Drug and Alcohol Dependence 204 (2019) 107571

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

Full length article

# Drug overdose mortality among residents of single room occupancy buildings in San Francisco, California, 2010–2017

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ARTICLE INFO

*Keywords:*
Drug overdose
Single room occupancy (SRO) buildings
Residential hotels
Urban health
Health disparities

ABSTRACT

*Background:* Single room occupancy (SRO) buildings, also known as residential hotels, are a form of affordable housing common to cities in North America, and residents of these buildings face elevated rates of substance use, physical and mental multimorbidity, and mortality. Identifying distinct populations at greater risk of overdose death is crucial to the planning of interventions aiming to reduce drug-related mortality, yet no studies have assessed the population burden of overdose mortality among SRO residents. The present study quantifies and characterizes drug overdose mortality among residents of SRO buildings in a large U.S. city.

*Methods:* We used mortality records and a database of SRO buildings to calculate rate ratios comparing overdose mortality due to opioids, cocaine, and methamphetamine among SRO residents and non-SRO residents in San Francisco, CA 2010–2017 and assessed bivariate differences in decedent and death location characteristics between SRO resident and other overdose decedents.

*Results:* There were 1,551 overdose deaths during the study period, with an overall rate of 21.3 per 100,000 residents (95%CI = 20.2–22.6). The rate among SRO residents (278.7, 95%CI = 252.9–306.5) was 19.3 (95%CI = 17.1–21.7) times that of non-SRO residents (21.3, 95%CI = 20.2–22.6). An additional 79 (5%) deaths among non-residents occurred in SRO buildings, and 86% of SRO resident decedents died at home compared to 64% of non-SRO residents ($p < 0.05$).

*Conclusions:* Overdose mortality was substantially higher among SRO residents, who were also more likely to die from overdose at home, which highlights the need for resources and targeted interventions directed towards residents of SRO buildings.

## 1. Introduction

Deaths from drug overdose in the United States increased between 1999 and 2017 (Hedegaard et al., 2017). Although increasing overdose mortality rates have been driven primarily by opioids, deaths due to methamphetamine and cocaine have also increased in recent years (Hedegaard et al., 2017; Seth et al., 2018). Notably, these increases have occurred across demographic groups and urbanization levels (Seth et al., 2018). Although overdose mortality rates in rural areas exceed those in urban areas, the number of deaths, and thus the scale of the problem, remains substantially greater in America's cities (Centers for Disease Control and Prevention, 2017; Mack et al., 2017). In 2015, there were more than six times as many drug overdose deaths in metropolitan counties compared to nonmetropolitan counties (Mack et al., 2017).

Sociodemographic disparities in overdose mortality rates in urban environments are well-documented. For example, drug overdose deaths have been shown to occur disproportionately among residents of neighborhoods of lower socioeconomic status (Rowe et al., 2016; Visconti et al., 2015) and greater income inequality (Galea et al., 2003) as well as among people experiencing homelessness (Baggett et al., 2015, 2013; Gambatese et al., 2013a, b; Riley et al., 2013). Identifying distinct populations that are at greater risk of overdose death is crucial to the planning and implementation of interventions aiming to reduce drug-related mortality. For example, such surveillance efforts have informed programs initiating buprenorphine-assisted treatment among opioid-dependent individuals experiencing homelessness (San Francisco Office of the Mayor, 2018) and those treated in the

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https://doi.org/10.1016/j.drugalcdep.2019.107571
Received 27 February 2019; Received in revised form 14 August 2019; Accepted 14 August 2019
Available online 21 September 2019

emergency department (Towfighi et al., 1989), as well as prescribing naloxone to individuals released from prison (Bird et al., 2017).

