



Original article

County-level socioeconomic factors and residential racial, Hispanic, poverty, and unemployment segregation associated with drug overdose deaths in the United States, 2013–2017



Cara L. Frankenfeld, PhD ^{a,*}, Timothy F. Leslie, PhD ^b

^a Department of Global and Community Health, George Mason University, Fairfax, VA

^b Department of Geography and Geoinformation Science, George Mason University, Fairfax, VA

ARTICLE INFO

Article history:

Received 16 January 2019

Accepted 25 April 2019

Available online 30 April 2019

Keywords:

Drug overdose

Race

Poverty

Unemployment

Residential segregation

ABSTRACT

Purpose: The purpose of the study was to evaluate overdose death rates in relation to socioeconomic characteristics and measures of socioeconomic residential segregation at substate geography.

Methods: County overdose deaths were linked to socioeconomic characteristics that are related to social vulnerability. Dissimilarity and isolation segregation (comparing individual counties to the adjacent counties and state) and diversity were calculated for race, Hispanic ethnicity, poverty, and unemployment. Negative binomial regression was used to compare county characteristics to death rates.

Results: Percent civilian disabled was positively associated with mortality across race and Hispanic ethnicity groups. Some discordant associations included racial and unemployment diversity (null for White, inverse for Hispanic and Black), percent unemployment (positive for White, inverse for Hispanic), percent crowded housing (positive for Black), uninsured (null for White, inverse for Black and Hispanic), and per capita income (positive for Black, inverse for Hispanic). Several residential segregation measures were also significantly associated with overdose death rates, and different magnitudes and directions of associations were observed by race and Hispanic ethnicity.

Conclusions: These results provide future directions, including roles of civilian disability, diversity, and evaluating differential impacts of segregation across racial and ethnic groups. Individual-level data, drug overdose incidence, or larger studies to evaluate interactions may help to elucidate mechanisms.

© 2019 Elsevier Inc. All rights reserved.

Introduction

The United States has seen an increase of drug overdose deaths from 1999 to 2014, with an estimated 16.3 per 100,000 overdose deaths occurring in 2014 [1], and overdose deaths have tracked along an exponential growth curve since at least the 1970s [2]. There are considerable state-by-state differences in death rates, with highest rates observed in West Virginia, New Hampshire, Kentucky, Ohio, and Rhode Island and lowest rates in Iowa, Texas, North Dakota, South Dakota, and Nebraska [1]. Notable county-level mortality variation exists within some states, such as ranges of too few to quantitate up to 81 per 100,000 in West Virginia, 79 per 100,000 in Kentucky, 23 per 100,000 in New Hampshire, and 28

per 100,000 in Texas [3]. Geography at different levels is an important factor associated with mortality in the United States for many cause-specific mortality outcomes [4–12], and these observations indicate a need to evaluate lower than state-level factors associated with drug overdose deaths.

Where people live influences health outcomes, including drug use and abuse [13–17]. Van Handel et al. observed notable geographic variation at the county level in acute Hepatitis C infection (a proxy for injection drug use), and infection rates were associated with social factors, including per capita income and White, non-Hispanic race–ethnicity [17]. There are many factors that comprise environment, including physical conditions and social structure [18,19]. Social structure takes on different forms, including absolute conditions (e.g., the proportion of people in poverty) and relative conditions (e.g., how the proportion of people in poverty in the near environment differ from the larger environment). Residential segregation reflects relative conditions. There is evidence to support that residential segregation may influence health outcomes differentially across social groups [20]. For

* Corresponding author. Department of Global and Community Health, George Mason University, 4400 University Drive, Fairfax, VA 22030. Tel.: +1-703-993-1911; fax: +1-703-993-1908.

E-mail address: cfranken@gmu.edu (C.L. Frankenfeld).

example, opposing directions of association across Black and Hispanic groups have been observed for cardiovascular disease [21] and birth outcomes [22], but little is known about residential segregation and drug abuse and associated conditions. These observations support the importance of evaluating absolute and relative conditions and considering different types of relative conditions for health outcomes across different socioeconomic groups.

Most overdose deaths occur in individuals who have some sort of drug dependence disorder [23,24]. Risk factors for drug addiction or dependence include family history, being male, coexisting mental health condition, peer pressure, lack of family involvement, and anxiety, depression, or loneliness [25–27]. Several of these factors are known to be associated with social support [28–34]. The underlying hypothesis that is driving the analysis is that residential segregation may serve as a proxy for social support [35–37], and the objective of this analysis was to evaluate overdose death rates in relation to county-level social, economic, and household characteristics and measures of residential segregation for race, Hispanic ethnicity, poverty, and unemployment. Counties are a good level of geography to study overdose deaths as they capture many aspects of geographically similar conditions that may contribute to mitigate overdose mortality.

Materials and methods

County-level overdose deaths were obtained from the Centers for Disease Control and Prevention (CDC Wonder) Underlying Cause of Death, 1999–2015 dataset (<https://wonder.cdc.gov>). Data for the years 2010–2015 for total deaths, deaths by race, and deaths by Hispanic ethnicity were abstracted for deaths with underlying ICD-10 codes: X40–44, X60–64, X85, Y10–14. Other racial groups were not included in the analysis due to insufficient number of counties with high enough death counts and population for analysis. This article does not contain any studies with human participants performed by any of the authors and is considered not human subjects research.

There are no agreed on covariates for geographic deprivation or social characteristics in the literature, and we used the Social Vulnerability Index as a guide. The Agency for Toxic Substances and Disease Registry Social Vulnerability Index is a tool created to

identify and map communities that will most likely need support before, during, and after a hazardous event [38]. Data obtained from the American Community Survey (2010–2014), 5-year data, for the social characteristics are listed in Table 1.

Residential segregation is a multifaceted concept, and isolation and dissimilarity were evaluated because of the availability of calculations that allow for an estimate of the segregation of that county compared with a larger geographic area [39]. Adjacent counties (touching by land border) and state were considered the larger geographic areas for each county. Five-year data from the American Community Survey (2010–2014) were used to calculate measures of racial, ethnic, unemployment, and poverty segregation for dissimilarity, isolation, and diversity, using the method by Oka and Wong 2014 [39]. Dissimilarity, as a measure of evenness, was calculated as the absolute value of the difference between (1) the composite population one group in the county divided by the composite population of that county plus the adjacent counties (or state) and (2) the composite population another group (e.g., Black) in the county divided by the composite population of that county plus the adjacent counties (or state). Isolation was calculated as one minus (1) the difference in total population minus a group (e.g., Black) at the county level divided by (2) the difference in total population minus the group population for the county and adjacent counties (or state). There is a limited literature to guide our analyses, and the comparison of adjacent counties and state analyses can help to inform future analyses. Albeit limited particular by differences in sizes of counties, county-to-adjacent county may provide a more neighborhood perspective of comparisons, and county-to-state comparisons may provide some perspective about differences in state-level policies versus county policies or programs.

