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Social Inequality

Using the Index of Concentration at the Extremes at multiple geographical levels to monitor health inequities in an era of growing spatial social polarization: Massachusetts, USA (2010–14)

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Abstract

Background: Metrics that quantify economic and social spatial polarization at multiple geographical levels are not routinely used by health agencies, despite rising inequalities.
Methods: We employed the Index of Concentration at the Extremes (ICE), which quantifies how persons in a specified area are concentrated into the top vs bottom of a specified societal distribution, to examine associations with Massachusetts mortality data (2010–14). Our a priori hypotheses were that these associations would: be greater at the local [census tract (CT)] compared with city/town level; vary by race/ethnicity but not gender; and be greatest for our new ICE for racialized economic segregation. Mortality outcomes comprised: child (< 5 years); premature (< 65 years); and cause-specific (cancer; cardiovascular; diabetes; suicide; HIV/AIDS; accidental poisoning; smoking-attributable).
Results: As illustrated by child mortality, in multilevel models jointly including CT and city/town metrics, the rate ratio comparing the worst to best-off ICE quintile for the total population ranged from 2.2 [95% confidence interval (CI) 1.6, 3.0] for the CT-level ICE for racialized economic segregation down to 1.1 (95% CI 0.8, 1.7) for the city/town-level ICE for racial segregation; similar patterns occurred by gender and for the non-Hispanic White population. Larger associations for the ICE for racialized economic segregation were at the CT-level for the Black non-Hispanic population (6.9; 95% CI 1.3, 36.9) and at the city/town level for the Hispanic population (6.4; 95% CI 1.2, 35.4).
Conclusions: Results indicate that health agencies should employ measures of spatial social polarization at multiple levels to monitor health inequities.

Key words: Accidental poisoning, chronic disease mortality, HIV/AIDS, income inequality, premature mortality, public health monitoring, racial inequality, residential segregation, social inequality, suicide

Key Messages

- Measures of spatial social polarization at multiple levels are not currently employed by health agencies to monitor health inequities, despite such inequalities growing both within and between nations.
- We employed the Index of Concentration at the Extremes (ICE), which measures the extent to which a population in a specified area is concentrated into best-off and worst-off extremes of a specified social distribution, and examined its associations with mortality data (Massachusetts, USA; 2010–14).
- In accord with our a priori hypotheses: (i) rate ratios comparing the worst with the best quintile were typically greater at the local (CT) compared with the city/town level, and the latter typically were the most attenuated in models employing both levels; (ii) rate ratios typically were greater for the ICE measures (especially for racialized economic segregation) compared with the poverty measure; and (iii) no effect modification of these patterns was observed in relation to gender, but did occur for race/ethnicity, whereby rate ratios for city/town measures were strongest for populations of colour.
- Health agencies should employ measures of spatial social polarization at multiple levels, stratified by relevant social groups, to monitor the embodied health impact of growing extreme concentrations of privilege and deprivation.

Introduction

Measures of spatial social polarization, whether at single or multiple levels, are not currently used in public health monitoring,[1,2] despite rising economic and social polarization within and between nations.[1,3–7] Instead, conventionally employed metrics focus primarily on individual- or household-level measures of deprivation[1,2,8] which render the wealthy and privileged invisible and ignore spatial social polarization.[9,10] Research on residential segregation and health, conducted chiefly in the USA, in turn has relied on measures of racial segregation at the city level or higher.[6,11] New research, however, indicates that spatial social inequality operating at multiple levels, involving both economic and racial/ethnic polarization, may adversely affect population health.[9,10,12,13]

In this study we newly test, in relation to multiple mortality outcomes, an alternative metric to quantify and monitor health inequities: the Index of Concentration at the Extremes (ICE). The ICE was introduced into the sociological literature by Massey in 2001 to measure economic polarization[14] but remains little used in population health.[9,12,13] In brief, the ICE quantifies the extent to which persons in a specified area are concentrated into the top vs bottom extremes of a specified social distribution; its formula is as follows:[14]

$$ICE_i = (A_i – P_i)/T_i$$

where A_i, P_i and T_i respectively correspond to the number of persons categorized, in the *i*th geographical area, as belonging to: the most privileged extreme, the most deprived extreme, and the total population whose privilege level was measured. For example for income, $Ai =$ number of persons in the top income quintile in neighbourhood I_i; $Pi =$ number of persons in the bottom income quintile in neighbourhood i; and $Ti =$ total population across all income quintiles in neighbourhood i. The ICE thus ranges from -1 to 1, whereby -1 and 1 respectively connote that 100% of the population is concentrated into the most extreme groups for deprivation and for privilege.[12–14]

Properties of the ICE that distinguish it from other measures of inequality are that: (i) in contrast to the poverty measure, it keeps visible both the most and least privileged groups;[9,13,14] and (ii) unlike such widely used metrics as the Gini Index for income inequality and the Index for Dissimilarity for racial segregation, which are uninformative at lower levels of geography (precisely because spatial polarization means people are more alike than different in smaller areas), the ICE can be meaningfully used at lower as well as at higher levels of geography.[12–14]

In our previous recent studies conducted in the USA—a country with large and growing inequities in income and wealth[3,7] and long history of structural racism[5,6]—we have taken the novel step of extending the ICE to measure both racial/ethnic segregation and racialized economic segregation.[9,13,15–18] Our initial investigations focused on individuals in two studies conducted within Boston, MA, analysing census tract (CT)-level measures in relation to air pollution[15] and hypertension.[16] We next analysed data for the total population of two cities (Boston, MA, and New York City, NY), with outcomes including preterm birth, infant mortality and diabetes mortality.[9,17,18] We then conducted statewide analyses for the 351 city/towns in Massachusetts, with multilevel analyses including both CT and city/town level measures in relation to fatal and non-fatal weapons-related assaults.[13] Throughout, we typically observed larger associations of the specified health outcomes with the ICE compared with the US poverty measure (defined by household income and the number of adults and children supported by this income)[8,19] and also at the CT compared with city/town level.[13]

In this study, we newly analyse the ICE at multiple levels in relation to multiple mortality outcomes and test for effect modification by gender and by race/ethnicity. Our a priori hypotheses, informed by our previous research[9,13,15–18] and ecosocial theory's conceptualization of how people embody their societal and ecological context,[12,20] were that we would observe: (i) at any geographical level, stronger associations for the ICE, and especially the ICE for racialized economic segregation, as compared with the poverty level; (ii) stronger associations at the CT compared with the city/town level in models including both levels; and (iii) effect modification of these patterns by race/ethnicity but not gender.

