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Years of Life Lost due to Opioid Overdose in Ohio: Temporal and Geographic Patterns of Excess Mortality

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Objectives: The aim of the study was to quantify the burden of premature mortality because of opioid overdose in Ohio, document the role of fentanyl poisoning in contribution to this evolving epidemic, examine geographic, demographic, and temporal patterns of mortality burden within Ohio, and measure the effect of opioid overdose on lifespan in the state.

Methods: A serial cross-sectional analysis was performed for all fatal opioid poisonings (N = 12,782) in the state of Ohio between January 1, 2010 and December 31, 2016. The burden of fatal opioid overdose was calculated in Years of Life Lost (YLL). YLL were mapped with respect to geographic and cultural region. The geographic spread of fentanyl poisoning was also mapped, and the shifting contribution of fentanyl poisoning to overall opioid mortality burden was assessed over time. Finally, the negative effect of opioid overdose on average lifespan was calculated.

Results: Opioid overdose resulted in 508,451 total YLL. In the year 2016 alone, there were 136,679 YLL attributable to opioid poisoning. Fentanyl-related YLL rose from 7.5% of all YLL because of opioid overdose in 2010 to 69.0% in 2016. In the same year, opioid overdose lowered the lifespan of an average Ohioan by 0.97 years.

Conclusions: Fatal opioid overdose accounted for over half a million YLL in Ohio during the 7-year study period. Opioid overdose mortality rose annually. Fentanyl involved overdoses accounted for a growing proportion of excess mortality. Burden was not equally distributed within the state. Two distinct geographical clusters of excess mortality were identified in the northeast and south.

Key Words: analgesics, drug overdose, epidemiology, fentanyl, mortality, opioid, premature

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Opioid overdose is an increasing cause of preventable mortality in the United States (Louisa et al., 2014; Gomes et al., 2018). The incidence of fatal opioid overdose escalated 5-fold between 1999 and 2016 (Centers for Disease Control, 2017). Ohio is among the states most impacted by drug overdose and the Ohio opioid epidemic has been well described (Daniulaityte et al., 2017; Caupp et al., 2018; Scholl et al., 2018). Fentanyl has emerged as a significant contributor to opioid overdose in Ohio and elsewhere in the United States (Peterson et al., 2016; Daniulaityte et al., 2017). Among fatal drug overdoses with death records mentioning at least 1 specific drug, fentanyl was the most frequently mentioned drug in 2016 (Hedegaard et al., 2018).

Loss of life because of opioid overdose is associated with personal and societal costs, which are compounded by the relatively young age of decedents (Inocencio et al., 2013). With death rates highest among 25- to 54-year-olds for prescription opioid overdose and 25- to 44-year-olds for heroin overdose, individuals succumbing to opioid poisoning are often deprived of many years of work, family, and community life (Centers for Disease Control, 2017).

In recent years, efforts have been made by government bodies and the medical profession to mitigate the trend in opioid overdose deaths (Kanouse and Compton, 2015). These have included broader implementation of state prescription drug monitoring programs, increased scrutiny of prescribing behavior, and expanded access to the opioid reversal agent naloxone as well as addiction treatment. However, despite these efforts, opioid-related death rates continue to climb (Kanouse and Compton, 2015; Gomes et al., 2018). As the annual incidence of fatal opioid poisoning is in flux in the United States, further studies are needed for ongoing surveillance of this evolving epidemic.

In addition to the rapid change in opioid-related death rates over time, there is significant regional variation in the burden of fatal opioid overdoses (Rudd, 2016; Rudd et al.,

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2016). Geographic differences in the incidence of fatal opioid poisoning necessitate detailed state and regional analyses to provide insights into potentially modifiable community risk factors and guide resource allocation with regard to preventative health measures. Prior research into the determinants of opioid mortality has identified factors including local prescriber behavior, sociodemographic differences, economic distress, and cultural norms regarding diversion of prescription opioids among others (King et al., 2014; Pear et al., 2019). Resources to combat the opioid epidemic in Ohio and elsewhere are finite. Therefore, it is crucial that areas of increased need are identified.

