Economic decline, incarceration, and mortality from drug use disorders in the USA between 1983 and 2014: an observational analysis

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Summary

Background Drug use disorders are an increasing cause of disability and early death in the USA, with substantial geographical variation. We aimed to investigate the associations between economic decline, incarceration rates, and age-standardised mortality from drug use disorders at the county level in the USA.

Methods In this observational analysis, we examined age-standardised mortality data from the US National Vital Statistics System and the Institute for Health Metrics and Evaluation, household income data from the US Census Bureau, and county-level jail and prison incarceration data from the Vera Institute of Justice for 2640 US counties between 1983 and 2014. We also extracted data on county-level control variables from the US Census Bureau, the National Center for Health Statistics, and the US Centers for Disease Control and Prevention. We used a two-way fixed-effects panel regression to examine the association between reduced household income, incarceration, and mortality from drug use disorders within counties over time. To assess between-county variation, we used coarsened exact matching and a simulation-based modelling approach.

Findings After adjusting for key confounders, each 1 SD decrease in median household income was associated with an increase of 12·8% (95% CI 11·0–14·6; p<0·0001) in drug-related deaths within counties. Each 1 SD increase in jail and prison incarceration rates was associated with an increase of 1·5% (95% CI 1·0–2·0; p<0·0001) and 2·6% (2·1–3·1; p<0·0001) in drug-related mortality, respectively. The association between drug-related mortality and income and incarceration persisted after controlling for local opioid prescription rates. Our model accounts for a large proportion of within-county variation in mortality from drug use disorders (R²=0·975). Between counties, high rates of incarceration were associated with a more than 50% increase in drug-related deaths.

Interpretation Reduced household income and high incarceration rates are associated with poor health. The rapid expansion of the prison and jail population in the USA over the past four decades might have contributed to the increasing number of deaths from drug use disorders.

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Introduction

The USA has an ongoing epidemic of opioid addiction, with age-standardised mortality rates from drug use disorders increasing by more than 600% since 1980.[1] More than 72 000 overdose deaths occurred in 2017, making drug use disorders the second leading cause of death nationwide for people aged 15–49 years in the USA.[1] The number of overdose deaths has increased in every county since 1980, but at considerably different rates, ranging from 8% to more than 8000%.[1] Popular understanding of the unprecedented increase in overdose deaths focuses on the role of pharmaceutical companies in increasing the availability of opioid pain medication and, once addiction has been established, affected individuals substituting prescription opioids with heroin and fentanyl.[2] Another body of research emphasises the increasing demand for drugs, driven by economic decline and downward social mobility.[3,4] However, this research remains inconclusive and does not explain the geographical variation in such deaths.[1,5,6] We argue that these two explanations, although valid, are incomplete and that incarceration represents another major driver of the epidemic in drug-related deaths. Extensive evidence has linked incarceration to various factors that are associated with drug overdoses, including stigma, unemployment, family disruption, and neighbourhood decline. In the USA, individuals are incarcerated in either state prison or local jail. In 2014, 1 562 300 people were incarcerated in state and federal prisons, usually serving a sentence of 1 year or longer, whereas 744 600 people were incarcerated in local jails, most of whom were in pretrial detention. Although at any timepoint jails hold about half as many people as state prisons, in 2014, 11·4 million people were admitted

Research in context

Evidence before this study
The US opioid epidemic has been the subject of extensive scientific attention and debate, but little is known about the main causes. We searched PubMed, Science Direct, Scopus, Web of Science, and Google Scholar from database inception until Jan 1, 2019, using various combinations of the search terms "opioid(s)", "overdose", "drug-use disorders", "substance abuse", "deaths of despair", "epidemic", "crisis", and "causes". We also searched for terms such as "economic decline", "inequality", "poverty", "unemployment", and "disadvantage", as well as "incarceration", "imprisonment", "penal state", and "criminal justice". We found that the public health and epidemiology literature focused on the supply of opioids and other drugs as determinants of the public health crisis in the USA, whereas economists and other social scientists highlighted social and economic factors such as unemployment, decline in income, and fractured family relations as determinants. However, few original empirical analyses have been done to investigate these determinants of the US opioid epidemic. Moreover, although a considerable body of literature has linked incarceration with drug use disorders, the emphasis is usually on drug use as the likely cause of incarceration, rather than incarceration as the cause of drug use disorders. To the best of our knowledge, no original empirical analyses have investigated the association between local jail and prison incarceration rates and mortality from drug use disorders at the county level.