Diversity was calculated as the negative of the summation of the percentage of mutually exclusive groups multiplied by its natural logarithm [39]. Racial diversity and Hispanic diversity estimates were calculated and used in the analysis. The mutually exclusive groups for racial diversity were White, Black, Asian, and others. The mutually exclusive groups for Hispanic diversity were Hispanic, non-Hispanic White, and other non-Hispanic race. Mutually exclusive groups for poverty were based on categories of poverty-to-income ratio: 0–0.49, 0.50–0.99, 1.00–1.24, 1.25–1.49, 1.50–1.84, 1.85–1.99, and, 2.00 or greater. Mutually exclusive groups for unemployment were unemployed and employed.

Table 1
Social vulnerability characteristics by categories of total overdose death rates and incidence rate ratios (IRRs) with overdose death rates

County characteristics*	Counties with >10 total deaths (n = 2067)		With >10 deaths in White, Black, and Hispanic subgroup (n = 164)		Imputed total deaths (n = 3142)	
	Mean (minimum to maximum)	IRR (95% CI)†	Mean (minimum to maximum)	IRR (95% CI)	Mean (minimum to maximum)	IRR (95% CI)
Less than poverty (%)	16.5 (3.7–42.5)	0.958 (0.925, 0.992)	16.4 (1.8–48.7)	0.999 (0.956, 1.043)	14.2 (4.6–30.5)	0.957 (0.869, 1.054)
Unemployed (%)	7.5 (0.3–21.8)	1.138 (1.079, 1.201)	7.1 (0–29.9)	1.031 (0.965, 1.101)	7.7 (4.4–15.7)	1.140 (0.958, 1.357)
Mean per capita income (\$)	2.5 (1.1–6.7)	1.048 (0.982, 1.118)	2.5 (1–6.7)	1.171 (1.071, 1.280)	3.2 (1.9–6.7)	1.011 (0.892, 1.147)
No high school diploma (%)	14 (2.1–41.5)	1.037 (1.002, 1.073)	14.2 (1.3–51.5)	0.972 (0.931, 1.014)	12.2 (4.7–31.4)	1.208 (1.063, 1.373)
Age ≥65 y (%)	16.6 (7–53.1)	0.941 (0.903, 0.981)	17.6 (3.9–53.1)	0.968 (0.915, 1.024)	14.2 (8.2–34)	1.006 (0.901, 1.122)
Age ≤17 y (%)	22.6 (7.5–36.1)	0.911 (0.857, 0.968)	22.6 (1.1–40.3)	0.943 (0.868, 1.025)	23 (13.5–30.1)	0.717 (0.607, 0.847)
Civilian disabled (%)	15.7 (4.7–36.9)	1.250 (1.199, 1.303)	15.8 (4.7–36.9)	1.226 (1.164, 1.292)	11.8 (6.7–18.1)	1.226 (1.000, 1.504)
Single-parent household (%)	8.9 (2.3–20)	1.057 (0.990, 1.128)	8.5 (0–25.5)	0.928 (0.853, 1.010)	9.6 (3.7–20)	1.259 (1.005, 1.578)
Racial/ethnicity minority (%)	22.9 (0.4–97.2)	0.979 (0.971, 0.988)	22.9 (0–99.2)	0.980 (0.969, 0.992)	41.1 (13.9–90.4)	0.964 (0.941, 0.987)
Speak English less than well (%)	1.8 (0–27)	1.008 (0.941, 1.081)	1.8 (0–32.7)	1.077 (0.990, 1.173)	4.8 (0.4–21.7)	0.750 (0.649, 0.867)
Multiunit structures (%)	5.7 (0–89.6)	0.991 (0.965, 1.017)	4.6 (0–89.6)	0.951 (0.916, 0.987)	15.2 (1.9–89.6)	0.985 (0.941, 1.031)
Mobile homes (%)	12.4 (0–53.9)	0.968 (0.952, 0.984)	13 (0–63.1)	0.977 (0.956, 0.998)	3.2 (0–21.7)	0.847 (0.783, 0.916)
Crowding (%)	2.4 (0–14.5)	0.848 (0.775, 0.929)	2.4 (0–37.9)	0.872 (0.791, 0.961)	3.2 (0.7–12.8)	0.964 (0.780, 1.191)
No vehicle available (%)	6.7 (0.5–77.3)	1.067 (1.030, 1.106)	6.5 (0–77.3)	1.100 (1.051, 1.151)	9.7 (2.7–77.3)	1.009 (0.964, 1.055)
Group quarters (%)	3.2 (0–35.6)	0.900 (0.868, 0.933)	3.5 (0–59.3)	0.930 (0.890, 0.971)	2.4 (0.4–8.5)	0.908 (0.744, 1.109)
Uninsured (%)	11.8 (2.1–40.7)	0.970 (0.938, 0.999)	12.3 (2.1–52)	1.060 (1.016, 1.106)	10.7 (2.1–23.8)	1.000 (0.907, 1.095)

CI = confidence intervals.

* Characteristics are included in negative binomial regression models in 5-unit increments, except for per capita income, which is included as \$10,000 unit.

† Characteristics in the table are mutually (multivariable) adjusted for the other characteristics in this table in negative binomial regression models.

Our goal was to look at a more neighborhood level of geography, but the evaluation of overdose deaths at lower levels of geography is challenged by suppressed death counts ($n < 11$), and county is the smallest geographic unit with a reasonable number of unsuppressed counts for analysis. A two-prong approach was taken to evaluate residential segregation and total overdose deaths: (1) evaluation in counties with more than 10 deaths ($n = 2067$), and (2) evaluation in all counties with deaths imputed for counties with less than 11 deaths ($n = 3142$). A multiple imputation approach was taken by 100 iterations of randomly selected a number between 0 and 10 for the counties with less than 11 deaths and maintaining the actual number for counties with 11 deaths or more, and summary statistics and regression models were run on the 100 imputed values with coefficients and standard errors adjusted for variability between imputations according to combination rules in Rubin [40]. Imputed for White, Black, and Hispanic deaths provided unlikely rate estimates, and imputed analyses were not further analyzed for these subgroups.

