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Research Paper

Characteristics of post-overdose outreach programs and municipal-level opioid overdose in Massachusetts

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ABSTRACT

Background: Post-overdose outreach programs have proliferated in response to opioid overdose. Implementing these programs is associated with reductions in overdose rates, but the role of specific program characteristics in overdose trends has not been evaluated.

Methods: Among 58 Massachusetts municipalities with post-overdose outreach programs, we examined associations between five domains of post-overdose outreach program characteristics (outreach contact rate, naloxone distribution, coercive practices, harm reduction activities, and social service provision or referral) and rates of fatal opioid overdoses and opioid-related emergency medical system responses (i.e., ambulance activations) per calendar quarter from 2013 to 2019 using segmented regression analyses with adjustment for municipal covariates and fixed effects. For both outcomes, each domain was modeled: a) individually, b) with other characteristics, and c) with other characteristics and municipal-level fixed effects.

Results: There were no significant associations ($p < 0.05$) between outreach contact rate, naloxone distribution, coercive practices, or harm reduction activities with municipal fatal overdose trends. Municipalities with programs providing or referring to more social services experienced 21% fewer fatal overdoses compared to programs providing or referring to more social services (Rate Ratio (RR) 0.79, 95% Confidence Interval (CI) 0.66–0.93, $p = 0.01$). Compared to municipalities in quarters when programs had no outreach contacts, municipalities with some, but less than the median outreach contacts, experienced 14% lower opioid-related emergency responses (RR 0.86, 95% CI 0.78–0.96, $p = 0.01$). Associations between naloxone distribution, coercive practices, harm reduction practices, or social services and opioid-related emergency responses were not consistently significant across modeling approaches.

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Conclusion: Municipalities with post-overdose outreach programs providing or referring to more social services had lower fatal opioid overdose rates. Municipalities in quarters when programs outreached to overdose survivors had fewer opioid-related emergency responses, but only among programs with below the median number of outreach contacts. Social service linkage should be core to post-overdose programs. Evaluations should assess program characteristics to optimize program design.

Introduction

There were more than 500,000 opioid-related overdose deaths in the United States between 1999 and 2019, with annual deaths surging above 81,000 in the 12-months before February 2022 (Ahmad et al., 2021; Hedegaard et al., 2020). Other countries including Canada and Scotland have also experienced high and rising opioid overdose rates (Penington Institute, 2022). Prior nonfatal opioid overdose is a significant risk factor for subsequent fatal overdose (Larochelle et al., 2018, 2019; Olfson et al., 2018; Stoové et al., 2009). In response, public health and medical interventions designed to reduce overdose deaths, including community naloxone distribution and expanded access to effective pharmacologic therapy for opioid use disorder, have been promoted by policy makers and public health experts (Larochelle et al., 2018; National Academies of Sciences Engineering & Medicine, 2019; Office of National Drug Control Strategy, 2022; Walley et al., 2013). In countries with especially high overdose rates such as the United States, Canada, and Scotland, post-overdose programs that perform outreach to overdose survivors and/or their social networks in homes, encampments, or public locations have emerged as a strategy to connect this high risk group with services to prevent subsequent overdose (Bagley et al., 2019; Canadian Broadcasting Corporation, 2022; Formica et al., 2018; Turning Point Scotland & Simon Community Scotland, 2022). Post-overdose outreach programs often include partnerships between public health professionals and public safety organizations (e.g., police, fire, emergency medical service [EMS]) who manage data with contact information from emergency service calls to locate and engage opioid overdose survivors 1–3 days after an overdose (Champagne-Langabeer et al., 2020; Formica et al., 2021; Grayken Center for Addiction, 2023; Yatsco et al., 2020). A quasi-experimental observational study from Massachusetts found that implementing post-overdose outreach programs was associated with a 6% annual decrease in municipal overdose fatality rate (Xuan et al., 2023).

Post-overdose outreach programs are generally organized by municipalities and vary considerably in team composition, funding, outreach contacts, as well as overdose prevention, addiction, medical, or social services delivered or referred during outreach (Formica et al., 2021). Services offered vary locally based on philosophy, infrastructure, partnerships, and capacity. As post-overdose outreach programs often combine public health and public safety professionals, there are differences in the degree to which they are guided by harm reduction or public safety and security principles (Champagne-Langabeer et al., 2020; Formica et al., 2018, 2021; Scott et al., 2020). Warrant-checking and involuntary civil commitment for substance use disorder are employed by some programs to coerce survivors into treatment (Tori et al., 2021). Harm reduction principles affirm the right and capacity of overdose survivors to make decisions about their health while simultaneously aiming to mitigate harms from substance use. Given the variation between post-overdose outreach programs, it is not known which program characteristics promote or hinder opioid-related outcomes (Bagley et al., 2019). Thus, the mechanisms for observed reduction in overdose mortality is unclear.