Added value of this study
We empirically tested the associations between reduced household income (as a measure of economic decline), incarceration, and age-standardised mortality rates from drug use disorders between 1983 and 2014. We used previously unavailable jail and prison incarceration county-level panel data from the Vera Institute of Justice and mortality data from the US National Vital Statistics System. We confirmed the association between household income and drug-related deaths that has been hypothesised in the existing literature, and highlight a second and largely neglected determinant of the overdose epidemic—jail and prison incarceration rates—which together might be better predictors of overdose deaths than local opioid prescription rates alone. Our study adds to the scientific understanding of the public health crisis in the USA and could have major implications for public policy.

Implications of all the available evidence
Reduced household income and high incarceration rates show strong associations with mortality from drug use disorders. The rapid expansion of the US prison population since the 1970s might have contributed substantially to the ongoing increase in overdose deaths.

to jail, which is almost 20 times higher than the 626 096 people admitted to prisons each year.

More than half a million drug-related deaths have occurred in the USA in the past three and half decades, however, no studies have investigated the association between these deaths and the expansion of the incarcerated population, which began in the mid-1970s. In this analysis, we aimed to use previously unavailable panel data to examine the association between incarceration rates and drug-related deaths.

Methods
Data sources
We obtained age-standardised mortality data from 1983–2014 from the US National Vital Statistics System and the Institute for Health Metrics and Evaluation using the Global Burden of Diseases, Injuries, and Risk Factors Study cause list (International Classification of Diseases [ICD], ninth edition diagnosis codes 292–292·9, 304·0–304·83, 305, 305·1–305·93, 760·7–760·79, E850–850·29; ICD, tenth edition codes F11–F16·99, F18–F19·99, P04·4-P04·49, P96·1, R78·1–78·5).[1] To measure local economic decline, we obtained median household income per county for the period 1983–2014 from the US Census Bureau.

We extracted county-level jail and prison incarceration data from the Vera Institute of Justice.[7–10] The Vera Institute of Justice collected and compiled jail incarceration data from the Census of Jails[11] and the Annual Survey of Jails[12] by the Bureau of Justice Statistics to generate annual county-level rates per 100 000 residents aged 15–64 years. Prison data obtained from state corrections sources and the National Corrections Reporting Program of the Bureau of Justice Statistics was used by the Vera Institute of Justice to tabulate the county of origin of state prisoners, yielding annual county-level rates per 100 000 residents aged 15–64 years, with the earliest available data from 1983.[9] Prison data at the state level are collected in the annual National Prisoner Statistics survey by the Bureau of Justice Statistics. We excluded six states (Alaska, Connecticut, Delaware, Hawaii, Rhode Island, and Vermont) because they do not have local jail systems. In these states, the prison system operates the pretrial detention and shorter sentences managed by county jails in other states. Thus, prison admissions data in those states are more comparable in magnitude to jail admissions data elsewhere, and the Bureau of Justice Statistics have not collected true prison admissions data in those states consistently. Due to discrepancies between data sources in measuring county boundaries and accounting for changes to counties over time, we excluded the state of Virginia and a number of counties from other states (77 counties in total) from the final analysis. Extreme outliers (ie, rates around 90 000 per 100 000 population),

potentially caused by measurement error in the Vera Institute of Justice dataset, were removed.

County-level control variables used to account for potential confounding were violent crime rate and the proportion of county residents who were African American, Hispanic, or other (non-white ethnicities). These variables were extracted from the US Census Bureau and the National Center for Health Statistics, with data derived from various census estimates, hence they are not available on an annual basis. To fill missing cells in the panel, linear interpolation was used to generate values between observations.[13] As an additional control variable, we obtained county-level retail opioid prescription rates dispensed per 100 persons for the years 2006–14 from the US Centers for Disease Control and Prevention.

Data analysis

To examine the association between economic decline, incarceration, and deaths from substance abuse, we estimated a two-way fixed-effects panel regression, focused on within-county variation, thus controlling for any time-invariant confounders. The fixed-effects model takes the natural logarithm of the mortality rate as the outcome, regressed on the median county household income and the county jail and prison admissions rates, controlling for education, crime rates, ethnicity, any time-invariant county-level confounders, and aggregate time trends using year dummies. As an additional sensitivity measure, we also controlled for all-cause mortality rates. All predictors were standardised by calculating deviations from the variable mean and dividing by 1 SD. To correct for the panel structure of the data, we estimated autocorrelation-consistent and heteroskedasticity-consistent SEs. R^2 was used to assess model performance. To assess model dependence, we also used a random-effects model (which pools within-county and between-county variation), a multilevel random intercept model (which allows between-county variation in the intercept term), and a pooled ordinary least squares regression (which runs a conventional ordinary least squares regression on a pooled set of county-years).