The present work aims to quantify the burden of premature mortality because of opioid overdose in Ohio, document the role of fentanyl poisoning in contribution to this evolving epidemic, examine geographic, demographic, and temporal patterns of mortality burden, and measure the effect of opioid overdose on average lifespan. Ohio was chosen for its mix of urban and rural locales, distinct cultural regions (Appalachia and Midwest) and high incidence of opioid overdose (Rudd, 2016). Mortality burden was expressed in years of life lost (YLL), a measure of mortality burden originally developed and employed by the World Health Organization Global Burden of Disease study (Murray and Acharya, 1997). YLL was chosen from available mortality statistics in order to account for the fact that opioid poisoning occurs in a youthful cohort by giving greater weight to deaths occurring among the young.

METHODS

Study Setting and Population

Ohio is the seventh most populous state in the United States with a population greater than 11.5 million in 2016 (United States Census Bureau, 2018). Within its borders are counties belonging to 2 distinct cultural regions; Appalachia and the Midwest. The Appalachian cultural region is known for elevated rates of poverty and related health disparities compared with other regions including the Midwest (Behringer and Friedell, 2006; Wewers et al., 2006).

A serial cross-sectional analysis was performed for all fatal opioid-related poisonings in the state of Ohio between January 1, 2010 and December 31, 2016. The Ohio Department of Health (ODH) maintains death certificate records on all persons with location of death within Ohio. From these records, ODH produces a drug overdose dataset including decedents with unintentional overdose as their primary cause of death. This dataset is available without restriction to the public. Institutional Review Boards of both the University of Michigan and Ohio University determined this research to be nonregulated.

Measures

Data were abstracted from the ODH, Bureau of Vital Statistics, Ohio Death Certificate File. All unintentional overdose death records between 2010 and 2016 were queried for relevant International Classification of Diseases codes. Overdose death records were further queried for mention of prescription or illicit opioid involvement. Decedents without documented opioid involvement were excluded.

Statistical Analysis

YLL were calculated by subtracting the age at death from the standard life expectancy for each decedent (YLL = - standard life expectancy − age at death). Cases were stratified by years of age (0–4, 5–14, 15–29, 30–44, 45–59, 60–69, 70–79, 80, and above) and sex. Male and female life expectancy at each individual age was determined from the Social Security Administration Period Life Table (United States Social Security Administration, 2013). YLL per 100,000 population were mapped at the county level using Quantum Geographic Information System software (QGIS Development Team, 2016, QGIS Geographic Information System, Open Source Geospatial Foundation, URL: http://qgis.osgeo.org). Mortality burden was divided into 3 strata for the purposes of mapping using the Jenks natural breaks classification method.

To determine the effect of opioid overdose on Ohio lifespan in 2016, a multistep procedure was conducted. First, the total number of Ohioans who died of any cause (n = 119,574) was multiplied by the average lifespan in the state for that year (72.91 years). Second, the total number of 2016 opioid overdose decedents (n = 3411) was multiplied by the average age of death (39.96 years) to determine the total number of years lived by opioid overdose decedents (136,304 years). Third, total years lived by opioid decedents were subtracted from the total years lived by all Ohio decedents (8,718,140 years − 136,304 years = 8,581,837 years) to find the total years lived by nonopioid overdose decedents. Fourth, opioid overdose decedents were subtracted from all-cause decedents to yield the number of nonopioid overdose fatalities in 2016 (119,574 decedents − 3411 decedents = 116,163 decedents). Fifth, the total years lived by nonopioid overdose decedents was divided by the number of nonopioid overdose fatalities in 2016 to give the average lifespan of Ohio decedents excluding opioid overdose fatalities (8,581,837 years/116,163 decedents = 73.88 years). Finally, the average lifespan of all-cause decedents was subtracted from the calculated average lifespan excluding opioid-overdose fatalities (72.91 − 73.88 years) to yield the average loss to Ohio lifespan in 2016 attributable to opioid poisoning that year.

