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RESEARCH ARTICLE

Opioid Overdoses Increase at Home During the COVID-19 Stay-At-Home Order Period in Cook County, Illinois



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Introduction: Stay-at-home orders during the COVID-19 pandemic decreased population mobility to reduce SARS-CoV-2 infection rates. We empirically tested the hypothesis that this public health measure was associated with a higher likelihood of opioid- and stimulant-involved deaths occurring in homes located in Cook County, Illinois.

Methods: The stay-at-home period was from March 21, 2020 to May 30, 2020. We analyzed overdose data from the Cook County Medical Examiner's Office using a death location description from case investigations categorized as home, medical, motel, scene, and other. Two groups of decedents were defined as either having an opioid or stimulant listed in the primary cause of death field. We modeled a weekly time series to detect changes in deaths (number) and trends during segmented time periods. Chi-square or Fisher's exact and adjusted logistic regression was used for testing the differences between the stay-at-home and a 13-week preceding period.

Results: There were 4,169 and 2,012 opioid- and stimulant-involved deaths, respectively, from 2018 to 2020. Both groups were demographically similar: 75% male, 52% White, and aged 45 years (mean). In the 13 weeks before stay-at-home orders, 51% of opioid-involved deaths occurred in homes, which increased to 59% ($p < 0.0001$) during the 10 weeks of the order and decreased back to 51% in the 18 weeks after the order expired. For stimulant-involved deaths, 51% were residential immediately before the orders, with a nonsignificant increase to 52% during the stay-at-home period. Before the pandemic, there were 20 deaths/week, increasing to 37 deaths/week ($p < 0.0001$) during stay-at-home enactment. Deaths involving fentanyl among the opioid-involved group increased from 76% to 89%, whereas those involving heroin decreased from 55% to 37%. The adjusted OR for opioid-involved fatal overdoses occurring at home during this period compared with that occurring the 13 weeks before was 1.37 (95% CI=1.05, 1.79).

Conclusions: The likelihood of a death occurring at home, especially for people using opioids, increased during the stay-at-home order period. Findings have implications for mitigating overdose risks during social isolation.

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INTRODUCTION

The stay-at-home orders issued during early 2020 in response to the coronavirus disease 2019 (COVID-19) pandemic decreased population mobility to reduce the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).^{1–3} The impact of stay-at-home orders on people with substance use disorders was exacerbated for multiple reasons, including increased mental health stressors, reduced medication access, and social isolation.^{4,5} According to the U.S. Centers for Disease Control and Prevention (CDC), Cook County, Illinois, home to the city of Chicago, was ranked second in the number of fatal overdoses in 2020 with 1,927 deaths, representing 2% of the U.S. total.⁶ Furthermore, the county was ranked in the top 20% of all U.S. counties for drug overdoses per 100,000 people in 2018 and was predicted to transition to the top 10% according to one model.^{7,8}

County-level mobility data clearly show that the stay-at-home order, the 10-week period of March 21, 2020–May 30, 2020, restricted the movement of the general population in Cook County.⁹ During this time, the number of opioid-related deaths increased by 23% from a baseline of 35.1–43.4 per week in the county.¹⁰ Weekly overdoses declined after orders were lifted but remained elevated well into late 2020 relative to the pre-pandemic levels.⁵ The well-documented intense increase of drug overdoses during the stay-at-home-order period in this urban/suburban context provides an opportunity to understand additional epidemiologic features at the intersection of COVID-19 and the substance use epidemic such as changes in place-based risk factors¹¹ and differences by primary drug type. In this paper, we examine the reported locations of fatal overdoses in Cook County to determine whether the stay-at-home-order period was associated with a higher likelihood of opioid- and stimulant-involved deaths occurring in the home.

METHODS

Study Sample

We accessed the Cook County Medical Examiner's Office's publicly available data on March 9, 2022. This is a deidentified data set that has information about deaths that occurred in Cook County and were under the Medical Examiner's jurisdiction.¹² The cause of death was based on autopsy and toxicology findings.

