Decomposing change in the age-standardized drug overdose death rate in the United States, 1999 to 2022

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Short abstract

The United States is in the midst of a drug overdose crisis. Between 1999 and 2022, the national age-standardized drug overdose death rate increased five-fold from around 6 to around 33 deaths per 100,000 population. The rise in the age-standardized drug overdose death rate in the United States is the result of multiple overlapping sub-epidemics involving different drugs as well as increasing polysubstance use. Yet, previous research that describes U.S. drug overdose mortality patterns often focuses on overall drug deaths, narrowly focuses on single substances, or double counts deaths in the presence of polydrug use. Moreover, previous research exhibits a limited investigation of drug overdose mortality dynamics at the subnational level—such as by geography or race/ethnicity—and how these have contributed to the national trend in the age-standardized drug overdose death rate. Here, we systematically decompose the year-to-year change in the national age-standardized drug overdose death rate in the United States between 1999 and 2022 using Kitagawa decomposition. We identify additive contributions from (a) change in the population composition, as defined by the intersection of state, sex, and race/ethnicity; and (b) change in the state–sex–race/ethnicity–age–substance-specific death rates, using 18 mutually exclusive categories of substances and substance combinations. Our analysis uncovers important changes in the drivers of the national age-standardized drug overdose death rate over time and

contributes to a more nuanced understanding of the complex mosaic of the U.S. drug overdose crisis.

Introduction and background

The United States is in the midst of a drug overdose crisis. Between 1999 and 2022, the national age-standardized drug overdose death rate increased five-fold from 6.0 to 32.8 deaths per 100,000 population (see Figure 1). This increase has been almost continuous and even accelerated after 2015. However, more recent data suggest that the steep rise in the age-standardized drug overdose death rate may be slowly coming to a halt (Ahmad et al., 2025).

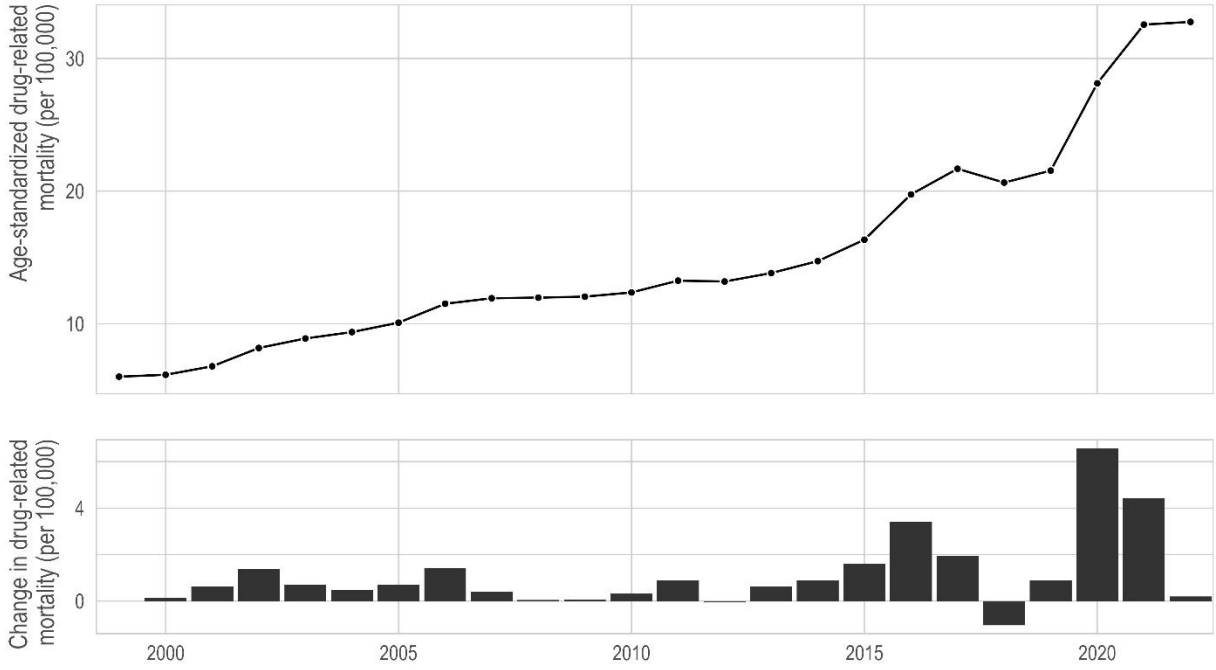

Figure 1. Age-standardized drug overdose death rate (top panel) and year-to-year change in the age-standardized drug overdose death rate (bottom panel) in the United States, 1999–2022. *Source*: Authors' own calculation.