$$\textit{Decline in life span} = \mu_{\textit{age of death}\ 2016} - \frac{\left(\textit{Decedents}_{\textit{all}\ 2016} \times \mu_{\textit{age of death}\ 2016}\right) - \left(\textit{Decedents}_{\textit{opipoid}\ 2016} \times \bar{x}_{\textit{age of death}\ 2016}\right)}{\left(\textit{Decedents}_{\textit{all}\ 2016} - \textit{Decedents}_{\textit{opipoid}\ 2016}\right)}$$

All analyses were performed in IBM SPSS Statistics for Windows (SPSS version 24; IBM Corporation, Armonk, NY).

RESULTS

From the 16,562 individuals who were identified as having died from any drug poisoning in Ohio during the period of study, 3780 cases were excluded because of lack of documented opioid involvement and no cases required exclusion because of missing data. Decedents' demographic profile was grossly consistent with previous national reports (Centers for Disease Control, 2017). Ohioans who died of opioid overdose were 91% white and 68% male individuals. Full descriptive characteristics of opioid overdose decedents are included in appendix 1 (online supplement, http://links. lww.com/JAM/A151).

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TABLE 1. Fatal Opioid Poisonings in Ohio 2010 to 2016

Year	Fatalities (Any Opioid)	Mean Age at Death	Mean YLL Per Decedent	Annual Total YLL	Fatalities (fentanyl involved)	Mean Age at Death	Mean YLL Per Decedent	Annual Total YLL
2010	974	40.68 ± 12.44	39.51 ± 11.12	38,483	77	43.14 ± 12.91	37.63 ± 10.99	2898
2011	1128	41.08 ± 11.96	39.16 ± 10.83	44,172	73	44.19 ± 12	36.64 ± 10.64	2675
2012	1233	40.2 ± 11.62	39.88 ± 10.58	49,172	74	43.99 ± 10.13	36.81 ± 8.98	2724
2013	1509	41.03 ± 11.95	39.06 ± 10.85	58,942	83	42.69 ± 12.19	37.88 ± 10.87	3144
2014	1985	40.52 ± 12.07	39.59 ± 10.93	78,586	501	37.98 ± 11.48	41.84 ± 10.46	20,962
2015	2542	39.75 ± 11.8	40.29 ± 10.76	102,417	1130	38.43 ± 11.28	41.35 ± 10.36	46,726
2016	3411	39.96 ± 12.05	40.07 ± 10.76	136,679	2318	39.12 ± 11.96	40.78 ± 10.93	94,528
All	12,782	40.31 ± 11.98	39.78 ± 10.88	508,451	4256	39.12 ± 11.78	40.80 ± 10.74	173,656

YLL = years of life lost.

All Fatal Opioid Overdoses

The number of deaths during the study period was 12,782. The overall mean age of death for all opioid poisonings was 40.31 ± 11.98. The overall average YLL was 39.78 ± 10.88 for all opioid poisonings. The overall mean age of death and mean YLL for all opioid poisonings was stable over the period of study with average YLL ranging between 39.75 and 41.08 years.

Opioid overdose accounted for 508,451 YLL in Ohio during the period of study. Average lifespan was lowered in Ohio by 0.97 years between January 1, 2016 and December 31, 2016 because of excess mortality related to fatal opioid overdose. Table 1 demonstrates annual and cumulative average and total YLL because of all fatal opioid overdoses. Figure 1 shows the geographic distribution of excess mortality in YLL per 100,000 population. This map shows population-adjusted burden was elevated in densely as well as some sparsely populated areas.