Negative binomial regression with death counts as the outcome variable and population count as the exposure were fit to calculate relative risks (incidence rate ratios) for residential segregation and county characteristics. Estimates of percent of population age 65 years or greater and less than 18 years were included in the model to adjust for county-level age distribution. To evaluate whether residential effects on race and ethnic subgroups were different in the presence of sufficient deaths across all subgroups, an additional analysis was conducted to evaluate residential segregation and overdose deaths in counties that had 11 deaths or more for White, Black, and Hispanic population ($n = 164$). Separate multivariable models were fit to each type of segregation: race, Hispanic ethnicity, poverty, and unemployment for dissimilarity and diversity. Black, Hispanic, poverty, and unemployment segregation were highly correlated (Supplemental Table 1, Pearson $r > 0.95$), and results for poverty isolation are presented as an overall representation of residential social isolation. Analyses were conducted using Stata 15.0 (StataCorp).

Results

There were 2067 counties with more than 10 overdose deaths in total (66% of total counties), and the mean crude death rate was 16.1

per 100,000. Most counties ($n = 2029$ [65%]) had at least 10 White overdose deaths (mean rate = 20.4 per 100,000). Smaller numbers of counties had at least 10 Black overdose deaths ($n = 355$ [11%], mean rate = 16.9 per 100,000) or at least 10 Hispanic overdose deaths ($n = 286$ [9%], mean rate = 12.9 per 100,000). Similar mean death rates were observed in the counties with that had at least 10 deaths for White, Black, and Hispanic populations (at least 10 in each group), with rates of 20.1 per 100,000 for total, 22.6 per 100,000 for White, 16.2 per 100,000 for Black, and 11.7 per 100,000 for Hispanic. In counties with at least 10 overdose deaths, total overdose death rate ranged from 2.9 to 86.9 per 100,000. Highest values were clustered in the West, West South Central, and Appalachia parts of the United States (Fig. 1).

There were some strong correlations between segregation factors, more for isolation than other characteristics, and analyses were limited to one measure of isolation (Supplemental Table 1). For other most segregation and socioeconomic factors were not strongly correlated (>0.8 or less than -0.8) with each other; with exceptions for Black isolation (county-to-adjacent county) and unemployed–other dissimilarity (county-to-adjacent county; $r = -0.80$); Hispanic isolation (county-to-adjacent county) and poverty–nonpoverty dissimilarity (county-to-adjacent county; $r = -0.81$); Hispanic isolation (county-to-adjacent county) and unemployed isolation (county-to-state; $r = -0.82$); percent poverty with poverty diversity ($r = 0.97$); and percent unemployment diversity ($r = 0.94$).

We ran our models with only counties with greater than 10 deaths and also using imputation counties with less than 10 deaths and show them both in Table 2. Counties with more than 10 deaths for White, Black, and Hispanic populations had lower percentages of civilian disabled and mobile home housing, and higher percentages of single-parent households, racial–ethnicity minority individuals, individuals that speak English than well, multiunit housing, and homes with no vehicle available (Table 1). In counties with more than 10 total deaths, overdose death rate was significantly, positively associated with county-level percent unemployment, percent without high school diploma, percent civilian disabled, and percent without a vehicle in home, with adjustment for the other county-level social characteristics. Significant inverse associations were observed for percent: poverty, age 65 years and older, age 17 years and younger, racial–ethnicity minority, housing

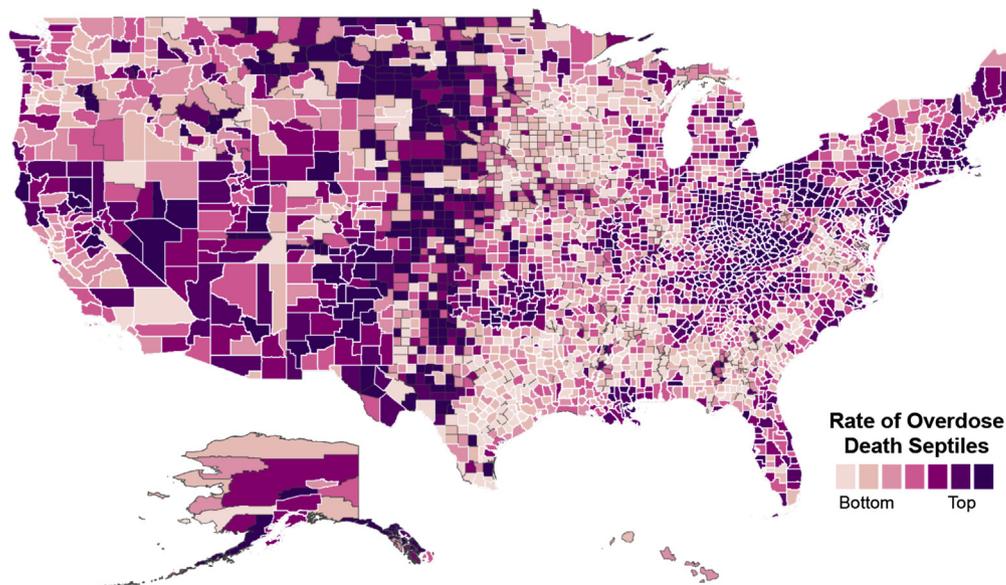


Fig. 1. Geographic distribution of county-level total overdose death rate. White borders indicate counties with actual data, and gray border indicates counties with imputed data.

Table 2
County residential segregation by categories of total overdose death rates and adjusted incidence rate ratios (IRRs) for segregation with overdose death rates