We also assessed variation between counties by specifying a 'between' model comparing counties with high versus low incarceration rates, controlling for other key characteristics. To reduce model uncertainty, we used coarsened exact matching.[14–16] The aim of matching is to reduce inefficiency, bias, and model dependence. Matching aims to select units of analysis (counties) that are similar if not identical to one another in all respects except for one: whether or not they are exposed to a key variable of interest. In our analysis, the quantity of interest was the effect of high rates of incarceration on drug-related mortality, over and above the endogenous associations between incarceration and factors such as income, education, or crime. We therefore applied the algorithm to match counties that share all other key characteristics, but which differed in having high (above median) versus low (below median) incarceration rates. Counties were matched on the following time-averaged (1983–2014) variables: median household income, the proportion of high school graduates, African Americans, Hispanics, or other non-White ethnicity, the violent crime rate, and the opioid prescription rate (2006–14).

After extracting a pruned dataset from the matching procedure and running a between-county specification, we adopted a simulation-based approach to present key quantities of interest, as described by King and colleagues.[17] This approach involves simulating numbers from the sampling distribution of our parameter estimates to account for model uncertainty. We then examined and visualised differences in the expected overdose mortality rate between counties with high and low incarceration rates, controlling for other factors. Let $T_i \in \{0, 1\}$ denote a dichotomous treatment variable, where $T=0$ denotes counties with incarceration rates at 1 SD below the global mean and $T=1$ designates counties at 1 SD above the global mean. Let X_i denote a series of pretreatment covariates (income, education, crime, drug environment, and ethnic composition). The simulations were done for $T=0$ and for $T=1$ separately before differences in the expected overdose mortality rate were examined. All statistical analyses were done using R (version 3.5.1), using the *dplyr*, *ggplot2*, *plm*, *MatchIt*, and *Zelig* software packages.

Role of the funding source

There was no funding source for this study.

	Observed county-years, n	Mean (SD)	Range
Age-standardised mortality rate from drug use disorders (per 100 000 population)	69 562	4·9 (4·7)	0·3–60·8
Jail admissions rate (per 100 000 population*)	67 172	7018·5 (3822·4)	20·2–18 445·2
Prison admissions rate (per 100 000 population*)	66 910	254·6 (160·3)	6·0–732·1
Median household income (US$)	69 562	46 841·9 (11 781·4)	17 582·8–125 704·6
High school graduates (proportion of county population)	69 562	0·8 (0·1)	0·3–1·0
Ethnicity (proportion of county population)			
African American	69 562	0·1 (0·2)	0·0–0·9
Hispanic	69 562	0·1 (0·1)	0·0–1·0
Other	69 562	0·02 (0·05)	0·0–0·9
Violent crime rate (per 100 000 population)	61 367	284·8 (265·3)	0·0–3894·3
Opioid prescription rate (per 100 000 population)	20 049	90·7 (45·7)	0·0–437·2
Age-standardised all-cause mortality rate (per 100 000 population)	69 562	980·0 (138·4)	323·3–1716·8

All measures are at the county level. *Aged 15–64 years.
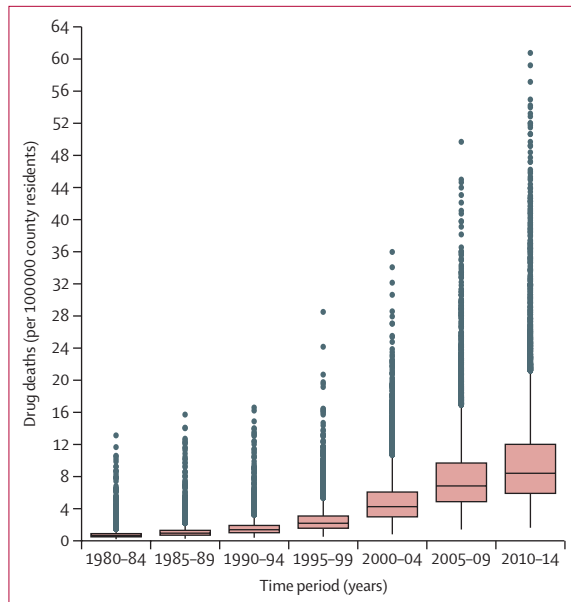
Table 1: Descriptive statistics