Although YLL increased for all groups during the period of study, mortality burden was not shared equally among races or between sexes. Whites accounted for 466,742 of the 508,451 total YLL during the study period. Blacks accounted for 37,066 YLL. There was notable rise in total annual YLL for both whites and blacks. Percent change from 2010 to 2016 was higher for blacks (387% change) than for whites (245% change). Limited data were available for other races. Increased fatal opioid overdose among blacks coincided with an increase in polydrug overdose fatalities among this group. For example, among black decedents, presence of opioids together with cocaine increased from 62 in 2010 to 220 in 2016, an overall 255% increase. Fentanyl was involved in a subset of these deaths with the number of blacks dying from fentanyl and cocaine rising from zero in 2010 to 110 by 2016. Cooccurrence of fentanyl and cocaine was involved in 36% of all fatal opioid overdoses among blacks in 2016. Male individuals experienced higher burden (336,564 YLL) than female individuals (171,884 YLL). Although burden increased annually in both groups, male individuals had a greater percent change in YLL (263% change) from 2010 to 2016 than female individuals (241% change) (Table 2).

Subset of Cases Involving Fentanyl

Fentanyl involved overdose fatalities increased annually from 77 deaths in 2010 to 2318 in 2016. A total of 4256 fentanyl involved fatal overdoses occurred during the period of study. The overall mean age of death among these cases was similar (39.12 ± 11.78) to all opioid overdoses considered together. The overall mean age of death and average YLL for fentanyl involved poisonings varied over time with average YLL ranging between 36.64 and 41.84.

Fentanyl involved opioid overdose fatalities accounted for 173,656 YLL in Ohio during the period of study. Fentanyl was associated with an increasing proportion of opioid poisoning-associated excess mortality accounting for 69% of total YLL because of opioid overdose in 2016. Table 1 presents annual and cumulative average YLL because of fentanyl-involved fatal opioid overdoses. Figure 2 shows the rapid increase and evolving geographic distribution of fentanyl involved poisonings over the period of study. Fentanyl-involved fatal overdoses were largely concentrated in densely populated urban areas. Figure 3 illustrates the relative contribution of fentanyl overdose to opioid-poisoning mortality and the increase of both over time.

Regional Variance in Mortality Burden

Mortality burden was not equally distributed within the state. Two distinct clusters of excess mortality were identified in the northeastern and southern geographic regions. Twelve of Ohio's 88 counties experienced the highest per capita burden. These included 7 Midwestern and 5 Appalachian counties. Central and eastern Appalachian counties did not bear increased per capita mortality burden despite elevated burden in adjacent counties to the north and south within the same cultural region. Fentanyl poisoning clustered around major metropolitan areas including Cleveland in the northeast, Dayton and Cincinnati in the southwest, and Columbus in central Ohio.

DISCUSSION

The present analysis confirmed that fatal opioid overdose was a significant and increasing cause of premature death in Ohio during the study period, measured the effect of opioid overdose on average lifespan in the state, provided insight into the evolving role of fentanyl poisoning in contribution to this epidemic, and examined geographic and temporal patterns of mortality burden within the state. Over half a million years of human life were lost, in just 7 years, in 1 American state, to a single preventable cause. Opioid overdose mortality rose annually. Increases in YLL were driven by fentanyl-associated poisonings even as nonfentanyl-related opioid mortality stabilized and then declined during the latter

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FIGURE 1. Years of life lost because of opioid overdose per 100,000 population for Ohio 2010 to 2016. YLL = years of life lost.

3 years of study. Opioid overdose had the effect of lowering the average lifespan of all cause decedents in Ohio by nearly 1 year in 2016.

Racial disparities were noted in opioid mortality burden. Although the vast majority of decedents were white, YLL increased in all racial groups. Blacks experienced a much greater percent change in mortality burden than did whites. The rise in fatal opioid overdose among blacks coincided with an increase in polydrug overdose fatalities among this group. Blacks may have experienced increased opioid overdose mortality in part because of accidental or intentional coadministration of drugs, such as cocaine with opioids including fentanyl. However, it is unclear from available data what role accidental coadministration might have played in these deaths. This demographic trend requires further monitoring.