Single room occupancy (SRO) buildings, also known as residential hotels, are a form of affordable housing common to cities in North America. They act as long-term housing for some, but many individuals experience shorter-terms stays, and transitions to or from homelessness are common (Knight et al., 2014), which leads researchers to classify them as unstable housing or, in some studies, as the equivalent to homelessness (Aidala et al., 2016). SRO buildings mostly contain single private bedrooms, and shared bathroom and kitchen facilities, or no kitchen at all, and can range widely in terms of structural and administrative quality and availability of on-site support services (Knight et al., 2014). There is no official census of the number of SRO buildings or residents in the United States and, due to variable definitions across jurisdictions and data limitations, quantifying SROs can be challenging (Stern and Yager, 2018; Wegmann and Mawhorter, 2017); however, a 1990 estimate placed the number of individuals living in residential hotels in the United States between one and two million (Groth, 1994) and SRO units accounted for 5% of all housing units in San Francisco, CA in 2018. In addition, several studies and reports note the importance of SRO buildings as a source of low-income housing in several North American cities, including New York City (Stern and Yager, 2018), Chicago (Bowen et al., 2016; Bowen and Mitchell, 2016), Vancouver (Barbic et al., 2018; Bardwell et al., 2018; Shannon et al., 2006; Vila-Rodriguez et al., 2013), and San Francisco (Knight et al., 2014; San Francisco Department of Public Health, 2016). These studies have also documented the myriad adversities affecting residents of SRO buildings, including frequent co-morbidities involving physical, mental, and neurological conditions (Barbic et al., 2018; Shannon et al., 2006; Vila-Rodriguez et al., 2013), high rates of mental illness (Knight et al., 2014), substance use and dependence (Barbic et al., 2018; Knight et al., 2014; Shannon et al., 2006), and food insecurity (Bowen et al., 2016), and increased risk of mortality relative to the general population (Barbic et al., 2018; Vila-Rodriguez et al., 2013). However, most of these studies are based on convenience samples of SRO residents and no studies have quantified the population burden of drug overdose mortality among SRO residents or compared it to that among non-SRO residents. Given the ongoing drug overdose crisis and the significant role of SROs in housing some of North America's most vulnerable urban residents, understanding the magnitude and nature of this problem among SRO residents could inform the development of intervention strategies specifically targeting this population. In the present study, we linked eight years of overdose-related mortality records in San Francisco, California to a database of SRO buildings that are regulated by the city. Our aim was to compare overdose-related mortality by SRO residence status, then compare demographic and clinical characteristics, substances involved, and the location of overdose deaths among SRO residents and non-SRO residents.

## 2. Methods

### 2.1. Study sample and data sources

We identified all methamphetamine, cocaine, and opioid overdose deaths in San Francisco, CA from 2010 to 2017 using comprehensive mortality records from the California Department of Public Health. Because the primary aim of this study was to examine overdose mortality by residential status in San Francisco, we also included deaths of San Francisco residents that occurred outside of San Francisco. Substance-specific deaths were identified using textual cause of death fields, which correspond to the causes documented on the death certificate. The involvement of specific substances are determined by the San Francisco Office of the Chief Medical Examiner's (OCME) Forensic Laboratory Division, which performs toxicological screenings and confirmatory assessments of urine and blood specimens for all deaths with an uncertain cause. Cases for which no specific substance was documented underwent manual review by two physicians in consultation with the chief forensic toxicologist of the San Francisco OCME to determine substances involved, as described elsewhere (Turner et al., 2018). To focus our analysis on accidental adult deaths, homicides, suicides, and decedents younger than 18 years were excluded.

Most SRO buildings in San Francisco are regulated under the Residential Hotel Unit Conversion and Demolition Ordinance (HCO), Chapter 41 of the city's Administrative Code, which was enacted in 1981 to preserve affordable housing in San Francisco. Specifically, the HCO applies to SRO residential units that were occupied by a permanent resident on September 23, 1979, and units that were constructed after that date as one-to-one replacements for converted or demolished units. To determine whether decedents were residents of SRO buildings regulated under the HCO ordinance, we obtained addresses of all HCO buildings from the San Francisco Department of Building Inspection, which administers the ordinance. Specifically, we obtained four lists dated between June 2015 and January 2018 that contained all SRO buildings regulated under the HCO as of the date the list was generated and we identified buildings that were present on at least one of the lists; historical lists dated prior to June 2015 were not available. This resulted in a final list of 512 unique SRO buildings (115 non-profit and 397 for-profit). There are other SRO buildings in San Francisco that are not regulated under the HCO, but we restricted our analysis to buildings regulated under the HCO in order to capture an objectively-defined census of buildings. We address this limitation in a sensitivity analysis described below. To estimate the total number of SRO residents in San Francisco each year for calculating annual mortality rates among SRO residents, we used the total number of SRO units in buildings regulated under the HCO each year 2010–2017, obtained from annual San Francisco Housing Inventory reports produced by the San Francisco Planning Department. This is an imperfect measure, as it does not account for vacant units or multiple adults living in a single unit, but there are no official or reliable estimates for the number of SRO residents in San Francisco. However, we attempt to address this limitation in a sensitivity analysis described below.