The rise in the age-standardized drug overdose death rate in the United States is the result of multiple overlapping sub-epidemics involving different drugs (Jalal et al., 2018). Increasing polysubstance use and diverging trends across geography and sociodemographic factors have further added to the complex mosaic of the U.S. drug overdose crisis (Alexander et al., 2018; Kiang

et al., 2019). Yet, previous research that describes U.S. drug overdose mortality patterns often focuses on overall drug deaths or narrowly focuses on one substance. In addition, when multiple drug groupings are considered, groups often involve double counting deaths in the presence of polydrug use. Finally, previous research also exhibits a limited investigation of variation by geography or sociodemographic factors, such as race/ethnicity.

Here, we aim to systematically decompose changes in the age-standardized drug overdose death rate in the United States between 1999 and 2022. We build on previous work by using mutually exclusive categories of both single and multiple substances and simultaneously decomposing change in the national age-standardized drug overdose death rate into contributions by state, sex, race/ethnicity, age, and substance(s) used.

Data & methods

We decompose the year-to-year change in the national age-standardized drug overdose death rate per 100,000 population in the United States over the period 1999 to 2022. We calculate the age-standardized drug overdose death rate as follows:

We use mortality data from the United States Center for Disease Prevention and Control National Vital Statistics System's (NVSS) restricted-use multiple cause of death files (https://www.cdc.gov/nchs/nvss/nvss-restricted-data.htm). These microlevel data contain information for every death that occurs in the United States including decedents' age at death, sex, county of residence, ethnicity, and race as well as information about the death including the county of death, underlying cause of death, and up to 20 contributing causes of death. Both underlying and contributing causes of death are coded using the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10). For each year and state, deaths were aggregated to sex-, race-, and ethnicity-specific groups in five-year age bins (0–4, 5–9, 10–14, …, 80–84, 85+). The NVSS categorizes sex as either male or female. Consistent with previous work, we defined racial and ethnic groupings as: Hispanic ethnicity (for all racial categories), non-Hispanic American Indian or Alaska Native, non-Hispanic Asian or Pacific Islander, non-Hispanic Black, or non-Hispanic white. Observations with missing state, sex, ethnicity, or race were dropped from the analysis.

Corresponding population counts were taken from the National Cancer Institute Surveillance, Epidemiology, and End Results (SEER) Program (https://seer.cancer.gov/popdata/download.html). We used the U.S. 2000 population as the standard population (Anderson & Rosenberg, 1998; Klein & Schoenborn, 2001).

Consistent with consensus recommendations (Injury and Surveillance Workgroup 7, 2012), drug overdose deaths are defined as deaths that contain both (1) an underlying cause of death with ICD-10 codes X40–X44 (accidental poisoning), X60–X64 (intentional self-harm), X85 (assault), or Y10–Y14 (undetermined intent) as well as (2) at least one contributing cause with a drug-related ICD-10 code T36.0–T50.9. Consistent with previous work, we identified and defined primary substances of interest as follows, referring to drug groupings by the most common drug within a drug-related ICD-10 code: heroin (T40.1); prescription opioids including both natural opioid analgesics such as morphine and codeine and semi-synthetic opioids such as oxycodone (T40.2); synthetic opioids excluding methadone (T40.4), such as fentanyl and its analogues (hereafter, "fentanyl"); cocaine (T40.5); psychostimulants with abuse potential (T43.6) such as methamphetamine (hereafter, "methamphetamine"); and xylazine, defined as deaths involving unspecified antiepileptic and sedative-hypnotic drugs (T42.7) or other antihypertensive drugs (T46.5) (Ahmad et al., 2025; Friedman, 2025).

Based on these six primary substances, we created 18 mutually exclusive categories. For most primary substances, we analyzed them alone, with fentanyl, and with an unspecified drug to create a total of 12 groups: heroin alone, heroin and fentanyl, heroin and unspecified drug, prescription opioid alone, prescription opioid and fentanyl, prescription opioid and unspecified drug, cocaine alone, cocaine and fentanyl, cocaine and unspecified drug, methamphetamine alone, methamphetamine and fentanyl, and methamphetamine and unspecified drug. We defined a xylazine-involved death as any death that involved xylazine (including those that involved xylazine alone or xylazine with a combination above). For fentanyl deaths, we defined deaths as those involving fentanyl alone, fentanyl with an unspecified drug, and all remaining fentanyl-involved deaths (noting a xylazine-involved death takes precedence). The remaining drug deaths

were then separated into those involving only unspecified drugs and all other remaining drug deaths.

