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RESEARCH REPORT

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Improving racial/ethnic health equity and naloxone access among people at risk for opioid overdose: A simulation modeling analysis of community-based naloxone distribution strategies in Massachusetts, United States

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Abstract

Background and Aims: During the COVID-19 pandemic, there was a surge in opioid overdose deaths (OODs) in Massachusetts, USA, particularly among Black and Hispanic/Latinx populations. Despite the increasing racial and ethnic disparities in OODs, there was no compensatory increase in naloxone distributed to these groups. We aimed to evaluate two community-based naloxone expansion strategies, with the objective of identifying approaches that could mitigate mortality and racial and ethnic disparities in OODs.

Design: Individual-based simulation model. We measured naloxone availability using naloxone kits per OOD and evaluated scenarios of achieving higher benchmarks for naloxone availability (i.e. 40, 60 and 80 kits per OOD) from 2022 levels (overall: 26.0, White: 28.8, Black: 17.3, Hispanic/Latinx: 18.9). We compared two naloxone distribution strategies: (1) proportional distribution: achieving the benchmark ratio at the overall population level while distributing additional kits proportional to the 2022 level for each racial/ethnic group (at 40 kits per OOD benchmark: overall: 40, White: 44.3, Black: 26.6, Hispanic/Latinx: 29.1), and (2) equity-focused distribution: achieving the benchmark ratio among each racial/ethnic group (at 40 kits per OOD benchmark: 40 for all groups).

Setting: Massachusetts, United States.

Participants: People at risk of OOD.

Measurements: Annual number and rate of OODs, total healthcare costs of increasing naloxone availability.

Findings: Both naloxone distribution strategies yielded comparable predicted reductions in total OODs in 2025 and incurred similar incremental costs. However, the relative reduction in the rate of OODs differed across groups. For achieving an 80 kits per OOD

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benchmark, proportional distribution resulted in a projected 6.7%, 6.5% and 7.1% reduction in annual OODs in 2025 among White, Black and Hispanic/Latinx populations, respectively. In contrast, equity-focused distribution achieved a reduction of 5.7%, 11.3% and 10.2% in the respective groups. In all scenarios, the cost per OOD averted was lower than the generally accepted thresholds for cost per life saved.

Conclusions: An equity-focused naloxone distribution strategy designed to reduce racial and ethnic disparities in naloxone availability could improve health equity among racial and ethnic groups while potentially improving overall population health at lower healthcare costs per opioid overdose death averted than a proportional distribution strategy.

KEYWORDS
community-based interventions, cost, naloxone distribution, opioid overdose death prevention, racial/ethnic equity, simulation modeling

INTRODUCTION

Opioid overdose mortality has grown exponentially in recent decades in the United States (US), with a pronounced increase during the coronavirus disease 2019 (COVID-19) pandemic [1, 2]. In 2022, nearly 83 000 people in the United States died because drug overdose involving an opioid—deaths driven largely by an unregulated drug supply and structural barriers to overdose prevention services [3, 4]. In Massachusetts in particular, the vast majority of overdose mortality is opioid-related and the state's opioid overdose death (OOD) rate consistently exceeds the national average (32.5 per 100 000 in 2021, compared to 24.7 nationally) [5]. The 2022 Massachusetts data shows a further increase in opioid-related overdose death rate, with 33.6 OODs per 100 000 [6].

Stigmatization and criminalization of people who use drugs embodied in structural racism promulgated by drug legislation shape persistent racial and ethnic inequities in overdose outcomes [7, 8]. In the context of the COVID-19 pandemic, these disparities widened as a result of shifts in the unregulated drug supply with increasing toxicity, inequitable access to harm reduction and treatment services and an excess burden of pandemic-related health and economic stressors in Black, Hispanic/Latinx and Indigenous communities [3, 9, 10]. Across the United States, the rate of OOD has grown most rapidly among Black and American Indian or Alaska Native individuals in recent years. In Massachusetts, although the age-adjusted rates of opioid-related overdose death among non-Hispanic White residents remained steady from 2019 to 2022, the rates increased by 134% among non-Hispanic Black residents and by 41% among Hispanic residents (both surpassing the rate for non-Hispanic White residents) [6].

Timely administration of naloxone can prevent opioid overdoses from becoming fatal, with widespread naloxone distribution representing a key component of the public health response to the opioid overdose epidemic [11–13]. Naloxone is administered either as a nasal spray or an injection, often by individuals who are most likely to witness an overdose, such as friends, family members and peers of individuals who use drugs. In the United States, the medication can be obtained through community-based overdose education and naloxone distribution (OEND) programs, health departments, as well as from pharmacies (including both prescribed and over-the-counter) and healthcare providers [14]. However, systemic barriers limit naloxone access and its effectiveness for many individuals, including gaps in naloxone availability at pharmacies in low-income or predominantly racial and ethnic minority communities, reduced access to healthcare more generally, concerns that carrying naloxone could potentially escalate familial, social or legal tensions and increased solitary drug use [15–17]. Prior research in Massachusetts found that, although municipalities with higher proportions of Black residents had higher naloxone coverage ratios (defined as counts of community-based naloxone kits distributed per opioid overdose death) [18], naloxone distribution rates (i.e. naloxone kits distributed per 100 000 people) for Black individuals in these municipalities were lower than the rates for White residents [19]. These findings suggest that distributing naloxone through programs operating in racially diverse communities is not sufficient to achieve equitable naloxone receipt. Another study in Massachusetts identified that, with the onset of the COVID-19 pandemic, there was a surge in OODs among Black residents, but no compensatory increase in naloxone distribution within these populations [20].

Recognizing that naloxone distribution is key to reducing overdose deaths, the Substance Abuse Mental Health Services Administration (SAMHSA) included community naloxone saturation goals as a condition of its 2022 $1.4 billion State Opioid Response grants to state and territorial agencies [21]. Although a specific definition of naloxone 'saturation' was not provided by SAMHSA, naloxone saturation goal setting requires grant recipients to use data-informed approaches to ensure that those most likely to witness an overdose in the places where overdoses are most likely to occur have ready access to naloxone [22]. Racial and ethnic equity-focused naloxone distribution strategies could help deliver on these goals. This study aims to adapt a previously developed simulation model to evaluate alternative naloxone expansion strategies in Massachusetts, with the objective of identifying approaches that can lessen opioid overdose mortality and simultaneously reduce racial and ethnic disparities in OODs.

METHODS

We adapted a previously developed, individual-based simulation model that is composed of a microsimulation model with an integrated decision tree model, PROFOUND [12], to assess the potential outcomes of naloxone distribution expansion strategies across racial and ethnic populations in Massachusetts. The work was deemed to not be human participants research by the Brown University and Boston University Medical Campus institutional review boards.

