Published in final edited form as:

Subst Use Misuse. 2022 ; 57(11): 1720–1731. doi:10.1080/10826084.2022.2112229.

Opioid-Involved Overdose Vulnerability in Wyoming: Measuring Risk in a Rural Environment

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Abstract

Background: Between 2009 and 2019 opioid-involved fatal overdose rates increased by 45% and the average opioid dispensing rate in Wyoming was higher than the national average. The opioid crisis is shaped by a complex set of socioeconomic, geopolitical, and health-related variables. We conducted a vulnerability assessment to identify Wyoming counties at higher risk of opioid-related harm, factors associated with this risk, and areas in need of overdose treatment access to inform priority responses.

Methods: We compiled 2016 to 2018 county-level aggregated and de-identified data. We created risk maps and ran spatial analyses in a geographic information system to depict the spatial distribution of overdose-related measures. We used addresses of opioid treatment programs and buprenorphine providers to develop drive-time maps and ran 2-step floating catchment area analyses to measure accessibility to treatment. We used a straightforward and replicable weighted ranks approach to calculate final county vulnerability scores and rankings from most to least vulnerable.

Findings: We found Hot Springs, Carbon, Natrona, Fremont, and Sweetwater Counties to be most vulnerable to opioid-involved overdose fatalities. Opioid prescribing rates were highest in Hot Springs County (97 per 100 persons), almost two times the national average (51 per 100 persons). Statewide, there were over 90 buprenorphine-waivered providers, however accessibility to these clinicians was limited to urban centers. Most individuals lived further than a four-hour round-trip drive to the nearest methadone treatment program.

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Disclaimer

The findings and conclusions in this report do not necessarily reflect the official position of the Centers for Disease Control and Prevention, or the authors' affiliated institutions.

Disclosure statement

The authors have no conflicts of interest to disclose.

Conclusions: Identifying Wyoming counties with high opioid overdose vulnerabilities and limited access to overdose treatment can inform public health and harm reduction responses.

Keywords

Opioids; substance use; Wyoming; vulnerability; spatial epidemiology

Background

The opioid overdose crisis has presented one of the most significant challenges to public health in the United States in the past two decades. Over 495,000 people died of an opioid-involved overdose between 1999 and 2019 (CDC, National Center for Health Statistics. n.d) and increases in opioid-related emergency department visits and unintentional opioid-involved overdose deaths were reported during the early stages of the SARS CoV-2 (COVID-19) pandemic in 2020 (Rodda et al., 2020,Centers for Disease Control & Prevention, 2020). Through December 2020, 12-month provisional data from the Centers for Disease Control and Prevention (CDC) recorded 68,821 opioid-involved overdose deaths nationwide, up from 50,178 in the 12 months ending December 2019, a 37% increase (Kaiser Family Foundation, 2021; National Center for Health Statistics & National Vital Statistics Rapid Release, 2020). While the devastation of the opioid crisis has been most pronounced in the Northeast and areas like Appalachia, western states where opioid-involved overdose fatality rates are comparatively lower have been largely overlooked by researchers.

Wyoming, like other less-densely populated states in the Plains and the Mountain West, has relatively low opioid-overdose counts (CDC, National Center for Health Statistics. n.d). However, rising rates of opioid-involved overdose deaths, higher than national average prescription opioid prescribing rates, rising influence of fentanyl in the region, and limited access to medication for opioid use disorder (MOUD) treatment are causes of concern (Haffajee et al., 2019; Langabeer et al., 2020; Mattson et al., 2021; Rigg et al., 2018). In 2010, Wyoming's opioid-involved overdose death rate was higher than the national rate (8.5 vs. 6.8 national) (Kaiser Family Foundation, 2021). In 2015, the national rate increased to 10.4, overtaking Wyoming (7.9), where fatal opioid-involved overdose rates have ranged in recent years from a low of 6.8 per 100,000 in 2018 to a high of 8.7 per 100,000 in 2016 and 2017 (Kaiser Family Foundation, 2021). Wyoming had 60 opioid-involved deaths in 2020, a 27% increase over 2019 (47) (Centers for Disease Control & Prevention NC for HS, 2020). In 2019, the opioid prescribing rate per 100 persons in Wyoming was 49.7, compared to the national rate of 46.7 (Centers for Disease Control & Prevention, 2021). Wyoming's prescribing rates for sub-categories of opioids, such as Long Acting/Extended Release (LA/ER) opioids, have also been higher than the national average (Centers for Disease Control & Prevention, 2019). In addition to the potential risk from higher opioid prescribing rates, the CDC recently reported that between 2018 and 2019, the largest increase (67.9%) in synthetic opioid-involved overdose death rates occurred in the West (Mattson et al., 2021). This trend continued into the early months of the COVID-19 pandemic; ten western states experienced the largest increase in synthetic opioid-involved deaths during the 12-months ending in May 2020 (Centers for Disease Control & Prevention, 2020; O'Donnell, 2021).

Finally, like other predominately rural states, access to MOUD in Wyoming is limited by supply and long distance travel (Haffajee et al., 2019; Rigg et al., 2018).