Male and female individuals were unequally affected by fatal opioid overdose with male individuals accounting for the majority of deaths and total YLL. This pattern was also observed among fentanyl involved opioid deaths. Mean age of death among fentanyl overdoses varied slightly over time.

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TABLE 2. Years of Lost Life by Age, Race, and Sex

		Total Years of Life Lost							
		Age			Race			Sex	
	Total deaths	≤50	51 to 64	≥65	Black	White	Other	Female	Male
2010	974	32,792	5495	195	2300	36,077	104	13,272	25,212
2011	1128	36,976	6903	290	2938	40,659	572	15,985	28,186
2012	1233	42,217	6725	224	3077	45,629	461	16,878	32,291
2013	1509	48,840	9750	352	4255	54,368	320	19,125	39,820
2014	1985	65,840	12,206	541	5368	72,288	930	26,477	52,113
2015	2542	88,152	13,651	608	7917	93,282	1212	34,946	67,468
2016	3411	116,993	18,704	975	11,210	124,440	1020	45,201	91,475
Total	12,782	431,812	73,434	3185	37,066	466,742	4620	171,884	336,564

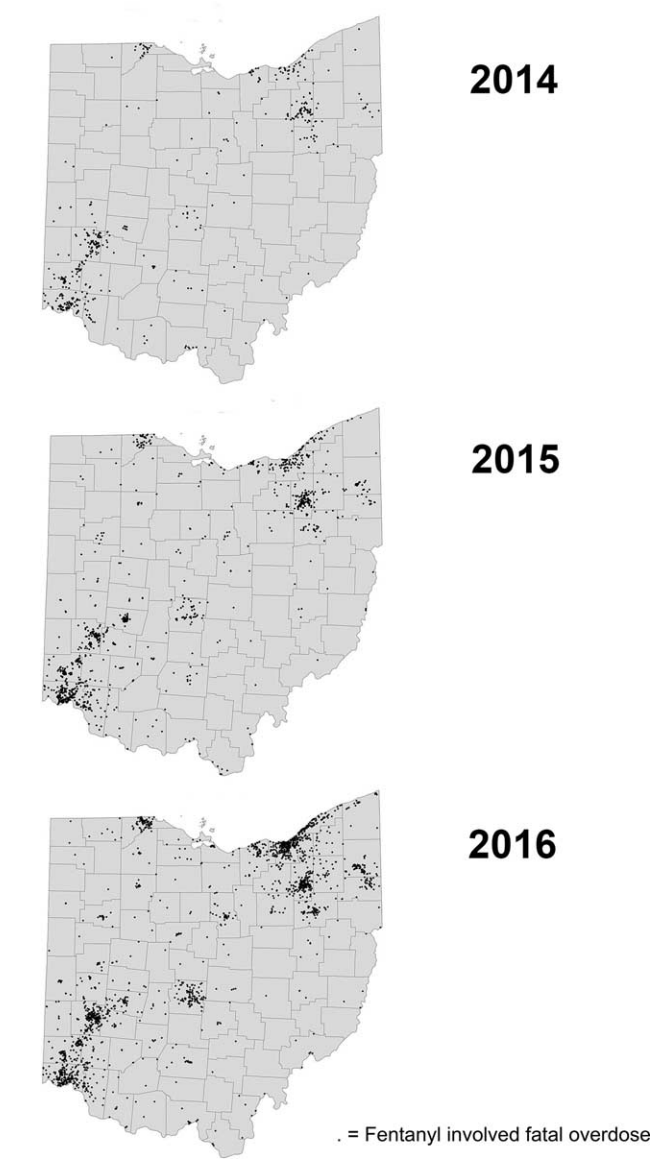

FIGURE 2. Evolving geography of fentanyl poisoning 2014 to 2016.

