

Overdose as a complex contagion: Modeling the community spread of overdose events following law enforcement efforts to disrupt the drug market.

Supplementary Materials

Sample Characteristics	2
Table S1. Sample characteristics	2
Figure S1. Spatial patterning of endemic variables.....	3
Model Diagnostics.....	4
Figure S2. Estimates of the scaled spatial (A1–A6) and temporal (B1-B6) step functions with 95% Monte Carlo confidence intervals.	5
Figure S3. The empirical cumulative density function of U_i , or the standardized residuals according to Ogata ¹ , with 95% Kolmogorov-Smirnov confidence bands (right side of each panel). A scatterplot of U_i and U_{i+1} to look for serial correlation (left side of each panel). ..	6
Table S2. Basic reproduction number and number of converged permutations for each twinstim model.	7
Table S3. Standard Knox test of spatiotemporal clustering for each twinstim model.	8
References	9

Sample Characteristics

Table S1. Sample characteristics

	Overall	Exposed	Unexposed
Outcome			
Nonfatal overdose events, n (%)	6442	459 (7.1%)	5983 (92.9%)
Epidemic measure			
Opioid-related drug seizures, n (%)	1926	-	-
Endemic measures			
COVID-19 lockdown period, n (%)	476 (7.4%)	26 (5.7%)	450 (7.0%)
Season			
Spring, n (%)	1621 (25.2%)	106 (23.1%)	1515 (25.3%)
Summer, n (%)	1959 (30.4%)	172 (37.5%)	1787 (29.9%)
Fall, n (%)	1606 (24.9%)	97 (21.1%)	1509 (25.2%)
Winter, n (%)	1256 (19.5%)	84 (18.3%)	1172 (19.6%)
Historical Redlining			
A – Best, n (%)	45 (0.7%)	0 (0.0%)	45 (0.8%)
B – Still Desirable, n (%)	505 (7.8%)	30 (6.5%)	475 (7.9%)
C – Definitely Declining, n (%)	1993 (30.9%)	91 (19.8%)	1902 (31.8%)
D – Hazardous, n (%)	1693 (26.3%)	116 (25.3%)	1577 (26.4%)
Mixed, n (%)	988 (15.3%)	123 (26.8%)	865 (14.5%)
Missing – suburban areas, n (%)	1218 (18.9%)	99 (21.6%)	1119 (18.7%)
Neighborhood Deprivation Index, mean (SD)	0.49 (1.00)	0.3 (1.2)	0.5 (1.0)
% Vacant households, mean (SD)	17.2 (12.7)	16.2 (11.9)	17.3 (12.7)

SD = standard deviation. Exposed refers to the number of nonfatal overdose events that occurred within 250 meters and 14 days of an opioid-related drug seizure, total and by endemic measure. Unexposed refers to the number of nonfatal overdose events that were not exposed to an opioid-related drug seizure within 250 meters and 14 days.

Figure S1. Spatial patterning of endemic variables.

Model Diagnostics

Step functions (Figure S2) were used to model both spatial and temporal interactions. Visual inspection of the pair correlation functions indicates that the data is significantly clustered in space and time.

To inspect goodness of fit of the twinstim models, we follow the suggestion by Ogata¹ by computing the residuals, or the fitted cumulative intensities over time, and transforming them to fit a uniform distribution (Figure S3). The transformed residuals with a 95% confidence band obtained by inverting the corresponding Kolmogorov-Smirnov test demonstrates no evidence for deviation from uniformity. The serial correlation plots suggests absence of serial correlation. Taken together, the fit of each twinstim model appears good with no noticeable deviations.

Figure S2. Estimates of the scaled spatial (A1–A6) and temporal (B1-B6) step functions with 95% Monte Carlo confidence intervals.

Figure S3. The empirical cumulative density function of U_i , or the standardized residuals according to Ogata¹, with 95% Kolmogorov-Smirnov confidence bands (right side of each panel). A scatterplot of U_i and U_{i+1} to look for serial correlation (left side of each panel).

Table S2. Basic reproduction number and number of converged permutations for each twinstim model.

Space-Time Kernel	R_0	Number Converged Permutations
100 Meters		
3 Days	0.05	914
7 Days	0.07	984
14 Days	0.11	999
250 Meters		
3 Days	0.06	992
7 Days	0.09	922
14 Days	0.15	710

For each space-time kernel, we estimated a twinstim model with all endemic predictors and no epidemic predictors was compared to 1000 permuted null models with randomly shuffled event times.² For each permutation we estimated the reproduction number (R_0), or the expected average number of future nonfatal overdoses that a nonfatal overdose triggers, which represents “infectivity”. A p-value was calculated by comparing the observed R_0 with the null distribution of the subset of permutations that converged. The likelihood ratio tests comparing the epidemic to the endemic twinstim models were significant at $p < 0.0001$.

Table S3. Standard Knox test of spatiotemporal clustering for each twinstim model.

		Space (Meters)		p-value	
		<= 100	>100		
Time (Days)	<=3	398	176,459	<0.0001	
	>3	16,550	20,488,689		
	<=7	650	410,482	<0.0001	
	>7	16,298	20,254,666		
	<=14	1,064	818,990	<0.0001	
	>14	15,884	19,846,158		
			<= 250	>250	
	<=3	596	176,346	<0.0001	
	>3	41,376	20,463,778		
	<=7	1,089	410,211	<0.0001	
	>7	40,883	20,229,913		
	<=14	2,071	817,788	<0.0001	
>14	39,901	19,822,336			

References

1. Ogata, Y. (1988). Statistical models for earthquake occurrences and residual analysis for point processes. *Journal of the American Statistical Association*, 83, 9:27.
2. Meyer S, Warnke I, Rössler W, Held L (2016) Model-based testing for space-time interaction using point processes: an application to psychiatric hospital admissions in an urban area. *Spat Spatio-Temporal Epidemiol* 17:15–25