Assessment of vulnerability to fatal opioid-involved overdose in Wyoming and other states with dispersed populations, and low overdose counts but high rates and limited access to MOUD, is critical to targeting prevention and treatment strategies. Wyoming's disparities in access to MOUD have been noted in recent studies, but as of this writing, a comprehensive synthesis of the overlap in treatment limitation and potential risk factors of fatal opioid-involved overdose is absent from the peer-reviewed literature (Haffajee et al., 2019; Langabeer et al., 2020; Kleinman, 2020). This assessment, conducted by a team comprised of researchers from the Tufts University School of Medicine, public health professionals in the Wyoming Department of Health (WDH), and staff from the CDC, and Council of State and Territorial Epidemiologists (CSTE), fills existing gaps by identifying Wyoming counties at higher risk for fatal opioid-involved overdoses and the factors associated with this risk, and assessing access to overdose prevention services, to inform a targeted public health response. Our approach employed a straightforward methodology that is replicable by other predominately rural states. We employed a geographic information system (GIS) to assess the spatial distribution of risk and access to services and rank-based statistical approaches to describe the overdose risk landscape, forming a foundation for local and state-level interventions and policies to reduce the impact of the opioid crisis.

Methods

Data sources

Beginning in 2019, we compiled county-level aggregated, de-identified data related to opioid-overdose mortality and a wide range of covariates for the most recent years for which they were complete at project initiation: 2016–2018. However, due to suppression of small case numbers for several Wyoming counties, we used data from a longer time frame (2008–2018) for the outcome measure, opioid-involved overdose fatalities, to allow for more robust analysis. We downloaded demographic and socioeconomic data from the U.S. Census Bureau's American Community Survey (ACS) 2014–2018 five-year estimates (U.S. Census Bureau, 2018).

We also compiled addresses for substance use treatment and mental health services, naloxone retailers, and drug take-back locations from WDH and the Substance Abuse Mental Health Services Administration (SAMHSA) online treatment locator. The WDH also shared buprenorphine prescription capacity data based on the U.S. Drug Enforcement Administration (DEA) Registration Data; aggregated to the ZIP code level and provided to the department by the CDC based on a restricted data set accessed July 5, 2019.

Units of analysis

We used counties as the unit of analysis (N = 23) for descriptive mapping and vulnerability score calculation. We used census tracts as the unit of analysis for the 2-step floating catchment area (2SFCA) analysis described below. Finally, we used the U.S. Department of Housing and Urban Development (HUD) ZIP code to county crosswalk file to aggregate

buprenorphine prescription capacity to allow for greater comparability on the county level (Din & Wilson, 2020).

Measures

We used five core indicators in the spatial and statistical analyses, based on previous publications and technical assistance provided by the CDC and the CSTE (Van Handel et al., 2016; Council of State & Territorial Epidemiologists, 2021). These included: opioid-involved overdose deaths and chronic hepatitis C virus (HCV) rates for individuals <36 years of age (WDH), drug-related crime (*Alcohol and Crime in Wyoming*), retail opioid prescriptions dispensed (CDC), and per capita income (ACS). Although acute HCV is considered a better proxy for injection drug use (IDU), when data on acute cases are not available or suppressed, chronic HCV infection rates for individuals younger than 35–40 are often substituted (Sharareh et al., 2020; Rickles et al., 2018; Altekruse et al., 2020). We compiled covariates related to demographic, socioeconomic, and contextual measures, also based on those selected in prior jurisdiction-level opioid vulnerability assessments and peer-reviewed literature (Table 1) (Van Handel et al., 2016; Rickles et al., 2018; Altekruse et al., 2020; Missouri Department of Health & Senior Services & Bureau of Reportable Disease Informatics, 2020; Sawyer et al., 2021).

Dataset

We compiled all data into a structured analytic dataset. County-level observations for the drug overdose variable with counts less than five were suppressed. For counties with suppressed counts, we rounded to the median of suppressed values and assigned the counties counts of three fatal overdoses. We then calculated rates based on the county population estimate provided by WDH. Within a GIS, we joined the structured dataset with the Wyoming county boundary shapefile using ArcMap 10.7.1. (ESRI, Redlands, CA). We used the ESRI World Geocoding Service to geocode addresses for prevention and treatment programs.

Descriptive mapping

We developed a series of thematic risk maps to depict the spatial distribution of all core measures and salient socio-demographic variables (Table 1) across Wyoming counties. We developed a series of descriptive maps using the address locations to portray the spatial landscape for Wyoming with regard to access to hospitals, treatment centers, and related overdose prevention services.

Accessibility analysis

We utilized two spatial methods to describe access to and availability of substance use treatment and harm reduction services in WY: drive-time maps and an accessibility index derived from 2SFCA.

Drive-time analyses

We calculated drive-times based on street networks and speed limits across Wyoming to develop 15, 30, 45, 60, and 120-minute drive-time buffers, using cut-points recommended by

WDH. We developed separate drive-time maps for buprenorphine-waivered clinicians and opioid treatment programs (OTP).

Accessibility index derived from 2SFCA

The 2SFCA method builds on the provider-to-population ratio (the number of providers divided by population in a specified region) by removing administrative boundaries and creating an accessibility index based on drive-time and the demand of services in the catchment area (Wang & Luo, 2005,Luo & Wang, 2003). We performed this analysis in two steps:

1. First, we calculated the provider-to-population ratio for all populations that were within a 45-minute drive-time threshold distance from the provider location.
2. Second, we added the provider-to-population ratios of all the providers that were within a 45-minute drive time of each census tract population centroid.