Measures

A descriptive location of death (e.g., apartment, hospital, park) is routinely collected, and we requested it separately. We grouped locations into 5 categories: home, medical, motel, scene, and other (see the [Appendix](#) for classification rules). Locations described as

scene or missing values were classified as home only when the (1) geocoded street address of the overdose and death location matched exactly (95% of records) and (2) coordinates of the overdose address mapped to either a single-family or multifamily housing land-use category from the Chicago Metropolitan Agency for Planning's 2015 Land Use Inventory file (the most recent year available).¹³

We defined 2 groups of decedents by either having an opioid or having a stimulant listed in text as the primary cause of death. Drug counts are not mutually exclusive because some determinations include multiple drug classes co-listed in the primary cause of death. We created a customized and publicly available drug name extraction tool for this purpose.¹⁴ The prevalence of co-occurring substances in opioid/stimulant classes and specific substances such as fentanyl, heroin, benzodiazepines, cocaine, methamphetamine, amphetamine, and alcohol were included.

We specified 5 time frames for this study: (1) pre-pandemic period (January 1, 2018–December 15, 2019), (2) 13-week pre-order period (December 16, 2019–March 20, 2020), (3) 10-week stay-at-home-order period (March 21, 2020–May 30, 2020), (4) 18-week postorder period (May 31, 2020–October 6, 2020), and (5) 12-week remainder period (October 7, 2020–December 31, 2020). These time periods were defined around the stay-at-home order to capture stepwise changes in the number of deaths with an additional 12-week period to complete the time series for 2020.¹⁰

Statistical Analysis

An autoregressive model was used to account for temporal correlation (if necessary) in the weekly intensive time series and test for changes in the number of deaths and linear trends during the segmented time periods. Chi-square or Fisher's exact testing was used for testing the differences between the 10-week stay-at-home period and the 13-week pre-order period immediately preceding it. Logistic regression was used to examine the odds of fatal overdose at home using a parsimonious model adjustment for demographics, including age, race, and sex. SAS 9.4 software was used for all analyses.¹⁵ This data set is public and deidentified.¹²

RESULTS

In Cook County, Illinois, there were 4,169 opioid- and 2,012 stimulant-involved deaths (i.e., listed by the medical examiner as the primary cause of death) from January 1, 2018 to December 31, 2020. The highest number of opioid- and stimulant-involved deaths in Cook County for any week in this 3-year period occurred during the stay-at-home order: 57 and 34 fatal overdoses, respectively. In the 2-year pre-pandemic period, there were 20 opioid-involved deaths per week on average, which changed in a stepwise fashion: increasing first to 26 deaths/week ($p=0.0002$), then to 37 deaths/week ($p<0.0001$) during the stay-at-home order, and returning to pre-pandemic levels by the end of 2020. [Figure 1A](#) shows the number of weekly opioid- and stimulant-involved fatal overdoses from 2018 to 2020.