### 2.2. Measures

Demographic characteristics, substances involved, and death location characteristics were obtained from mortality records. Specifically, we identified the age, race/ethnicity, and sex of each decedent. In addition to the involvement of opioids, cocaine, and methamphetamine, we also determined the involvement of specific opioids (e.g., heroin, fentanyl, methadone). For assessing polysubstance involvement, we defined the involvement of multiple substances as the involvement of more than one of the following: any opioid, methamphetamine, cocaine. We used the decedent's residential address and the location of their death to determine whether each death occurred at the decedent's home, outside San Francisco, in a public space, or outdoors (which is a subset of public spaces).

We linked decedents' residential addresses to our database of SRO buildings to define the residential status of each decedent using the following mutually exclusive categories: San Francisco SRO residents, San Francisco non-SRO residents, individuals with an out-of-city address, and those with no known address. Decedents were classified as San Francisco SRO residents if their residential address matched an address present in our database of SRO buildings, regardless of where their death occurred. Individuals with an out-of-city address and those with no known address were separated because we hypothesized that they represent distinct populations. Unless we explicitly state otherwise, "non-SRO residents" refers to San Francisco non-SRO residents and does not include individuals with an out-of-city address or those with no known address.

We also linked decedents' death addresses to our database of SRO buildings to identify whether or not each death occurred in an SRO building, regardless of the decedent's residential status or address.

**Table 1**
Average annual overdose mortality rates by single room occupancy (SRO) residential status in San Francisco, 2010–2017*.

| | Mortality Rates | | | | | | Unadjusted Rate Ratio Comparing SRO Residents to Non-SRO Residents | |
|---|---|---|---|---|---|---|---|---|
| | All Residents | | SRO Residents† | | Non-SRO Residents | | | |
| | Rate | (95% CI) | Rate | (95% CI) | Rate | (95% CI) | Rate Ratio | (95% CI) |
| All Overdose Deaths‡ | 21.3 | (20.2–22.6) | 278.7 | (252.9–306.5) | 14.5 | (13.5–15.5) | 19.3 | (17.1–21.7) |
| Opioid-Related Overdose Deaths | 13.0 | (12.1–14.0) | 157.8 | (138.5–179.0) | 9.2 | (8.4–10.0) | 17.2 | (14.7–20.1) |
| Cocaine-Related Overdose Deaths | 8.8 | (8.1–9.6) | 134.8 | (117.0–154.5) | 5.5 | (4.9–6.1) | 24.5 | (20.5–29.3) |
| Methamphetamine-Related Overdose Deaths | 6.7 | (6.1–7.4) | 97.3 | (82.3–114.3) | 4.3 | (3.8–4.9) | 22.7 | (18.4–27.9) |

* Overdose death rates only include decedents with valid San Francisco addresses.
† Annual population denominators for rates among SRO residents estimated by the number of SRO residential units in San Francisco in each year.
‡ Includes opioid-, cocaine-, and methamphetamine-related overdose deaths.

To add context to the involvement of methadone in overdose deaths, we also assessed whether each decedent had been receiving publicly funded methadone maintenance treatment in San Francisco at the time of his/her death. Specifically, we matched mortality records to records of publicly funded methadone maintenance treatment by name and date of birth and identified decedents who had received a dose of methadone within 7 days prior to their death.

### 2.3. Analysis

We calculated annual overdose mortality rates, total rates over the entire study period (January 2010 to December 2017), and 95% confidence intervals for methamphetamine, cocaine, and opioids together and for each substance separately. We completed calculations among all San Francisco adult residents, San Francisco SRO residents, and San Francisco non-SRO residents. The rates over the entire study period were then used to calculate rate ratios and 95% confidence intervals comparing the overdose mortality rates among SRO residents to those among non-SRO residents. Rates were not calculated for the other residential categories (individuals with an out-of-city address and those with no known address) because there were no population denominators available for these populations.

We assessed differences in overdose mortality trends between SRO residents and non-SRO residents for each substance using negative binomial regression models with robust standard errors. Specifically, we constructed a dataset that included the number of substance-specific overdose deaths and population denominators for each year and residential category that were used to calculate annual rates above (SRO residents and non-SRO residents of San Francisco only). For each substance separately, we regressed the annual number of deaths on an indicator variable for SRO resident deaths, continuous year, an interaction term between the two, and a population offset. The coefficients on the interaction terms represent the ratio of the linear trend in mortality rates between SRO residents and non-SRO residents for each substance. To capture the most recent single linear trend for each substance, we restricted this analysis to 2013–2017 for opioid and cocaine deaths but used the entire 2010–2017 study period for methamphetamine deaths.