The model we employed was expressed as follows:

$$A_i = \sum_{j=1, d<D}^{n} \frac{S_j}{\sum_{k=1, d<D}^{m} P_k} \quad (1)$$

Where, S_j was the number of providers at location j; d was the drive-time between the provider and the population centroid; P_k was the population of location k, where the centroid of the census tract was located within the threshold distance; D was the threshold distance for the search radius; and A_i was the accessibility score at location i.

A recently published study reported an average 48 minute drive-time to opioid treatment programs in rural census tracts (Joudrey et al., 2020). Our recommendation of using a 45 minute drive-time threshold was further supported by Wyoming stakeholders. Buprenorphine capacity (i.e., number of treatment slots) for each provider was not available; we assumed that the number of providers at each location was constant across all sites and assigned it a value of 1. We conducted the spatial analysis using R 4.0.2 and the osrm package (Vienna, Austria) (Giraud, n.d).

Vulnerability scores and ranking

We used a weighted ranks approach to calculate vulnerability scores, ranking counties from most to least vulnerable. First, we calculated Pearson correlation coefficients to determine the direction of association between fatal opioid overdose rate and each of the five core measures and the covariates listed in Table 2. Next, we assigned quintile ranks to all core measures and covariates by county based on direction of association from the Pearson correlation coefficient, with 5 = high and 1 = low. For per capita income and percentage of married couple households, we relied on *a-priori* information about their direction of association (negative) with opioid vulnerability (Altekruse et al., 2020). Next, we multiplied the quintile rank for each core measure by three given their stronger association with opioid overdose, based on the literature (Missouri Department of Health & Senior Services &

Bureau of Reportable Disease Informatics, 2020). We summed the weighted quintile ranks for each county to calculate the vulnerability score. We then sorted vulnerability scores from highest to lowest to assign final ranks. We mapped the ranks according to quintiles and created a table displaying the vulnerability scores and ranks by county. We used Stata 16 (College Station, TX) to conduct statistical analysis, ArcMap 10.7.1 (ESRI, Redlands, CA) to create all descriptive maps, and ArcGIS Pro 2.5 (ESRI, Redlands, CA) to conduct and map network analyses. This assessment was reviewed and approved by the Tufts University Health Sciences Institutional Review Board.

Results

Core indicators

Quintile ranks for core measures and covariates included in the vulnerability assessment are presented in Table 3. Uinta (15), Big Horn (14), Platte (12), Hot Springs (11), and Sweetwater (11) Counties had the highest rates per 100,000 population of age-adjusted opioid-involved overdose deaths, whereas Goshen (count below 5), Lincoln (count below 5), Sublette (3 per 100,000 population), and Niobrara (0 cases) Counties had the lowest rates between 2008–2018 (Figure 1a). Hot Springs (97), Uinta (95), Sweetwater (79), and Washakie (75) had the highest opioid prescription rates per 100 persons (Figure 1b) whereas Sheridan (37), Weston (35), Goshen (30), Crook (0), and Niobrara (0) had the lowest rates. Geographically, eastern counties in Wyoming had the lowest opioid prescription rates; high opioid prescribing counties were located centrally and in the southwest. The opioid prescription rates also showed substantial overlap with age-adjusted opioid-involved overdose mortality rates.

The spatial distribution of chronic HCV cases among individuals under age 36 is depicted in Figure 1c. Goshen (243), Niobrara (221), Hot Springs (75), and Park (69) Counties had the highest rates per 100,000, whereas Albany (9), Crook (7), Lincoln (7), Platte (7), and Johnson (0) Counties had the lowest. Goshen County is home to the Wyoming Department of Corrections intake facility and Niobrara houses the women’s correctional facility, which may account for their significantly higher rates, but this could not be distinguished in the available data. Three counties in eastern Wyoming, Carbon (5259), Campbell (3249), and Converse (3158), had higher rates of arrests involving drugs per 100,000 and are located along major interstates (I-80, I-90, and I-25, respectively–Figure 1d). Teton ($53,703), Park ($35,059), Johnson ($34,885), and Sheridan ($34,059) Counties had the highest per capita income (Figure 1e) in Wyoming. Lowest income counties were Washakie ($27,556), Uinta ($27,009), Albany ($26,665), Big Horn ($23,978), and Niobrara ($22,688).

Covariates

We assessed twelve covariates that have been commonly associated with opioid-related outcomes in the scientific literature (Table 3). Hot Springs and Fremont Counties had among the highest rates of non-fatal drug overdose, measured by Emergency Room visits and hospitalizations (for both all drugs and opioids, specifically). Among other counties that ranked in the upper quintile for non-fatal drug overdose, Washakie County also had higher percentages of unemployed and uninsured residents and Uinta County ranked in the upper

quintile for percentages of residents with a disability and unemployed. Although arrests involving alcohol and involving methamphetamine were not included in the weighted ranks analysis, maps for these measures depicted Hot Springs County in the upper quintile.