For our decomposition analysis, we work with five-year age groups (0–4, 5–9, 10–14, …, 80–84, 85+). For each five-year age group, we define subpopulation strata as combinations of [1] state (50 U.S. states plus the District of Columbia), [2] sex (male, female), and [3] race/ethnicity (Hispanic, non-Hispanic American Indian or Alaska Native, non-Hispanic Asian or Pacific Islander, non-Hispanic Black, or non-Hispanic white).

Our decomposition analysis proceeds in three steps: First, we derive age-specific contributions to the year-to-year change in the national age-standardized drug overdose death rate. We do this by expressing the change in the age-standardized drug overdose death rate as the sum of changes in age-specific drug overdose death rates weighted by the corresponding age-specific standard population. Second, using Kitagawa decomposition (Preston et al., 2001), the change in each national age-specific drug overdose death rate is disaggregated into contributions from (a) change in population composition (where subpopulations are defined by geography, sex, and race/ethnicity), and (b) change in the age-specific drug overdose death rates of the various subpopulation strata. Third, for each subpopulation, the contribution from the change in the age-specific drug overdose death rate is further disaggregated by substance or substance combination.

The result of our decomposition analysis are additive contributions to the year-to-year change in the national age-standardized drug overdose death rate from (a) change in the population composition, as defined by the intersection of state, sex, and race/ethnicity; and (b) change in the state–sex–race/ethnicity–age–substance-specific death rates. For parsimony, we sum contributions over age by (a) sex and race/ethnicity, (b) state, and (c) substance in this abstract. In the final analysis, we will also consider intersections of these categories.

Preliminary results

After removing observations with missing race or ethnicity (N=207,471; 0.33%), we identified 1,156,371 drug deaths (1.8%) out of a total of 62,396,276 deaths from 1999 through 2022. Over

the whole period, 29% of drug deaths were categorized as “other drug”, 17% as “unspecified drug”, and 54% falling into one of the 16 remaining drug categories.

Figure 2 shows the sex–race/ethnicity-specific contributions to the change in the national age-standardized drug overdose death rate. Non-Hispanic white individuals contributed most to the national trend, followed by non-Hispanic Black and Hispanic individuals. Until around 2013, women and men contributed similarly to the national trend. Since then, the national trend has been predominantly driven by men.

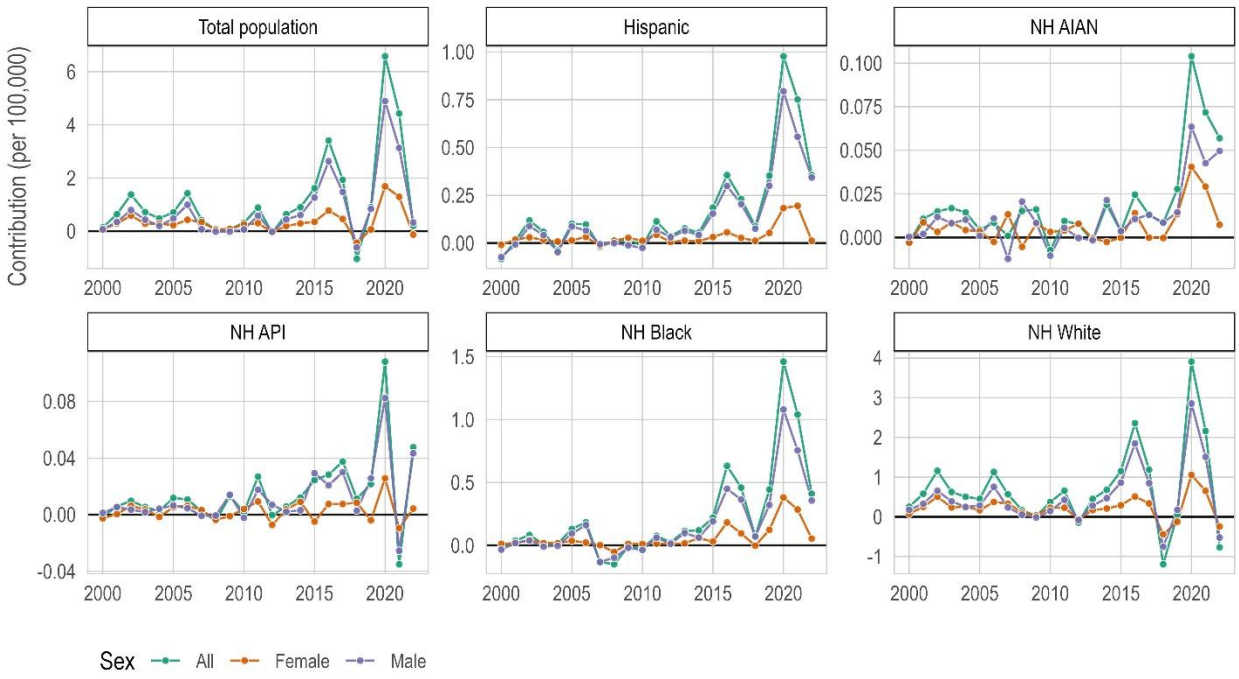

Figure 2. Change in the national age-standardized drug overdose death rate attributable to different sex–race/ethnicity combinations, 1999–2022. *Source*: Authors’ own calculation.