A rigorous exploration of program characteristics that could promote overdose prevention may shed light on this gap. Equipping overdose survivors with naloxone directly, having higher outreach contact rates, and engaging in more harm reduction activities like distributing syringes, may promote positive interactions and support receipt of life-saving supplies. On the other hand, programs with more coercive practices, such as warrant checking and facilitation of involuntary treatment, could decrease engagement, moderating the programs' impact on overdose rates. Programs that provide or refer to social services that improve access to employment, housing, food, and transportation, could signify a better safety net for people at risk for overdose. As a next step to understanding the mechanisms by which post-overdose outreach program implementation was associated with municipal-level overdose in Massachusetts, we evaluated the associations of post-overdose outreach program characteristics (naloxone distribution at outreach, number of outreach contacts per population, engagement practices, harm reduction activities, and social service provision and referral) with two overdose-related outcomes – municipal fatal opioid overdose rate and opioid-related emergency medical system responses for fatal and non-fatal overdose. We hypothesized that programs which engaged in more proactive outreach, provided naloxone, had less coercive practices, engaged in greater harm reduction activities, and provided or referred to more social services would be associated with reductions in fatal overdoses. For opioid-related emergency responses, we considered our analyses exploratory because the findings could be attributed to changes in number of overdoses or in help-seeking behavior.

Methods

Study design and setting

This study is part of a larger multi-aim evaluation of post-overdose outreach programs in Massachusetts funded by Centers for Disease Control and Prevention. To examine program characteristics associated with fatal overdose and opioid-related EMS responses (fatal and non-fatal), we used a segmented regression design which accounts for baseline trends and implementation of a post-overdose outreach program between calendar Quarter 1, 2013 and Quarter 2, 2019, and included program characteristics as exposure terms during the post-implementation period (Wagner et al., 2002). Using clinical and theoretical background from the literature, we selected five program characteristics and examined their associations with the two overdose outcomes (Bagley et al., 2019; Formica et al., 2018, 2021). Two program characteristics were selected *a priori* (outreach contact rate and naloxone distribution during outreach) and three additional sets of characteristics (coercive practices, harm reduction activities, and social service provision or referral) were selected for exploration after review of post-overdose outreach program surveys which have been previously described (Formica et al., 2021). Our models included time trends, municipal-level covariates, and municipal-level fixed effects to adjust for confounding.

Participants and selection

Between February and November 2019, a two-phase cross-sectional survey was conducted with all 351 municipalities in Massachusetts (Formica et al., 2021). An initial screener was sent to all public safety agencies, emergency response chiefs, and state-funded Overdose Education and Naloxone Distribution (OEND) programs in Massachusetts, and a second detailed survey was sent to organizations reporting the existence of a post-overdose outreach program in their municipality ($n = 157$). There was a 100% response rate to the initial screener and an 88% response rate to the detailed post-overdose outreach program

survey which we used to develop our independent variables *for the five key domains of program characteristics*. Survey development, sampling, and results have been previously reported (Formica et al., 2021). Massachusetts communities with 30 or more opioid-related emergency medical system encounters (about 7.5 overdose encounters per quarter) in 2015, with post-overdose outreach programs, and which completed a survey describing program characteristics were included in the cohort. By selecting communities with a substantial overdose prevalence, we reduced the impact of random variation in overdose levels and better assessed the impact of outreach programs on overdose.

Outcome variables

Fatal opioid overdose rate

We calculated rates of fatal opioid overdose by municipality of residence using data on opioid-related drug poisonings from the Massachusetts Registry of Vital Records and Statistics maintained by the Massachusetts Department of Public Health (DPH). Massachusetts uses a single centralized statewide office of the chief medical examiner to ascertain cause of death reported on the death certificate. As in previous studies, we used International Classification of Diseases, 10th Revision (ICD-10) codes indicating unintentional or undetermined intentional poisoning (X40-X44, Y10-Y14) in the underlying cause of death field and an opioid or narcotic code, including fentanyl (T40.0-T40.4, T40.6), in the multiple cause of death field (Walley et al., 2013).

Opioid-related emergency medical system response rate

We used the Massachusetts Ambulance Trip Record Information System (MATRIS) to calculate the opioid-related emergency response rate per 100,000 residents. MATRIS is a statewide database with emergency response services data from licensed ambulance services in Massachusetts. Reporting to MATRIS was first required of licensed providers in 2013. The Massachusetts DPH generates municipal-level quarterly opioid-related emergency response data based on MATRIS classifications. These encounters include emergency responses (i.e., ambulance activations) for fatal and non-fatal overdose based on records indicating a poisoning, naloxone being administered, or patient self-reported drug use (Massachusetts Department of Public Health, 2021). These data do not include overdose events without municipal emergency responses.

Independent variables

Main exposure variables – a priori

Responses to surveys about outreach contact rate and naloxone distribution during outreach were selected *a priori* as program characteristics for examination because these two measures indicated higher intensity and higher dose of municipal post-overdose outreach, respectively. We defined outreach contact rate (initial outreach contacts per municipal population) as a three-category quarterly time-varying variable: “None” when there were no contacts in a quarter, and among the quarters when there were any contacts, we categorized municipalities as “high” or “low” based on the median number of initial outreach visits per municipal population. When the outreach contact rate was at the median, it was categorized with the higher group. All quarters for each community after program inception were included for analysis based on this three-level variable (“none” vs. “high” vs. “low”). Naloxone distribution was classified as a dichotomous variable (any naloxone yes/no) for all quarters after community program inception based on survey responses about providing naloxone during outreach visits.