Vulnerability scores and ranking

Based on the weighted quintile ranks analysis, we found Hot Springs, Carbon, Natrona, Fremont, and Sweetwater Counties to be most vulnerable to fatal opioid-involved overdose (Figure 1f). Hot Springs County ranked in the top quintile for all but one core measure (per capita income) and was in the top quintile for non-fatal drug overdose hospitalizations and ER visits. Hot Springs, Carbon, Natrona, and Fremont ranked in the second highest category for fatal opioid-involved overdose but the highest quintile for non-fatal drug overdose hospitalizations.

Asset maps

Maps of geocoded addresses for substance use disorder and mental health treatment, drug take-back sites, and naloxone access, indicated that higher densities and diversity of services for people with opioid use disorder (OUD) were primarily located in urban centers and populous counties (Figure 2a–f). Naloxone and drug take-back sites were the most common assets and could be found in all counties (Figure 2b). Buprenorphine patient capacity is highest in Natrona, Laramie, and Sweetwater Counties (Figure 2c).

Drive-time analysis

We found that residents in many regions of Wyoming have to drive 60–120 minutes to access buprenorphine (Figure 2e). Fremont County has several providers near the center of the county, supporting an area of shorter (30–45 minute one-way) drive-times. Crook and Weston Counties in the northeast and Laramie and Albany Counties, home to the cities of Laramie and Cheyenne, respectively, also had pockets of similarly short drive-times. However, for the majority of the state, 60–120 minutes was the length of a one-way trip. Wyoming does not currently offer methadone as an option for treatment. The nearest SAMHSA-certified methadone programs are located in adjacent states, well over a four-hour roundtrip drive by car (Figure 2f).

Accessibility to treatment: 2-step floating catchment area analysis

We found that the majority of census tracts in Wyoming had low accessibility to buprenorphine-waivered clinicians; the highest areas of access were generally closest to population centers. These include Casper (Natrona County), Laramie (city and county), and Jackson (Teton County). Uinta also has high accessibility, but the presence of the Wyoming State Hospital in this county may bias this result (Figure 2d). The floating catchment area accounts for the distribution of both providers and the underlying population served by them. We found that large portions of the most vulnerable counties of Sweetwater, Natrona, and Carbon had low accessibility based on this analysis, despite the fact that Sweetwater and Natrona had among the highest patient capacity county-wide.

Discussion

In this assessment, we used a range of public health, demographic, and socioeconomic measures to estimate fatal opioid-involved overdose vulnerability in Wyoming. We found that counties with higher rates of opioid-involved overdose deaths also had high rates of opioid prescriptions and non-fatal opioid overdose, and in-state access to buprenorphine and methadone were limited to urban centers or absent, respectively. We identified five counties with higher vulnerability: Hot Springs, Carbon, Natrona, Fremont, and Sweetwater. Targeted and tailored intervention approaches, which take into consideration each county's mix of risk and protective factors related to opioid-related morbidity and mortality, are needed. Although our primary focus for this assessment was the state of Wyoming, the methods we used are straightforward and replicable by any state or local public health jurisdiction interested in measuring vulnerability to opioid-involved mortality or similar outcomes.

Our vulnerability assessment suggests that prescription opioids may still be an issue of concern in the state. Wyoming's opioid prescribing rate declined from 57.1 per 100 persons in 2018 to 49.7 in 2019, although the state's rate continued to be slightly higher than the national rate of 46.7 per 100 (Centers for Disease Control & Prevention, 2021). Updated opioid prescribing guidelines and the implementation of Prescription Drug Monitoring Programs (PDMPs) that require clinicians to check patient prescription records before prescribing an opioid have likely resulted in decreasing opioid prescribing rates since 2012 (Dowell et al., 2016; Haffajee, 2019; Haffajee et al., 2018). Most states experienced a stabilization or abatement of prescription opioid-related deaths after 2011, only to experience a sub-sequent rise in heroin-involved overdose deaths, followed by the arrival of synthetic opioids (namely fentanyl) in the illicit drug supply (Centers for Disease Control & Prevention, 2020; Ciccarone, 2019; Zoorob, 2019). Our vulnerability assessment suggests that prescription opioids continue to influence fatal opioid-involved overdose rates in Wyoming, as they do in other rural areas (Rigg et al., 2018; Keyes et al., 2014; García, 2019). Our findings concur with data from the WDH, Substance Abuse Prevention dashboard, which indicates that prescription opioids are a significant contributor to non-fatal opioid overdose. Between 2016–2019, prescription opioids were involved in 14 percent of opioid-related ER visits and 92 percent of opioid-related hospitalizations (Wyoming Department of Health, n.d). Wyoming does have a wide network of drug take-back locations, with at least one per county, but at least one recent study indicated that patients lack knowledge about proper disposal of excess medications (Ehrhart et al., 2020). Wyoming might look to successful interventions piloted in rural communities, such as opioid buy-back programs, to reduce the amount of excess prescription opioids in circulation (Liu et al., 2020).