Figure 3 shows the state-specific contributions to the change in the national age-standardized drug overdose death rate, focusing on the top nine states in terms of total contribution to the national rate. This figure highlights the heterogeneous trends in drug overdose death rates by geography. For example, while California is the largest U.S. state in terms of population size, it started to meaningfully contribute to the national trend only after 2015. Similarly, Texas (the second most populous state) did not start meaningfully contributing to the national trend until about 2020. In

contrast, Ohio (seventh most populous) and New York (fourth most populous) have been consistently contributing to the national trend since the early 2000s. Tennessee, despite being a smaller state (15th most populous) contributed significantly around 2019.

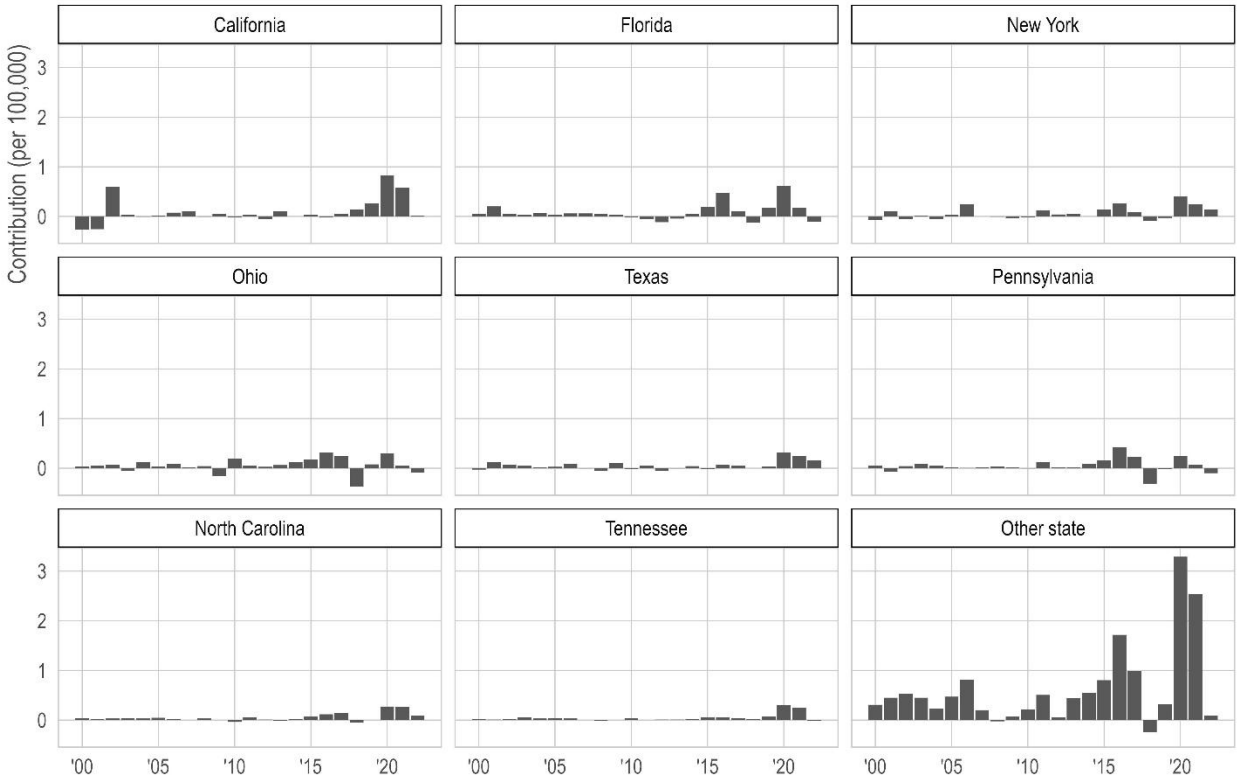

Figure 3. Change in the national age-standardized drug overdose death rate attributable to different states, 1999–2022. *Source*: Authors' own calculation.