Main exposure variables – exploratory

To further explore the relationship between program characteristics and overdose, we used survey responses to establish three characteristic domains to measure the degree to which programs: 1) used coercive practices, 2) delivered harm reduction services, and 3) provided or referred to social services. Each of these characteristics sets described key program features that varied among the post-overdose programs, which we hypothesized based on our research describing these programs could contribute mechanistically to the associations between post-overdose outreach programs and overdose outcomes. Each set was comprised of four equally weighted dichotomous items that were summed to create scores reflecting distinct domains of the program feature available from existing program data. After examination of the score distributions, we stratified each of these scales as high or low at the median. When program scores were at the median, they were classified in the higher group, creating two groups of similar size for the analyses. The items included in the coercive domain were: 1) arresting outreach contacts on outstanding warrants, 2) serving as the primary petitioner for involuntary civil commitment (court-mandated substance use treatment), 3) reported a program philosophy rooted in public safety, and 4) having a marked police car or outreach member in a police uniform during the initial visit. The items included in the harm reduction domain were: 1) providing safer drug use supplies, 2) offering HIV and Hepatitis C Virus testing during outreach or through referral, 3) having a harm reductionist present at the initial outreach visit, and 4) reporting a program philosophy rooted in harm reduction. Public safety and harm reduction philosophy were queried separately, and variables were defined as responding that the program was “focused” on that respective philosophy (1 or 2 on 1–5 scale) in response to questions about program philosophy. The iterms included in the social services domain were: providing or refering for: 1) employment, 2) housing, 3) food, and 4) transportation to addiction treatment or other health providers. Naloxone, coercive practices, harm reduction, and social service variables were defined at a single time point based on survey responses.

Post-overdose program implementation

To account for time trends in overdose, we used a segmented regression analysis that designated before and after implementation of the post-overdose outreach program in each municipality. Communities reported program inceptions in response to surveys. These inception times varied during the study period with two municipalities reporting programs by the 4th quarter of 2013 and all municipalities reporting programs by the 2nd quarter of 2019.

Covariates

We obtained data on municipal-level covariates to adjust for potential confounding by municipality. We used data from the American Community Survey 5-year estimates (2013–2018) to obtain estimates for the number of residents, age groups, gender, race/ethnicity, education (high-school or less), and residence vacancy rates. To describe and adjust for level of overdose prevention activities in each municipality, we included number of naloxone kits distributed to each municipality by the Massachusetts DPH OEND program. To describe and adjust for level of opioid use disorder treatment in each municipality, we obtained methadone treatment and residential treatment admission rates from the Massachusetts Bureau of Substance Addiction Services and rate of buprenorphine prescriptions from the Massachusetts Prescription Monitoring Program. These covariates have been used in previous studies of opioid use (Altekruse et al., 2020; Walley et al., 2013; Yamamoto et al., 2019).

To adjust for increased risk of overdose following incarceration, we obtained municipality release rates from the Massachusetts Department of Correction (Joudrey et al., 2019; Massachusetts Department of Public Health, 2016). To adjust for increased risk of overdose when fentanyl is present in the drug supply, we included proportion of overdose deaths attributed to fentanyl from the Massachusetts Registry of Vital Records and Statistics (Gladden et al., 2019). Given the involvement of public safety personnel in post-overdose outreach programs, we included dichotomous municipal-level indicators of whether public safety personnel carry naloxone and whether the municipality had a drug court or jail diversion program which may be associated with decreased risk of

Table 1
Characteristics of 58 Massachusetts municipalities with a post-overdose outreach program in 2019 and 30 or more opioid-related emergency responses in 2015.

	Municipalities (n = community quarters)		
	Post-program Intervention (n = 667) average	Post-program Intervention (n = 58) first quarter after implementation	Post-program Intervention (n = 58) 2019Q2
Age			
Under 25 per 1000 population	286.5 ± 44.1	295.0 ± 42.5	287.6 ± 42.3
25–44 per 1000 population	253.7 ± 54.9	256.1 ± 55.2	252.1 ± 54.8
45–54 per 1000 population	140.7 ± 20.9	146.1 ± 22.5	135.0 ± 21.6
55–64 per 1000 population	138.3 ± 24.1	135.2 ± 23.2	138.7 ± 22.8
65+ per 1000 population	180.8 ± 60.1	167.8 ± 49.0	186.7 ± 50.2
Male residents per 1000 population	482.8 ± 16.1	483.8 ± 16.6	484.0 ± 14.8
Race/Ethnicity			
White residents per 1000 population	822.7 ± 140.2	833.3 ± 132.9	825.0 ± 135.0
African American/Black residents per 1000 population	53.5 ± 69.7	52.9 ± 69.9	53.9 ± 69.0
American Indian residents per 1000 population	3 ± 7.1	2.1 ± 3.4	2.0 ± 4.8
Asian residents per 1000 population	50.3 ± 56.2	49.8 ± 54.6	52.0 ± 53.6
Pacific islander residents per 1000 population	0.3 ± 0.6	0.1 ± 0.4	0.4 ± 0.4
Hispanic residents per 1000 population	91.5 ± 113.9	87.9 ± 115.1	92.1 ± 114.3
High school education or less per 1000 population	367.2 ± 125.7	367.6 ± 124.8	356.3 ± 125.4
Vacancy units per 1000 population	73 ± 123.7	54.2 ± 100.7	52.5 ± 100.0
Naloxone kits distributed by OEND program per 1000 population	1.1 ± 0.9	0.8 ± 0.6	1.2 ± 1.2
Releases from incarceration per 100,000 population	15 ± 12	13.2 ± 11.1	11.1 ± 10.1
Drug arrests per 100,000 population	26.2 ± 27.7	23.3 ± 25.0	22.7 ± 33.8
BSAS methadone admissions per 1000 population[a]	0.3 ± 0.4	0.3 ± 0.3	0.03 ± 0.05
BSAS residential admissions per 1000 population	2.4 ± 1.4	2.3 ± 1.4	2.1 ± 1.4
Buprenorphine prescriptions per 1000 population	10.5 ± 4.4	9.3 ± 3.7	11.1 ± 4.9
Fentanyl associated death per 100 overdose deaths	71.8 ± 38.8	62.2 ± 41.8	78.6 ± 37.4
MOAPC program established[b]	416 (62%)	26 (44.8%)	36 (62.1%)
Public safety equipped with naloxone (Yes)	263 (39.4%)	20 (34.5%)	20 (34.5%)
Having a drug court or a jail diversion program (Yes)	344 (51.6%)	29 (50%)	29 (50%)
Fatal overdose per 100,000 population	8.4 ± 6.6	7.7 ± 5.6	7.4 ± 6.0
MATRIS opioid overdose responses - by municipality of residence	88.6 ± 55.9	76.0 ± 49.0	79.3 ± 50.8