Given the small number of opioid-involved overdoses per county, non-fatal overdose, which is more prevalent, is a useful proxy for fatal overdose risk. Although hospitals in three counties (Crook, Niobrara, and Teton) did not participate in the Wyoming Hospital Discharge dataset and three counties had data suppressed due to low counts (Johnson and Weston) or lack of a hospital in the county (Sublette), nine of the remaining seventeen Wyoming counties had non-fatal opioid-involved emergency department visit rates higher than the state average of 18.8 per 100,000. All five counties we identified as vulnerable

were among this group: Carbon (30.0 per 100,000), Fremont (24.1), Hot Springs (35.7), Natrona (21.5), and Sweetwater (41.6). Wambeam and colleagues also documented 737 cases of naloxone administration by EMS in 92,537 ambulance trips over the period of January 1, 2016 to June 30, 2017. This translates to 126 naloxone EMS administrations per 100,000 population during that 18-month period. Four counties had rates higher than the state average: Fremont (286 per 100,000 population), Sweetwater (249), Laramie (176), and Carbon (147) (Wambeam et al., 2018). In our analysis, Fremont, Sweetwater, and Carbon rank among the highest quintile for opioid-related overdose vulnerability.

People with OUD in Wyoming are likely to find treatment difficult to access due to long travel times. One of the most significant gaps in OUD treatment is the absence of in-state methadone clinics, requiring residents to drive to neighboring states for this treatment (Furst et al., 2022). Based on our drive-time analyses, the closest opioid treatment programs are more than 4-hour round-trip drives. Our results are similar to those of recent studies that calculated mean driving times and/or distance between census tract centroids and the nearest methadone and buprenorphine treatment (Langabeer et al., 2020,Joudrey et al., 2020). Kleinman et al.'s recent comparison of driving times to opioid treatment programs and pharmacies in the U.S. found that Wyoming had the longest mean one-way drives by distance (153.7 miles) and time (143.4 minutes) and the highest one-way costs ($30.74 estimated driving cost; $16.85 fuel cost) (Kleinman, 2020). Given that methadone typically must be accessed daily, distance to these services is a critical factor. Several studies have demonstrated that greater distance to methadone is associated with lower uptake and adherence (Amiri et al., 2018; Beardsley et al., 2003; Rosenblum et al., 2011). For people in the most vulnerable interior counties in Wyoming, such as Fremont and Natrona, access to methadone would be particularly difficult.

In light of the current absence of methadone treatment programs in Wyoming, a more viable option may be expansion of buprenorphine treatment (Andrilla et al., 2019). Our maps of patient capacity, drive-time, and accessibility suggest an imbalance in the potential need for buprenorphine and the location of buprenorphine-waivered clinicians. Of the most vulnerable counties, Natrona has the highest patient capacity in the city of Casper and the northeast corner of the county, highlighted by high accessibility in the 2SFCA analysis. However, much of the county is still a 120-minute drive, each way, from this treatment. Fremont County also has shorter drive-times, with better accessibility across much of the county. There are similar pockets of shorter drives in the other three vulnerable counties, but lower patient capacity. Several lower vulnerability counties have significant areas with shorter drive-times, better accessibility, and higher capacity. These include Teton, which is home to Jackson and has a much higher per capita income ($53,703) than the state average ($32,295), and Laramie, the home of the University of Wyoming.

Although the COVID-19 pandemic has disrupted healthcare access in many ways, it has also inspired creative thinking related to reaching patients remotely via telemedicine following the loosening of restrictions related to MOUD that could ultimately be adopted by rural states, and may be one avenue for expanding buprenorphine access in Wyoming (Leppla & Gross, 2020; Pena & Ahmed, 2020; Wendt et al., 2021). New practice guidelines for the administration of buprenorphine for treating OUD, which went into effect in

April 2021, allow licensed and DEA-registered clinicians to apply for a 30-patient waiver without completing additional training and may expand access to buprenorphine (Practice Guidelines for the Administration of Buprenorphine for Treating Opioid Use Disorder, 2021). Canada, Australia, and the United Kingdom have policies that allow pharmacies to dispense methadone for treatment of OUD (Cochran et al., 2020). This innovation would support many rural and frontier areas given recent findings that 98 percent of U.S. residents lived in census tracts where the drive to the nearest pharmacy was shorter than to the nearest OTP (Kleinman, 2020).