We also described demographic and clinical characteristics, substances involved, and death location characteristics by the four categories of residential status (San Francisco SRO residents, San Francisco non-SRO residents, individuals with an out-of-city address, and those with no known address) and assessed differences using analysis of variance and chi-squared tests, or fisher's exact test when cell sizes were $< 5$.

### 2.4. Sensitivity analysis

We conducted sensitivity analyses to address uncertainty in our use of the annual number of SRO units as an estimate for the total number of adult SRO residents per year. Specifically, we calculated overdose rates and rate ratios using alternative estimates for the number of adult SRO residents in San Francisco. First, as a plausible lower bound, we estimated the number of adult SRO residents as 77% of the total number of SRO units each year. The parameter of 77% was derived from occupancy data (as of October 15, 2017) reported by for-profit SROs to the San Francisco Department of Building Inspections. Data for non-profit buildings or other years were not available. This likely underestimates the true number as it assumes that units vacant on a single day were vacant the entire year and does not account for the possibility of multiple adults living in single units. Second, as a plausible upper bound, we estimated the number of adult SRO residents as 599 more than the total number of SRO units each year. The parameter of 599 was derived from a 2015 report by a local community-based organization that estimated there were 599 families living in SROs in San Francisco (SRO Families United Collaborative, 2015). This likely overestimates the true number as it assumes 100% occupancy and that all families have two adult members. We note that these alternative estimates rely on strong assumptions and should be considered as rough approximations; however, they represent plausible bounds for the true number of adult SRO residents in San Francisco.

To address the limitation that there are SRO buildings in San Francisco that are not regulated under the HCO, we conducted an additional sensitivity analysis in which we expanded our database of SRO buildings to include an additional 44 SRO buildings identified from multiple sources. All analyses described above and conducted using only the HCO SRO buildings were also conducted using this expanded list of 556 SRO buildings. Detailed methods are included in the appendix.

## 3. Results

The mean annual overdose mortality rate in San Francisco, CA from 2010 to 2017 was 21.3 per 100,000 adult residents (95% confidence interval (CI) = 20.2–22.5) for opioids, cocaine, and methamphetamine combined (Table 1). For all substances combined and each individual substance, the unadjusted overdose mortality rate was higher among SRO residents compared to non-SRO residents (Rate ratio (RR) = 19.3, 95% confidence interval = 17.1–21.7 for opioids, cocaine, and methamphetamine combined; RR = 17.2, 95%CI = 14.7–20.1 for opioids; RR = 24.5, 95%CI = 20.5–29.3 for cocaine; RR = 22.7, 95%CI = 18.4–27.9 for methamphetamine).

Overall and substance-specific mortality rates for each year during the study period among all residents, SRO residents, and non-SRO residents are presented in a supplementary table in the appendix. Among the three substances, opioid and cocaine overdose mortality trends were significantly different between SRO residents and non-SRO residents (Incidence rate ratio comparing the linear trend in annual mortality rates among SRO residents relative to that of non-SRO residents for opioids = 0.82; 95%CI = 0.71–0.94; and for

**Table 2**
Difference in linear trends of mortality rates by single room occupancy (SRO) residential status in San Francisco, 2010–2017*.

| | Linear Trend Among SRO Residents | | Linear Trend Among Non-SRO Residents | | Multiplicative Interaction Term† | |
|---|---|---|---|---|---|---|
| | IRR | (95% CI) | IRR | (95% CI) | IRR | (95% CI) |
| Opioid-Related Overdose Deaths‡ | 0.77 | (0.74–0.82) | 0.95 | (0.90–1.00) | 0.82 | (0.76–0.88) |
| Cocaine-Related Overdose Deaths‡ | 0.84 | (0.81–0.87) | 0.95 | (0.88–1.02) | 0.88 | (0.82–0.96) |
| Methamphetamine-Related Overdose Deaths‡ | 1.18 | (1.13–1.23) | 1.12 | (1.06–1.19) | 1.05 | (0.98–1.13) |

* Differences assessed using negative binomial regression models regressing annual substance-specific counts of overdose deaths by an indicator variable for SRO resident counts, continuous year, an interaction between the two, a population offset, and robust standard errors.