[a] BSAS is the Bureau of Substance Addiction Services in the Massachusetts Department of Public Health.
[b] MOAPC is the Massachusetts Opioid Abuse Prevention Collaboration refers to a MA DPH supported coalition focused on reducing fatal and non-fatal opioid overdoses at the community level.

fatal overdose. All covariates are time varying except for public safety use of naloxone and municipality drug court or jail diversion programs which were each obtained once in 2019 from the Massachusetts DPH Bureau of Addiction Services and the Department of Mental Health, respectively.

Statistical analyses

We analyzed municipal-level fatal opioid overdose rates and opioid-related emergency response (fatal and non-fatal opioid overdose) rates on a quarterly basis and divided the study into pre-intervention and post-intervention periods for each municipality. As in prior studies of overdose and OEND programs and post-overdose outreach programs, we used Poisson regression models with over-dispersion adjustment to model rates with a log-linear statistical model accounting for municipal-level covariates (Kuhn et al., 1994; Walley et al., 2013; Xuan et al., 2023). We used segmented regression including terms for baseline trend as well as level and trend changes following the implementation of the program. Implementation time varied by for the municipality. To account for these different implementation times, we used multiple time series with a generalized estimation equations approach to account for the clustering of repeated measures and evaluate population-average changes in level and slope after implementation of each program.

We examined the correlation matrix on the independent variables and covariates. We found that naloxone distributed during outreach was correlated with coercion practices ($r = 0.64$) and with harm reduction activities ($r = 0.62$), and that harm reduction activities was correlated with social service ($r = 0.67$). Given these high correlations, we first performed individual analyses for each of the five exposure variables including all covariates as well as terms for baseline trend, level, and slope change (Models 1–5). We then included a full model with all five exposure variables simultaneously in addition to covariates and terms for trend, level, and slope change (Model 6). Lastly, as a final model (Model 7), to adjust for potential unmeasured municipal-level confounders, we added dummy indicators for municipal fixed effects to the modeling approach. This modeling approach facilitated comparisons across similar communities by controlling for unmeasured confounding but assumed differences did not vary over time. As a sensitivity analysis, we repeated analyses where outreach contact rate, coercive practices, harm reduction activities, and social services were modeled as continuous rather than categorical variables for both outcomes. Regression results estimated absolute effects with 95% confidence intervals for each outcome. All tests of significance were based on p-value of 0.05. Analyses were conducted using SAS version 9.4. The study was designated as not human subjects research by the Institutional Review Boards of the Boston University Medical Center and the Massachusetts Department of Public Health.

Table 2
Post-overdose program characteristics in Massachusetts, 2019[a] in communities with 30 or more opioid-related emergency responses in 2015.

	Sample survey respondents ($N = 58$)
Outreach contact rate categories (number of initial outreach visits per municipal population per quarter)[b]	
(median = 27.7 contacts per 100,000 population per quarter)	
None	16 (27.6%)
Low (less than the median)	18 (31.0%)
High (median or greater)	24 (41.4%)
Naloxone distributed during outreach (Yes)	44 (75.9%)
Coercion characteristics	
(median = 1 characteristic)	
Coercion, High (median or greater)	36 (62.1%)
Arrest people on warrants	5 (8.6%)
Primary petitioner for involuntary civil commitment	27 (46.6%)
Public Safety Philosophy[c]	3 (5.2%)
Police car present OR first responder shows up in police uniform	19 (32.8%)
Harm reduction characteristics	
(median = 2 characteristics)	
Harm reduction, High (median or greater)	30 (51.7%)
Safer drug use supplies	30 (51.7%)
HIV/HCV testing	14 (24.1%)
Harm reduction provider present at first outreach visit	22 (37.9%)
Harm reduction philosophy[d]	34 (58.6%)
Social service characteristics	
(median = 2 characteristics)	
Social services, High (median or greater)	31 (53.4%)
Employment	25 (43.1%)
Housing	29 (50.0%)
Food	27 (46.6%)
Transportation	51 (87.9%)

[a] Program characteristics used to establish exposure variables for subsequent analyses. Social coercion, harm reduction, and social services categories were classified as high or low with a split at the median. Those programs at the median were classified in the higher category.
[b] Data is from Quarter 2, 2019, the last quarter for which we have data. Outreach category data is time varying in analyses.
[c] Public safety philosophy defined as having a 1 or 2 on a scale of public safety philosophy (1–5) where 1 is "very focused" on public safety.
[d] Harm reduction philosophy defined as having a 1 or 2 on a harm reduction scale (1–5) where 1 is "very focused" on reducing harms.