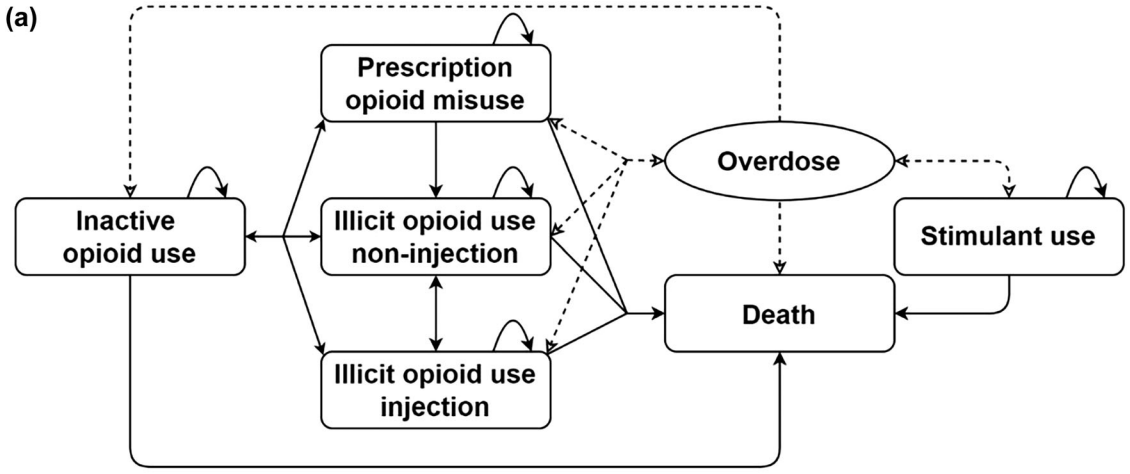
Model description

We adapted the PROFOUND model to simulate a virtual cohort representing all individuals in Massachusetts who are at risk for opioid overdose (Figure S1, Tables S1–S3). Each simulated individual was characterized by sex, age, race and ethnicity, geographic region of residence, patterns of drug use, prior opioid overdose history and fentanyl exposure; this allowed us to reflect heterogeneities in overdose risk and naloxone access across different population groups and geographic locations. Because small sample sizes (resulting in large variation) for certain racial and ethnic populations (e.g. American Indian, Asian/Pacific Islander), as well as the inconsistencies in defining and stratifying race and ethnicity across data sources, we narrowed our analysis to three mutually exclusive racial and ethnic groups: non-Hispanic White (White), non-Hispanic Black (Black), Hispanic/Latinx (any race) (Hispanic). We excluded other populations. Given that Massachusetts has 351 municipalities within only 14 counties, we defined study geographic regions as: (1) municipalities with over 40 000 residents or with an actively operating syringe services program (n = 58); and (2) geographic regions that each include all other municipalities within one emergency services catchment area (developed by the Massachusetts Behavioral Health Partnership) [23], excluding those described in (1) (n = 21). This yielded 79 distinct geographic regions in total (Figure S2).

The state-transition microsimulation model with a monthly cycle length was used to simulate transitions between different drug use states (prescription opioid misuse, illicit opioid use [non-injection], illicit opioid use [injection], inactive opioid use, stimulant use and death) among the simulated individuals and to project the number of opioid overdose events in each month (Figure 1, Tables S4–S6). We considered key factors associated with elevated risk for overdose, including exposure to fentanyl [24], using opioids through injection [25, 26], overdose history [27] and during the first month following transitioning out of the inactive opioid use state [24]. Given the rarity of multiple overdoses within a single month for the same individual, we limited the model to one overdose per individual per month while allowing for the possibility of overdoses occurring in consecutive months for the same individual. We, then, used the decision tree model to assess the potential pathway and consequence of each overdose event in each month, including the setting of overdose (public or private/semi-private), overdose witnessing (witnessed or not), naloxone administration (administered or not), emergency medical services (EMS) dispatch (yes or no), emergency department (ED) care (yes or no) and overdose survival (survived or died) (Figure 1, Table S7). In the decision tree, we incorporated a naloxone availability algorithm in which we assumed that the probability of naloxone being available in an overdose event was a nonlinear function of the number of naloxone kits in circulation and the number of individuals at risk for opioid overdose, with this probability varying by geographic region, race and ethnicity and time. We included naloxone kits distributed to each racial and ethnic group in each region in each year through both OEND programs and pharmacies in this algorithm (see Supporting information).

Model calibration

To ensure that our model reflected the distinct patterns of the opioid epidemic both before and after the onset of the COVID-19 pandemic, we calibrated the model using a random search approach separately for the pre-COVID-19 period (2016–2019) and COVID-19 period (2020–2022) against three sets of targets from surveillance at the state level: (1) annual number of OODs, stratified by race and ethnicity; (2) percentage of OODs involving fentanyl, stratified by race and ethnicity; and (3) annual number of ED visits for opioid overdoses, total among White, Black and Hispanic individuals only. For the pre-COVID-19 period, we used a Latin hypercube sampling method [28] to draw 100 000 random samples for 20 key parameters pertaining to fentanyl exposure, overdose risk, overdose witnessing, response (e.g. calling EMS) and consequence (e.g. mortality) to ensure uncertainty coverage of prior ranges, compared to the calibration targets and retained 100 best-fitting sets. For the COVID-19 period, we maintained these previously calibrated parameters at their calibrated values, extended model simulation to 2022 and incorporated two new sets of parameters to account for the observed changes during the COVID-19 pandemic: (1) percentage of fentanyl exposure among people who exclusively use stimulants, stratified by race and ethnicity; and (2) the rate at which people who use opioids transition to an inactive opioid use state (as a proxy for interruptions to access to medications for opioid use disorder [MOUD]), stratified by race and ethnicity. We used the same Latin hypercube sampling method to draw 100 sets of random samples for these parameters, appended them with each of the previously calibrated parameter set (a total of 10 000 samples) and retained only the best-fitting parameter set for each set of calibrated parameters from the pre-COVID period, resulting in the selection of 100 final calibrated parameter sets for subsequent analysis. This calibration method allowed us to capture both the parameter uncertainty and stochasticity inherent in a microsimulation model. Figure 2 shows the model calibration results compared to target data. All model results are presented as post-calibration mean estimates and 95% simulation intervals (95% SIs). More details regarding the calibration process are described in Figure S3 and Tables S8–S9.