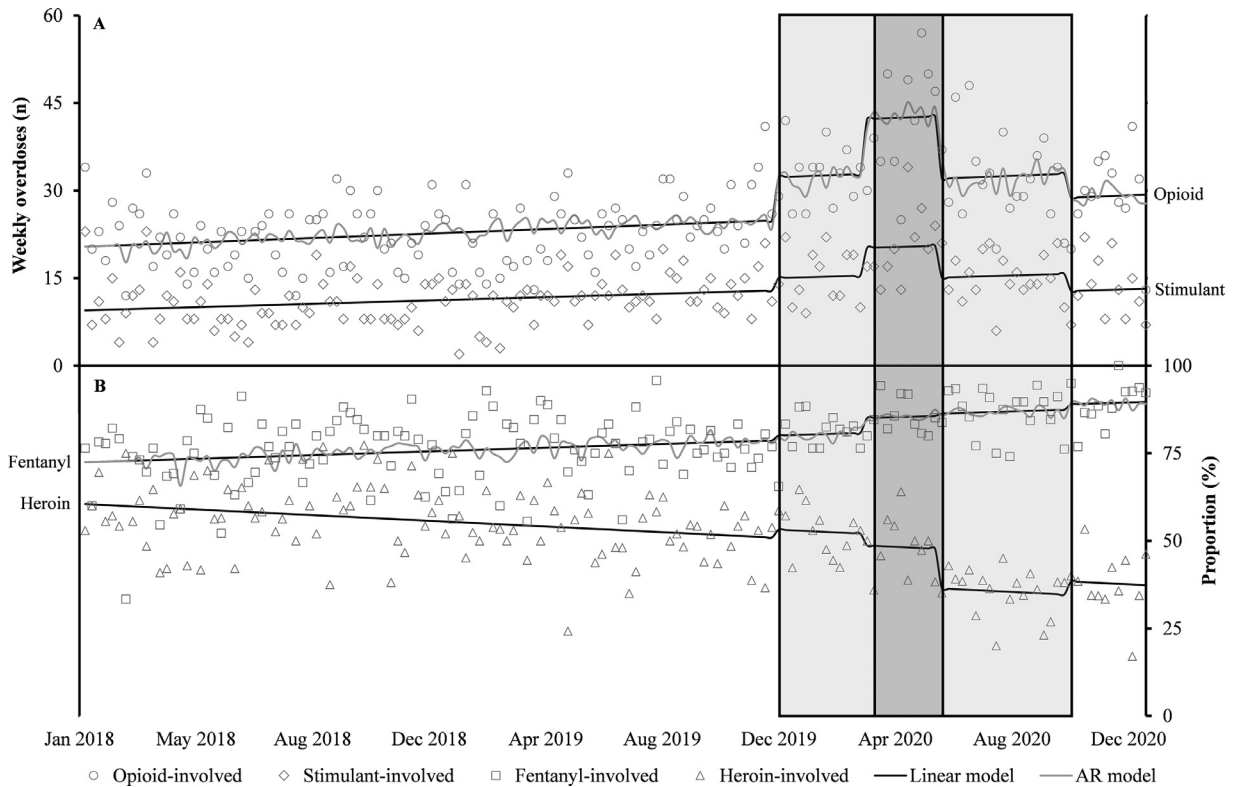


Figure 1. (A) Opioid- and stimulant-involved deaths, weekly counts, Cook County and Illinois, 2018–2020. (B) Percentage of opioid-involved deaths with fentanyl and heroin present. Linear and AR trendlines are shown with estimated level changes in periods (only the opioids and fentanyl series had a seasonal autoregressive component). The 10-week stay-at-home order period (March 21, 2020–May 30, 2020) is shown with the darkest shading.

Apr, April; AR, autoregressive; Aug, August; Dec, December; Jan, January.

The trend in opioid-involved deaths was increasing significantly by 0.05 deaths/week ($p=0.0176$) in the pre-pandemic period. For the opioid-involved weekly time series, we accounted for significant autocorrelation detected by the model. For stimulants, the pre-pandemic number of weekly deaths was 9.5, abruptly increasing during stay-at-home orders to 16.3 ($p=0.0001$) and immediately returning to pre-pandemic levels. The trend in stimulant-involved deaths was increasing significantly by 0.034 deaths/week ($p=0.0177$) in the pre-pandemic period.

For the demographics of opioid-involved deaths, 75% were male, 52% were White, the mean age was 45 years, the vast majority were accidental (97%), and 1.4% were coded as suicide. Trends in the presence of co-occurring drugs from the pre-pandemic period to the end of 2020 included proportional increases in fentanyl-involved cases (76%–89%), decreases in heroin (55%–37%), and benzodiazepine involvement (21%–13%). Figure 1B shows the weekly proportion of opioid-involved deaths attributable to fentanyl and heroin from 2018 to 2020.