Results

Municipality characteristics

A total of 58 municipalities met the criteria for inclusion in this analysis. Table 1 presents municipality characteristics after implementation of a post-overdose outreach program in these 58 Massachusetts communities. The full post-intervention sample represents 667 municipality-quarters. Compared to the first quarter after implementation, in Quarter 2, 2019, there were modest increases in naloxone distributed per 1000 population (1.2 ± SD 1.2 vs 0.8 ± SD 0.6) and buprenorphine prescriptions per 1000 population (11.1 ± SD 4.9 vs 9.3 ± SD 3.7), fentanyl was present more commonly per 100 overdose deaths (78.6 ± SD 37.4 vs 62.2 ± SD 41.8), while fatal overdoses per 100,000 population (7.4 ± SD 6.0 vs 7.7 ± SD 5.6) and municipal opioid emergency responses (79.3 ± SD 50.8 vs 76.0 ± SD 49.0) remained similar.

Program characteristics

The median outreach contact rate for post-overdose outreach programs was 27.7 contacts per 100,000 population per quarter. During Q2, 2019, the last quarter in our data, 41.4% of programs engaged in median outreach contact rate or greater (high), 31% had less than the median (low) and 27.6% had no outreach contacts (none). Naloxone was distributed during outreach by 75.9% of programs. The median number of coercion characteristics was one out of four; 62.1% of programs had one or more coercion characteristics (high). The most common coercion characteristic was being the primary petitioner for involuntary civil commitment for substance use treatment (46.6%). The median number of harm reduction characteristics was two out of four; 51.7% of programs had two or more harm reduction characteristics (high). The most common harm reduction characteristic was reporting a harm reduction philosophy (58.6%). The median number of social services provided or referred was two; 53.4% of programs provided or referred to two or more social services (high). The most common social services referred to or provided was transportation to addiction treatment or other health providers (87.9%) (Table 2).

Adjusted model results: post-overdose outreach program characteristics and fatal opioid overdose rates

In models adjusting for municipal covariates and time trends including changes associated with the implementation of a post-overdose outreach program, there was no significant association between outreach contact rate, naloxone provision, coercive practices, or harm reduction activities and fatal opioid overdose rates in the individual (Models 1–4) or fully adjusted models (Model 6–7). Compared to municipalities with post-overdose outreach programs with below the median number of social services referred to or provided, programs in municipalities with more social services had 17% lower fatal overdose rates when evaluated individually (Model 5: Rate Ratio (RR) 0.83, 95% CI 0.72, 0.96, $p = 0.01$), 19% lower in the model including all program characteristics (Model 6: RR 0.81, 95%CI 0.70, 0.94, $p = 0.01$) and 21% lower in the full model which also included municipal fixed effects (Model 7: RR 0.79, 95%CI 0.66, 0.93, $p = 0.01$) (Table 3). Model results with all covariates are available in Supplemental Tables 1–7. Sensitivity analyses where independent variables (other than naloxone provision) were modeled continuously produced substantially similar findings (Supplemental Table 15).

Adjusted model results: post-overdose outreach program characteristics and opioid-related emergency response rates

In models adjusting for municipal covariates and time trends, including changes associated with the implementation of a post-overdose outreach program, an outreach contact rate below the median (low) was associated with 16% fewer opioid-related emergency

Table 3
Model results for post-overdose outreach program characteristics and municipal-level fatal overdose in Massachusetts (1st quarter of 2013 to 2nd quarter of 2019)[a].

		Model 1: Outreach Intensity				Model 2: Naloxone				Model 3: Coercion				Model 4: Harm reduction				Model 5: Social services				Model 6: Selected PROGRAM CHARACTEristics				Model 7: Selected program characteristics with municipal fixed effects			
		RR[b]	LCI[c]	UCI[d]	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P
Outreach	None	Ref	Ref	Ref																		Ref	Ref	Ref		Ref	Ref	Ref	
Outreach	Low	0.92	0.78	1.09	0.35																	0.91	0.77	1.07	0.27	0.94	0.78	1.12	0.48
Outreach	High	0.97	0.85	1.10	0.60																	0.98	0.87	1.12	0.81	0.95	0.82	1.10	0.52
Naloxone	Yes					0.99	0.80	1.22	0.90													1.11	0.88	1.39	0.38	1.06	0.79	1.42	0.72
Coercive Practices	High									1.05	0.91	1.21	0.50									1.02	0.88	1.18	0.79	1.10	0.92	1.32	0.31
Harm Reduction Activities	High													0.90	0.78	1.03	0.13					0.95	0.81	1.13	0.57	1.12	0.91	1.38	0.28
Social Services																		0.83	0.72	0.96	0.01	0.81	0.70	0.94	0.01	0.79	0.66	0.93	0.01
Level Change		1.11	0.97	1.28	0.13	1.11	0.89	1.39	0.37	1.06	0.90	1.26	0.49	1.17	0.99	1.38	0.06	1.24	1.04	1.47	0.01	1.19	0.92	1.54	0.18	1.03	0.79	1.34	0.84
Slope change		0.98	0.97	1.00	0.02	0.98	0.97	1.00	0.02	0.98	0.97	1.00	0.02	0.98	0.97	1.00	0.01	0.98	0.97	1.00	0.01	0.98	0.97	1.00	0.02	0.97	0.96	0.99	0.00
Baseline trend		0.99	0.98	1.01	0.25	0.99	0.98	1.01	0.24	0.99	0.98	1.01	0.24	0.99	0.98	1.01	0.28	0.99	0.98	1.01	0.26	0.99	0.98	1.01	0.30	0.99	0.97	1.01	0.43