† Incidence rate ratio of the interaction term between an SRO indicator and continuous year, representing the ratio of linear trend in mortality rates between SRO residents and non-SRO resident.

‡ Opioid and cocaine models only include 2013–2017 (n = 10); methamphetamine model includes 2010–2017 (n = 16).

**Table 3**
Characteristics of overdose deaths and decedents by residential status of decedents in San Francisco (SF), 2010–2017 (n = 1551).

| | All Decedents | | SRO SF Residents | | Non-SRO SF Residents | | Decedents with Out-of-City Address | | Decedents with No Known Address | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | (%) | n | (%) | n | (%) | n | (%) | n | (%) |
| Total | 1551 | | 424 | | 827 | | 209 | | 91 | |
| Year* | | | | | | | | | | |
| 2010 | 175 | (11.3) | 49 | (11.6) | 91 | (11.0) | 30 | (14.4) | < 10 | (§) |
| 2011 | 179 | (11.5) | 57 | (13.4) | 91 | (11.0) | 21 | (10.0) | 10 | (11.0) |
| 2012 | 184 | (11.9) | 56 | (13.2) | 98 | (11.9) | 20 | (9.6) | 10 | (11.0) |
| 2013 | 215 | (13.9) | 64 | (15.1) | 120 | (14.5) | 27 | (12.9) | < 10 | (§) |
| 2014 | 213 | (13.7) | 62 | (14.6) | 118 | (14.3) | 24 | (11.5) | < 10 | (§) |
| 2015 | 191 | (12.3) | 44 | (10.4) | 110 | (13.3) | 26 | (12.4) | 11 | (12.1) |
| 2016 | 193 | (12.4) | 46 | (10.8) | 96 | (11.6) | 26 | (12.4) | 25 | (27.5) |
| 2017 | 201 | (13.0) | 46 | (10.8) | 103 | (12.5) | 35 | (16.7) | 17 | (18.7) |
| Demographic Characteristics | | | | | | | | | | |
| Age*, *mean (SD)* | 49.4 | (12.9) | 53.5 | (10.1) | 49.7 | (13.1) | 40.9 | (13.0) | 47.6 | (12.7) |
| Race/Ethnicity* | | | | | | | | | | |
| White | 848 | (54.7) | 235 | (55.4) | 432 | (52.2) | 130 | (62.2) | 51 | (56.0) |
| Black/African-American | 403 | (26.0) | 126 | (29.7) | 222 | (26.8) | 39 | (18.7) | 16 | (17.6) |
| Hispanic/Latinx | 168 | (10.8) | 31 | (7.3) | 91 | (11.0) | 27 | (12.9) | 19 | (20.9) |
| Asian/Pacific Islander | 72 | (4.6) | 13 | (3.1) | 52 | (6.3) | < 10 | (§) | < 10 | (§) |
| Other/Mixed | 53 | (3.4) | 17 | (4.0) | 25 | (3.0) | < 10 | (§) | < 10 | (§) |
| Gender | | | | | | | | | | |
| Female | 397 | (25.6) | 95 | (22.4) | 225 | (27.2) | 57 | (27.3) | 20 | (22.0) |
| Male | 1154 | (74.4) | 329 | (77.6) | 602 | (72.8) | 152 | (72.7) | 71 | (78.0) |
| Substances Involved in Death | | | | | | | | | | |
| Any opioid | 949 | (61.2) | 240 | (56.6) | 523 | (63.2) | 134 | (64.1) | 52 | (57.1) |
| Heroin* | 222 | (14.3) | 46 | (10.8) | 106 | (12.8) | 51 | (24.4) | 19 | (20.9) |
| Fentanyl* | 97 | (6.3) | 15 | (3.5) | 53 | (6.4) | 19 | (9.1) | 10 | (11.0) |
| Morphine | 228 | (14.7) | 63 | (14.9) | 128 | (15.5) | 26 | (12.4) | 11 | (12.1) |
| Oxycodone* | 151 | (9.7) | 31 | (7.3) | 98 | (11.9) | 19 | (9.1) | < 10 | (§) |
| Methadone* | 323 | (20.8) | 114 | (26.9) | 163 | (19.7) | 30 | (14.4) | 16 | (17.6) |
| Cocaine* | 641 | (41.3) | 205 | (48.3) | 314 | (38.0) | 76 | (36.4) | 46 | (50.5) |
| Methamphetamine* | 505 | (32.6) | 148 | (34.9) | 245 | (29.6) | 72 | (34.4) | 40 | (44.0) |
| Multiple substances*,** | 488 | (31.5) | 145 | (34.2) | 237 | (28.7) | 66 | (31.6) | 40 | (44.0) |
| Clinical Characteristics | | | | | | | | | | |
| On methadone maintenance at time of death*,† | 120 | (7.7) | 55 | (13.0) | 56 | (6.8) | < 10 | (§) | < 10 | (§) |
| Death Location Characteristics | | | | | | | | | | |
| Died at home*,‡ | 893 | (57.6) | 363 | (85.6) | 530 | (64.1) | 0 | (0.0) | 0 | (0.0) |
| Died in an SRO building* | 446 | (28.8) | 367 | (86.6) | 29 | (3.5) | 36 | (17.2) | 14 | (15.4) |
| Died outside San Francisco*,‡ | 31 | (2.0) | < 10 | (§) | 30 | (3.6) | 0 | (0.0) | 0 | (0.0) |
| Died in public space* | 189 | (12.2) | 20 | (4.7) | 73 | (8.8) | 47 | (22.5) | 49 | (53.8) |
| Died outdoors* | 112 | (7.2) | < 10 | (§) | 46 | (5.6) | 19 | (9.1) | 43 | (47.3) |