Methods

Study population

All residents and decedents in Massachusetts (2010–14) comprised the study base for our cross-sectional investigation. Data on deaths ($N = 263\ 266$) were obtained from vital statistics;[21] and denominator data were obtained from the American Community Survey (ACS), using the 5-year estimate for 2010–14.[22] The study was approved by the institutional review boards of the Harvard T.H. Chan School of Public Health (Protocol 16-1325) and the Massachusetts Department of Public Health (Protocol 946302-2).

Each mortality record included data on the decedent's age, gender, race/ethnicity (using US census categories provided below), residential address at the time of death and coded cause of death following the International Classification of Diseases 10th Revision[23] (ICD-10) (see Table S1, available as Supplementary data at *IJE* online). For these analyses, we conceptualized race/ethnicity as a social construct arising from inequitable race relations that historically have been linked to inequitable social class relations.[5,6,20] We employed ArcMap 10.4.1[24] to geocode the residential address of each case to its latitude and longitude, which were used to assign the CT and city/town geocodes; only 1337 (0.5%) of the decedents could not be geocoded to this level of precision. To create a multilevel data structure in which all city/towns contained at least 1 CT, we aggregated the 59 small towns (out of the state's 351 city/towns) that were nested within CTs that contained two or more towns into 21 'super towns' containing one CT each; the population in these small towns accounted for 1.1% of the total population.

Outcomes

Mortality outcomes were selected because of their well-known social gradients and population burdens.[25,26] They comprised: (i) early death: all-cause child (< 5 years) and premature (< 65 years) mortality; (ii) chronic disease mortality: cancer, cardiovascular disease, diabetes; (iii) non-chronic disease mortality: suicide, HIV/AIDS and accidental poisoning (which includes drug overdoses); and (iv) deaths attributable to smoking as determined by the US Centers for Disease Control and Prevention (see ICD-10 codes in Table S1).[27,28]

Area-based measures

We used the 2010–14 ACS data[22] to compute the CT and city/town ICE measures and the proportion of the population below the federal poverty line (ACS variable B17001). We generated three ICE measures, whose extremes we conceptualized in relation to economic and racial privilege[9,13,14] as follows:

i. ICE for income: low vs. high US household income (20th vs. 80th percentile) (ACS variable B19001), using the cut-points of < \$20,000 and ≥ \$125,000;[29]
ii. ICE for race/ethnicity: non-Hispanic Black vs non-Hispanic White (ACS variable B03002); and
iii. ICE for race/ethnicity + income (i.e. racialized economic segregation): Black population in low-income households vs the non-Hispanic White population in high-income households (ACS variables B19001H, B19001B).

Informing choice of these contrasts, not only is Black vs White residential segregation the most extreme and persistent form of US racial segregation but, as Massey has also documented, Black low-income vs White high-income households 'continue to occupy opposite ends of the socioeconomic spectrum in the United States' (p. 324).[30] We computed quintiles for the ICE and poverty measures based on the distribution within Massachusetts, and set Q5 (best-off) as the referent group.[13] We obtained data on urbanicity (large metro, small and medium metro, non-metro), for control as a potential confounder,[10,11] using designations from the US National Center for Health Statistics.[31]

Statistical analyses

Drawing on standard multilevel approaches for modelling small-area disease rates in which individuals are nested within different levels of geography,[32] we used mixed effects Poisson models to analyse relationships between, respectively, the CT and city/town measures and the specified mortality outcomes. For all analyses, we used the observed data, given virtually no missing data (0% for most variables, 0.2–1.5% for race/ethnicity and urbanicity). We fit all models in STATA (version 14)[33] using the mepoisson function with expected counts as the offset, with these counts based on the Massachusetts-wide age-standardized mortality rate for each population group in the model, in strata defined by gender and race/ethnicity. In these models, the observed/expected ratio is equivalent to a rate ratio.[32,33] We assessed model goodness-of-fit with the AIC and BIC statistics.[34] Following standard approaches for analysing inequality,[8] we focused on the Q1 vs Q5 comparison, an approach which avoids assumptions of linearity.

To test our a priori hypotheses, we employed three sets of models: Model 1a included only CT measures for ICE or poverty; Model 1b included only city/town measures; and Model 2 included both levels. These models included gender, race/ethnicity and urbanicity as covariates and included random intercepts for the CT and city/town levels. To assess effect modification, we repeated these analyses stratified by: (i) gender (men/women), and (ii) race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic). Small sample size, leading to unreliable estimates, precluded us from running models for Asian and Pacific Islanders and for American Indians and Alaska Natives (also the two racial/ethnic groups whose race/ethnicity is least accurately identified in US vital statistics),[35] and jointly stratified by gender and race/ethnicity (except for the non-Hispanic White women and men; tables available upon request).

Results

Distributions of the individual-level and area-based variables for the Massachusetts population (6.5 million residents; 75% White non-Hispanic, residing chiefly in large metro areas) and 263 266 decedents (2010–14) used to test our study hypotheses are presented in Table 1. Corresponding age-standardized mortality rates are shown in Table 2, and exhibited expected patterns by gender and race/ethnicity. Also as expected, the area-based measures exhibited greater heterogeneity and were more sensitive to deprivation at the lower (CT) compared with higher (city/town) geographical level. For example, the mean and standard deviation (SD) at the CT and city/town levels were, respectively, for the ICE for race/ethnicity: 0.67 (SD 0.34) and 0.85 (SD 0.15), and for the proportion below poverty, 12.9% (SD 12.1) and 7.6% (SD 5.2).