However, it is unclear if this difference was because of too few data points early in the period of study. Future research should continue to follow trends in the demography of fentanyl poisoning.

Fentanyl-related deaths have increased dramatically in Ohio. Given that such a rapid shift is implausibly because of increased medical use, targeted law enforcement efforts, and public health interventions are needed particularly in the locales we have identified as experiencing the highest fentanyl-related mortality burden. Further studies are needed to monitor the widening zones of increased fentanyl mortality in Ohio. YLL should be assessed annually in order to facilitate this monitoring.

Notable regional variance in mortality burden was discovered. Twelve of Ohio's 88 counties experienced the highest burden. The majority of this burden occurred in 2 distinct clusters located in the northeastern and southern geographic regions including counties in both the Appalachian and Midwestern cultural regions. Elevated burden was noted in both cultural regions. Interestingly, central and eastern Appalachian counties represented a pocket of relatively lower burden despite elevated per capita YLL in adjacent counties within the same cultural region. It is unclear if underreporting, misclassification of deaths or other factors, such as drug trafficking patterns and disproportionate access to illicit opioids contributed to the appearance of lower mortality burden in these counties. Additional research is needed to identify potential underlying protective features or sources of underreporting. Future research should involve mapping YLL by county and cultural region in other states experiencing disproportionately elevated opioid mortality burden. Of note, the states with the highest death rates have been reported as West Virginia, Ohio, Pennsylvania and Kentucky; each of which contains a large number of Appalachian counties (Scholl et al., 2018; Appalachian Regional Commision, 2019).

The purpose of the present work was not to provide policy prescriptions but instead demonstrate a methodology by which zones of elevated burden might be identified for future intervention. However, several evidence-based approaches are known to reduce the incidence of opioid overdose. Primary prevention may include public education, medication take-back drives, and statewide prescription drug monitoring programs (PDMP), such as the Ohio Automated

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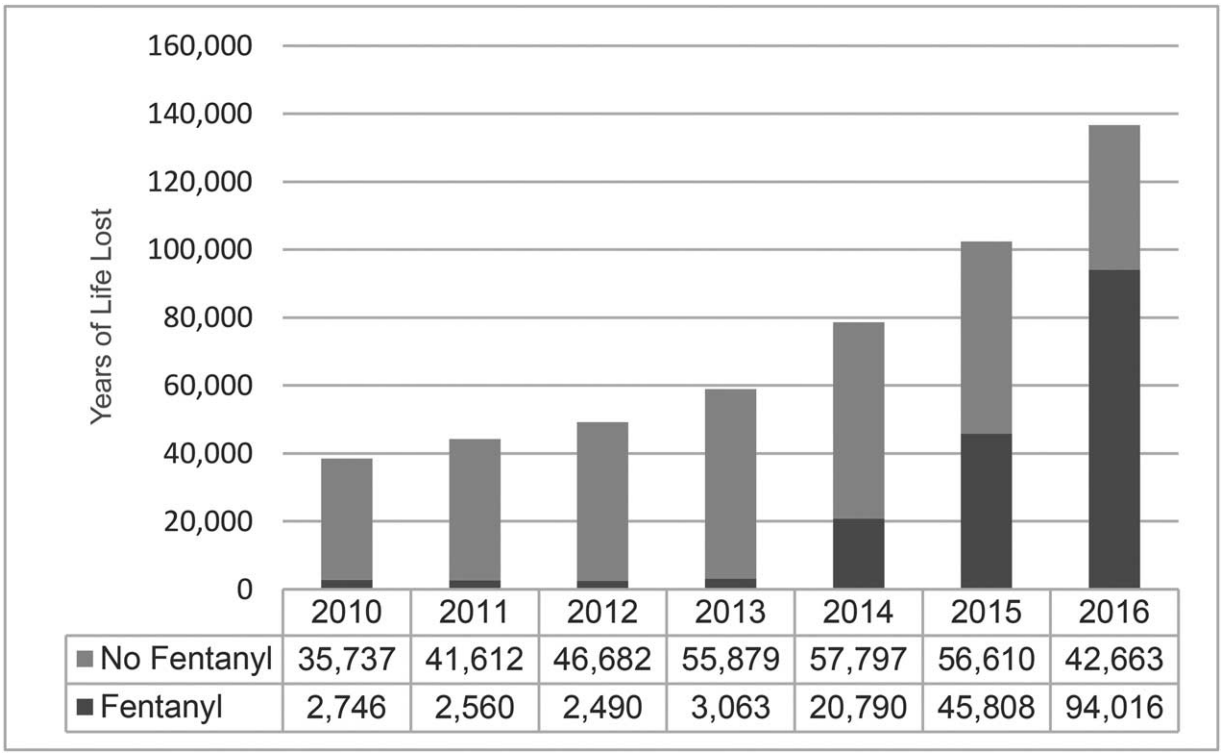