***Figure 1:* Drug deaths per 100 000 county residents, 1980–2014**
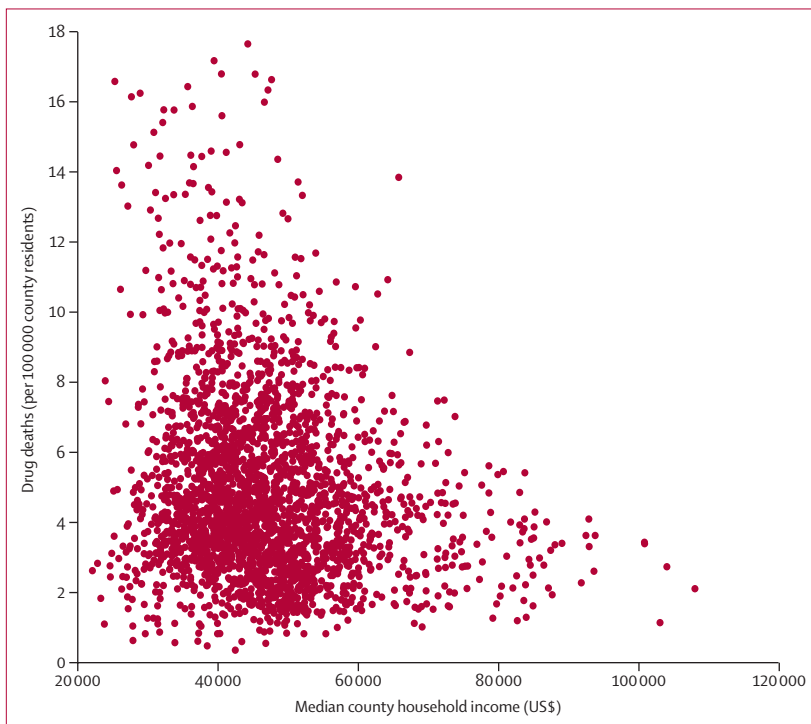Boxes show 50% of observations, lines show median, whiskers show IQR, and dots show individual counties.

***Figure 2:* Drug deaths per 100 000 county residents by median household income, 1983–2014**

Results

Our outcome variable was the annual age-standardised mortality rate from drug use disorders per 100 000 population for 2640 US counties between 1983 and 2014. Descriptive statistics are shown in table 1 and a correlation matrix is included in the appendix (p 1). The mortality rate from

drug use disorders increased across counties between 1980 and 2014 (figure 1), and between-county inequality in drug-related mortality also increased over time. Mortality rates were associated with economic hardship (figure 2), whereby low economic income was associated with a higher number of drug deaths; however, substantial heterogeneity was identified across counties with median incomes of less than US$60 000 per year.

Complete regression results from the fixed-effects model are shown in the appendix (p 2). The parameter estimates of the fixed-effects model suggest that both jail and prison incarceration rates are associated with elevated mortality rates from drug use disorders, while controlling for aforementioned control variables (table 2). An increase of 1 SD in admissions rates to local jail (mean 7018 [SE 3822] per 100 000 population) and prison (mean 254·6 [SD 160·3] per 100 000 population) was associated with a 1·5% (95% CI 1·0–2·0; p<0·0001) and a 2·6% (2·1–3·1; p<0·0001) increase in the mortality rate from drug use disorders, respectively. This suggests that high incarceration rates can compound the deleterious health effects of reduced median county household income, which is associated with a 12·8% (95% CI 11·0–14·6; p<0·0001) increase in deaths from drug use disorders. Our model explained almost all of the within-county variation in mortality rates (R^2=0·975). Median household income and jail and prison rates alone account for almost all of this variation (R^2=0·969).

The random-effects, multilevel random intercept, and pooled ordinary least squares regression models suggest that although the initial parameter estimates from the fixed-effects model are subject to some degree of model dependence, the substantive results remained the same (table 2). The estimates produced by the random-effects and multilevel random intercept models were almost identical to those produced by the fixed-effects model, whereas the estimates generated by the pooled ordinary least squares regression model were more variable.