Our findings should be considered in the context of several limitations. First, we were unable to obtain detailed data related to opioid prescribing (such as average morphine milligram equivalents (MME) per person or numbers or rates of prescribing of different types of prescription opioids) from the Wyoming Prescription Drug Monitoring Program (PDMP). Instead, we relied on county-level data for all opioid prescriptions reported by the CDC. Given the association between prescription opioids and opioid overdose vulnerability reported here, county-level data related to high-dose opioid prescription rates (e.g., MME > 90) might have offered an opportunity for a more nuanced analysis of prescribing patterns. Second, the number of counties in Wyoming (N = 23) was too small to support robust statistical modeling, which might have revealed more about the strength of association between opioid overdose mortality and the core indicators and covariates. We did conduct a regression analysis using a robust spatial CAR model, which showed a statistically significant association between opioid prescribing rates and overdose rates; however, the residuals were not spatially autocorrelated to warrant further assessment. Third, our analyses of buprenorphine accessibility should be used with caution. The SAMHSA treatment locator data may underestimate the number of buprenorphine-waivered clinicians (Beetham et al., 2019). Although we were provided with an aggregated measure of capacity by ZIP code, we did not have access to capacity for each provider; therefore, we chose to assume equal capacity in the 2SFCA analysis (Sawyer et al., 2021). This also acknowledges that waivered clinicians typically prescribe well below their approved capacity (Cabreros et al., 2021; Thomas et al., 2017; Valenstein-Mah et al., 2018). Fourth, this assessment started just as the response to the COVID-19 pandemic began to shut down much of the United States, both physically and economically, so this assessment does not reflect changes in the OUD and treatment landscape in Wyoming since the arrival of COVID-19. Many states are currently experiencing rising opioid-involved overdoses which may be due to challenges associated with treatment disruptions, isolation, and other issues during the pandemic (Centers for Disease Control & Prevention, 2020; Becker & Fiellin, 2020). Therefore, these results should be considered within the context of possible disruptions that may have led to changes in trends of substance use and misuse and access to treatment for OUD (Centers for Disease Control & Prevention, 2020). Fifth, using the county as the spatial unit may not have been small enough to capture nuanced spatial variation. County-level data was deemed most appropriate and actionable by state partners and the assessment team. We recognize that due to the modified areal unit problem (MAUP), analysis using a smaller spatial unit would likely provide different results. Finally, with the exception of OTP locations, which were part of a national publicly available dataset, we only had access to data from Wyoming; therefore, we could not assess the impact of out-of-state healthcare on opioid-related

overdose vulnerability, beyond the drive-time analyses described above. Therefore, there may be edge effects near the state borders that could not be addressed in the 2SFCA analysis. Although we used more recent service location data than the years included in our analysis, which does limit the ability to compare opioid-overdose fatality estimates to accessibility, our decision was based on data availability and the desire for treatment access to reflect more current and actionable realities (Sawyer et al., 2021).

The strength of this assessment lies, in part, in the ability of the composite vulnerability score to summarize the impact of multiple risk factors for each county. We deliberately used a weighted ranks approach that would be suitable for a smaller sample size and easy for other similar states to replicate. High opioid vulnerability can serve as a proxy for opioid-related mortality risk, and this measure can serve as a tool for policy education, and targeted placement and enhancement of harm reduction, prevention and treatment services. This assessment was also strengthened by the collaborative approach that guided the process from inception to conclusion. Our Wyoming partners and their stakeholders shared important local knowledge and regular feedback related to our findings, helping to "ground truth" maps, spatial analyses, and statistical findings, which were especially critical during pandemic travel restrictions. The findings from this assessment can be critical in guiding future interventions for targeted communities with highest opioid vulnerabilities but limited access to substance use treatment.

Acknowledgments

The authors wish to acknowledge Debi Anderson, CPM, Wyoming Department of Health, for her assistance with this assessment.

Financial disclosure statement

The Council of State and Territorial Epidemiologists (CSTE) provided technical assistance to this Wyoming Opioid Overdose Vulnerability Assessment through Tufts University. This project is funded through the Centers for Disease Control and Prevention's (CDC) National Center for Injury Prevention and Control (NCIPC) and supported by Cooperative Agreement number CDC-RFA-OT18-1804: Technical Assistance for Response to Public Health or Healthcare Crises.

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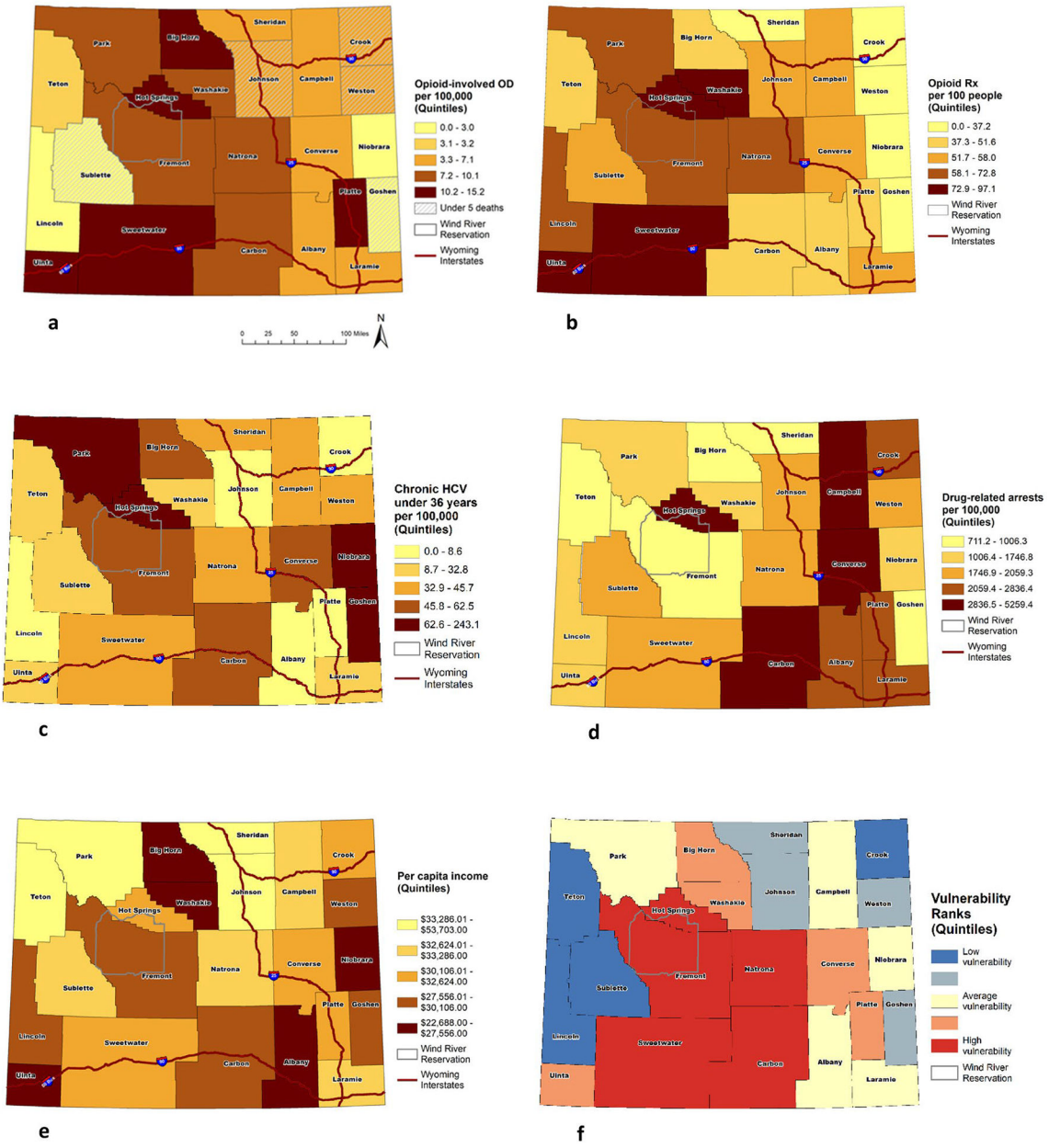