	2010	2011	2012	2013	2014	2015	2016
No Fentanyl	35,737	41,612	46,682	55,879	57,797	56,610	42,663
Fentanyl	2,746	2,560	2,490	3,063	20,790	45,808	94,016

FIGURE 3. Proportion of years of life lost attributable to fentanyl poisoning 2010 to 2016.

Rx Reporting System (OARRS; Hawk et al., 2015). Medication-assisted treatment (MAT) involves pharmacologic and behavioral health therapies to treat opioid use disorder. In Ohio, the projected need for MAT far exceeded treatment capacity during the study period (Jones et al., 2015).

Ohio's efforts at harm reduction have centered on the distribution of the opioid reversal agent naloxone. Since 2012, it has distributed naloxone to bystanders at sites known as Opioid Overdose Prevention Programs (OOPP); however, stigma and the cost of naloxone remain significant barriers (Winstanley et al., 2016). Beginning in late 2015, Ohio law allowed private pharmacies to dispense naloxone without a prescription. There are now more than 1600 pharmacies in the state with naloxone-dispensing capacity (State of Ohio Board of Pharmacy). Future efforts to reduce opioid mortality should be guided by serial assessment and mapping of YLL. This would facilitate the deployment of targeted interventions in the most highly impacted areas of Ohio and other states, saving lives and concentrating resources where they are most needed.

Study Limitations

The present study relied on death certificate data aggregated by the state of Ohio. Prior work has shown state governments likely underestimate opioid overdose mortality because of incomplete cause-of-death reporting (Buchanich et al., 2018). Additionally, ODH typically uses primary underlying cause of death to ascertain overdose. Therefore, it is possible that an unknown number of individuals were excluded because of overdose having been listed as a secondary rather than primary cause of death. A related limitation is that the scope of our study was focused on deaths for which opioid overdose was the immediate cause. Therefore, it underestimated the total mortality burden attributable to opioids by excluding drug-related accidents, assaults, infections, and medical complications. Finally, Ohioans whom died while visiting other states were excluded, thereby creating slight underestimations for our results.

CONCLUSION

Opioid overdose is an important cause of excess mortality in Ohio with a measurable impact on average lifespan. Significant geographic variation exists. Detailed state and regional analyses mirroring the present work are needed to increase understanding of this phenomenon. Our results may be used to guide resource allocation and inform further research. YLL should be serially assessed in Ohio and other locales with elevated opioid overdose burden in order to surveil the geographic spread of fentanyl and other opioid poisonings, identify community profiles and potential protective factors and evaluate the efficacy of ongoing and future efforts to control the epidemic. Areas identified as bearing a disproportionate share of mortality burden should be targeted for increased access to evidence-based addiction treatment, the opioid overdose reversal agent naloxone, harm reduction and prevention programs, and law enforcement.

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