When used as the sole regressor (adjusted for time trends), opioid prescription rates were associated with higher rates of mortality from drug use disorders (β=0·5%; 95% CI 0·2–0·8; p=0·02; appendix p 3). However, when controlling for income, incarceration, and crime, the estimated coefficient was not statistically significant. Thus, opioid prescription rates are not significantly associated with an increased mortality risk of drug use disorders when socioeconomic and incarceration variables are accounted for. In the full model including all covariates, we found that the parameter estimates for incarceration rates were reduced in size (by around one percentage point each), but remained statistically significant (appendix p 3). The statistical significance of our results was robust when controlling for all-cause mortality rates, suggesting that counties with high incarceration rates are not generically more deadly, but rather that they are more deadly in specific ways.

	Fixed-effects model coefficient	Random-effects model	Multilevel random intercept model*	Pooled ordinary least squares model
Decline in household income	12·8%† (0·9)	13·1%† (0·9)	13·0%† (0·2)	1·5%‡ (1·0)
Jail admission rate per 100 000 population	1·5%† (0·3)	1·8%† (0·3)	1·7%† (0·1)	5·7%† (0·7)
Prison admission rate per 100 000 population	2·6%† (0·2)	2·9%† (0·2)	2·8%† (0·1)	8·2%† (0·7)
Observations, n	57 732	57 732	57 732	57 732
Adjusted R²	0·975	0·974	NA	0·808

Model coefficients are interpreted as percentage change in the drug-related mortality rate associated with a 1 SD increase in each predictor, for each of the four regression models specified. Panel-corrected SEs are given in parentheses. The model outcome variable was the natural logarithm of the age-standardised county mortality rate from drug use disorders. The model controls for county violent crime rate, the proportion of high school graduates, African American individuals, Hispanic individuals, and individuals of other ethnicities (non-white) in the county population, and aggregate time trends using year dummies (not shown). All predictors were standardised by calculating deviations from the variable mean and dividing by 1 SD. NA=not applicable. *Conventional SEs shown in parentheses. †p<0·0001. ‡p=0·141.

Table 2: Panel data models of county-level variation in mortality from drug use disorders

The matching algorithm resulted in a pruned dataset including 963 counties. The diagnostics confirmed that the matching procedure achieved a high degree of balance improvement, since the empirical covariate distributions in both the treatment and control groups were similar, meaning the reduced sample size strengthens rather than undermines the subsequent statistical inference. Hence, we estimated a between model using simple linear regression, where the outcome, Y, is regressed on the dichotomous treatment variable T.

As shown in figure 3A, the expected overdose mortality rate for counties in the control group was 3·5 deaths per 100 000 county residents (95% CI 3·3–3·7; p<0·0001). The second density plot (figure 3B) showed that the treatment group had an estimated overdose rate of 5·4 deaths per 100 000 county residents (95% CI 5·2–5·6; p<0·0001). As shown by the third and final density (figure 3C), these results suggest that, on average, high incarceration rates correspond to 1·9 excess deaths per 100 000 county residents (95% CI 1·5–2·2; p<0·0001), corresponding to a treatment effect equal to a 53·5% increase in the mortality rate from drug use disorders.