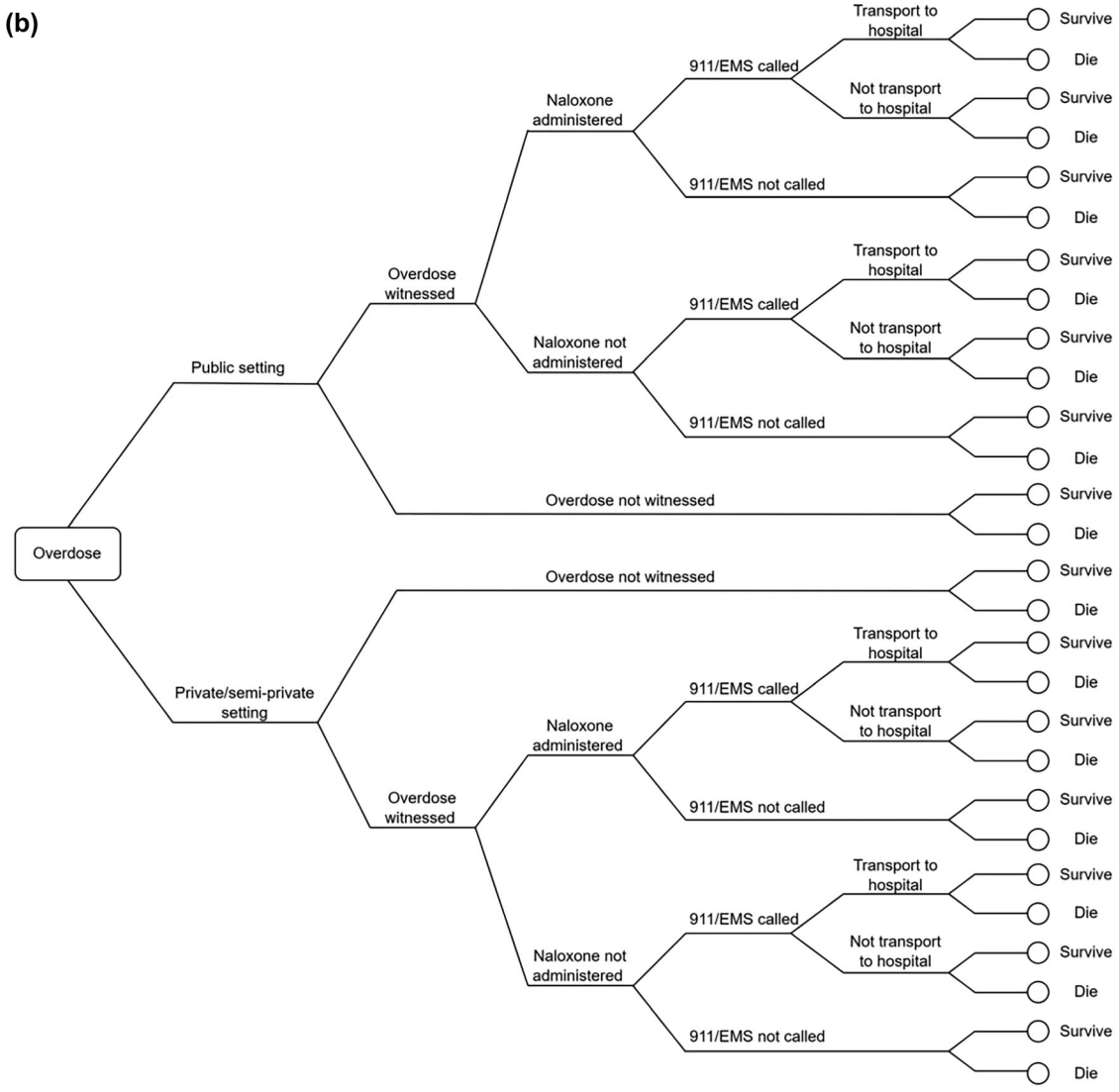


FIGURE 1 Model structure diagram. (a) Microsimulation model for health and drug use states; (b) decision tree model for overdose events. EMS, emergency medical services. In (a), the solid lines represent transitions among health states, whereas the dotted lines represent transitions between health states and overdose.

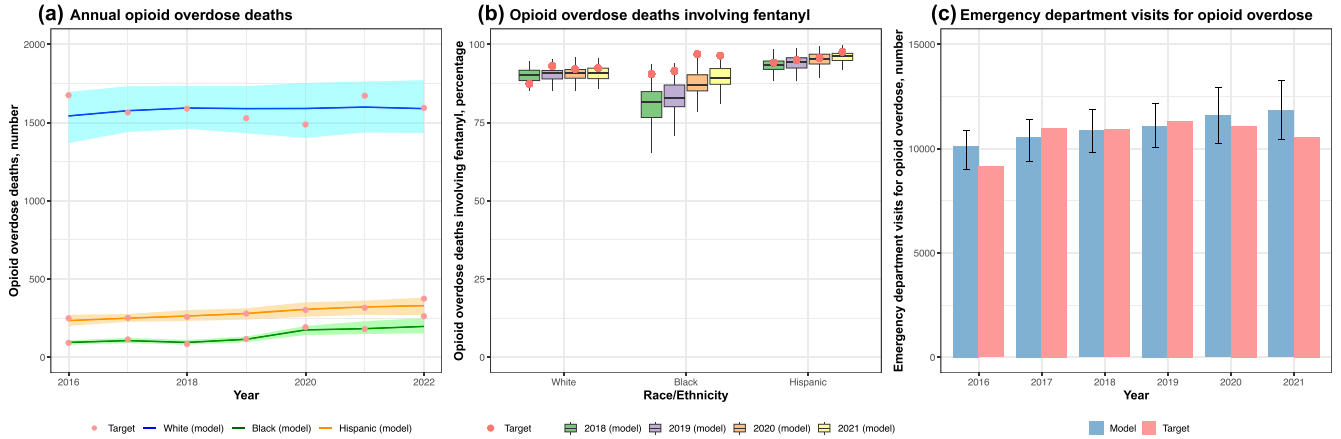


FIGURE 2 Model calibration to observed opioid overdose–related targets in Massachusetts.

TABLE 1 Ratio of naloxone kits from overdose education and naloxone distribution programs per OOD for each racial and ethnic population in 2022 and under different naloxone distribution scenarios.

	Overall[a]	White	Black	Hispanic/Latinx
Status quo (2022 level)	26.0	28.8	17.3	18.9
Proportional distribution				
40 kits per OOD ratio	40	44.3	26.6	29.1
60 kits per OOD ratio	60	66.5	39.9	43.6
80 kits per OOD ratio	80	88.6	53.2	58.2
Equity-focused distribution				
40 kits per OOD ratio	40	40	40	40
60 kits per OOD ratio	60	60	60	60
80 kits per OOD ratio	80	80	80	80

Abbreviation: OOD, opioid overdose death.
[a]The overall only includes White, Black and Hispanic/Latinx populations.