Characteristic*	Counties with >10 total deaths (n = 2029)		With >10 deaths in White, Black, and Hispanic subgroup (n = 193)		Imputed total deaths (n = 3142)	
	Mean (minimum to maximum)	IRR (95% CI)*	Mean (Minimum to maximum)	IRR (95% CI)	Mean (minimum to maximum)	IRR (95% CI)
County-to-adjacent county						
White–Black dissimilarity	8.1 (0, 56.5)	1.020 (1.008, 1.032)	14.4 (0, 48)	1.024 (1.003, 1.046)	7.3 (0, 71.0)	1.024 (1.008, 1.040)
Hispanic–NHW dissimilarity	5.6 (0, 50.8)	0.999 (0.982, 1.016)	10.0 (0, 46.6)	1.024 (0.995, 1.054)	5.1 (0, 52.7)	0.987 (0.965, 1.009)
Poverty–nonpoverty dissimilarity	5.5 (0, 52.5)	1.011 (0.997, 1.026)	12.5 (0, 47.3)	1.027 (1.002, 1.052)	4.4 (0, 52.5)	1.019 (0.999, 1.040)
Unemployed–others dissimilarity	4.4 (0, 50.9)	0.994 (0.978, 1.010)	9.6 (0.05, 40.1)	1.025 (0.996, 1.054)	3.8 (0, 50.9)	1.009 (0.987, 1.032)
Poverty isolation	87.3 (52.6, 99.8)	1.008 (0.995, 1.021)	79.7 (59.6, 95.0)	0.984 (0.956, 1.013)	89.3 (52.6, 100)	1.019 (1.001, 1.037)
County-to-state						
White–Black dissimilarity	1.6 (0, 57.4)	1.064 (1.040, 1.090)	6.7 (0, 57.4)	1.031 (1.009, 1.054)	1.2 (0, 57.4)	1.086 (1.050, 1.124)
Hispanic–NHW dissimilarity	1.2 (0, 38.1)	1.091 (1.050, 1.133)	5.1 (0, 38.1)	1.029 (0.993, 1.065)	0.9 (0, 38.1)	1.117 (1.058, 1.180)
Poverty–nonpoverty dissimilarity	0.6 (0, 16.7)	1.158 (1.073, 1.251)	2.2 (0, 16.7)	1.088 (1.008, 1.175)	0.4 (0, 16.7)	1.216 (1.089, 1.357)
Unemployed–others dissimilarity	0.4 (0, 8.5)	1.345 (1.178, 1.536)	1.3 (0, 8.5)	1.190 (1.043, 1.357)	0.3 (0, 8.5)	1.470 (1.216, 1.778)
Poverty isolation	97.7 (0, 100)	0.949 (0.931, 0.968)	90.5 (0, 99.3)	0.974 (0.958, 0.989)	98.4 (0, 100)	0.938 (0.911, 0.965)
Diversity						
Race diversity	49.3 (0.5, 100)	0.995 (0.987, 1.002)	80.6 (38.5, 100)	0.991 (0.972, 1.011)	45.3 (0, 100)	0.990 (0.981, 1.000)
Hispanic diversity	55.8 (2.4, 100)	0.999 (0.991, 1.006)	84.7 (50.9, 100)	0.988 (0.967, 1.010)	53.0 (0, 100)	0.993 (0.983, 1.003)
Unemployed diversity	42.7 (15.9, 67.4)	1.014 (0.897, 1.145)	39.4 (18.4, 60.9)	1.404 (0.885, 2.226)	42.2 (9.1, 69.1)	0.839 (0.715, 0.984)
Poverty diversity	14.9 (0.7, 30.8)	1.108 (1.041, 1.179)	16.4 (11.4, 25.0)	0.993 (0.830, 1.187)	13.9 (0, 38.4)	1.007 (0.927, 1.093)

CI = confidence intervals; NHW = non-Hispanic White.

* Characteristics are included in negative binomial regression models in 5-unit increments, and multivariable adjusted for the characteristics in Table 2.

that was mobile homes, housing that was group quarters, crowded housing, and uninsured. Similar results, in terms of directions of association, were observed with the imputed deaths, but statistical significance differed from analysis with counties that had more than 10 overdose deaths. When stratified by race and ethnicity, there were some notable similar and dissimilar associations with county-level socioeconomic characteristics (Fig. 2).

Residential segregation measures were significantly associated with total overdose death rates (Table 2), adjusted for other county-level socioeconomic factors. The strongest association was observed for unemployment dissimilarity, with a 5-unit increase being associated with 35% higher death rate (incidence rate ratio = 1.345 [1.178, 1.536]). Results were similar, magnitude and statistical significance, for imputed data. When stratified by race and Hispanic ethnicity, there were some notable similar and dissimilar associations with county-level residential segregation for county-to-adjacent county comparisons in counties with more than 10 White deaths, adjusted for other county-level socioeconomic factors (Table 3).

Discussion

This analysis focused on evaluating the smallest geographic area possible with accessible and relatively stable data. Dissimilarity represents the difference in the proportion of Black or Hispanic in the county relative to the larger area from the proportion of White in the county relative to the larger area. Lower values indicate a more even distribution, and higher values indicate a less even distribution across race or ethnic groups. The isolation measure used in this analysis provides an estimate of how many people are not in that group (Black or Hispanic) in the county compared with how many people are not that group in the larger area, where larger values indicate that there is a lower concentration of individuals in that group in the county. Isolation was strongly correlated across all these characteristics within geographic comparisons (county-to-adjacent county vs. county-to-state). This observation suggests that isolation may not have good discriminatory power to distinguish between isolation based on different socioeconomic characteristics. Additional work with lower levels of geography may reveal different types and magnitudes of associations.

Massey and Denton proposed that lower levels of comparisons (e.g., tracts) may provide information about the level of segregation experienced for a neighborhood, and higher levels provide information about comparisons to potential laws or policies [41]. For some of the associations, the magnitude of association was stronger for the county-to-state segregation measure than the county-to-adjacent county segregation measure. County-to-adjacent county may cross state lines, and it is possible that the state-level policies or laws have are more influential on county-level segregation measures. This difference between county-to-adjacent county and county-to-state may also reflect, in part, differences in overall ranges in values of residential segregation and diversity measures across the two larger geographic comparison areas. Differences that were observed were between significant and nonsignificant in the same direction, suggesting that both geographic levels support similar theoretical effects of county residential segregation influence.

Racial dissimilarity has been associated with other adverse health outcomes, including higher lung cancer mortality [42], poorer survival for hemodialysis patients [43], and higher overall mortality rates [44] in Blacks in more dissimilar areas. However, in this analysis, there were few associations with Black death rates; only county-to-state White–Black dissimilarity was significantly associated, independent of other socioeconomic characteristics of the counties. This may support that structural racism specific to Black individuals is more important to Blacks than individual socioeconomic characteristics. In general, dissimilarity and isolation associations were more similar across White and Black death rates than Hispanic death rates; whereas, measures of diversity associations were more similar across Black and Hispanic death rates than White death rates. For Hispanic death rates, few associations were statistically significant, but this may represent lack of statistical power for the smaller number of counties that had useable data. An interesting observation is that where there were significant associations, the associations were inverse for isolation and diversity. There is limited work related to overdose deaths or drug use, but some studies have evaluated mental health outcomes and residential segregation in Hispanic groups. In recent work by Nobles et al., isolation and dissimilarity were both inversely associated with mental distress [45]. However, findings are mixed, with other studies of mental health in Hispanic populations