[a] All models are adjusted for municipal level distributions of age, sex, race/ethnicity, rates of high school education or less, vacancy, naloxone kit distribution by opioid overdose education and naloxone program, releases from incarceration, drug arrests, Bureau of Substance Addiction Services methadone admissions and residential treatment admissions, buprenorphine prescriptions, fentanyl associated deaths among all overdose deaths, presence of a Massachusetts Opioid Abuse Prevention Collaboration, public safety equipped with naloxone, and presence of a drug court diversion program.
[b] RR, rate ratio.
[c] LCI, lower 95% confidence interval.
[d] UCI, upper 95% confidence interval.

Table 4
Model results for selected post-overdose outreach program characteristics and municipal-level opioid-related emergency response in Massachusetts (fatal and non-fatal overdose, 1st quarter of 2013 to 2nd quarter of 2019)[a].

		Model 1: outreach intensity				Model 2: naloxone				Model 3: coercion				Model 4: harm reduction				Model 5: social services				Model 6: selected program characteristics				Model 7: selected program characteristics with municipal fixed effects			
		RR[b]	LCI[c]	UCI[d]	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P	RR	LCI	UCI	P
Outreach	None	Ref	Ref	Ref																		Ref	Ref	Ref		Ref	Ref	Ref	
Outreach	Low	0.84	0.77	0.92	0.00																	0.84	0.77	0.91	0.00	0.86	0.78	0.96	0.01
Outreach	High	0.94	0.85	1.04	0.21																	0.94	0.86	1.04	0.24	0.97	0.86	1.08	0.54
Naloxone	Yes					1.08	0.90	1.29	0.42													1.31	1.10	1.57	0.00	1.27	0.96	1.68	0.09
Coercive Practices	High									0.96	0.84	1.10	0.58									0.88	0.78	1.00	0.05	0.87	0.72	1.04	0.11
Harm Reduction Activities	High													0.92	0.79	1.05	0.22					0.79	0.70	0.90	0.00	0.84	0.70	1.02	0.07
Social Services																		0.97	0.86	1.10	0.65	0.96	0.87	1.06	0.39	0.95	0.84	1.07	0.42
Level Change		1.15	1.06	1.24	0.00	1.04	0.88	1.24	0.62	1.14	1.00	1.30	0.06	1.18	1.03	1.35	0.02	1.13	1.01	1.27	0.03	1.19	0.96	1.46	0.11	1.15	0.88	1.50	0.31
Slope change		0.98	0.97	0.99	0.00	0.98	0.97	0.99	0.00	0.98	0.97	0.99	0.00	0.98	0.97	0.99	0.00	0.98	0.97	0.99	0.00	0.98	0.97	0.99	0.00	0.98	0.96	0.99	0.01
Baseline trend		1.02	1.02	1.03	0.00	1.02	1.01	1.03	0.00	1.02	1.01	1.03	0.00	1.02	1.01	1.03	0.00	1.02	1.01	1.03	0.00	1.03	1.02	1.03	0.00	1.03	1.02	1.04	0.00

[a] All models are adjusted for municipal level distributions of age, sex, race/ethnicity, rates of high school education or less, vacancy, naloxone kit distribution by opioid overdose education and naloxone program, releases from incarceration, drug arrests, Bureau of Substance Addiction Services methadone admissions and residential treatment admissions, buprenorphine prescriptions, fentanyl associated deaths among all overdose deaths, presence of a Massachusetts Opioid Abuse Prevention Collaboration, public safety equipped with naloxone, and presence of a drug court diversion program.
[b] RR, rate ratio.
[c] LCI, lower 95% confidence interval.
[d] UCI, upper 95% confidence interval.

responses compared to municipal quarters with no contacts when evaluated individually (Model 1) (RR 0.84, 95% CI 0.77, 0.92), $p < 0.01$), 16% in the model including all program characteristics (Model 6) (RR 0.84, 95%CI 0.77–0.91, $p < 0.01$), and 14% lower in the full model accounting for municipal fixed effects (RR 0.86, 95%CI 0.78–0.96, $p = 0.01$) (Table 4). A greater than median contact rate was not significantly associated with changes in emergency responses in any of the modeling strategies. When evaluated individually, naloxone provision during outreach (Model 2) was not associated with a change in opioid-related emergency responses (RR 1.08, 95%CI 0.90–1.29), $p = 0.42$). Naloxone provision during outreach was associated with 31% increased opioid-related emergency responses in Model 6 with all program characteristics included (RR 1.31, 95%CI 1.10–1.57, $p < 0.01$), but was not significant in the Model 7 which included municipal fixed effects (RR 1.27, 95%CI 0.96–1.68, $p = 0.09$). High coercive practices (median or greater; one or more characteristics) was not significantly associated with opioid-related emergency responses in any of the models. High harm reduction activities (median or greater; two or more characteristics) resulted in a consistent negative effect estimate on opioid-related emergency responses but was significant only in Model 6 that included all programs characteristics (Model 4, individually: RR 0.92, 95%CI 0.79–1.05, $p = 0.22$; Model 6, with all program characteristics: RR 0.96, 95%CI 0.87–1.06, $p < 0.01$; Model 7 with municipal fixed effects: RR 0.84, 95%CI 0.70–1.02, $p = 0.07$). Providing or referring to more social services (median or greater; two or more characteristics) was not significantly associated with opioid-related emergency responses in any of the models. Model results with all covariates are available in the Supplemental Tables 8–14. Sensitivity analyses where independent variables (other than naloxone provision) were modeled continuously produced substantially similar findings (Supplemental Table 16).