We present tests of the study hypotheses visually. Figure 1–10 shows the multilevel multivariable model results for the total population [see Tables S2–S6 for the parameter estimates and their 95% confidence intervals (CI), available as Supplementary data at *IJE* online]. Figure 11–20 presents analogous results stratified, respectively, by gender (parameter estimates in Table S7) and by race/ethnicity (parameter estimates in Table S8). Results were in accord with our a priori hypotheses, as summarized by the selected findings for each mortality outcome we highlight below. Model fit typically was best for Model 2, which included both the CT and city/town level measures (Tables S3–S8, available as Supplementary data at *IJE* online).

Early death

The predominant pattern was illustrated by child mortality (Figures 1, 11), whereby in multilevel models jointly including CT and city/town metrics, the rate ratio comparing the worst to best-off ICE quintile for the total population ranged from 2.2 (95% CI 1.6, 3.0) for the CT-level ICE for racialized economic segregation down to 1.1 (95% CI 0.8, 1.7) for the city/town-level ICE for racial segregation; similar patterns occurred by gender and for the non-Hispanic White population. Larger associations for the ICE for racialized economic segregation were at the CT-level for the Black non-Hispanic population (6.9; 95% CI 1.3, 36.9) and at the city/town level for the Hispanic population (6.4; 95% CI 1.2, 35.4). Results for premature mortality for the total population (Figure 2) were similar to those for child mortality; however, among both the non-Hispanic Black and Hispanic populations, associations at the city/town level were on par with or exceeded those at the CT level (Figure 12).

Chronic disease mortality

For cancer, cardiovascular and diabetes mortality, parameter estimates for the ICE and poverty measures for the total population (Figure 3–5) and the White non-Hispanic population (Figure 13–15) were, by contrast, similar within each set of models, with no effect modification by gender. However, for the non-Hispanic Black population, the ICE

Table 1. All-cause and cause-specific mortalities and total population: individual, county, city/town and census tract characteristics, Massachusetts, American Community Survey, 2010–14

	Total (MA)	All-cause mortality cases		Cause-specific mortality cases[a]							
		Child mortality (< 5 years)	Premature mortality (< 65 years)	Cancer (all site)	Cardiovascular disease	Diabetes	Suicide	HIV/AIDS	Accidental poisoning	Due to smoking	Not due to smoking
Total population count: N	6540189	1707	56931	63373	75130	5545	2906	469	4731	126081	137185
Age (years)											
Continuous: mean (SD)		0.34 (0.82)	49.9 (14.3)	72.5 (13.6)	80.5 (13.8)	74.7 (14.1)	45.8 (17.1)	52.9 (10.3)	41.6 (12.9)	78.1 (14.7)	74.3 (19.2)
Categorical (years): N (%)											
< 5	349670 (5.3%)	1707 (100%)	1707 (3.0%)	44 (0.1%)	35 (0.0%)				3 (0.1%)	702 (0.6%)	1005 (0.7%)
5 to 14	757475 (11.6%)		321 (0.6%)	59 (0.1%)	21 (0.0%)	2 (0.0%)	24 (0.8%)		4 (0.1%)	36 (0.0%)	285 (0.2%)
15 to 24	925794 (14.2%)		2053 (3.6%)	127 (0.2%)	79 (0.1%)	5 (0.1%)	349 (12.0%)	5 (1.1%)	381 (8.1%)	120 (0.1%)	1,933 (1.4%)
25 to 34	875309 (13.4%)		3635 (6.4%)	299 (0.5%)	261 (0.3%)	40 (0.7%)	451 (15.5%)	15 (3.2%)	1247 (26.4%)	370 (0.3%)	3,265 (2.4%)
35 to 44	844979 (12.9%)		5747 (10.1%)	1113 (1.8%)	864 (1.2%)	105 (1.9%)	500 (17.2%)	70 (14.9%)	1102 (23.3%)	1294 (1.0%)	4,453 (3.2%)
45 to 54	991625 (15.2%)		15383 (27.0%)	4560 (7.2%)	3131 (4.2%)	359 (6.5%)	711 (24.5%)	172 (36.7%)	1266 (26.8%)	5673 (4.5%)	9,710 (7.1%)
55 to 64	843510 (12.9%)		28085 (49.3%)	11223 (17.7%)	6170 (8.2%)	805 (14.5%)	508 (17.5%)	163 (34.8%)	572 (12.1%)	13261 (10.5%)	14,824 (10.8%)
65 to 74	505744 (7.7%)			15191 (24.0%)	9327 (12.4%)	1129 (20.4%)	197 (6.8%)	35 (7.5%)	87 (1.8%)	20744 (16.5%)	18,187 (13.3%)
75 to 84	296445 (4.5%)			17610 (27.8%)	18284 (24.3%)	1468 (26.5%)	102 (3.5%)	7 (1.5%)	37 (0.8%)	33285 (26.4%)	31,879 (23.2%)
85+	149638 (2.3%)			13147 (20.8%)	36958 (49.2%)	1632 (29.4%)	64 (2.2%)	2 (0.4%)	32 (0.7%)	50596 (40.1%)	51,643 (37.6%)
(Unknown)											1 (0.0%)
Gender: N (%)											
Men	3166730 (48.4%)	970 (56.9%)	35563 (62.5%)	32103 (50.7%)	35587 (47.4%)	2946 (53.1%)	2207 (76.0%)	318 (67.8%)	3366 (71.1%)	61369 (48.7%)	64,158 (46.8%)
Women	3373459 (51.6%)	734 (43.1%)	21362 (37.5%)	31268 (49.3%)	39536 (52.6%)	2599 (46.9%)	698 (24.0%)	151 (32.2%)	1365 (28.9%)	64701 (51.3%)	73,018 (53.2%)
(Unknown)		3 (0.2%)	6 (0.0%)	2 (0.0%)	7 (0.0%)		1 (0.0%)			11 (0.0%)	9 (0.0%)
Race/ethnicity: N (%)[b]											
White non-Hispanic	4992644 (76.3%)	874 (52.0%)	46913 (82.8%)	57336 (90.7%)	69361 (92.5%)	4661 (84.3%)	2567 (88.6%)	214 (45.8%)	4112 (87.1%)	116305 (92.5%)	123,252 (90.1%)
Black non-Hispanic	465792 (7.1%)	331 (19.7%)	4713 (8.3%)	2899 (4.6%)	3135 (4.2%)	490 (8.9%)	113 (3.9%)	143 (30.6%)	237 (5.0%)	4992 (4.0%)	6,620 (4.8%)
Hispanic	681824 (10.4%)	376 (22.4%)	3846 (6.8%)	1671 (2.6%)	1512 (2.0%)	282 (5.1%)	133 (4.6%)	106 (22.7%)	343 (7.3%)	2703 (2.1%)	4,727 (3.5%)
Asian and Pacific Islander non-Hispanic	386287 (5.9%)	96 (5.7%)	1094 (1.9%)	1226 (1.9%)	866 (1.2%)	84 (1.5%)	75 (2.6%)	3 (0.6%)	22 (0.5%)	1663 (1.3%)	2,045 (1.5%)
American Indian/ Alaska Native non-Hispanic	13642 (0.2%)	4 (0.2%)	95 (0.2%)	76 (0.1%)	79 (0.1%)	9 (0.2%)	8 (0.3%)	1 (0.2%)	8 (0.2%)	129 (0.1%)	156 (0.1%)
(Unknown)		26 (1.5%)	270(0.5%)	165 (0.3%)	177 (0.2%)	19 (0.3%)	10 (0.3%)	2 (0.4%)	9 (0.2%)	289(0.2%)	385 (0.3%)
Urbanicity: N (%)[c]											
Large metro	4688217 (71.7%)	1138 (67.0%)	38692 (68.3%)	43318 (68.7%)	50149 (67.1%)	3649 (66.1%)	1927 (66.7%)	326 (69.7%)	3356 (71.3%)	84271 (67.2%)	93,397 (68.4%)
Small and medium metro	1755449 (26.8%)	539 (31.7%)	17033 (30.1%)	18772 (29.8%)	23402 (31.3%)	1783 (32.3%)	903 (31.3%)	141 (30.1%)	1290 (27.4%)	39151 (31.2%)	41,007 (30.0%)
Non-metro	96523 (1.5%)	22 (1.3%)	918 (1.6%)	987 (1.6%)	1230 (1.6%)	90 (1.6%)	60 (2.1%)	1 (0.2%)	61 (1.3%)	2065 (1.7%)	2,140 (1.6%)
(Unknown)		8 (0.5%)	288 (0.5%)	296 (0.5%)	349 (0.5%)	23 (0.4%)	16 (0.6%)	1 (0.2%)	24 (0.5%)	594 (0.5%)	641 (0.5%)
City/town characteristics:											
City/town: N (%)[d]	313 (100%)										
(Unknown)		8 (0.5%)	288(0.5%)	296 (0.5%)	349 (0.5%)	23 (0.4%)	16 (0.6%)	1 (0.2%)	24 (0.5%)	594(0.5%)	641 (0.5%)