Discussion

Following a decline in prison incarceration rates in the 1960s, the number of people held in state and federal prisons increased from less than 200 000 in 1970 to nearly 1 million in 1995. Between 1972 and 2007, the prison and jail incarceration rate reached almost 800 incarcerations per 100 000 residents, which corresponds to more than 2·2 million incarcerated people.[18,19] However, the incarcerated population accounts for only a quarter of individuals under correctional supervision when people on probation and parole are included. Thus, the overall correctional population has grown rapidly since 1972, amounting to 7 million individuals in 2012.[18] Research has established that the rise in incarceration was not merely the result of increases in crime rates.[19,20] Rather, it was primarily the result of a series of sentencing reforms that included mandatory sentences for drug convictions— ie, so-called three strikes and truth in sentencing laws. These policies were established in response to a
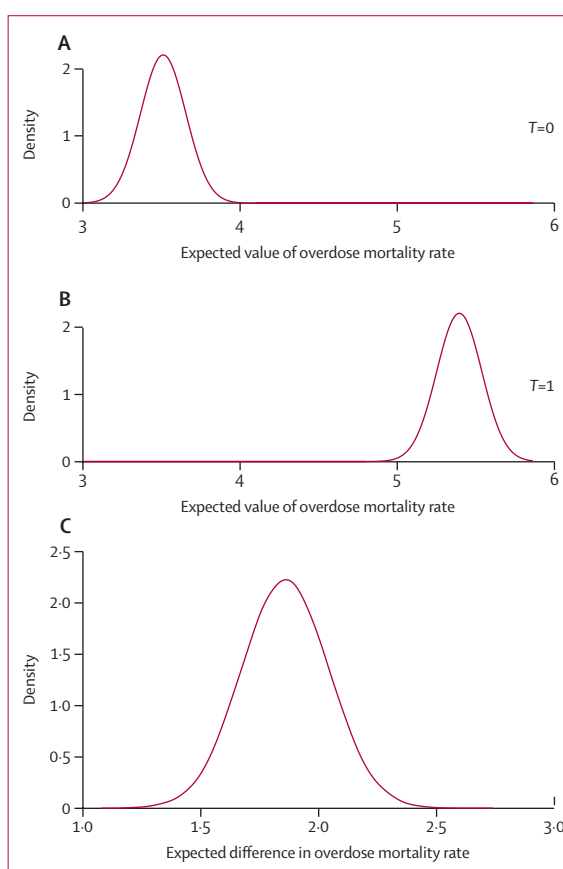

Figure 3: Estimated differences in county-level mortality rates from drug use disorders by incarceration rate
Expected overdose mortality rate by incarceration rate, where $T=0$ denotes counties with incarceration rates 1 SD below the global mean (A) and $T=1$ denotes counties with incarceration rates 1 SD above the global mean (B), and expected difference in overdose mortality rate between countries with high and low levels of incarceration (C).

heightened focus on crime, reflected in the media and electoral campaigns—in which Democrat and Republican candidates competed to be tough on crime.[21–23]

Our findings suggest a strong association between the rise in incarceration rates and mortality rates from drug
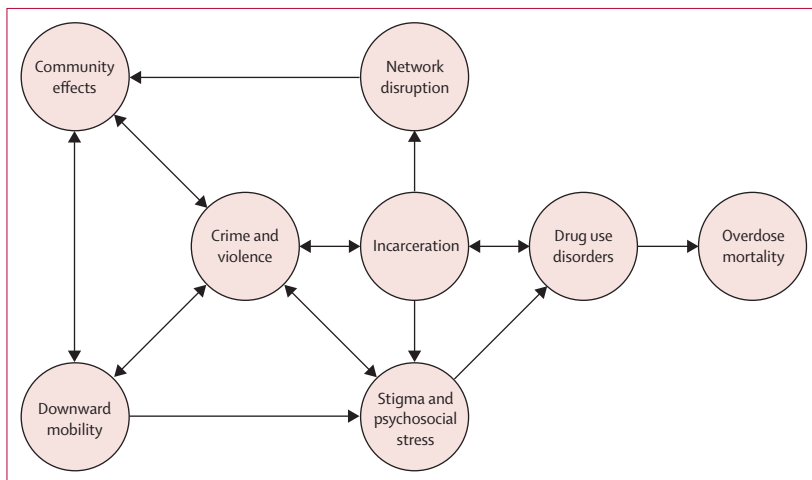
Figure 4: Schematic diagram of potential interactions between socioeconomic factors, incarceration, and drug-related mortality

use disorders, over and above the potential effects of low household income and other important confounders. We also highlight a largely neglected dimension of the US criminal justice system—local jails—which are independently associated with drug deaths. Our panel data showed regional inequalities over time and might contribute to the understanding of directionality of relevant associations that were identified in a previous cross-sectional study.[24]

Previous research has shown that mortality rates among former inmates are nearly 13 times higher than that of the general population, former inmates are at high risk of mortality during the first 2 weeks post release,[25] and high incarceration rates exert cascading effects spanning generations, local communities, and other networks of current or former incarcerated people.[18,19,21,22] Incarceration is directly associated with stigma, discrimination, poor mental health, and chronic economic hardship,[18–20,26,27] all of which are linked to drug use disorders.[28] Moreover, the interaction between substance abuse and incarceration interferes with treatment and reduces the likelihood of recovery.[29–31] The incarceration of a family member has been shown to impair the wellbeing of non-incarcerated partners and children, as a result of declining household income, reduced parental investment, unstable social relationships, and psychosocial stress.[26,27,32–37] A mother's risk of a major depressive episode and her level of life dissatisfaction is heightened as a result of her partner's incarceration.[38] Children with an incarcerated parent are at increased risk of various health problems associated with adverse childhood experiences, including post-traumatic stress disorder.[34,35,38,39]