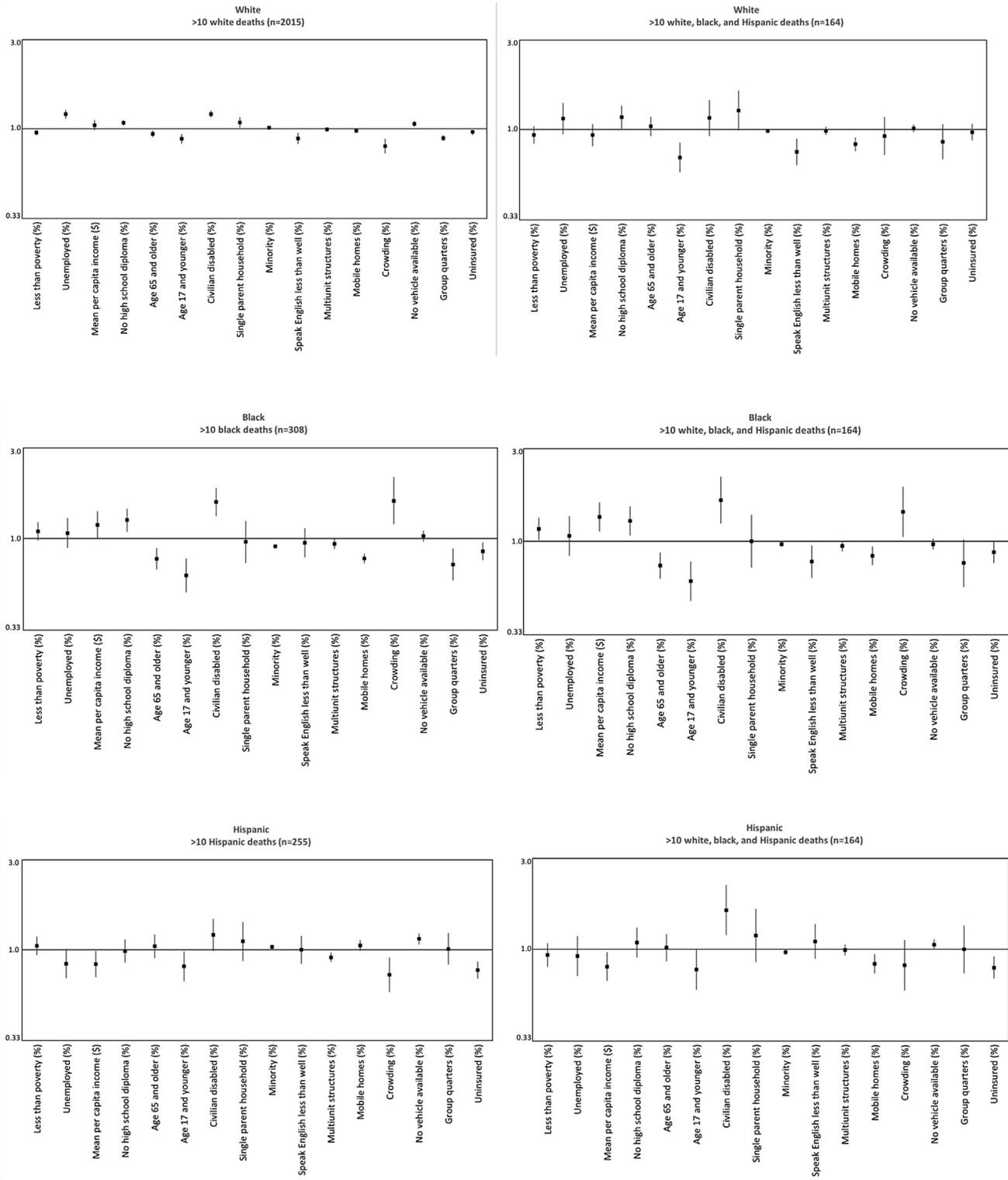


Fig. 2. Incidence rate ratios, with 95% confidence interval bars, for associations of social vulnerability characteristics and overdose death rates in White, Black, and Hispanic populations in counties with at least 10 deaths for the race or Hispanic population and with at least 10 for all race and Hispanic populations.

observing similar protective associations [46,47] and others observing no or adverse associations [48,49]. One possible mechanism for differences across these studies is possible differences by Hispanic ethnicity subgroups (e.g., Cuban, Puerto Rican, Mexican). However, caution should be exercised in comparing White, Black, and Hispanic death rate results to the total results

because suppressed counties were excluded from the race and Hispanic analyses.

Some socioeconomic drivers of drug overdose deaths were consistent across race and Hispanic groups, and other factors differed across the groups. Consistent positive associations included percent civilian disabled, and consistent inverse

Table 3
Country residential segregation incidence rate ratios (IRRs) for overdose death rates by race and Hispanic death rates