Figure 1.

Core vulnerability measures related to fatal opioid overdose rates and vulnerability ranks in Wyoming counties, 2016–2018: a) Opioid-involved fatal overdose rates (ODs) per 100,000 population; b) opioid prescription (Rx) rates per 100 population; c) chronic hepatitis C virus (HcV) infection rates for people under 36 years of age per 100,000 population; d) drug-related arrests per 100,000 population; e) per capita income; f) opioid-involved overdose vulnerability rankings, taking all core measures and covariates into consideration using a weighted ranks approach.

Figure 2.

Population density and access to opioid use disorder treatment and related services in Wyoming, 2019–2020: a) Wyoming population per square mile; b) Location of treatment and service assets (MOuD includes all formulations except methadone); c) buprenorphine patient capacity (i.e., treatment slots); d) two-step floating catchment area analysis assessment of accessibility to buprenorphine-waivered prescribers at the census tract level; e) drive-time accessibility to buprenorphine-waivered clinicians; f) Drive-time accessibility to opioid treatment programs offering methadone treatment.

Table 1.

Core and covariate measures, years, and data sources used in the Wyoming opioid overdose vulnerability assessment.

Measure	Years	Source
Core		
Age-adjusted opioid-involved overdose death rate per 100,000	2008–18	Wyoming Department of Health
Newly reported confirmed and probable chronic HCV in individuals <36 years of age rate per 100,000	2015–19	Wyoming Department of Health
Drug-related arrest rate per 100,000	2016–19	*Alcohol and Crime in Wyoming*, 2016–19. Wyoming association of Sheriffs and Chiefs of Police.
Retail opioid dispensing rate per 100	2018	CDC, https://www.cdc.gov/drugoverdose/maps/rxrate-maps.html
Per capita income	2014–18	American Community Survey (ACS) five-year estimates (U.S. Census Bureau, 2018)
Covariates		
Percent of households that are renters	2014–18	American Community Survey (ACS) five-year estimates
Percent of married couple households	2014–18	American Community Survey (ACS) five-year estimates
Percent of female-led households	2014–18	American Community Survey (ACS) five-year estimates
Percent of population that is uninsured	2014–18	American Community Survey (ACS) five-year estimates
Percent of population that does not have a vehicle	2014–18	American Community Survey (ACS) five-year estimates
Percent of population non-Hispanic White	2014–18	American Community Survey (ACS) five-year estimates
Percent of population male	2014–18	American Community Survey (ACS) five-year estimates
Gini index (measure of wealth inequality)	2014–18	American Community Survey (ACS) five-year estimates
Percent of population without Internet access	2014–18	American Community Survey (ACS) five-year estimates
Non-fatal drug poisoning hospitalization rate per 100,000, primary diagnosis *	2016–18	Wyoming Department of Health
Non-fatal drug poisoning emergency room visits rate per 100,000, any diagnosis *	2016–18	Wyoming Department of Health
County located in a High-intensity Drug Trafficking area	2019	https://rmhidta.org/

* Based on reporting hospitals only.

Table 2.

Descriptive summary of core-indicators and covariates, Wyoming counties (N = 23).