(continued)

Table 1. Continued

	Total (MA)	All-cause mortality cases		Cause-specific mortality cases[a]							
		Child mortality (< 5 years)	Premature mortality (< 65 years)	Cancer (all site)	Cardiovascular disease	Diabetes	Suicide	HIV/AIDS	Accidental poisoning	Due to smoking	Not due to smoking
City/town: Index of Concentration at the Extreme (ICE): mean (SD)											
ICE: income (low vs high income)	0.15 (0.18)	0.01 (0.19)	0.03 (0.18)	0.07 (0.19)	0.07 (0.19)	0.04 (0.18)	0.07 (0.18)	−0.05 (0.16)	0.07 (0.10)	0.07 (0.19)	0.07 (0.19)
ICE: race/ethnicity (Black vs White non-Hispanic)	0.85 (0.15)	0.59 (0.29)	0.67 (0.27)	0.71 (0.25)	0.71 (0.25)	0.68 (0.27)	0.72 (0.24)	0.49 (0.28)	0.69 (0.17)	0.71 (0.25)	0.70 (0.25)
ICE: race/ethnicity + income (low income Black vs high income White non-Hispanic)	0.24 (0.13)	0.14 (0.12)	0.16 (0.12)	0.19 (0.12)	0.19 (0.12)	0.17 (0.12)	0.19 (0.12)	0.10 (0.10)	0.18 (0.06)	0.18 (0.12)	0.19 (0.13)
City/town: % below poverty: mean (SD)	7.6% (5.2)	14.6% (8.3)	12.9% (7.8)	11.3% (7.4)	11.4% (7.5)	12.5% (7.7)	11.4% (7.3)	18.1% (7.6)	11.9% (4.4)	11.4% (7.4)	11.6% (7.6)
Census tract (CT) characteristics:											
CT: *N* (%)	1478 (100%)										
(Unknown)[e]		8 (0.5%)	323(0.6%)	331 (0.5%)	372 (0.5%)	25 (0.5%)	20 (0.7%)	1 (0.2%)	26 (0.5%)	644(0.5%)	693 (0.5%)
CT: Index of Concentration at the Extreme (ICE): mean (SD)											
ICE: income (low vs high income)	0.06 (0.25)	−0.02 (0.25)	0.02 (0.24)	0.08 (0.23)	0.07 (0.23)	0.03 (0.24)	0.06 (0.23)	−0.11 (0.25)	−0.01 (0.23)	0.07 (0.23)	0.07 (0.23)
ICE: race/ethnicity (Black vs White non-Hispanic)	0.67 (0.34)	0.53 (0.42)	0.65 (0.36)	0.72 (0.30)	0.73 (0.29)	0.67 (0.35)	0.72 (0.30)	0.42 (0.41)	0.63 (0.34)	0.72 (0.29)	0.71 (0.31)
ICE: race/ethnicity + income (low-income Black vs high-income White non-Hispanic)	0.18 (0.17)	0.12 (0.17)	0.15 (0.16)	0.19 (0.15)	0.19 (0.15)	0.16 (0.16)	0.18 (0.15)	0.07 (0.15)	0.13 (0.14)	0.19 (0.15)	0.19 (0.15)
CT: % below poverty: mean (SD)	12.9% (12.1)	15.8% (13.1)	13.6% (11.8)	10.9% (9.8)	11.0% (9.8)	12.8% (11.3)	11.7% (10.4)	21.7% (14.0)	14.9% (12.2)	11.0% (9.9)	11.3% (10.2)

Percent distribution is based on observed values; percentage for unknown is based on total population,

[a]ICD-10 codes used for underlying cause of death.