* $p < 0.05$ by analysis of variance and chi-squared test, or fisher's exact test when cell sizes were < 5.

** Multiple substances defined as involvement of more than one of the following: any opioid, cocaine, methamphetamine.

† Defined as receiving a publicly funded methadone maintenance dose within seven days prior to death.

‡ Statistical tests conducted only among SRO SF Residents and Non-SRO SF Residents due to zero counts for decedents with an out-of-city address and those with no known address.

§ Count and percentage suppressed for cells with fewer than 10 decedents.

cocaine = 0.88; 95%CI = 0.82–0.96) (Table 2).

Table 3 presents decedent and death characteristics by residential status. Of the 1,551 overdose decedents in San Francisco during the study period, 424 (27.3%) were SRO residents. Compared to deaths among other residential categories, deaths among SRO residents were less likely to involve heroin but more likely to involve methadone and cocaine, and more likely to have occurred at the decedent's home. Deaths among SRO residents and those with no known address were both more likely to involve multiple substance compared to deaths among other residential categories. Deaths among individuals with no known address were more likely to involve heroin than deaths among SF residents and more likely to involve methamphetamine and to have occurred in a public space or outdoors than deaths among all other residential categories. Deaths among individuals with an out-of-city address as well as those with no known address were more likely to die in SRO buildings compared to non-SRO residents of San Francisco.

The results of our sensitivity analysis using different estimates for the annual number of adult SRO residents in San Francisco are presented in the appendix. When using 77% of the number of SRO units as the estimate for the number of adult SRO residents (lower bound), the rate ratio comparing all-substance overdose mortality among SRO residents to non-residents was 25.2 (95%CI = 22.3–28.3) (Supplemental Table 2). When using the total number of SRO units plus 599 as the estimate for the number of adult SRO residents (upper bound), the rate ratio comparing all-substance overdose mortality among SRO residents to non-residents was 18.6 (95%CI = 16.4–20.8) (Supplemental Table 3).

The results of our sensitivity analysis using the expanded database of 556 SRO buildings were largely consistent with those of our primary analysis and are presented in the appendix. However, using the expanded database of buildings resulted in larger mortality rate ratios comparing overdose mortality among SRO residents to non-SRO residents.

## 4. Discussion

This is the first study to assess the population burden of drug overdose mortality among SRO residents in any geography and to compare it to that among the general population, and we found that overdose mortality rates among SRO residents were considerably higher than among the general population; indeed, despite making up only approximately 3% of the adult population in San Francisco, SRO residents accounted for more than one-quarter of overdose decedents during the study period. In addition, deaths of SRO residents were more likely to occur at home compared to those of non-SRO residents, and a nontrivial number of non-SRO residents died in SRO buildings. These findings are consistent with previous studies that have documented high rates of substance use and elevated all-cause mortality among SRO residents in San Francisco and other cities (Barbic et al., 2018; Knight et al., 2014; Shannon et al., 2006; Vila-Rodriguez et al., 2013). They also provide a clear picture of the magnitude of the overdose-related mortality burden among SRO residents in San Francisco and identify important characteristics of these deaths, which can draw attention to this critical issue and inform the development of interventions. Another important finding of this study is that, while overdose deaths were high in SROs, both opioid- and cocaine-related overdose mortality decreased more over time in SROs compared to deaths outside of SROs.