The age, race, and sex demographic characteristics of the stimulant-involved decedents were similar to those of the opioid-involved decedents. Trends in the presence of co-occurring drugs in this group from the pre-pandemic period to the end of 2020 include increases in fentanyl (57%–75%) and methamphetamine (5.8%–8.6%) and decreases in heroin (42%–28%) and benzodiazepines (18%–9%). Table 1 shows the sociodemographic, location of death, and co-occurring drug characteristics of people with an opioid- or stimulant-involved fatal overdose in Cook County for the study period.

Immediately before stay-at-home orders, 51% of opioid-involved deaths occurred in residential locations, increasing to 59% ($p<0.0001$) during the order and decreasing back to 51% after the order expired (Figure 2). The adjusted OR (aOR) for opioid-involved fatal overdoses occurring at home during this period compared with that occurring the 13 weeks before was 1.37 (95% CI=1.05, 1.79) (Table 2). In this group, Black people were less likely to die at home than White people (aOR=0.80; CI=0.70, 0.91), as were males (aOR=0.86;

Table 1. Opioid- and stimulant-involved deaths by weekly periods, Cook County and Illinois, 2018–2020.

Characteristics	Opioid involved										Stimulant involved															
	Jan 1, 2018–Dec 15, 2019		Dec 15, 2019–Mar 20, 2020		Mar 21, 2020–May 30, 2020 (Stay at home)		May 31, 2020–Oct 6, 2020		Oct 7, 2020–Dec 31, 2020		2018–2020		p-value	Jan 1, 2018–Dec 15, 2019		Dec 15, 2019–Mar 20, 2020		Mar 21, 2020–May 30, 2020 (Stay at home)		May 31, 2020–Oct 6, 2020		Oct 7, 2020–Dec 31, 2020		2018–2020		p-value
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	
Sex																										
Male	1,728	(74.8)	331	(72.4)	329	(77.1)	473	(77.7)	282	(77.1)	3,143	(75.4)	0.1008	846	(74.3)	157	(73.0)	165	(79.7)	230	(79.6)	119	(73.0)	1,517	(75.4)	0.1063
Race/ethnicity																										
Black	1,032	(44.7)	236	(51.6)	204	(47.8)	282	(46.3)	189	(51.6)	1,943	(46.6)	0.5372	527	(46.3)	102	(47.4)	97	(46.9)	146	(50.5)	80	(49.1)	952	(47.3)	0.7871
White	1,257	(54.4)	214	(46.8)	216	(50.6)	319	(52.4)	176	(48.1)	2,182	(52.3)		598	(52.6)	108	(50.2)	107	(51.7)	139	(48.1)	83	(50.9)	1,035	(51.4)	
Other	21	(0.9)	7	(1.5)	7	(1.6)	8	(1.3)	1	(0.3)	44	(1.1)		13	(1.1)	5	(2.3)	3	(1.5)	4	(1.4)	.	.	25	(1.2)	
Age group, years																										
0–24	138	(6.0)	24	(5.3)	31	(7.3)	39	(6.4)	16	(4.4)	248	(6.0)	0.1186	35	(3.1)	11	(5.1)	6	(2.9)	15	(5.2)	3	(1.8)	70	(3.5)	0.2009
25–34	421	(18.2)	68	(14.9)	87	(20.4)	96	(15.8)	62	(16.9)	734	(17.6)		220	(19.3)	36	(16.7)	48	(23.2)	42	(14.5)	28	(17.2)	374	(18.6)	