[b]We included decedents classified as Cape Verdean in the non-Hispanic Black category.

[c]Using 2013 National Center for Health Statistics, 'large metro' was defined as counties in metropolitan statistical areas of 1 million or more population; 'small and medium metro' was defined as counties in metropolitan statistical areas of population of less than 1 million; 'non-metro' was defined as counties in micropolitan statistical areas and those that did not qualify as micropolitan.

[d]Using 2010 Census boundaries, 59 of 351 Massachusetts towns were nested within census tracts containing two or more towns. To ensure that these towns conformed to the multilevel structure of the rest of the data (i.e. at least one census tract nested within a town), we aggregated these 59 towns into 21 super-towns.

[e]The number of unknown (%) reflects the maximum number of missing cases. The number of missing cases differed for different CT measures because ICE measures for race/ethnicity and poverty were calculated based on individuals, whereas ICE measures for income and race/ethnicity + income were calculated from households. The number of missing ranged from 305 to 323 for premature mortality; 322 to 331 for cancer; 363 to 372 for cardiovascular disease; 24 to 25 for diabetes; 16 to 20 for suicide; 25 to 26 for accidental poisoning; 629 to 644 for mortality due to smoking; and 676 to 693 for mortality not due to smoking.

Table 2. Average annual age-standardized mortality rates for each outcome by individual, CT and city/town characteristics, Massachusetts, American Community Survey, 2010–14[a]

