing various

fluctuations, all opioids, except methadone, experienced increased mortality rates after 2010, with synthetic opioids other than methadone being the leading cause of opioid-involved mortality. Stimulants also experienced similar increases in mortality. These findings are consistent with U.S. Health and Human Services drug-specific fatal overdose data, which showcase opioids, specifically synthetic opioids, as the primary contributor to drug overdoses, and also emphasize that stimulant overdose mortality, such as cocaine and psychostimulants, has dramatically increased in recent years.[14, 15]

Spatial analysis provided information on the geographic distribution of drug overdose mortality across Georgia during four time periods, revealing clusters of elevated overdose mortality rates throughout the two-decade span. Particularly, the north and southeastern regions of the state consistently bore the highest burden of overdose throughout the entire study period. In the early 2000s, Georgia counties of particular concern included rural counties in the northwest, along the border with Alabama. Between 2010 and 2020, a transition point in overdose mortality was witnesses with the overdose burden shifting from rural counties to more urban metropolitan areas across all regions of the state. The presence of increased overdose mortality in the Atlanta metropolitan area, including rural counties in the north and southeast, parallels a similar spatial analysis conducted by the Centers for Disease Control from 2000 to 2016, which shows the burden of mortality in the Atlanta metropolitan area and central Georgia, with pockets of elevated mortality across the north and southeast regions of the state.[16] These notable increases over time shows the need for targeted intervention strategies and comprehensive preventative action aimed at reducing the burden of drug overdoses in counties of particular concern.

While the study provided information on drug overdose mortality, it is important to acknowledge several limitations that may have impacted the results. The study's mortality data relied on information obtained from death certificates. Death certificates are valuable documents that may be subject to reporting errors and inaccuracies due to variations in reporting practices or unclear/misclassified causes of death. These limitations may fail to allow us to capture the full extent of drug overdose-related mortality. In addition, the study relied exclusively on overdose fatalities, failing to encompass the larger segment of overdose-related non-fatal injuries nor the wide net of individuals struggling with substance use disorders.

Future research studies should incorporate all drug overdose-related injuries, not only fatal drug overdose cases. This would allow for a better understanding of Georgia's drug overdose landscape and provide insight into the true burden of substance misuse in the state. In addition, the incorporation of information pertaining to alcohol-involved drug overdoses would be crucial in understanding the association between alcohol consumption and drug overdose, allowing for the identification of at-risk populations and the implementation of interventions to help deter alcohol and drug misuse and subsequent overdose injuries. Lastly, research into substance use disorder treatment and intervention strategies is crucial to help avoid overdose events and reduce casualties in this community of at risk individuals.

Overall, drug overdose mortality has worsened over the two-decade period, particularly in the north and southeast regions of Georgia. Overdose fatalities primarily affected males, White, non-Hispanics, and ages 35 to 54. Unintentional overdose fatalities were the primary leading cause of death with opioids, specifically synthetic opioids other than methadone, leading the overdose fatality rate. All in all, a better understanding of these shifting overdose trends is critical to formulate and develop targeted public health initiatives and interventions aimed at

reducing overdose mortality rates and addressing the underlying determinants of these fatalities. By understanding why and where overdose mortality is increasing, we can better target these interventions into communities at high risk of overdose fatalities. We must move away from medical intervention after the overdose event and implement preventative support efforts that assist people who use drugs and those battling addiction. By addressing these issue that contribute to substance use and overdose, lives and health outcomes for all individuals affected by drugs use can improve.

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