There have been similar efforts to understand the burden of overdose-related mortality among other vulnerable populations, such as individuals experiencing homelessness (Baggett et al., 2013; Gambatese et al., 2013a; Riley et al., 2013) and military veterans (Bohnert et al., 2011, 2014; Larney et al., 2015), which have motivated calls for public health and clinical care initiatives tailored to these groups. The high overdose mortality rates found in this study, in combination with previous findings of extensive physical and mental multimorbidity and economic hardship among SRO residents (Barbic et al., 2018; Bowen et al., 2016; Shannon et al., 2006; Vila-Rodriguez et al., 2013), underscore the elevated risk and vulnerability of this population and thus the need for SRO-specific services and interventions that aim to mitigate substance use related harms within SRO buildings. Although published literature regarding SRO-specific overdose interventions is limited, a recent study explored opportunities and challenges from a tenant-led naloxone training and distribution intervention in SRO buildings in Vancouver, Canada and found that the program had high acceptability among tenants and was able to engage isolated tenants but also that it was constrained by a lack of emotional support for tenant organizers, a lack of support among building management, and lack of dedicated physical space for program supplies (Bardwell et al., 2018). It is critical that similarly tailored interventions be implemented and evaluated in order to identify workable solutions to the high rates of overdose mortality among SRO residents.

Deaths among SRO residents were significantly more likely to occur at the decedent's residence compared to non-SRO residents. A study of opioid-related mortality in San Francisco from 1997 to 2000 noted this link between living in an SRO and risk of death (Davidson et al., 2003), which led to a shift in the focus of overdose prevention efforts in San Francisco. Notwithstanding a recent reduction in mortality among SRO residents, the persistence of this disparity suggests a need for innovative approaches such as targeted buprenorphine treatment outreach for SRO residents, as has been implemented for individuals experiencing homelessness in San Francisco (San Francisco Office of the Mayor, 2018), or wearable technologies (Volkow and Collins, 2017).

The study period overlapped with a national opioid crisis in which rates of opioid overdose death were increasing drastically across the country, so it is notable both that opioid overdose mortality rates declined among all San Francisco residents and that SRO residents experienced greater declines compared to non-SRO residents. This latter finding could suggest some benefit from interventions targeting SRO residents. The Drug Overdose Prevention and Education (DOPE) Project has distributed naloxone to staff and residents of participating SRO buildings since 2003, which may have contributed to reductions in opioid-related overdose mortality (Enteen et al., 2010; Rowe et al., 2015). However, naloxone distribution efforts targeting SROs in San Francisco have consistently been challenged by variable levels of support by SRO management within and across buildings (Wheeler, 2018), which mirrors the programmatic barriers reported in Vancouver (Bardwell et al., 2018). In addition, nursing staff of the San Francisco Department of Public Health who provide nursing case management within SROs began actively furnishing naloxone to SRO residents in 2013 (Eagen, 2018), around the same time that safety net clinics in San Francisco began offering naloxone as well (Coffin et al., 2016). Regardless of this downward trend or its causes, stark disparities remain.

A study among female SRO residents in San Francisco found that both the physical environment and conduct of management of SROs can have critical influence on the mental health of residents (Knight et al., 2014). This influence, along with the management-related barriers encountered by SRO-targeted overdose prevention efforts (Bardwell et al., 2018; Wheeler, 2018), highlights the essential role of SRO management in facilitating the health of their residents. A recent health impact assessment conducted by the San Francisco Department of Public Health found that SRO management generally lacked knowledge, practices, and resources to effectively work with residents to support their physical and mental health and recommended trainings and educational materials to support SRO management in this and other regards (San Francisco Department of Public Health, 2016). Given the substantial burden of overdose-related mortality affecting SRO residents, it is important that efforts to train or educate SRO management address issues related to mental health and substance use among residents, which could facilitate opportunities for related interventions within SROs.

Our category of residents with no valid address may capture decedents who were homeless at the time of their death, which is consistent

with our finding that deaths among this group were more likely to occur outdoors or in public. However, housing status is not captured as part of death certificates, which makes estimating mortality rates among this particularly vulnerable group difficult, requiring focused surveillance efforts. A recent national increase in homelessness (United States Department of Housing and Urban Development (United States Department of Housing and Urban Development (HUD, 2017) and the elevated risk of overdose mortality among this group (Baggett et al., 2013; Gambatese et al., 2013a; Riley et al., 2013) highlight the need for these focused surveillance efforts to identify changes in mortality risk or assess the effectiveness of targeted interventions.