Figure 4 shows the substance-specific contributions to the change in the national age-standardized drug overdose death rate, separating deaths that do and do not involve fentanyl. Fentanyl-involving deaths have been primarily responsible for the increase in the national age-standardized drug overdose death rate since 2015. However, declines in the death rates for some fentanyl combinations with other substances contributed to the levelling off in the national age-standardized drug overdose death rate in 2022. Recent changes in the drug overdose death rate are largely due to fentanyl and cocaine and fentanyl and methamphetamine combinations.

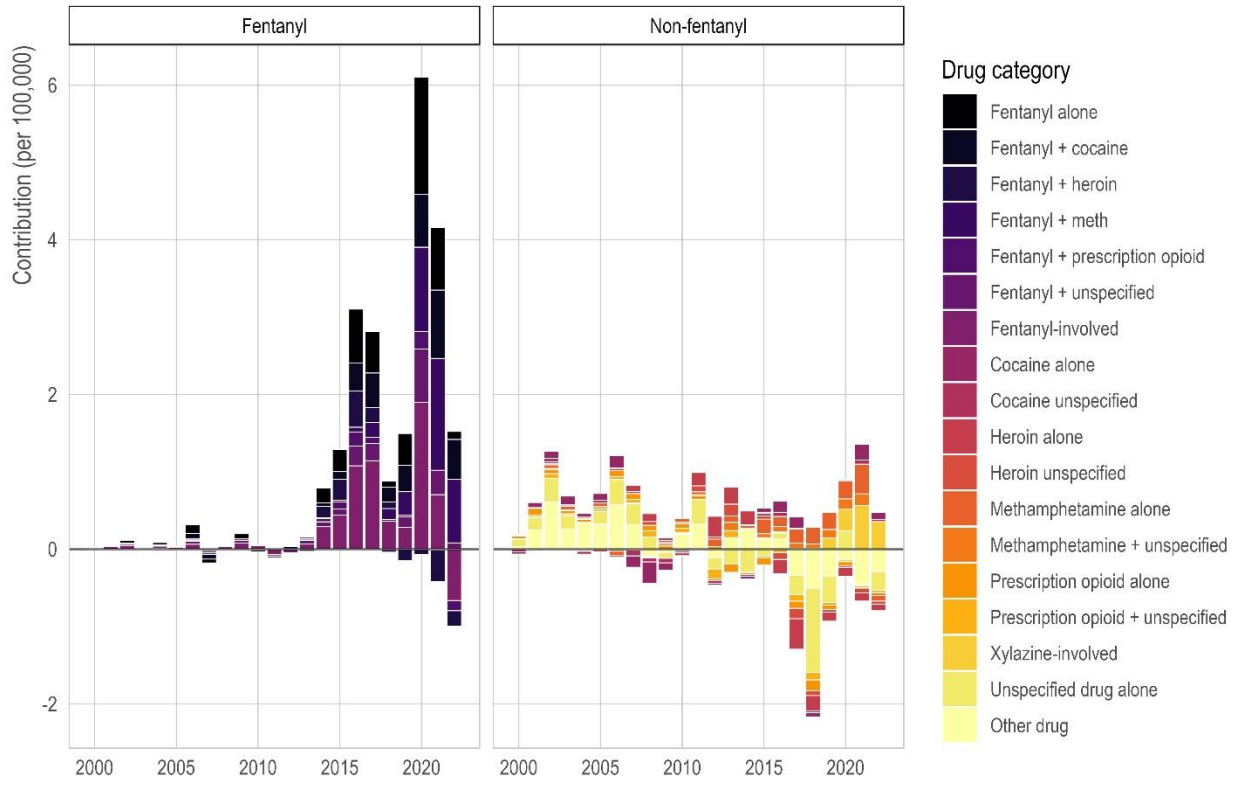

Figure 4. Change in the national age-standardized drug overdose death rate attributable to different substances and substance combinations, 1999–2022. *Source*: Authors' own calculation.

Next steps

Due to data access restrictions, our analysis currently ends in 2022. Between 2022 and 2023, the age-standardized drug overdose death rate in the United States declined. Ahead of the *European Population Conference*, we plan to extend our analysis through 2023. Our analysis will reveal (a) to what extent the decline in the national age-standardized drug overdose death rate in 2022–2023 was shared between different population subgroups; and (b) which (combinations of) substances were primarily responsible for this decline. To reflect stochastic uncertainty around the state–sex–race/ethnicity–age–substance-specific contributions from our decomposition analysis, we will incorporate a bootstrapping routine into our analysis (Hendi, 2023).

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