Characteristic*	White		Black		Hispanic	
	>10 White deaths (n = 1973)	With >10 White, Black, and Hispanic deaths (n = 193)	>10 Black deaths (n = 355)	With >10 White, Black, and Hispanic deaths (n = 193)	>10 Hispanic deaths (n = 286)	With >10 Hispanic, Black, and Hispanic deaths (n = 193)
County-to-adjacent county						
White–Black dissimilarity	1.019 (1.007, 1.031)	1.029 (1.006, 1.053)	1.009 (0.986, 1.033)	1.020 (0.992, 1.049)	0.991 (0.960, 1.023)	0.992 (0.961, 1.024)
Hispanic–NHW dissimilarity	1.001 (0.985, 1.018)	1.038 (1.006, 1.071)	0.977 (0.942, 1.014)	0.970 (0.933, 1.009)	0.995 (0.954, 1.038)	0.988 (0.947, 1.031)
Poverty–nonpoverty dissimilarity	1.006 (0.991, 1.020)	1.021 (0.995, 1.049)	1.030 (1.002, 1.06)	1.046 (1.012, 1.080)	0.985 (0.953, 1.018)	1.006 (0.970, 1.043)
Unemployed–others dissimilarity	0.989 (0.973, 1.004)	1.019 (0.988, 1.051)	1.024 (0.991, 1.057)	1.048 (1.011, 1.087)	0.967 (0.933, 1.003)	1.009 (0.969, 1.050)
Poverty isolation	1.008 (0.995, 1.021)	0.982 (0.952, 1.013)	1.006 (0.975, 1.039)	0.979 (0.942, 1.017)	1.015 (0.978, 1.053)	0.977 (0.938, 1.018)
County-to-state						
White–Black dissimilarity	1.061 (1.037, 1.086)	1.037 (1.012, 1.062)	1.049 (1.018, 1.082)	1.026 (0.997, 1.056)	1.025 (0.989, 1.062)	1.026 (0.994, 1.059)
Hispanic–NHW dissimilarity	1.090 (1.050, 1.131)	1.034 (0.995, 1.074)	1.044 (0.993, 1.098)	1.013 (0.967, 1.060)	1.022 (0.969, 1.078)	0.999 (0.951, 1.049)
Poverty–nonpoverty dissimilarity	1.148 (1.065, 1.239)	1.109 (1.018, 1.207)	1.115 (1.001, 1.241)	1.018 (0.919, 1.126)	1.078 (0.951, 1.223)	1.104 (0.985, 1.238)
Unemployed–others dissimilarity	1.299 (1.139, 1.481)	1.197 (1.034, 1.386)	1.548 (1.296, 1.848)	1.286 (1.085, 1.526)	1.101 (0.896, 1.354)	1.210 (1.003, 1.460)
Poverty isolation	0.956 (0.937, 0.974)	0.987 (0.969, 1.005)	0.961 (0.940, 0.983)	0.972 (0.952, 0.992)	0.978 (0.952, 1.006)	0.979 (0.957, 1.003)
Diversity						
Race diversity	1.003 (0.996, 1.010)	1.008 (0.986, 1.030)	0.952 (0.931, 0.973)	0.968 (0.943, 0.995)	0.955 (0.935, 0.974)	0.962 (0.935, 0.990)
Hispanic diversity	1.000 (0.993, 1.008)	0.998 (0.975, 1.022)	0.954 (0.932, 0.975)	0.958 (0.929, 0.987)	0.955 (0.935, 0.976)	0.985 (0.953, 1.017)
Unemployed diversity	0.965 (0.853, 1.091)	1.139 (0.688, 1.887)	1.085 (0.706, 1.667)	2.166 (1.145, 4.097)	1.792 (1.063, 3.021)	1.487 (0.746, 2.963)
Poverty diversity	1.062 (0.997, 1.131)	0.899 (0.740, 1.092)	1.204 (0.995, 1.456)	1.305 (1.030, 1.652)	0.834 (0.685, 1.014)	1.034 (0.794, 1.348)

NHW = non-Hispanic White.

* Characteristics are included in negative binomial regression models in 5-unit increments, and adjusted for characteristics in Table 1.

associations included percentages age 17 years and younger. Inverse associations with higher proportions of younger groups may reflect that these groups are less likely to be drug users, as drug use is highest in late teens and early 20s [27]. Disability is associated with higher alcohol abuse and drug abuse in cross-sectional studies [50,51], but the directionality of the relationship is unclear, and more longitudinal studies are needed. Our results suggest additional work evaluating the broader geographic issues around disability, and drug use may also be an important avenue of exploration. Some interesting associations that were discordant across the groups included percent poverty, per capita income, percent single-parent households, percent racial–ethnicity minority, mobile homes, and percent uninsured. Although work in drug use deaths is limited, research for other health conditions indicate that the sociogeographic environment may have different influences on race or ethnic subgroups. Opposing directions of association across Black and Hispanic groups have been observed for cardiovascular disease [21] and birth outcomes [22] in relation to percent density of the group, with higher risk observed for Blacks and lower risks observed for Hispanics. The subsample analysis indicated that these relationships are unlikely to be entirely explained by the differences in which counties have sufficient data for White, Black, or Hispanic overdose deaths, but the difference in health outcome and individual level versus ecological level analysis may be a driving factor.

There is a somewhat limited base of evidence about the effects of sociogeographic factors and residential segregation within or to population groups, particularly as it may influence drug overdose deaths to provide explanations for the associations observed. We cautiously offer some hypotheses for some observations that could be evaluated more thoroughly with other study designs or types of data. We observed an inverse association between poverty and overdose death rates. We hypothesize that these areas may include individuals that are more regular drug users and may have fewer deaths from first-time drug users that overdose due to inexperience. These may also be areas that have more urgent care or emergency centers equipped to respond to drug overdoses, resulting in fewer deaths. Sources of data on drug overdoses that do

not lead to deaths, such as hospital admissions, may provide a means to evaluate these hypotheses. We also observed differences in the direction of associations with unemployment across measures and across population groups. Percentage unemployment was positively associated with death rates in Whites and inversely associated for Hispanics. We hypothesize that areas with high unemployment may have more of a mental health toll on Whites, whereas Hispanic populations may form supportive enclaves. It may be possible to evaluate joint effects of types of segregation and individual-level unemployment in other sources of data to evaluate this hypothesis. Similar mechanisms or hypotheses may underline other associations observed.

It was clear that areas that have at least 10 deaths in White, Black, and Hispanic populations are different from the larger group of more than 10 total deaths. These areas are more populated and diverse, as indicated by higher percent racial–ethnicity minority, percent individuals that speak English less than well, racial and ethnic dissimilarity, and race and Hispanic diversity. These areas may be more urban, given the housing structure, but, on average, are not different in poverty, education, or unemployment. In these higher population and diversity areas, associations were generally similar to the associations in counties with more than 10 total deaths. This may suggest county-level social factors and residential segregation exert similar influence on overdose death rates across counties, regardless of size and racial or Hispanic diversity.

Some limitations of the study should be considered in the interpretation. (1) Associations observed at an ecological level may not translate to the individual level. However, this work provides a novel insight into group-level characteristics that are worth further consideration in future individual-level studies, including positive associations civilian disability, unemployment, and measures of isolation and diversity. (2) The unit of analysis was at the county as publicly available data overdose deaths for lower levels of geography are not available. Counties differ notably in size and proximity to other counties, and the influence of segregation based on those relationships may be more diluted or exaggerated than what might be seen at lower levels of geography. However, there are no nationally representative studies for lower levels of geography, and this analysis