35–44	472	(20.4)	88	(19.3)	79	(18.5)	129	(21.2)	75	(20.5)	843	(20.2)		264	(23.2)	54	(25.1)	37	(17.9)	66	(22.8)	50	(30.7)	471	(23.4)	
45–54	641	(27.8)	126	(27.6)	107	(25.1)	169	(27.8)	87	(23.8)	1,130	(27.1)		324	(28.5)	47	(21.9)	53	(25.6)	80	(27.7)	34	(20.9)	538	(26.7)	
55–64	522	(22.6)	116	(25.4)	86	(20.1)	136	(22.3)	99	(27.1)	959	(23.0)		245	(21.5)	53	(24.7)	47	(22.7)	72	(24.9)	40	(24.5)	457	(22.7)	
≥65	113	(4.9)	33	(7.2)	37	(8.7)	38	(6.2)	27	(7.4)	248	(6.0)		47	(4.1)	13	(6.1)	16	(7.7)	13	(4.5)	8	(4.9)	97	(4.8)	
Location of death																										
Home	1,209	(52.3)	235	(51.4)	252	(59.0)	311	(51.1)	197	(53.8)	2,204	(52.9)	<0.0001	563	(49.5)	109	(50.7)	108	(52.2)	134	(46.4)	76	(46.6)	990	(49.2)	0.2617
Medical	663	(28.7)	143	(31.3)	75	(17.6)	144	(23.7)	94	(25.7)	1,119	(26.8)		346	(30.4)	65	(30.2)	46	(22.2)	74	(25.6)	48	(29.5)	579	(28.8)	
Motel	77	(3.3)	20	(4.4)	17	(4.0)	31	(5.1)	11	(3.0)	156	(3.7)		56	(4.9)	11	(5.1)	12	(5.8)	19	(6.6)	7	(4.3)	105	(5.2)	
Other	207	(9.0)	30	(6.6)	46	(10.8)	65	(10.7)	29	(7.9)	377	(9.0)		101	(8.9)	16	(7.4)	25	(12.1)	33	(11.4)	12	(7.4)	187	(9.3)	
Scene	154	(6.7)	29	(6.4)	37	(8.7)	58	(9.5)	35	(9.6)	313	(7.5)		72	(6.3)	14	(6.5)	16	(7.7)	29	(10.0)	20	(12.3)	151	(7.5)	
Co-occurring drugs																										
Fentanyl	1,753	(75.9)	367	(80.3)	364	(85.3)	531	(87.2)	325	(88.8)	3,340	(80.1)	0.0543	653	(57.4)	135	(62.8)	150	(72.5)	204	(70.6)	123	(75.5)	1,265	(62.9)	0.0339
Heroin	1,277	(55.3)	243	(53.2)	202	(47.3)	219	(36.0)	134	(36.6)	2,075	(49.8)	0.0874	484	(42.5)	85	(39.5)	75	(36.2)	71	(24.6)	46	(28.2)	761	(37.8)	0.4845
Any stimulant/opioid	879	(38.1)	167	(36.5)	176	(41.2)	236	(38.8)	135	(36.9)	1,593	(38.2)	0.1460	879	(77.2)	167	(77.7)	176	(85.0)	236	(81.7)	135	(82.8)	1,593	(79.2)	0.0530
Cocaine	795	(34.4)	148	(32.4)	165	(38.6)	213	(35.0)	119	(32.5)	1,440	(34.5)	0.0488	1,023	(89.9)	193	(89.8)	191	(92.3)	259	(89.6)	144	(88.3)	1,810	(90.0)	0.3692
Methamphetamine	49	(2.1)	15	(3.3)	6	(1.4)	21	(3.5)	12	(3.3)	103	(2.5)	0.0787	66	(5.8)	17	(7.9)	10	(4.8)	23	(8.0)	14	(8.6)	130	(6.5)	0.1968
Amphetamine	49	(2.1)	8	(1.8)	5	(1.2)	9	(1.5)	9	(2.5)	80	(1.9)	0.5813	57	(5.0)	9	(4.2)	7	(3.4)	13	(4.5)	10	(6.1)	96	(4.8)	0.8004
Benzodiazepines	481	(20.8)	65	(14.2)	69	(16.2)	94	(15.4)	46	(12.6)	755	(18.1)	0.4140	207	(18.2)	30	(14.0)	26	(12.6)	41	(14.2)	15	(9.2)	319	(15.9)	0.6732
Alcohol	642	(27.8)	102	(22.3)	103	(24.1)	160	(26.3)	96	(26.2)	1,103	(26.5)	0.5133	350	(30.8)	59	(27.4)	64	(30.9)	72	(24.9)	47	(28.8)	592	(29.4)	0.4322
Total	2,310		457		427		609		366		4,169			1,138		215		207		289		163		2,012		