	All-cause mortality rates (per 100000) and 95% CI		Cause-specific mortality rates (per 100,000) and 95% CI [b]							
	Child mortality (< 5 years)	Premature mortality (< 65 years)	Cancer (all site)	Cardiovascular disease	Diabetes	Suicide	HIV/AIDS	Accidental poisoning	Due to smoking	Not due to smoking
Overall rate for Massachusetts	97.0 (92.4, 101.7)	168.8 (167.4, 170.2)	161.8 (160.5, 163.1)	182.1 (180.8, 183.5)	14.0 (13.6, 14.3)	8.4 (8.1, 8.7)	1.3 (1.1, 1.4)	14.3 (13.9, 14.7)	312.0 (310.3, 313.7)	346.2 (344.3, 348.0)
Age (years)[c]										
< 5	97.0 (92.4, 101.7)	97.0 (92.4, 101.7)	2.5 (1.8, 3.4)	2.0 (1.4, 2.8)				0.2 (0.0, 0.5)	39.9 (37.0, 42.9)	57.1 (53.7, 60.8)
5 to 14		8.5 (7.6, 9.5)	1.6 (1.2, 2.0)	0.6 (0.3, 0.8)	0.1 (0.0, 0.2)	0.6 (0.4, 0.9)		0.1 (0.0, 0.3)	1.0 (0.7, 1.3)	7.5 (6.7, 8.5)
15 to 24		44.2 (42.3, 46.1)	2.7 (2.3, 3.3)	1.7 (1.4, 2.1)	0.1 (0.0, 0.3)	7.5 (6.7, 8.3)	0.1 (0.0, 0.3)	8.2 (7.4, 9.1)	2.6 (2.2, 3.1)	41.6 (39.7, 43.5)
25 to 34		82.8 (80.1, 85.5)	6.8 (6.1, 7.7)	5.9 (5.2, 6.7)	0.9 (0.7, 1.2)	10.3 (9.3, 11.3)	0.3 (0.2, 0.6)	28.4 (26.9, 30.0)	8.4 (7.6, 9.3)	74.4 (71.8, 77.0)
35 to 44		135.5 (132.0, 139.0)	26.2 (24.7, 27.8)	20.4 (19.1, 21.8)	2.5 (2.0, 3.0)	11.8 (10.8, 12.8)	1.7 (1.3, 2.1)	25.9 (24.4, 27.5)	30.5 (28.9, 32.2)	104.9 (101.9, 108.1)
45 to 54		308.5 (303.6, 313.4)	91.4 (88.8, 94.1)	62.8 (60.6, 65.0)	7.2 (6.5, 8.0)	14.3 (13.2, 15.4)	3.4 (3.0, 4.0)	25.4 (24.0, 26.8)	113.6 (110.7, 116.6)	194.9 (191.0, 198.8)
55 to 64		662.4 (654.6, 670.2)	265.0 (260.1, 269.9)	145.3 (141.6, 148.9)	19.1 (17.8, 20.4)	12.0 (11.0, 13.1)	3.9 (3.3, 4.5)	13.5 (12.4, 14.6)	312.7 (307.4, 318.1)	349.6 (344.0, 355.3)
65 to 74			598.1 (588.6, 607.7)	367.5 (360.1, 375.0)	44.5 (41.9, 47.1)	7.8 (6.7, 9.0)	1.4 (1.0, 1.9)	3.4 (2.8, 4.2)	817.0 (805.9, 828.2)	716.1 (705.7, 726.6)
75 to 84			1181.9 (1164.5, 1199.6)	1227.0 (1209.2, 1245.0)	98.6 (93.6, 103.8)	6.7 (5.5, 8.2)	0.5 (0.2, 1.0)	2.5 (1.8, 3.4)	2234.1 (2210.1, 2258.3)	2140.2 (2116.7, 2163.9)
85+			1749.6 (1719.7, 1779.8)	4918.3 (4868.1, 4968.8)	216.9 (206.5, 227.7)	8.4 (6.5, 10.8)	0.3 (0.0, 1.0)	4.3 (2.9, 6.0)	6732.1 (6673.4, 6791.2)	6869.8 (6810.5, 6929.4)
Gender:										
Men	108.2 (101.5, 115.3)	217.2 (214.9, 219.5)	195.0 (192.8, 197.2)	224.8 (222.5, 227.1)	18.0 (17.3, 18.6)	13.3 (12.7, 13.9)	1.8 (1.6, 2.0)	20.8 (20.1, 21.6)	384.3 (381.3, 387.3)	402.5 (399.4, 405.6)
Women	86.1 (80.0, 92.6)	122.8 (121.1, 124.5)	139.5 (137.9, 141.1)	150.1 (148.6, 151.6)	11.0 (10.5, 11.4)	3.9 (3.6, 4.2)	0.8 (0.7, 0.9)	8.0 (7.6, 8.5)	259.3 (257.3, 261.4)	301.1 (298.9, 303.4)
Race/ethnicity:[d]										
White non-Hispanic	78.2 (73.1, 83.6)	172.0 (170.4, 173.7)	166.1 (164.7, 167.5)	186.1 (184.7, 187.5)	13.2 (12.8, 13.6)	9.6 (9.2, 10.0)	0.7 (0.6, 0.8)	16.6 (16.0, 17.1)	320.7 (318.8, 322.5)	352.7 (350.7, 354.7)
Black non-Hispanic	193.0 (172.8, 215.0)	221.4 (215.0, 227.7)	167.6 (161.3, 173.9)	194.5 (187.6, 201.5)	29.3 (26.6, 31.9)	4.7 (3.8, 5.5)	6.3 (5.2, 7.3)	10.4 (9.0, 11.7)	303.1 (294.6, 311.7)	379.7 (370.3, 389.1)
Hispanic	113.0 (101.8, 125.0)	144.4 (139.8, 149.1)	102.4 (97.1, 107.8)	104.9 (99.2, 110.6)	19.4 (16.9, 21.8)	4.2 (3.4, 5.0)	4.1 (3.3, 4.9)	10.7 (9.6, 11.9)	177.4 (170.1, 184.7)	262.6 (254.1, 271.0)
Asian and Pacific Islander non-Hispanic	77.9 (63.1, 95.1)	65.0 (61.2, 68.9)	96.3 (90.7, 102.0)	79.3 (73.9, 84.7)	7.5 (5.8, 9.1)	4.0 (3.1, 5.0)	0.2 (0.0, 0.4)	1.0 (0.6, 1.5)	146.7 (139.4, 153.9)	170.7 (163.1, 178.4)
American Indian/ Alaska Native non-Hispanic	135.8 (37.0, 347.8)	147.3 (117.0, 177.7)	147.2 (110.2, 184.1)	210.4 (160.5, 260.3)	20.0 (5.4, 34.6)	10.9 (3.2, 18.5)	1.3 (0.0, 3.8)	11.2 (3.3, 19.0)	310.6 (252.7, 368.5)	335.4 (277.6, 393.1)
Urbanicity:[e]										
Large metro	87.3 (82.3, 92.6)	160.0 (158.3, 161.6)	159.2 (157.7, 160.7)	175.7 (174.2, 177.3)	13.2 (12.8, 13.6)	7.7 (7.4, 8.1)	1.2 (1.1, 1.4)	13.9 (13.4, 14.4)	301.1 (299.0, 303.1)	338.0 (335.8, 340.2)
Small and medium metro	118.8 (109.0, 129.4)	186.7 (183.8, 189.7)	164.8 (162.4, 167.1)	193.1 (190.6, 195.6)	15.4 (14.7, 16.1)	9.8 (9.2, 10.5)	1.4 (1.1, 1.6)	15.2 (14.4, 16.1)	330.8 (327.5, 334.1)	358.3 (354.8, 361.9)
Non-metro	94.8 (59.4, 143.5)	164.5 (153.0, 176.0)	149.9 (140.3, 159.5)	183.5 (173.1, 193.8)	14.1 (11.1, 17.1)	12.0 (8.8, 15.1)	0.2 (0.0, 0.5)	12.4 (9.2, 15.7)	311.5 (297.9, 325.1)	338.1 (323.4, 352.8)
City/town characteristics:[f]										
City/town: Index of Concentration at the Extreme (ICE):										
ICE: income (low vs high income)										
Q1 (worst off)	127.2 (119.1, 135.7)	220.9 (218.2, 223.6)	174.1 (171.8, 176.4)	198.0 (195.7, 200.4)	17.9 (17.2, 18.6)	8.3 (7.8, 8.8)	2.7 (2.4, 3.0)	19.0 (18.2, 19.8)	343.8 (340.7, 346.9)	382.8 (379.5, 386.1)
Q2	89.5 (79.0, 101.0)	172.0 (168.6, 175.4)	163.0 (160.1, 165.8)	189.1 (186.2, 192.1)	14.0 (13.2, 14.9)	9.5 (8.7, 10.2)	0.7 (0.5, 1.0)	15.6 (14.6, 16.6)	321.6 (317.7, 325.5)	343.7 (339.5, 347.8)
Q3	74.9 (64.0, 87.1)	151.9 (148.3, 155.4)	159.2 (155.9, 162.5)	181.0 (177.6, 184.4)	12.9 (12.0, 13.8)	9.3 (8.4, 10.1)	0.6 (0.4, 0.8)	13.2 (12.1, 14.2)	309.2 (304.8, 313.7)	339.4 (334.6, 344.1)
Q4	68.7 (59.1, 79.5)	131.4 (128.3, 134.5)	155.5 (152.4, 158.7)	170.5 (167.4, 173.7)	10.9 (10.1, 11.7)	8.1 (7.3, 8.9)	0.3 (0.2, 0.4)	10.8 (9.8, 11.7)	291.3 (287.2, 295.5)	320.9 (316.4, 325.3)
Q5 (best off)	56.6 (47.5, 66.9)	94.3 (91.5, 97.2)	135.5 (132.5, 138.6)	143.4 (140.4, 146.4)	8.7 (8.0, 9.5)	6.7 (5.9, 7.4)	0.3 (0.2, 0.4)	6.7 (5.8, 7.6)	239.5 (235.6, 243.4)	284.0 (279.7, 288.4)

(continued)