Naloxone distribution implementation strategies

In previous studies [29, 30], we proposed the ratio of naloxone kits per OOD as a measure for naloxone availability for a given population or region. In this study, we calculated total and race and ethnicity stratified, ratios of naloxone kits from OEND programs per OOD in 2022 and compared four counterfactual scenarios to achieve higher levels of naloxone distribution from OEND programs per OOD ratios in Massachusetts: (1) maintaining 2022 level of kits per OOD (status quo) and increasing to (2) 40 kits per OOD, (3) 60 kits per OOD or (4) 80 kits per OOD. For each scenario, we considered two sets of naloxone expansion strategies: (1) proportional distribution—achieving the benchmark ratio at the population level and distributing additional kits proportionally to the 2022 level of naloxone distribution from OEND programs for each racial/ethnic group; and (2) equity-focused distribution—achieving benchmark naloxone kits per OOD ratios among each racial/ethnic group. We present in Table 1 the status quo ratio of naloxone kits per OOD for each racial and ethnic group and resulting ratios for naloxone expansion scenarios with the two different distribution strategies. Although we included naloxone distributed through both OEND programs and pharmacies in the baseline model, we modeled expanded naloxone distribution exclusively through OEND programs, because OEND programs have been found to be significantly more likely to reach the individuals at high risk of opioid overdose and provide targeted distribution [31].

We projected health outcomes from 2023 to 2025, including the annual number of OODs and rate of OODs per 100 000 for each racial and ethnic population. We also assessed the healthcare sector costs (in 2022 US dollars) of each naloxone distribution strategy, calculating the cost per OOD averted over the 3-year evaluation period. Healthcare sector costs included costs of naloxone kit (medication), costs for naloxone distribution (staff time spent receiving OEND training and delivering OEND), costs related to overdose response (EMS runs and ED visits) and costs for other healthcare excluding naloxone and overdose related healthcare for different health states (Table S10). Additional outcomes are estimated and presented in Tables S11–S12.

Given the likelihood of higher costs for engaging underserved populations under the equity-focused distribution, we conducted a threshold analysis on the added costs attributable to targeted

distribution. We varied the added cost as a multiplier to baseline unit cost of naloxone distribution ranging from 1 to 1.5 when distributing expanded naloxone kits to Black or Hispanic individuals and determine the threshold at which each distribution strategy is less costly per OOD averted.

Data inputs

We determined the number of people living in each geographic region who are at risk for opioid overdose, their demographic characteristics and different drug use patterns using data from the US Census Bureau [32] (for population sizes and demographics for each region) and National Survey on Drug Use and Health [33] (NSDUH, national data for the prevalence of opioid misuse among each sociodemographic group). We adjusted these prevalence estimates based on the difference between the overall prevalence estimate from NSDUH and one from a previous capture-recapture prevalence study for Massachusetts [34]. To inform the model for the distribution of naloxone at baseline, we obtained OEND program naloxone data from 2016 to 2022 provided by the Massachusetts Department of Public Health (MDPH), which included individual-level information of the recipient of naloxone kit, including their race, ethnicity and zip code of residence. The demographic information was self-reported by participants and documented by OEND program staff. Because substantial missing data (nearly 60%) regarding the demographic information of OEND naloxone recipients between 2020 to 2022, we imputed the missing data assuming the same distribution of race and ethnicity based on naloxone data with complete information for each respective year (see more details in the Supporting information). We also acquired data for naloxone distributed by pharmacies from both MDPH and Symphony Health Solutions (pharmaceutical claims data from retail pharmacies), where data from the MDPH provided the total number of naloxone kits distributed from pharmacies each year and Symphony Health data contained information about the racial and ethnic distribution of pharmacy naloxone recipients.

Unit cost associated with per naloxone kit distributed was based on the purchasing price to MDPH ($44.8, purchasing price at the time of the study) and the programmatic costs of OEND per naloxone kit distributed established ($104) from prior work [12, 35]. Costs related to overdose responses were derived from a prior costing analysis and were adjusted to the Massachusetts context [36]. Other healthcare costs for different health states were estimated from a previous cost-effectiveness analysis using person-level data from a clinical trial [37, 38]. To inform model calibration targets and the calculation of the ratio of naloxone kits per OOD, we extracted race- and ethnicity-stratified OODs (classified as unintentional) and OODs involving fentanyl from data collected by the Injury Surveillance Program at the MDPH. We also derived annual ED visits related to opioid overdoses from the MDPH Syndromic Surveillance program. We present in the Supporting information more details of model parameterization and other parameters of interests that were estimated from previous literature.

This analysis was not pre-registered and should be considered exploratory in nature.

RESULTS

In the status quo scenario of maintaining the 2022 level of naloxone distribution, we estimated a total of 2037 (95% SI = 1800-2232) OODs in 2025 among White, Black and Hispanic populations and a rate of OOD of 31.5 (27.6–35.0), 28.0 (21.1–35.9) and 35.2 (30.1–40.5) per 100 000 people for the three populations, respectively (Table 2, Figure 3). Increasing the ratio of naloxone kits from OEND programs per OOD to 40, 60 and 80 with a proportional distribution strategy reduced the total OODs among all three populations in 2025 to 1992 (1749–2195, 2.2% relative reduction), 1939 (1732–2154, 4.8% reduction) and 1900 (1671–2142, 6.7% reduction). Total OOD results for the equity-focused distribution strategy were similar, with 1988 (1756–2207, 2.4% reduction), 1939 (1711–2162, 4.8% reduction) and 1897 (1665–2138, 6.9%) OODs in 2025 when reaching the 40, 60 and 80 benchmark ratios, respectively.

Although the reductions in total OODs were similar between the two naloxone distribution strategies, they led to different reductions in annual OODs in 2025 across racial and ethnic groups. Reaching proportional distribution strategy benchmark ratios of 40, 60 and 80 resulted in greater reductions in annual OODs among the White population (relative reduction: 2.4%, 5.0% and 6.7%, respectively; absolute reduction: 35.7, 77.0 and 101.8), compared to the reductions with an equity-focused distribution strategy (relative reduction: 1.8%, 3.9% and 5.7%; absolute reduction: 27.5, 60.4 and 87.0) (Table 2, Figure 3). In contrast, we found greater reductions with an equity-focused among Black individuals (relative reduction: 4.3%, 7.0% and 11.3%; absolute reduction: 8.1, 13.2 and 20.8) compared to a proportional strategy (relative reduction: 2.7%, 4.3% and 6.5%; absolute reduction: 4.9, 7.8 and 12.1). A similar pattern was observed for Hispanic individuals for the equity-focused strategy (relative reduction: 4.0%, 7.8% and 10.2%; absolute reduction: 12.6, 24.1 and 32.3) compared with the proportional strategy (relative reduction: 1.6%, 4.0% and 7.1%; absolute reduction: 4.2, 12.7 and 22.9).