provides hypotheses about factors that may be important to evaluate in future studies. (3) Even using the county as the unit of analysis, there were counties with suppressed (<11 deaths, as defined by the CDC) or unreliable (11–20 deaths, as defined by the CDC) overdose death rates. To still capture information on the characteristics of those counties, we chose to evaluate crude death rates and include two variable indicators for age distribution in the analysis. We observed similar results across the imputed and complete data analyses, suggesting that there may be some ability to generalize. However, generalizability for Black and Hispanic may not be warranted as some parts of the United States have low minority (not non-Hispanic White) populations, and application to areas with higher minority populations may be more reliant on the complete data analyses. Some residual confounding by age may be present. We observed results that were similar across counties with more than 10 total deaths and imputed data, suggesting that there is little bias in estimates by evaluating only counties with more than 10 total deaths. (4) A combined overdose death rate was used and did not look specifically at specifics of the overdose death, such as specific drug or intentionality. Similarly, deaths that occur among individuals who are drug-addicted may not be attributed to the drug use, even if there is a connection, and we have missed some drug-related deaths. However, the ICD codes used in this analysis capture any deaths where overdose was an underlying cause and are consistent with other studies, providing comparability to other research. This nonspecificity may have masked stronger associations that might be observed for specific characteristics. Although not a limitation, it is important to acknowledge overlap in individuals exists for Hispanic and race groups because Hispanic individuals will have also identified as a particular racial group. It is then interesting to observe that there are these differences that are associated with Hispanic death rates, and these might be more magnified a combined race, and Hispanic death rate (e.g., non-Hispanic Black vs. Hispanic Black) was evaluated.

Conclusion

These results suggest residential segregation may exert independent effects on drug overdose mortality beyond county socioeconomic characteristics, and effects differ across race and ethnic groups. Opportunities and resources are unevenly spatially distributed, and residential segregation may offer insight into the socioeconomic well-being of a group. We hypothesize several underlying mechanisms in response to the results of this analysis. Associations may be a result of factors such as access to health care, either positively or negatively, as overdose deaths related to prescription medications are increasing [27]. Other factors that may be influential include access to drug addiction resources or normalized beliefs about drug use in spatially similar populations. Alternatively, cultural or social characteristics of a group may strength in isolated communities and provide a foundation for social support. There is little published work on the topic of overdose deaths in a community context, and these results provide directions for future studies, including the roles of civilian disability, diversity, and evaluating differential impacts of segregation across racial and ethnic groups.

Acknowledgment

This research did not receive any specific grant from funding agencies in the public, commercial, or non-for-profit sectors.

Supplementary data

Supplementary data associated with this article can be found in the online version at <https://doi.org/10.1016/j.annepidem.2019.04.009>.

References

- [1] Rudd RA, Seth P, David F, Scholl L. Increases in drug and opioid-involved overdose deaths - United States, 2010-2015. *MMWR Morb Mortal Wkly Rep* 2016;65:1445–52.
- [2] Jalal H, Buchanich J, Roberts M, Balmert L, Zhang K, Burke D. Changing dynamics of the drug overdose epidemic in the United States from 1979 through 2016. *Science* 2018;361(6408):1–6. <https://doi.org/10.1126/science.aau1184>.
- [3] County Health Rankings, Roadmaps. Drug overdose deaths. www.countyhealthrankings.org/measure/drug-overdose-deaths. [Accessed 6 March 2017].
- [4] Limdi NA, Howard VJ, Higginbotham J, Parton J, Safford MM, Howard G. US mortality: influence of race, geography and cardiovascular risk among participants in the population-based REGARDS cohort. *J Racial Ethn Heal Disparities* 2016;3:599–607.
- [5] Toprani A, Li W, Hadler JL. Trends in mortality disparities by area-based poverty in New York City, 1990-2010. *J Urban Health* 2016;93:538–50.
- [6] James W, Cossman JS. Long-Term trends in Black and White mortality in the rural United States: evidence of a race-specific rural mortality penalty. *J Rural Health* 2017;33:21–31.
- [7] Ford MM, Highfield LD. Exploring the spatial association between social deprivation and cardiovascular disease mortality at the neighborhood level. *PLoS One* 2016;11:e0146085.
- [8] Vaughan AS, Quick H, Pathak EB, Kramer MR, Casper M. Disparities in temporal and geographic patterns of declining heart disease mortality by race and sex in the United States, 1973-2010. *J Am Heart Assoc* 2015;4. <https://doi.org/10.1161/JAHA.115.002567>.
- [9] Singh GK, Azuine RE, Siahpush M, Williams SD. Widening geographical disparities in cardiovascular disease mortality in the United States, 1969-2011. *Int J MCH AIDS* 2015;3:134–49.
- [10] King NB, Fraser V, Boikos C, Richardson R, Harper S. Determinants of increased opioid-related mortality in the United States and Canada, 1990-2013: a systematic review. *Am J Public Health* 2014;104:e32–42.
- [11] Moschetti K, Cummings PL, Sorvillo F, Kuo T. Burden of Alzheimer's disease-related mortality in the United States, 1999-2008. *J Am Geriatr Soc* 2012;60:1509–14.
- [12] Miller M, Azrael D, Barber C. Suicide mortality in the United States: the importance of attending to method in understanding population-level disparities in the burden of suicide. *Annu Rev Public Health* 2012;33:393–408.
- [13] Keyes KM, Cerda M, Brady JE, Havens JR, Galea S. Understanding the rural-urban differences in nonmedical prescription opioid use and abuse in the United States. *Am J Public Health* 2014;104:e52–9.
- [14] Young AM, Havens JR, Leukefeld CG. A comparison of rural and urban nonmedical prescription opioid users' lifetime and recent drug use. *Am J Drug Alcohol Abuse* 2012;38:220–7.
- [15] Monnat SM, Rigg KK. Examining rural/urban differences in prescription opioid misuse among US adolescents. *J Rural Health* 2016;32:204–18.
- [16] Rigg KK, Monnat SM. Urban vs. rural differences in prescription opioid misuse among adults in the United States: informing region specific drug policies and interventions. *Int J Drug Policy* 2015;26:484–91.
- [17] van Handel M, Rose C, Hallisey E, Kolling J, Zibbell J, Lewis B, et al. County-level vulnerability assessment for rapid dissemination of HIV or HCV infections among persons who inject drugs, United States. *J Acquir Immune Defic Syndr* 2016;73:323–31.
- [18] Cutchin MP. The need for the “new health geography” in epidemiologic studies of environment and health. *Health Place* 2007;13:725–42.
- [19] Oishi S. Socioecological psychology. *Annu Rev Psychol* 2014;65:581–609.
- [20] White K, Borrell LN. Racial/ethnic residential segregation: Framing the context of health risk and health disparities. *Health Place* 2011;17:438–48.
- [21] Kershaw KN, Osypuk TL, Do DP, De Chavez PJ, Diez Roux AV. Neighborhood-level racial/ethnic residential segregation and incident cardiovascular disease: the multi-ethnic study of atherosclerosis. *Circulation* 2015;131:141–8.
- [22] Mason SM, Kaufman JS, Daniels JL, Emch ME, Hogan VK, Savitz DA. Neighborhood ethnic density and preterm birth across seven ethnic groups in New York City. *Health Place* 2011;17:280–8.
- [23] Hall AJ, Logan JE, Toblin RL, Kaplan JA, Kraner JC, Bixler D, et al. Patterns of abuse among unintentional pharmaceutical overdose fatalities. *JAMA* 2008;300:2613–20.
- [24] Martins SS, Sampson L, Cerda M, Galea S. Worldwide prevalence and trends in unintentional drug overdose: a systematic review of the literature. *Am J Public Health* 2015;105:e29–49.
- [25] SAMSHA Center for Application of Preventive Technologies. Preventing prescription drug misuse: overview of factors and strategies. 2016. <http://ncpreventionta.org/content/resources/preventing-prescription-drug-misuse-overview-of-factors-and-strategies/preventing-prescription-drug-misuse-overview-4.pdf>.
- [26] SAMSHA Center for Application of Preventive Technologies. Preventing prescription drug misuse: understanding who is at risk. 2016. https://www.michigan.gov/documents/mdhhs/UnderstandingWhosAtRisk_547024_7.pdf.
- [27] Center for Behavioral Health Statistics and Quality. Behavioral health trends in the United States: Results from the 2014 National Survey on Drug Use and Health. 2015. <https://www.samhsa.gov/data/sites/default/files/NSDUH-FRR1-2014/NSDUH-FRR1-2014.pdf>.