There are several limitations to our study. First, there is no official definition of an SRO building. We focused our primary analysis on SRO buildings regulated under a particular city ordinance in San Francisco in order to leverage an objective definition; however, this limited definition excludes some SRO buildings and may limit the generalizability of our results to cities that do not have such an ordinance. In order to address these limitations, we included a sensitivity analysis that included additional SRO buildings not regulated under the ordinance. In addition, there is no official estimate of the number of SRO residents in San Francisco, which precludes exact estimates of mortality rates in this population. However, we sought to address the uncertainty around the number of SRO residents in San Francisco by using alternative SRO population estimates in sensitivity analyses; Regardless of which estimate is used, the mortality rates among SRO residents far exceed those among non-SRO residents. We also only had access to lists of HCO-regulated SRO buildings as of 2015, so if pre-2015 decedents lived in SRO buildings that closed prior to that year, they would have been misclassified as non-SRO residents; however, the number of HCO-regulated SRO units actually increased from 2010 to 2015, suggesting that there were likely not substantial SRO closures during that time. In addition, we did not have any information regarding the demographic distribution of SRO residents in San Francisco, thus we could not calculate standardized mortality rates for comparison with those of non-SRO residents. Anecdotal evidence as well as samples of SRO residents from other cities suggest that SRO residents tend to be older than the general population (Bowen et al., 2016; Vila-Rodriguez et al., 2013), and San Francisco overdose decedents tend to be older than the general population as well (Turner et al., 2018; Visconti et al., 2015); thus, it is likely that some of the disparity in mortality is driven by the incompatible age structures between SRO and non-SRO residents. Another limitation is that the economic, housing, and substance use landscapes in San Francisco may not be comparable to those of other North American cities, and thus our findings may not be generalizable to other cities. However, given the wide geographic range of the overdose crisis (Seth et al., 2018) and the similar economic, physical, and mental health problems that affect SRO residents across cities (Barbic et al., 2018; Bowen et al., 2016; Knight et al., 2014; Shannon et al., 2006; Vila-Rodriguez et al., 2013), it is plausible that the disparities identified in San Francisco also affect SRO residents elsewhere.

Although the present study does not explore the specific factors or mechanisms that influence overdose risk among SRO residents, it is clear that SRO buildings are spaces of concentrated disadvantage, with residents disproportionately affected by physical, psychosocial, and economic adversity. Rhodes' "risk environment" framework for understanding drug-related harm offers a suitable lens through which to examine the health of SRO residents (Rhodes, 2002, 2009), and has been applied to multiple studies of SRO residents (Bardwell et al., 2018; Knight et al., 2014). This framework focuses on the interaction of overlapping environments—physical, social, economic, policy—across multiple levels of influence to produce drug-related harms. Prior qualitative research using this framework suggests that the physical organization of SROs (e.g., crowding people with addiction and mental health issues into a single space) in combination with chaos related to drug/sex economy interactions (drug dealers, runners, pimps and sex workers), and rapid cycling of new tenants all contribute to drug-related risks (Knight et al., 2014). Regardless of the exact mechanisms, it is clear that SRO residents in San Francisco, and likely elsewhere, are at disproportionately higher risk of drug overdose mortality compared to other urban residents. These disparities and the fact that SRO residents were more likely to overdose at home highlight the urgent need to develop interventions tailored to SRO communities to reduce overdose-related mortality among this vulnerable population.

## Role of funding source

This study was supported by funding from the National Institutes of Health (Grant #K24DA042720); funder had no involvement in the design, implementation, or interpretation of study results or the decision to submit for publication.

## Contributors

C.L. Rowe conceived the study, conducted the analysis, and led the writing of the manuscript. E.D. Riley contributed to study design, analysis methods, and the writing of the manuscript. K. Eagen contributed to data collection, study design and the writing of the manuscript. B. Zevin contributed to study design and writing of the manuscript. P.O. Coffin contributed to study design and the writing of the manuscript. All authors have read and approved the final manuscript.

## Disclaimer statement

The authors are solely responsible for the content of this article, which does not necessarily represent the official views of the San Francisco Department or Public Health.

## Declaration of Competing Interest

No conflict declared.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.drugalcdep.2019.107571.

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