Multiple pathways exist by which incarceration might lead to an increased number of drug deaths at the population level. A proposed set of mechanisms at the aggregate level is shown in figure 4. At the community level, the criminal justice system is pivotal in shaping the trajectories of neighbourhoods by removing prime working age men from their local communities, separating families, and disrupting social networks.[18–20] When coupled with economic hardship, the operations of the prison and jail systems constitute an upstream determinant of despair, whereby regular exposures to neighbourhood violence, unstable social and family relationships, and psychosocial stress trigger destructive behaviours.[26,27,32–37] These are mechanisms that operate over and above the endogenous association between illegal drug use and incarceration, which does not account for the increased use of jails and prisons in recent decades.[40] Since the rise in incarceration was primarily caused by statutory sentencing reforms in the USA, the so-called war on drugs itself seems to be an upstream determinant of the epidemic of drug-related mortality. Although policies that might reverse regional economic decline are likely to be both difficult and expensive to implement, reform of the criminal justice system is technically simple and would not only be economical, but could potentially save many lives. However, we acknowledge that such reform would face major political challenges, particularly from institutional forces that have a vested interest in increasing incarceration rates.

Our study had some limitations. Due to the observational nature of the study, we cannot rule out whether the observed associations can be explained by another factor that was unaccounted for. However, considerable unmeasured confounding would be needed to explain away our model estimates, which are adjusted for the most likely confounders in the context of the USA. Most notably, we found that incarceration rates were significantly associated with overdose deaths even after controlling for local opioid prescription rates since 2006. This result does not preclude the possibility that the criminal justice system is located on the pathway leading from increased opioid prescription to heightened risk of mortality from overdoses, but it does indicate a robust connection between penal expansion and the current public health crisis in the USA. Moreover, existing research on the effects of incarceration on a range of social, economic, and health outcomes is consistent with our principal hypothesis that the combination of economic decline and incarceration is a likely driver of regional variation in drug-related mortality.[19,26,27] A further limitation of our data is the distribution of missing values for county prison rates. Since the data did not meet the criteria for multiple imputation, we excluded around 15% of our observations using list-wise deletion of missing values, which could have skewed the sample away from Southern states where incarceration rates are the highest. Although our dataset does not include all states, it contains empirical data on jail and prison incarceration rates at the county level for the very first time. Our measurement of economic decline is at the aggregate level and would ideally be complemented by local employment data,[6]

considering the link between de-industrialisation and health inequalities, which highlights the importance of the manufacturing sector.[41]

Our models do not explain the complex associations between overdose deaths and incarceration, or the heterogeneity that exists across the sexes and age groups. Moreover, we were unable to examine important state-level differences in the quality of post-incarceration support offered to former inmates, which is an important predictor of health and employment outcomes.[42] Our different model specifications yield results of differing magnitudes, but these pertain to differences in the distribution of variation within and between counties, and we consider these reasonable bounds on the magnitude of potential associations. Moreover, the fixed-effects, random-effects, and multilevel random intercept models yielded similar parameter estimates. Our substantive findings are robust to alternative specifications, and our parsimonious models successfully capture a substantial amount of variation in our data. The matching algorithm helped to reduce model dependence and strongly indicates that incarceration is a driver of the spatial patterning of the ongoing overdose epidemic, over and above other associated factors.

The reasons for the substantial regional variation in drug-mortality rates need to be understood to enable the development of prevention and intervention strategies.[1] We have shown that incarceration might be an important upstream determinant of mortality from drug use disorders in the USA, beyond economic decline and local opioid prescription rates. Jails and prisons are associated with heightened mortality risk, not only for incarcerated individuals, but also for their relatives and the general population. Thus, the rapid expansion of the prison and jail population over the past few decades might have made a substantial contribution to the increasing number of deaths from drug use disorders. Future research and policy should focus on the impacts of incarceration, or more broadly, of punitive social policy, on population health.

Contributors
EN and LPK designed the study. JK-B provided the incarceration data. EN collected other data, specified the statistical models, and drafted the paper. All authors contributed to interpreting the findings and writing up the final manuscript.

Declaration of interests
We declare no competing interests.

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