Discussion

In this study of 58 Massachusetts communities with active post-overdose outreach programs, we examined five program characteristics to determine which were associated with changes in overdose rates and opioid-related emergency response rates for fatal and non-fatal overdose. Social service provision and referral was the only characteristic consistently associated with lower opioid overdose death rates. Outreach contact rates were not associated with fatal overdose, but during quarters when programs outreached to overdose survivors, municipalities had fewer opioid-related emergency responses than municipalities with no contacts, but only for municipalities with outreach contacts below the median (less than 27.7 contacts per 100,000 population per quarter). These findings provide some guidance about how post-overdose outreach programs should design their approach and raise further questions.

Most promising was that post-overdose outreach programs that provided or referred overdose survivors to social services were associated with decreased municipal-level fatal opioid overdose rate, consistent with research linking social determinants of health with opioid overdose rates (Altekruse et al., 2020; Bohler, Thomas, Clark, & Horgan, 2021; Dasgupta et al., 2018). In particular, there is substantial evidence that unemployment, economic downturns, and poverty increase risk of opioid-related harms including overdose (Case & Deaton, 2015; Dean & Kimmel, 2019; Hollingsworth et al., 2017; Venkataramani et al., 2020). Further, employment is associated with reduction of substance use and progression through treatment for substance use disorder (Sahker et al., 2019). Similarly, experiencing homelessness increases the risk of overdose and the likelihood of stopping medication treatment (Fine et al., 2022; Galea & Vlahov, 2002; Reif et al., 2014; The Commonwealth of Massachusetts, 2017). Making housing, employment, education, and transportation services more accessible to people who use drugs by incorporating these social services into post-overdose outreach programming potentially helped survivors and their families meet concrete needs, thereby reducing overdose risk. As a composite set of social service characteristics was examined, additional research is needed to examine the impact of each social service component and determine which social services and delivery approach (direct provision versus referral) is most impactful and responsive to the needs of opioid overdose survivors and their families. Though we adjusted models for confounding, lower relative overdose rates associated with this variable may reflect greater municipal-level capacity to meet social service needs rather than direct effects of post-overdose outreach programs. Engagement with social services, such as transportation, may increase access to other interventions shown to reduce risk of fatal overdose such as effective pharmacologic treatment for opioid use disorder.

Post-overdose outreach was associated with decreased opioid-related emergency response rates (fatal and non-fatal overdose) using multiple modeling approaches but only in programs initiating fewer than the median number of outreach visits (median = 27.7 contacts per 100,000 population per quarter) compared to communities in quarters where there were no contacts. Emergency response rates were lower in communities that had greater than the median contacts, though the effect size magnitude was smaller and not statistically significant. These findings are not consistent with a dose effect one would expect if this association were causal. While decreased opioid-related emergency response rates could signify fewer overall overdoses, they could alternatively signify decreased help-seeking/911 calling following an overdose, an unintended consequence and potential harm resulting from implementation of these programs (Lim et al., 2019). In this study we focused only on initial contacts (outreach contact rate), yet evidence from other addiction treatment programs suggest that pro-active and successful outreach over time can improve engagement and ultimately treatment retention (Scott et al., 2005, 2020). It is possible that multiple outreach contacts from a team equipped to address an acute event may have diminishing returns. Programs and future research should consider and evaluate in more detail how post-overdose outreach programs affect help-seeking and how to conduct pro-active outreach over multiple visits.

We hypothesized that naloxone distributed during post-overdose outreach visits would be associated with fewer fatal overdoses, but this was not observed, perhaps reflecting residual confounding – communities with programs that provide naloxone may be distinct from those that do not in ways that we cannot entirely control for in our analyses. We did control for volume of overall municipal naloxone distribution as a covariate. As naloxone is funded and distributed at the state level in Massachusetts, it is possible that this service might be more impactful in states with less naloxone availability. Naloxone distributed during post-overdose outreach visits was significantly associated with more opioid-related emergency responses in some modeling approaches (Model 6). We are unable to differentiate in these data if this reflects a true increase in the number of overdoses or greater help-seeking in places where naloxone is distributed — perhaps reflecting a heightened level of trust that the response system will be supportive and helpful. These findings also lose significance when fixed effects are included, suggesting that uncontrolled differences across communities may account for these findings.