Compared to the status quo scenario, expanding OEND naloxone distribution to reach the 40, 60 and 80 benchmark ratios would incur an incremental cost of $13.87 million, $33.61 million and $52.82 million, with a proportional strategy, corresponding to $131 671, $147 658, $160 515 per OOD averted, respectively (Table 2). In comparison, the equity-focused strategy would incur an incremental cost of $13.88 million, $33.66 million and $52.95 million to reach the three benchmark ratios, corresponding to $122 419, $144 369 and $156 248 per OOD averted, respectively. Over 95% of the incremental costs are attributable to costs associated with naloxone distribution. The costs per OOD death averted were significantly lower than the US Department of Health and Human Services recommended value of a statistical life for 2022 ($10–12 million) [39]. In the threshold analysis, we found that increasing naloxone distribution under

TABLE 2 Model results for different naloxone distribution scenarios.

Distribution strategy		Proportional distribution			Equity-focused distribution		
Naloxone distribution benchmarks	Status quo	40 kits per OOD	60 kits per OOD	80 kits per OOD	40 kits per OOD	60 kits per OOD	80 kits per OOD
Annual OODs in 2025 (95% simulation interval)	2037 (1800–2232)	1992 (1749–2195)	1939 (1732–2154)	1900 (1671–2142)	1988 (1756–2207)	1939 (1711–2162)	1897 (1665–2138)
Rate of OODs in 2025							
Total (% reduction[a])	31.6	30.9 (2.2%)	30.1 (4.8%)	29.5 (6.7%)	30.9 (2.4%)	30.1 (4.8%)	29.5 (6.9%)
White (% reduction[a])	31.5	30.7 (2.3%)	29.9 (5.0%)	29.4 (6.7%)	30.9 (1.8%)	30.2 (3.9%)	29.7 (5.7%)
Black (% reduction[a])	28.0	27.3 (2.7%)	26.9 (4.2%)	26.2 (6.5%)	26.8 (4.3%)	26.1 (7.1%)	24.9 (11.2%)
Hispanic (% reduction[a])	35.2	34.7 (1.3%)	33.8 (3.9%)	32.7 (7.1%)	33.8 (3.9%)	32.5 (7.5%)	31.6 (10.0%)
Total OODs, 2023–2025	6138	6033	5910	5809	6025	5905	5799
Total OODs averted[a]	–	105	228	329	113	233	339
Total costs, 2023–2025	$15.23B	$15.24B	$15.26B	$15.28B	$15.24B	$15.26B	$15.28B
Incremental costs[a]	–	$13.87M	$33.61M	$52.82M	$13.88M	$33.66M	$52.95M
Costs per OOD averted	–	$131 671	$147 658	$160 515	$122 419	$144 369	$156 248

Abbreviation: OOD, opioid overdose deaths.
[a]Compared to the status quo.

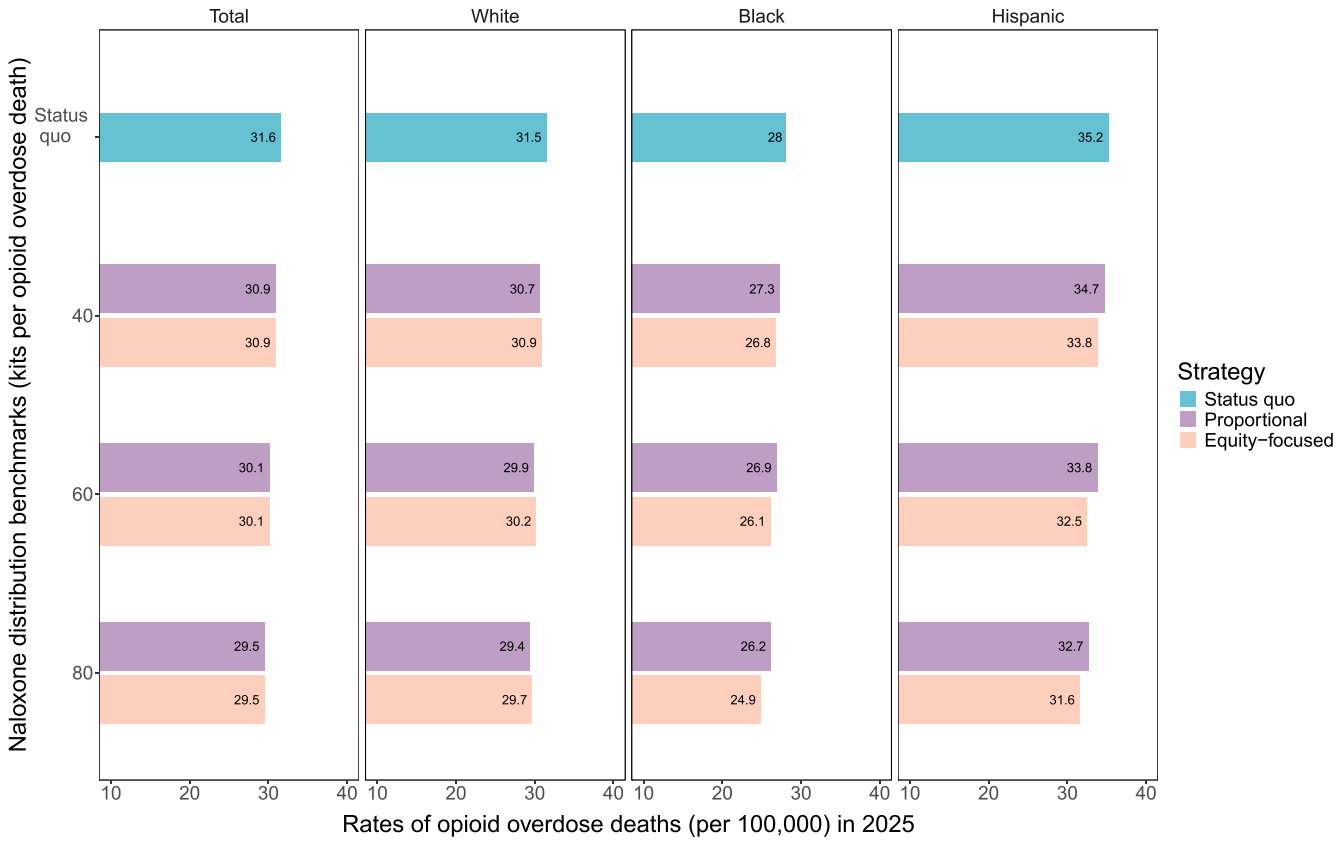


FIGURE 3 Projected rate of opioid overdose deaths per 100 000 people in 2025 in Massachusetts in different naloxone distribution scenarios, stratified by race and ethnicity.

the equity-focused distribution could cost 1.1 (at 80 benchmark ratio) to 1.25 (at 40 benchmark ratio) times more and would still be less costly per OOD averted than the proportional distribution (Figure S4).