Note: Boldface indicates statistical significance ($p < 0.05$). Stay-at-home order period was March 21, 2020–May 30, 2020. Statistical testing for differences between italicized periods corresponding to the 10-week stay-at-home period and the preceding 13-week period. The following listed drugs were used to identify opioids: opioid/opiate, heroin, methadone, hydromorphone, morphine, oxymorphone, oxycodone, hydrocodone, butorphanol, codeine, buprenorphine, meperidine, nalbuphine, tramadol, tapentadol, pentazocine, dihydrocodeine, levomethorphan, levorphanol, U-47700, U-49900, fentanyl, acetyl fentanyl, ANPP, butryl, carfentanil, cyclopropyl, FIBF, furanyl, methoxyacetyl, norfentanyl, FBF, and valeryl fentanyl; the following listed drugs were used to identify stimulants: cocaine, amphetamine, methamphetamine, methylphenidate, cathinone, mitragynine, topiramate, and phentermine. There were 5 missing/unknown sex and 7 missing age group for opioids and 5 missing age group for stimulants. ANPP, Anilino-N-phenethyl-piperidine; Dec, December; FBF, fluorobutryl fentanyl; FIBF, fluoroisobutryl fentanyl; Jan, January; Mar, March; Oct, October.

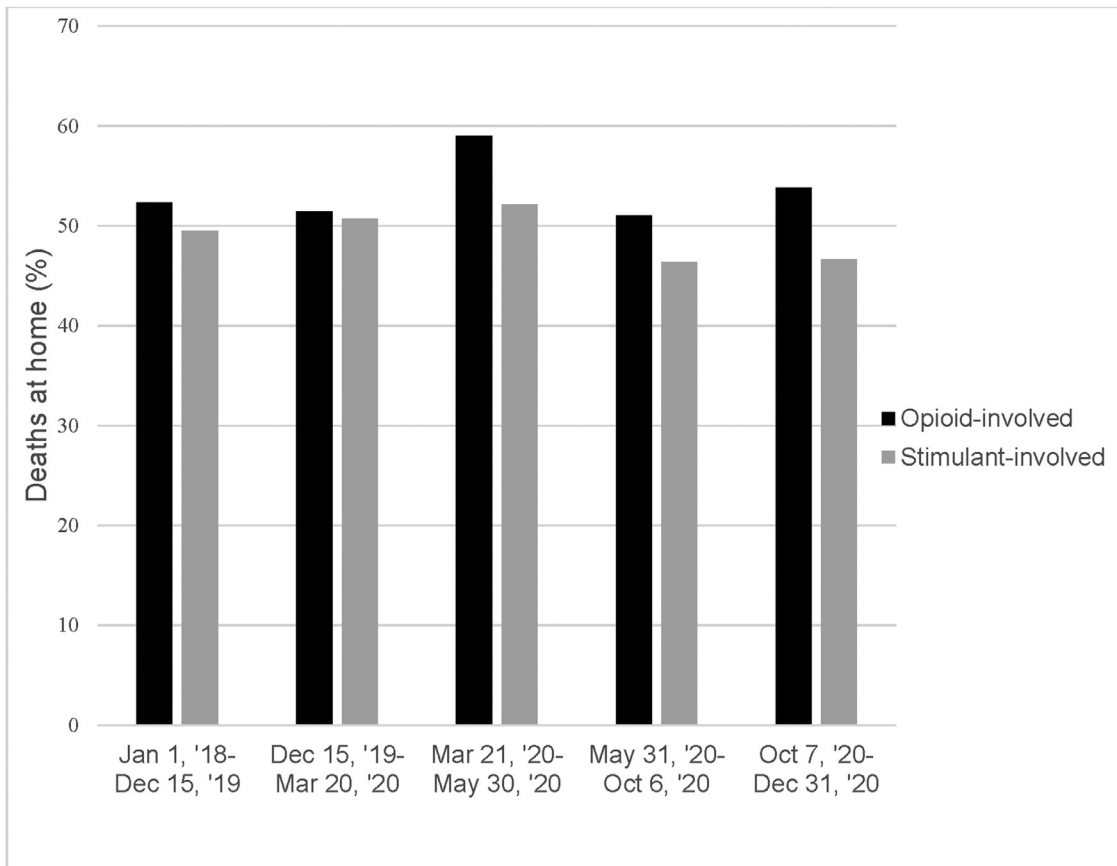


Figure 2. Percentage of opioid- and stimulant-involved fatal overdoses attributed to homes by period, Cook County, Illinois, 2018–2020. The stay-at-home order period was Mar 21, 2020–May 30, 2020.

Dec, December; Jan, January; Mar, March; Oct, October.

95% CI=0.75, 0.99). Medical facilities accounted for only 17.6% of opioid-involved deaths during the stay-at-home period, decreasing from 31.2% in the preorder period. For stimulant-involved deaths, 50.7% occurred at home locations immediately before the order, with a nonsignificant increase to 52.2% during the stay-at-home period. Deaths involving stimulants at medical facilities declined from 30.2% to 22.2% of the total from the preorder to the stay-at-home-order period, respectively.

DISCUSSION

There were 427 opioid-involved deaths during the enactment of the stay-at-home order in Cook County, Illinois, with 59% of these people found at home. The odds of dying at home were 37% greater in this period than in the preorder period. The proportional increase to home locations was modest for stimulant-involved deaths and similar to location changes seen in all-cause mortality at the national level (unpublished data from CDC).⁶ These