Table 2. Continued

	All-cause mortality rates (per 100000) and 95% CI		Cause-specific mortality rates (per 100,000) and 95% CI [b]							
	Child mortality (< 5 years)	Premature mortality (< 65 years)	Cancer (all site)	Cardiovascular disease	Diabetes	Suicide	HIV/AIDS	Accidental poisoning	Due to smoking	Not due to smoking
ICE: race/ethnicity (Black vs White non-Hispanic)										
Q1 (most Black)	109.1 (102.7, 115.8)	187.5 (185.3, 189.6)	165.7 (163.8, 167.6)	184.4 (182.5, 186.4)	15.9 (15.3, 16.4)	7.5 (7.1, 7.9)	2.1 (1.9, 2.4)	15.8 (15.2, 16.4)	316.4 (313.8, 318.9)	358.0 (355.2, 360.7)
Q2	88.3 (78.4, 99.0)	155.2 (152.1, 158.2)	158.9 (156.2, 161.5)	179.3 (176.5, 182.0)	12.2 (11.5, 12.9)	9.5 (8.7, 10.3)	0.5 (0.3, 0.6)	13.7 (12.7, 14.6)	306.3 (302.7, 309.9)	340.7 (336.8, 344.6)
Q3	77.2 (65.6, 90.2)	150.1 (146.4, 153.8)	158.6 (155.3, 161.9)	175.2 (171.8, 178.5)	12.3 (11.3, 13.2)	8.8 (7.9, 9.7)	0.5 (0.3, 0.7)	13.1 (11.9, 14.2)	302.8 (298.3, 307.2)	329.6 (324.8, 334.4)
Q4	61.4 (48.9, 76.1)	145.5 (141.1, 150.0)	154.7 (150.7, 158.8)	175.5 (171.2, 179.8)	11.8 (10.6, 12.9)	10.1 (8.9, 11.3)	0.4 (0.2, 0.6)	14.0 (12.5, 15.5)	304.5 (298.8, 310.1)	325.6 (319.6, 331.6)
Q5 (most White)	68.3 (52.7, 87.1)	146.3 (141.0, 151.6)	147.9 (143.4, 152.3)	185.0 (180.1, 189.9)	12.9 (11.6, 14.2)	9.8 (8.4, 11.3)	0.4 (0.2, 0.6)	13.6 (11.8, 15.4)	304.2 (297.9, 310.5)	323.4 (316.6, 330.2)
ICE: race/ethnicity + income (low-income Black vs high-income White non-Hispanic)										
Q1 (most Black and low income)	126.6 (118.6, 134.9)	221.7 (218.9, 224.4)	174.2 (172.0, 176.5)	197.6 (195.3, 199.9)	17.9 (17.2, 18.7)	8.3 (7.8, 8.8)	2.7 (2.4, 2.9)	19.4 (18.6, 20.2)	343.4 (340.3, 346.4)	381.3 (378.0, 384.5)
Q2	92.4 (81.9, 104.0)	163.7 (160.4, 166.9)	162.0 (159.2, 164.9)	187.3 (184.4, 190.2)	13.6 (12.8, 14.4)	9.5 (8.7, 10.2)	0.7 (0.5, 0.9)	13.9 (12.9, 14.0)	318.8 (315.0, 322.7)	343.4 (339.3, 347.5)
Q3	68.0 (57.5, 79.8)	159.1 (155.4, 162.8)	161.1 (157.8, 164.4)	187.3 (183.8, 190.7)	12.9 (12.0, 13.8)	9.1 (8.2, 9.9)	0.6 (0.4, 0.8)	14.4 (13.3, 15.6)	316.4 (311.9, 320.9)	346.2 (341.4, 351.0)
Q4	64.9 (55.3, 75.7)	126.5 (123.4, 129.7)	154.3 (151.1, 157.5)	166.1 (162.9, 169.4)	11.4 (10.5, 12.2)	8.2 (7.4, 9.0)	0.3 (0.2, 0.5)	10.2 (9.3, 11.1)	286.5 (282.2, 290.7)	316.3 (311.8, 320.9)
Q5 (most White and high income)	58.6 (49.1, 69.4)	94.4 (91.4, 97.3)	134.1 (131.0, 137.2)	142.2 (139.2, 145.2)	8.2 (7.5, 9.0)	6.6 (5.8, 7.4)	0.2 (0.1, 0.4)	6.8 (5.9, 7.7)	236.9 (233.0, 240.8)	280.5 (276.1, 284.9)
City/town: % below poverty										
Q1 (most impoverished)	120.8 (113.4, 128.5)	209.6 (207.1, 212.1)	169.8 (167.7, 171.9)	192.1 (189.9, 194.2)	17.3 (16.6, 17.9)	8.2 (7.7, 8.7)	2.5 (2.2, 2.8)	17.7 (17.0, 18.4)	331.8 (328.9, 334.7)	371.5 (368.4, 374.5)
Q2	84.2 (73.7, 95.7)	172.2 (168.7, 175.7)	167.4 (164.4, 170.4)	192.7 (189.6, 195.8)	13.7 (12.8, 14.5)	10.0 (9.2, 10.8)	0.7 (0.5, 0.9)	15.3 (14.3, 16.4)	330.2 (326.1, 334.3)	353.1 (348.8, 357.4)
Q3	71.0 (59.9, 83.4)	145.8 (142.2, 149.4)	153.1 (149.8, 156.3)	171.1 (167.8, 174.5)	11.9 (11.0, 12.8)	8.5 (7.7, 9.4)	0.5 (0.3, 0.6)	14.3 (13.1, 15.5)	291.7 (287.3, 296.0)	326.4 (321.6, 331.2)
Q4	76.0 (65.3, 88.0)	125.8 (122.6, 129.0)	150.6 (147.5, 153.7)	168.6 (165.4, 171.8)	11.1 (10.2, 11.9)	7.5 (6.7, 8.3)	0.3 (0.2, 0.4)	10.4 (9.4, 11.4)	284.7 (280.5, 288.9)	320.0 (315.5, 324.6)
Q5 (least impoverished)	56.9 (47.1, 68.2)	111.1 (107.8, 114.4)	145.4 (142.0, 148.8)	157.1 (153.7, 160.6)	9.8 (9.0, 10.7)	7.8 (6.9, 8.7)	0.3 (0.1, 0.4)	8.9 (7.9, 9.9)	266.5 (262.0, 271.0)	297.1 (292.2, 302.0)
Census tract (CT) characteristics:										
CT: Index of Concentration at the Extreme (ICE):										
ICE: income (low vs high income)										
Q1 (worst off)	134.6 (123.1, 146.8)	271.3 (266.7, 276.0)	180.0 (176.4, 183.6)	213.9 (210.1, 217.8)	21.4 (20.2, 22.7)	9.2 (8.4, 10.0)	3.9 (3.3, 4.4)	24.4 (23.1, 25.8)	370.1 (365.0, 375.2)	407.4 (402.1, 412.7)
Q2	113.7 (102.6, 125.6)	202.4 (198.8, 206.0)	171.0 (168.1, 174.0)	193.1 (190.1, 196.1)	15.8 (14.9, 16.7)	9.2 (8.5, 10.0)	1.7 (1.4, 2.0)	17.3 (16.3, 18.4)	334.6 (330.6, 338.7)	371.5 (367.2, 375.8)
Q3	93.4 (83.1, 104.6)	162.4 (159.3, 165.5)	162.0 (159.3, 164.7)	183.7 (180.9, 186.5)	13.5 (12.7, 14.3)	8.6 (7.9, 9.2)	0.8 (0.6, 1.0)	14.4 (13.5, 15.3)	313.9 (310.2, 317.6)	336.6 (332.7, 340.5)
Q4	77.3 (68.3, 87.1)	140.5 (137.7, 143.2)	157.8 (155.1, 160.4)	176.8 (174.1, 179.6)	12.7 (11.9, 13.4)	8.2 (7.6, 8.9)	0.5 (0.4, 0.7)	11.6 (10.8, 12.4)	301.8 (298.2, 305.4)	334.6 (330.7, 338.4)
Q5 (best off)	57.5 (50.0, 65.8)	103.4 (101.0, 105.7)	142.4 (139.9, 145.0)	152.1 (149.5, 154.6)	9.1 (8.5, 9.8)	7.0 (6.4, 7.6)	0.4 (0.3, 0.5)	7.5 (6.8, 8.2)	256.3 (252.9, 259.6)	294.9 (291.3, 298.6)
ICE: race/ethnicity (Black vs White non-Hispanic)										
Q1 (most Black)	130.9 (120.4, 142.1)	235.1 (231.1, 239.2)	175.1 (171.0, 178.7)	195.5 (191.7, 199.2)	20.3 (19.1, 21.5)	7.4 (6.7, 8.1)	3.8 (3.3, 4.3)	20.2 (19.1, 21.4)	337.1 (332.2, 342.1)	388.1 (382.8, 393.3)
Q2	102.6 (91.9, 114.1)	182.9 (179.4, 186.4)	166.8 (163.7, 169.8)	183.8 (180.7, 186.9)	15.3 (14.4, 16.2)	8.1 (7.4, 8.7)	1.7 (1.4, 2.0)	15.8 (14.8, 16.7)	319.1 (315.0, 323.2)	355.1 (350.8, 359.5)
Q3	88.0 (78.3, 98.5)	145.1 (142.2, 148.0)	155.1 (152.4, 157.7)	177.2 (174.5, 180.0)	12.5 (11.7, 13.2)	7.8 (7.1, 8.4)	0.7 (0.5, 0.9)	11.6 (10.8, 12.4)	300.7 (297.1, 304.4)	329.6 (325.7, 333.4)
Q4	72.5 (63.7, 82.0)	149.0 (146.1, 151.8)	159.7 (157.1, 162.2)	176.5 (173.9, 179.1)	12.3 (11.5, 13.0)	8.9 (8.2, 9.6)	0.4 (0.3, 0.6)	13.3 (12.4, 14.2)	302.0 (298.6, 305.5)	337.1 (333.4, 340.9)
Q5 (most White)	71.1 (61.8, 81.4)	147.8 (144.8, 150.8)	153.2 (150.6, 155.8)	176.7 (174.0, 179.4)	12.0 (11.2, 12.7)	9.8 (9.0, 10.6)	0.4 (0.3, 0.5)	13.6 (12.6, 14.6)	300.4 (296.9, 304.0)	324.4 (320.6, 328.3)