DISCUSSION

We examined racial and ethnic disparities in naloxone access and opioid-related overdose deaths among people who are at risk for

opioid overdose. We also examined outcomes and cost of a proportional naloxone expansion strategy compared to an equity-focused strategy. Although both OODs and racial and ethnic disparities in OOD rates worsened during the COVID-19 period in Massachusetts, increasing naloxone availability to reach an 80 naloxone kits-per-OOD ratio benchmark could reduce the annual number of OODs by as much as 7% through 2025. The cost of such a strategy would be approximately $156 000 per OOD averted when reaching an 80 naloxone kits-per-OOD ratio benchmark with equity-focused distribution. We found that distributing additional naloxone kits resulted in similar total OODs averted between the two naloxone distribution strategies (i.e. proportional and equity-focused). This outcome is likely attributable to the similar rates of naloxone kits distributed to each racial and ethnic population at baseline (kits per at-risk individual), leading to a comparable marginal benefit across these groups. We would expect that, in settings with more substantial racial/ethnic inequities in naloxone access, the effects of these two scenarios may be significantly different and warrant further study. However, our results suggest that a more equitable naloxone distribution strategy designed to reduce racial and ethnic inequalities in naloxone availability could substantially improve health equity at a slightly lower cost per OOD averted than a proportional distribution strategy.

Health inequities in opioid overdose outcomes have become more pronounced in recent years. The relative reduction in naloxone availability compared to need (kits-per-OOD ratio) among Black and Hispanic populations was driven primarily by the surge of opioid overdoses; a previous study by this research team showed that the rate of naloxone distribution to these two populations continued to increase during the COVID-19 pandemic period [20]. High potency opioids in the unregulated drug supply (particularly the presence of fentanyl and its analogs) is one of the main causes of the recent surge in OODs, which has disproportionally affected Indigenous, Black and Hispanic communities [9]. Fentanyl contamination and/or substitution of the unregulated non-opioid drug supply, including stimulants, have been recognized as the leading factor for the 'fourth wave' of the US overdose crisis [40]. Further, the longstanding effects of structural racism on housing, employment and access to healthcare were exacerbated by COVID-19 [41].

Despite the continuous efforts to expand naloxone distribution in Massachusetts, the worsening opioid overdose crisis and burgeoning racial/ethnic disparities underscore the inadequacy of the current approach to meeting the escalating need for naloxone and other harm reduction services. Although Massachusetts has exceeded the naloxone distribution goals outlined in SAMHSA's Naloxone Saturation Plan on an aggregate level, uncertainties persist regarding whether these goals were uniformly met across diverse communities and populations [42]. Accessing naloxone often requires in-person attendance, which could be hindered by barriers that disproportionately affect Black and Hispanic communities, such as lack of transportation, stigma, medical mistrust and inequitable service provision by health professionals [43, 44]. Racialized criminalization also acts as a barrier to naloxone possession and utilization, because Black and Hispanic/Latinx individuals are more likely to be subject to punitive governance related to the possession of naloxone and other drug use equipment [17]. Effective strategies to enhance more equitable naloxone access may include increasing naloxone availability in neighborhoods with high proportions of Black and Hispanic families through mail orders, naloxone vending machines and partnering with trusted institutions (e.g. churches, social service organizations), social network interventions, culturally tailored overdose prevention awareness campaigns and increasing MOUD access and naloxone on release in jails or prisons [44]. In addition to supporting expanded naloxone distribution in populations facing higher risk of OOD, new efforts are also required to increase access and reduce barriers to treatment for all people with opioid use disorders. A portfolio of strategies to decrease OODs and eliminate disparities will require providing population-tailored outreach efforts, raising awareness about the unpredictability of the unregulated drug supply, and reducing stigma around treatment and harm reduction services.

Disparities in access to naloxone are understudied in the United States, because there are limited data on individual-level naloxone access and utilization in most settings. Massachusetts serves as a promising example of proactive measures to address this gap. The MDPH began funding existing harm reduction programs in 2007 to expand their naloxone distribution among people who use drugs. Using standardized data collection processes, these funded programs collect information on naloxone recipients that include self-described race and ethnicity during each individual naloxone distribution encounter and report this data to the MDPH on an ongoing basis [45]. Although the lack of demographic information may perpetuates structural racism, collecting such data enables programs, communities and policymakers to monitor inequities systematically and design tailored interventions thereby promoting greater equity in access to lifesaving medications [46].

This study has several limitations. First, in calibrating the model to account for the increase of OODs (mainly among the Black and Hispanic populations) during the COVID-19 period, we only considered changes to fentanyl exposure among people who use stimulants and the transition rate from an active to inactive opioid use state. Although some parameters were calibrated to the upper bound of the prior credible ranges (especially for the Black population), our model was not able to fully replicate the rapid increase in OODs among Black and Hispanic populations in 2022 (a 46% and 19% increase compared to 2021, and a 124% and 48% increase compared to 2019, respectively). As such, we might have underestimated OODs in these two populations in and after 2022, as well as the equity impact of the equity-focused distribution strategy. Other potential contributing factors, including other unexpected changes in the unregulated drug supply, interruptions to emergency medical services and increased solitary drug use [47, 48], were not considered in this analysis, as prior studies showed mixed findings about the impact of these variables [49]. Second, although the American Indian (non-Hispanic) population persists in having the highest rate of OODs in Massachusetts, we did not include this population in the analysis for two principal reasons: (1) the small population size (0.5% of the total population) led to substantial variations in parameter estimation; and (2) some input data

for this specific population was not available (e.g. pharmacy naloxone data). Third, the missing data for OEND naloxone during 2020 to 2022 may lead to uncertainty to model results. We imputed the missing data assuming the same distribution of race and ethnicity based on data with complete information in the same year. Although other imputation methods could be used [50], we investigated five different imputation strategies in a previous study (including one similar to the one used in this study), and these methods yielded very similar results for naloxone availability [20]. Last, although we considered the same unit cost for the two strategies for naloxone expansion, the equity-focused distribution may require additional costs and investments to meet these goals, and we performed threshold analysis to determine the threshold at which equity-focused distribution remained less costly per OOD averted.

The increased racial and ethnic disparities in opioid overdose mortality and naloxone availability that occurred amid the COVID-19 pandemic underscore that the existing systems of naloxone distribution may be insufficient to reach Black and non-White Hispanic/Latinx populations that were disproportionately affected. Despite our study's focus on a single state with well-established naloxone distribution programs, we believe the findings have broader implications, because the disparities in opioid overdose deaths and naloxone distribution observed in Massachusetts are likely present in other states or regions with diverse populations and varying levels of access to healthcare resources. Eliminating these disparities is possible and a critical public health objective in addressing the ongoing overdose crisis characterized by polysubstance use and a widespread presence of contaminated drug supply. Achieving this goal necessitates a combination of policy changes, equity-focused programmatic interventions and robust data collection efforts.