- [28] Garipey G, Honkaniemi H, Quesnel-Vallee A. Social support and protection from depression: systematic review of current findings in Western countries. *Br J Psychiatry* 2016;209:284–93.
- [29] Marroquin B. Interpersonal emotion regulation as a mechanism of social support in depression. *Clin Psychol Rev* 2011;31:1276–90.
- [30] Arthur HM. Depression, isolation, social support, and cardiovascular disease in older adults. *J Cardiovasc Nurs* 2006;21:S2–7. quiz S8–S9.
- [31] Paykel ES. Life events, social support and depression. *Acta Psychiatr Scand Suppl* 1994;377:50–8.
- [32] Ruppel EK, McKinley CJ. Social support and social anxiety in use and perceptions of online mental health resources: exploring social compensation and enhancement. *Cyberpsychol Behav Soc Netw* 2015;18:462–7.
- [33] Wang J, Chen Y, Tan C, Zhao X. Family functioning, social support, and quality of life for patients with anxiety disorder. *Int J Soc Psychiatry* 2016;62:5–11.
- [34] Mahmoud JSR, Staten RT, Lennie TA, Hall LA. The relationships of coping, negative thinking, life satisfaction, social support, and selected demographics with anxiety of young adult college students. *J Child Adolesc Psychiatr Nurs* 2015;28:97–108.
- [35] Gracia-Lazaro C, Lafuerza LF, Floria LM, Moreno Y. Residential segregation and cultural dissemination: an Axelrod-Schelling model. *Phys Rev E Stat Nonlin Soft Matter Phys* 2009;80:46123.
- [36] Henry AD, Pralat P, Zhang C-Q. Emergence of segregation in evolving social networks. *Proc Natl Acad Sci U S A* 2011;108:8605–10.
- [37] Suglia SF, Shelton RC, Hsiao A, Wang YC, Rundle A, Link BG. Why the neighborhood social environment is critical in obesity prevention. *J Urban Health* 2016;93:206–12.
- [38] Flanagan BE, Gregory EW, Hallisey EJ, Heitgard JL, Lewis B. A social vulnerability index for disaster management. *J Homel Secur Emerg Manag* 2011;8: 1–22.
- [39] Oka M, Wong DWS. Capturing the two dimensions of residential segregation at the neighborhood level for health research. *Front Public Health* 2014;2:118.
- [40] Rubin DB. Multiple imputation for nonresponse in surveys. New York, NY: John Wiley & Sons, Inc.; 1987.
- [41] Massey DS, Denton NA. The dimensions of residential segregation. *Soc Forces* 1988;67:281–315.
- [42] Hayanga AJ, Zeliadt SB, Backhus LM. Residential segregation and lung cancer mortality in the United States. *JAMA Surg* 2013;148:37–42.
- [43] Kimmel PL, Fwu CW, Eggers PW. Segregation, income disparities, and survival in hemodialysis patients. *J Am Soc Nephrol* 2013;24:293–301.
- [44] Hart KD, Kunitz SJ, Sell RR, Mukamel DB. Metropolitan governance, residential segregation, and mortality among African Americans. *Am J Public Health* 1998;88:434–8.
- [45] Nobles CJ, Valentine SE, Zepeda ED, Wang Y, Ahles EM, Shtasel DL, et al. Residential segregation and mental health among Latinos in a nationally representative survey. *J Epidemiol Community Health* 2016;71:318–23.
- [46] Mair C, Diez Roux AV, Osypuk TL, Rapp SR, Seeman T, Watson KE. Is neighborhood racial/ethnic composition associated with depressive symptoms? The multi-ethnic study of atherosclerosis. *Soc Sci Med* 2010;71:541–50.
- [47] Lee M-J, Liechty JM. Longitudinal associations between immigrant ethnic density, neighborhood processes, and latino immigrant youth depression. *J Immigr Minor Health* 2015;17:983–91.
- [48] Denton E-GD, Shaffer JA, Alcantara C, Cadermil E. Neighborhood matters: the impact of Hispanic ethnic density on future depressive symptoms 1-year following an ACS event among Hispanic patients. *J Behav Med* 2016;39: 28–40.
- [49] Lee M-A. Neighborhood residential segregation and mental health: a multi-level analysis on Hispanic Americans in Chicago. *Soc Sci Med* 2009;68: 1975–84.
- [50] Hasin DS, Stinson FS, Ogburn E, Grant BF. Prevalence, correlates, disability, and comorbidity of DSM-IV alcohol abuse and dependence in the United States: results from the National Epidemiologic Survey on alcohol and related conditions. *Arch Gen Psychiatry* 2007;64:830–42.
- [51] Compton WM, Thomas YF, Stinson FS, Grant BF. Prevalence, correlates, disability, and comorbidity of DSM-IV drug abuse and dependence in the United States: results from the national epidemiologic survey on alcohol and related conditions. *Arch Gen Psychiatry* 2007;64:566–76.