We hypothesized that programs which incorporated more coercive approaches might reduce the likelihood that overdose survivors and their networks would seek help. This could occur because of concerns about legal consequences of engagement with law enforcement including the proliferation of drug-induced homicide prosecutions (Carroll et al., 2021; Tori et al., 2021). We did not detect statistically significant associations, though the direction of the effect estimates were consistent with a greater degree of coercive practices associated with increased fatal overdose and decreased opioid-related emergency responses. If demonstrated in other studies, this pattern would be consistent with coercive measures independently contributing to overdose which has been shown with incarceration (Binswanger et al., 2013; Davis et al., 2005; Rafful et al., 2018). Furthermore it would be

worthwhile to determine if this association is more pronounced among Indigenous, Black, Hispanic or Latino people who have experienced disparate harms due to criminalization of substance use and structural racism (Kunins, 2020; Larochelle et al., 2021). Amidst rising overdose rates among Black people in Massachusetts, it is crucial to ensure that interventions designed to reduce overdoses do not exacerbate inequalities (Larochelle et al., 2021). More broadly, the imperative to jettison coercive and punitive approaches to substance use is supported by intrinsic ethical, racial justice, and rights-based considerations and the best role for public safety in these efforts requires additional investigation (Grayken Center for Addiction, 2023; Sinha et al., 2020).

The strengths of this study contribute to improved understanding of post-overdose outreach programs. We used a multi-site, quasi-experimental, segmented regression design over more than 6 years in 58 communities, which allowed us to model the relationship between post-overdose outreach programs and our overdose outcomes while accounting for baseline overdose trend and municipal-level factors. Additionally, this analysis allowed examination of key program characteristics assessed during surveys and overdose.

This study's findings must be interpreted in the context of its limitations. First, despite using a quasi-experimental design and municipal fixed effects, this is an observational study subject to residual confounding including unmeasured municipal-level time-varying covariates and confounding between program characteristics and municipalities. Second, a key threat to this study design is co-occurring interventions (e.g., infusion of grant funding contemporaneously supporting other overdose prevention programming). By conducting our analysis at the municipal level, we modeled local program implementation, minimizing this threat. Third, these findings may not be generalizable to other locations or time periods (e.g., this analysis predates the COVID-19 pandemic). Fourth, as has been described previously, opioid fatalities and opioid-related emergency responses may be misclassified despite processes to ascertain if an event was related to opioids. This misclassification may systematically bias data to erase overdose among racially and ethnically minoritized individuals (Latimore et al., 2022). Fifth, our exposure measures are not validated and in some cases are based on self-reported approach (e.g., public safety or harm reduction). A group of addiction, overdose, and legal experts selected these measures and weighting of the responses by consensus to test theoretically and empirically driven hypotheses after reviewing distributions of survey responses and employed sensitivity analyses as a robustness check. Additional research is needed to better measure, validate, and examine the relationship between these program characteristics and overdose prevention and to consider variation in program operation in communities with differential demographic composition. Finally, this analysis is unable to differentiate between individual- and municipal-level effects and given the use of a population-level rather than individual outcome assessment, we cannot definitively exclude an ecological fallacy. Similarly, our data does not include information on subsequent outreach contacts. Future studies should examine if the program characteristics contribute to overdose risk reduction for the overdose survivor, that individual's social network, or the broader municipality.

Conclusion

Post-overdose outreach programs have proliferated as Massachusetts communities seek to respond to opioid overdose, driven by fentanyl in the illicit opioid supply and exacerbated by the COVID-19 pandemic. However, these programs, which have been recommended by the Centers for Disease Control (CDC) and received federal funding (Center for Disease Control & Prevention, 2020), differ considerably based on philosophy, components, staffing models, and outreach volume. Overdose survivors and other people who use drugs should be involved in the development, implementation, leadership and staffing of post-overdose outreach programs to ensure they provide relevant and timely services that are acceptable to potential overdose survivors and their networks (Grayken Center for Addiction, 2023; Wagner et al., 2019). By analyzing several key program characteristics, this analysis sought to improve the evidence base used to guide public health department and post-overdose outreach programs. Our findings suggest that post-overdose outreach programs which incorporate social services to address social determinants of health driving overdose risk may be effective at reducing overdose. Post-overdose outreach programs should be cognizant of how their interventions impact help-seeking behavior. Further program development and community research is needed to understand how best post-overdose outreach programs can effectively reduce overdose and engage overdose survivors in effective overdose prevention.

Ethics approval

The authors declare that they have obtained ethics approval from an appropriately constituted ethics committee/institutional review board where the research entailed animal or human participation. The study was reviewed and designated as not human subjects research by the Institutional Review Boards of the Boston University Medical Center and the Massachusetts Department of Public Health.

CRediT authorship contribution statement

Simeon D. Kimmel: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Ziming Xuan:** Conceptualization, Investigation, Methodology, Supervision, Writing – review & editing. **Shapei Yan:** Data curation, Formal analysis, Investigation, Methodology, Writing – review & editing. **Audrey M. Lambert:** Investigation, Methodology, Writing – review & editing. **Scott W. Formica:** Investigation, Methodology, Writing – review & editing. **Traci C. Green:** Investigation, Methodology, Writing – review & editing. **Jennifer J. Carroll:** Investigation, Methodology, Writing – review & editing. **Sarah M. Bagley:** Investigation, Methodology, Writing – review & editing. **David Rosenbloom:** Investigation, Methodology, Writing – review & editing. **Leo Beletsky:** Investigation, Methodology, Writing – review & editing. **Alexander Y. Walley:** Conceptualization, Investigation, Supervision, Funding acquisition, Writing – review & editing.

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Supplementary materials

Supplementary material associated with this article can be found, in

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