AUTHOR CONTRIBUTIONS

Xiao Zang: Conceptualization (lead); data curation (lead); formal analysis (lead); funding acquisition (equal); investigation (equal); methodology (equal); visualization (equal); writing—original draft (equal). **Alexandra Skinner:** Investigation (equal); writing—original draft (equal). **Zongbo Li:** Formal analysis (equal); visualization (equal); writing—original draft (equal). **Leah C. Shaw:** Writing—original draft (equal). **Czarina N. Behrends:** Data curation (equal); writing—review and editing (equal). **Avik Chatterjee:** Writing—review and editing (equal). **Ali Jalali:** Writing—review and editing (equal). **Ashly E. Jordan:** Writing—review and editing (equal). **Jake R. Morgan:** Data curation (equal). **Shayla Nolen:** Data curation (equal); writing—review and editing (equal). **Bruce R. Schackman:** Conceptualization (equal); funding acquisition (equal); supervision (equal). **Brandon D. L. Marshall:** Conceptualization (equal); funding acquisition (equal); supervision (equal). **Alexander Y. Walley:** Conceptualization (equal); data curation (equal); investigation (equal); supervision (equal).

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DECLARATIONS OF INTERESTS

None.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

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REFERENCES

1. Mattson CL, Tanz LJ, Quinn K, Kariisa M, Patel P, Davis NL. Trends and geographic patterns in drug and synthetic opioid overdose deaths—United States, 2013–2019. Morb Mortal Wkly Rep. 2021;70(6):202–7. https://doi.org/10.15585/mmwr.mm7006a4
2. Kuehn BM. Accelerated overdose deaths linked with COVID-19. JAMA. 2021;325(6):523. https://doi.org/10.1001/jama.2021.0074
3. Kariisa M, Davis NL, Kumar S, Seth P, Mattson CL, Chowdhury F, et al. Vital signs: drug overdose deaths, by selected sociodemographic and social determinants of health characteristics—25 states and the District of Columbia, 2019–2020. Morb Mortal Wkly Rep. 2022;71(29):940–7. https://doi.org/10.15585/mmwr.mm7129e2
4. National Institute on Drug Abuse. Drug overdose death rates; 2023.
5. KFF. Opioid overdose death rates and all drug overdose death rates per 100,000 population (age-adjusted).
6. Massachusetts Department of Public Health. Current opioid statistics.
7. Bailey ZD, Krieger N, Agénor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. Lancet. 2017;389(10077):1453–63. https://doi.org/10.1016/S0140-6736(17)30569-X
8. Pamplin JR, Rouhani S, Davis CS, King C, Townsend TN. Persistent criminalization and structural racism in US drug policy: the case of overdose good Samaritan Laws. Am J Public Health. 2023;113(S1):S43–8. https://doi.org/10.2105/AJPH.2022.307037
9. Friedman JR, Hansen H. Evaluation of increases in drug overdose mortality rates in the US by race and ethnicity before and during the COVID-19 pandemic. JAMA Psychiatry. 2022;79(4):379–81. https://doi.org/10.1001/jamapsychiatry.2022.0004
10. Han B, Einstein EB, Jones CM, Cotto J, Compton WM, Volkow ND. Racial and ethnic disparities in drug overdose deaths in the US during the COVID-19 pandemic. JAMA Netw Open. 2022;5(9):e2232314. https://doi.org/10.1001/jamanetworkopen.2022.32314
11. Irvine MA, Oller D, Boggis J, Bishop B, Coombs D, Wheeler E, et al. Estimating naloxone need in the USA across fentanyl, heroin, and prescription opioid epidemics: a modelling study. Lancet Public Health. 2022;7(3):e210–8. https://doi.org/10.1016/S2468-2667(21)00304-2