Variable	Mean	SD	Min	Max	Direction of association	Wt
Core indicators						
Age-adjusted opioid-involved overdose death rate per 100,000 population	13.5	5.8	4.5	24.7	Ref	3
Newly reported confirmed and probable chronic HcV in individuals <36 years of age rate per 100,000	76.2	60.2	28.2	269.6	Positive	3
Drug-related arrest rate per 100,000	2011.4	1068.5	711.22	5259.4	Positive	3
Retail opioid prescription rate per 100	52.8	23.5	0	97.1	Positive	3
Per capita income (dollars)	31455.1	5915.9	22688.0	53703.0	Negative	3
Covariates						
Percent of households that are renters	27.9%	7.2	16.3%	50.3%	Positive	1
Percent of married couple households	53.6%	5.2	38.7%	63.8%	Positive	1
Percent of female-led households	8.1%	2.9	3.4%	14.4%	Positive	1
Percent of population that is uninsured	11.9%	2.7	7.4%	18%	Positive	1
Percent of population that does not have a vehicle	1.4%	0.7	0%	2.7%	Negative	1
Percent of population non-Hispanic White	92.6%	4.8	72.8%	96.3%	Negative	1
Percent of population male	51.2%	1.8	46.9%	55.6%	Positive	1
Gini index (measure of wealth inequality)	0.43	0.03	0.36	0.49	Negative	1
Percent of population without internet access	16.1%	5.0	7.3%	26.4%	Negative	1
Non-fatal drug poisoning hospitalization rate per 100,000, primary diagnosis *	52.4	26.9	14.0	130.9	Positive	1
Non-fatal drug poisoning emergency room visits rate per 100,000, any diagnosis *	161.2	62.1	75.5	324.2	Positive	1
Proportion of counties designated as high intensity drug trafficking area	26.1%	–	–	–	Positive	1

* Based on reporting hospitals only. SD: Standard deviation; Min: Minimum, Max: Maximum; Wt: Weights applied for vulnerability assessment.

Table 3.

Quintile ranks for core measures, covariates, and opioid overdose vulnerability, Wyoming, 2020.

			Core measures					Covariates												
County	**Total Score**	**Rank**	**Opioid-involved OD**	**Chronic HCV**	**Drug-Related Arrest**	**Per capita income**	**Opioid Rx**	**% Renters**	**% Married couple HH**	**% Femaleled HH**	**% Uninsured**	**% No vehicle**	**% NH White**	**HIDTA**	**% Male**	**Gini index**	**% Without Internet**	**Non-fatal drug poisoning hospitalization**	**Non-fatal drug poisoning ER visits**
Hot Springs	**109**	**1**	5	5	5	3	5	2	3	5	2	4	5	1	2	3	3	5	5
Carbon	**96**	**2**	4	4	5	4	2	4	4	5	2	2	2	1	5	2	4	5	3
Natrona	**96**	**3**	4	3	4	2	4	5	5	4	4	2	3	4	2	4	3	5	4
Fremont	**92**	**4**	4	4	1	4	4	4	5	4	5	3	1	1	1	3	4	5	5
Sweetwater	**87**	**5**	4	3	3	2	5	2	4	4	3	2	2	4	4	2	1	4	4
Uinta	**87**	**6**	5	2	2	5	5	2	2	3	3	2	3	4	2	2	1	1	5
Converse	**82**	**7**	3	4	5	3	4	3	1	1	1	1	5	1	3	1	2	2	4
Big Horn	**81**	**8**	5	4	1	5	2	3	3	2	5	3	4	1	2	1	4	1	1
Washakie	**81**	**9**	3	2	2	5	5	1	2	2	5	4	1	1	1	1	3	4	5
Platte	**80**	**10**	5	1	4	3	2	3	3	2	2	1	4	1	4	5	5	3	2
Niobrara	**78**	**11**	1	5	2	5	1	2	3	1	5	2	2	1	5	4	5	3	3
Park	**78**	**12**	4	5	2	1	4	4	2	2	3	4	3	1	2	4	2	2	1
Albany	**77**	**13**	2	1	4	5	2	5	5	1	1	5	1	4	4	5	1	2	1
Campbell	**77**	**14**	3	3	5	2	3	3	2	3	1	5	4	4	1	1	1	2	2
Laramie	**76**	**15**	3	2	4	2	3	4	4	4	1	3	1	4	2	3	2	4	2
Johnson	**74**	**16**	2	1	3	1	3	4	4	5	4	5	2	1	5	5	5	2	2
Weston	**68**	**17**	2	3	3	4	1	1	4	3	4	3	2	1	1	3	4	1	2
Sheridan	**65**	**18**	2	4	1	1	1	5	5	5	1	4	4	1	1	4	3	4	1
Goshen	**64**	**19**	1	5	1	4	1	2	2	2	3	1	2	1	4	2	5	1	3
Crook	**63**	**20**	2	1	4	3	1	1	1	1	2	4	4	1	2	4	4	3	3
Sublette	**61**	**21**	1	2	3	2	3	1	1	1	4	1	5	1	5	1	2	3	3
Lincoln	**60**	**22**	1	1	2	4	4	1	1	3	4	1	5	1	2	2	2	1	1
Teton	**60**	**23**	1	2	1	1	2	5	5	4	2	5	1	1	4	5	1	3	3

OD: Overdose, Rx: Prescription, HH: household, NH: Non-Hispanic, HIDTA: High intensity drug trafficking area, ER: Emergency Room.