dynamics are consistent with decreasing use of medical facilities during the early phases of the COVID-19 pandemic. Although it may now seem obvious that deaths at home could increase with mobility restrictions, we tested this hypothesis empirically and further found variability by drug type.

The intersection of social isolation, the potential fear of seeking medical treatment during the COVID-19 pandemic, geographic context, and the intervening influence of emergency medical services during this time is complex. For example, a study of Chicago area emergency department (ED) presentations reported no increase in the number of opioid-related visits immediately after the pandemic started. Likewise, in a sample of Washington, District of Columbia/Baltimore area EDs, opioid overdoses did not increase (although other drug overdoses did).^{16,17} Our findings could be consistent with those of these studies because if more people have fatal opioid overdoses at home, then transport to the ED is unnecessary. However, research from Kentucky showed that EMS transports for opioid overdoses increased by 17%,

Table 2. ORs Estimates and 95% CIs for Fatal Overdoses Occurring in the Home During the Stay-At-Home-Order Period, Cook County and Illinois, 2018–2020

Opioid involved			
Effect	OR	95% Wald confidence limits	
Demographics			
Age	1.010	1.005	1.015
Black versus White	0.798	0.697	0.913
Other versus White	0.891	0.481	1.649
Male versus female	0.860	0.746	0.993
Time periods			
Prepandemic versus before	1.033	0.844	1.265
Stay-at-home versus before	1.371	1.049	1.792
After versus before	0.988	0.774	1.262
Remainder 2020 versus before	1.101	0.835	1.452
Stimulant involved			
Effect	OR	95% Wald confidence limits	
Demographics			
Age	1.011	1.003	1.019
Black versus White	0.824	0.675	1.006
Other versus White	1.477	0.655	3.327
Male versus female	0.897	0.731	1.101
Time periods			
Prepandemic versus before	0.952	0.710	1.276
Stay-at-home versus before	1.062	0.724	1.559
After versus before	0.852	0.597	1.215
Remainder 2020 versus before	0.854	0.567	1.287

Notes: *Before* refers to the 13-week period immediately before stay-at-home orders, December 15, 2019–March 20, 2020.

and national data also showed sharp weekly increases in opioid overdoses after the start of the pandemic.^{18,19}