12. Zang X, Bessey SE, Krieger MS, Hallowell BD, Koziol JA, Nolen S, et al. Comparing projected fatal overdose outcomes and costs of strategies to expand community-based distribution of naloxone in Rhode Island. JAMA Netw Open. 2022;5(11):e2241174. https://doi.org/10.1001/jamanetworkopen.2022.41174
13. Fairbairn N, Coffin PO, Walley AY. Naloxone for heroin, prescription opioid, and illicitly made fentanyl overdoses: challenges and innovations responding to a dynamic epidemic. Int J Drug Policy. 2017;46:172–9. https://doi.org/10.1016/j.drugpo.2017.06.005
14. Weiner J, Murphy SM, Behrends C. Expanding access to naloxone: a review of distribution strategies 23 Penn LDIIssue Brief; 2019. p. 132.
15. Owczarzak J, Weicker N, Urquhart G, Morris M, Park JN, Sherman SG. "We know the streets:" race, place, and the politics of harm reduction. Health Place. 2020;64:102376. https://doi.org/10.1016/j.healthplace.2020.102376
16. Lopez AM, Thomann M, Dhatt Z, Ferrera J, Al-Nassir M, Ambrose M, et al. Understanding racial inequities in the implementation of harm reduction initiatives. Am J Public Health. 2022;112(S2):S173–81. https://doi.org/10.2105/AJPH.2022.306767
17. Khan MR, Hoff L, Elliott L, Scheidell JD, Pamplin JR, Townsend TN, et al. Racial/ethnic disparities in opioid overdose prevention: comparison of the naloxone care cascade in White, Latinx, and black people who use opioids in new York City. Harm Reduct J. 2023;20(1):24. https://doi.org/10.1186/s12954-023-00736-7
18. Nolen S, Zang X, Chatterjee A, Behrends CN, Green TC, Kumar A, et al. Community-based naloxone coverage equity for the prevention of opioid overdose fatalities in racial/ethnic minority communities in Massachusetts and Rhode Island. Addiction. 2022;117(5):1372–81. https://doi.org/10.1111/add.15759
19. Nolen S, Zang X, Chatterjee A, Behrends CN, Green TC, Linas BP, et al. Evaluating equity in community-based naloxone access among racial/ethnic groups in Massachusetts. Drug Alcohol Depend. 2022;241:109668. https://doi.org/10.1016/j.drugalcdep.2022.109668
20. Zang X, Walley AY, Chatterjee A, Kimmel SD, Morgan JR, Murphy SM, et al. Changes to opioid overdose deaths and community naloxone access among black, Hispanic and White people from 2016 to 2021 with the onset of the COVID-19 pandemic: an interrupted time-series analysis in Massachusetts, USA. Addiction. 2023;118(12):2413–23. https://doi.org/10.1111/add.16324
21. Substance Abuse and Mental Health Services Administration State Opioid Response Grants; 2023.
22. Sugarman OK, Hulsey EG, Heller D. Achieving the potential of naloxone saturation by measuring distribution. JAMA Health Forum: Am Med Assoc. 2023;4(10):e233338. https://doi.org/10.1001/jamahealthforum.2023.3338
23. Massachusetts behavioral health partnership MBHP Massachusetts Emergency Services Program Overview Presentation; 2016.
24. Merrall EL, Kariminia A, Binswanger IA, Hobbs MS, Farrell M, Marsden J, et al. Meta-analysis of drug-related deaths soon after release from prison. Addiction. 2010;105(9):1545–54. https://doi.org/10.1111/j.1360-0443.2010.02990.x
25. Kerr T, Fairbairn N, Tyndall M, Marsh D, Li K, Montaner J, et al. Predictors of non-fatal overdose among a cohort of polysubstance-using injection drug users. Drug Alcohol Depend. 2007;87(1):39–45. https://doi.org/10.1016/j.drugalcdep.2006.07.009
26. Brugal MT, Barrio G, Fuente LDL, Regidor E, Royuela L, Suelves JM. Factors associated with non-fatal heroin overdose: assessing the effect of frequency and route of heroin administration. Addiction. 2002;97(3):319–27. https://doi.org/10.1046/j.1360-0443.2002.00058.x
27. Darke S, Williamson A, Ross J, Mills KL, Havard A, Teesson M. Patterns of nonfatal heroin overdose over a 3-year period: findings from the Australian treatment outcome study. J Urban Health. 2007;84(2):283–91. https://doi.org/10.1007/s11524-006-9156-0
28. Helton JC, Davis FJ. Latin hypercube sampling and the propagation of uncertainty in analyses of complex systems. Reliabil Eng Syst Saf. 2003;81(1):23–69. https://doi.org/10.1016/S0951-8320(03)00058-9
29. Bird SM, Parmar MK, Strang J. Take-home naloxone to prevent fatalities from opiate-overdose: protocol for Scotland's public health policy evaluation, and a new measure to assess impact. Drugs: Educ Prev pol. 2015;22(1):66–76. https://doi.org/10.3109/09687637.2014.981509
30. Zang X, Macmadu A, Krieger MS, Behrends CN, Green TC, Morgan JR, et al. Targeting community-based naloxone distribution using opioid overdose death rates: a descriptive analysis of naloxone rescue kits and opioid overdose deaths in Massachusetts and Rhode Island. Int J Drug Policy. 2021;98:103435. https://doi.org/10.1016/j.drugpo.2021.103435
31. Moustaqim-Barrette A, Papamihali K, Mamdani Z, Williams S, Buxton JA. Accessing take-home naloxone in British Columbia and the role of community pharmacies: results from the analysis of administrative data. PLoS ONE. 2020;15(9):e0238618. https://doi.org/10.1371/journal.pone.0238618
32. Social Explorer Tables (SE). Census Census Bureau; 2020.
33. Substance Abuse and Mental Health Services Administration. National Survey on drug use and health: 2-year RDSA (2018-2019).
34. Barocas JA, White LF, Wang J, Walley AY, LaRochelle MR, Bernson D, et al. Estimated prevalence of opioid use disorder in Massachusetts, 2011–2015: a capture–recapture analysis. Am J Public Health. 2018;108(12):1675–81. https://doi.org/10.2105/AJPH.2018.304673
35. Behrends CN, Gutkind S, Winkelstein E, Wright M, Dolatshahi J, Welch A, et al. Costs of opioid overdose education and naloxone distribution in new York City. Subst Abus. 2021;43(1):1–7. https://doi.org/10.1080/08897077.2021.1986877
36. Behrends CN, Paone D, Nolan ML, Tuazon E, Murphy SM, Kapadia SN, et al. Estimated impact of supervised injection facilities on overdose fatalities and healthcare costs in new York City. J Subst Abuse Treat. 2019;106:79–88. https://doi.org/10.1016/j.jsat.2019.08.010
37. Savinkina A, Madushani RW, Eftekhari YG, Wang J, Barocas JA, Morgan JR, et al. Population-level impact of initiating pharmacotherapy and linking to care people with opioid use disorder at inpatient medically managed withdrawal programs: an effectiveness and cost-effectiveness analysis. Addiction. 2022;117(9):2450–61. https://doi.org/10.1111/add.15879
38. Murphy SM, McCollister KE, Leff JA, Yang X, Jeng PJ, Lee JD, et al. Cost-effectiveness of buprenorphine–naloxone versus extended-release naltrexone to prevent opioid relapse. Ann Intern Med. 2019;170(2):90–8. https://doi.org/10.7326/M18-0227
39. The White House. Circular no. A-4, regulatory analysis; 2023.
40. Friedman J, Shover CL. Charting the fourth wave: Geographic, temporal, race/ethnicity and demographic trends in polysubstance fentanyl overdose deaths in the United States, 2010–2021. Addiction. 2023;118(12):2477–85.
41. Mehra R, Franck LS. Structural racism and social distancing: implications for COVID-19. EClinicalMedicine. 2021;35:100869. https://doi.org/10.1016/j.eclinm.2021.100869
42. Massachusetts Department of Public Health. Massachusetts opioid-related overdose deaths rose 2.5 percent in 2022; 2023.
43. Rosales R, Janssen T, Yermash J, Yap KR, Ball EL, Hartzler B, et al. Persons from racial and ethnic minority groups receiving medication for opioid use disorder experienced increased difficulty accessing harm reduction services during COVID-19. J Subst Abuse Treat. 2022;132:108648.
44. Dayton L, Tobin K, Falade-Nwulia O, Davey-Rothwell M, Al-Tayyib A, Saleem H, et al. Racial disparities in overdose prevention among people who inject drugs. J Urban Health. 2020;97(6):823–30. https://doi.org/10.1007/s11524-020-00439-5

45. Massachusetts Bureau of Substance Addiction Services. Naloxone distribution program locator.
46. Volkow ND, Chandler RK, Villani J. Need for comprehensive and timely data to address the opioid overdose epidemic without a blindfold. Wiley Online Library. 2022;117(8):2132–4. https://doi.org/10.1111/add.15957
47. Mistler CB, Sullivan MC, Copenhaver MM, Meyer JP, Roth AM, Shenoi SV, et al. Differential impacts of COVID-19 across racial-ethnic identities in persons with opioid use disorder. J Subst Abuse Treat. 2021;129:108387. https://doi.org/10.1016/j.jsat.2021.108387
48. Schneider KE, Allen ST, Rouhani S, Morris M, Haney K, Saloner B, et al. Increased solitary drug use during COVID-19: an unintended consequence of social distancing. Int J Drug Policy. 2023;111:103923. https://doi.org/10.1016/j.drugpo.2022.103923
49. Simha S, Ahmed Y, Brummett CM, Waljee JF, Englesbe MJ, Bicket MC. Impact of the COVID-19 pandemic on opioid overdose and other adverse events in the USA and Canada: a systematic review. Reg Anesth Pain Med. 2023;48(1):37–43. https://doi.org/10.1136/rapm-2022-103591
50. Jalali A, Tamimi RM, McPherson SM, Murphy SM. Econometric issues in prospective economic evaluations alongside clinical trials: combining the nonparametric bootstrap with methods that address missing data. Epidemiol Rev. 2022;44(1):67–77. https://doi.org/10.1093/epirev/mxac006

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