Findings that opioid-involved deaths were more likely to occur at home than stimulant-involved deaths may reflect the underlying differences in social determinants between these populations associated with their use of opioid and stimulant combinations. Specifically, in terms of housing stability, Barocas et al.²⁰ found that people experiencing a fatal overdose involving stimulants were more likely to be homeless than those experiencing overdoses involving opioids alone, and a national study found that respondents who used methamphetamine alone were more likely to have unstable housing than those who used opioids alone.²¹ A larger proportion of patients with opioid use disorder were found to have unstable housing if they were also positive for amphetamines.²² Likewise, around 30% of people with opioid

use disorder experiencing homelessness reported stimulant abuse compared with 9% among those with stable housing.²³ Thus, our findings may reflect the reality that people who use stimulants were less likely to die from those drugs at home during the pandemic because they were less likely to have homes to die in. We could not effectively examine these underlying causes of housing instability or homelessness with the available open data beyond an occasional note from the medical examiner's case investigation in the location of death field. Future research will involve extracting these social determinants of health from case investigation notes using natural language processing.²⁴

Previous studies from Cook County left the question as to whether opioid-involved deaths were accelerating before stay-at-home orders unanswered.^{5,10} We found that opioid- and stimulant-involved deaths were indeed increasing weekly from 2018 to 2019.¹⁰ Although the COVID-19 pandemic and isolation have made the substance use epidemic worse by many metrics, a return to the intensifying prepandemic norms is not ideal. Unfortunately, Cook County data for 2021 show that annual deaths from opioids and stimulants have surpassed 2020 levels, which appears to be a national trend according to CDC's provisional data as of November 2021.²⁵

Opposing trends in the proportional contributions to opioid-involved mortality attributable to fentanyl and heroin continued unabated throughout this period. There is some compelling visual evidence (Figure 1) that abrupt changes in the heroin supply occurred immediately after the stay-at-home order. By the end of 2020, fentanyl was involved in 89% of opioid-involved overdoses, a level maintained in Cook County in 2021 (unpublished analysis from this data set). Research on fentanyl-involved deaths in Cook County found that these fatalities were concentrated in more socially deprived neighborhoods.¹¹ Recent declines in the apparent prevalence of heroin are consistent with the findings of several studies.^{5,26–28}

Our study relied on medical examiner investigation notes, which are valuable for rapidly identifying the location of overdose fatalities and showed sensitivity to large-scale shifts in population mobility. This information can help to target specific places for intervention. For example, we found that approximately 156 (3.7%) and 105 (5.2%) of opioid- and stimulant-involved deaths, respectively, occurred at motels or hotels, with 23 of these location addresses detected more than once. These locations could be local hot spots suitable for naloxone kit placement. The Cook County data have both street addresses for incident and death locations; further research comparing these locations is possible. Linking

addresses to land-use files in the absence of medical examiner–described locations may be a viable alternative to monitoring place-based risk factors.

Limitations

Our weekly counts may differ slightly from previous reports owing to either increased sensitivity in our newer methods to detect drugs from text written in the cause of death field, the continuously updated open data file, and/or our counts derived from regression models. Overall, the proportion of opioid- and stimulant-involved deaths occurring at home in Cook County was lower than that reported for 25 states from January 2019 to June 2019 (79.9% for any home setting).²⁹ Our results remained unchanged when we restricted the data to this time frame. This difference highlights the fact that CDC, states, and other jurisdictions may document these locations differently. Our categorization of the location of death is subject to misclassification owing to judgments made about nonspecific locations (e.g., bathroom). Our categories for opioid- and stimulant-involved deaths were not mutually exclusive.

Future localized studies could address other changes occurring during this period that would impact drug use behavior in the home, such as illegal offline and online drug market restructuring including the increased use of alcohol delivery services.^{30,31}

CONCLUSIONS

The stay-at-home order time period in Cook County increased the likelihood that a fatal overdose would occur at home for people dying from opioids compared with that for those dying from stimulants. This work has implications for detecting, mitigating, and responding to overdose risks during times of social isolation and drug use behaviors occurring in the home.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at [doi:10.1016/j.focus.2022.100007](https://doi.org/10.1016/j.focus.2022.100007).

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