(continued)

Table 2. Continued

	All-cause mortality rates (per 100000) and 95% CI		Cause-specific mortality rates (per 100,000) and 95% CI [b]							
	Child mortality (< 5 years)	Premature mortality (< 65 years)	Cancer (all site)	Cardiovascular disease	Diabetes	Suicide	HIV/AIDS	Accidental poisoning	Due to smoking	Not due to smoking
ICE: race/ethnicity + income (low-income Black vs high-income White non-Hispanic)										
Q1 (most Black and low income)	139.7 (128.4, 151.7)	265.6 (261.1, 270.1)	176.4 (172.8, 180.0)	207.8 (203.9, 211.7)	21.3 (20.0, 22.5)	8.2 (7.5, 9.0)	4.0 (3.5, 4.6)	23.3 (22.0, 24.6)	357.1 (352.0, 362.2)	403.0 (397.7, 408.4)
Q2	111.3 (100.2, 123.4)	204.2 (200.5, 207.8)	174.9 (171.9, 177.9)	196.3 (193.2, 199.3)	16.2 (15.3, 17.1)	9.7 (8.9, 10.4)	1.6 (1.3, 1.9)	18.4 (17.3, 19.4)	343.0 (338.9, 347.1)	368.8 (364.4, 373.1)
Q3	95.1 (84.7, 106.5)	165.1 (162.0, 168.2)	164.6 (161.9, 167.4)	189.6 (186.7, 192.5)	13.7 (12.9, 14.5)	8.8 (8.1, 9.5)	0.8 (0.6, 1.0)	13.8 (12.9, 14.7)	324.3 (320.5, 328.0)	350.5 (346.5, 354.5)
Q4	72.8 (64.2, 82.3)	138.1 (135.4, 140.8)	154.9 (152.3, 157.4)	173.8 (171.2, 176.5)	12.5 (11.8, 13.2)	8.6 (7.9, 9.2)	0.4 (0.3, 0.6)	11.9 (11.0, 12.7)	295.6 (292.1, 299.0)	326.2 (322.5, 329.9)
Q5 (most White and high income)	53.5 (46.2, 61.7)	103.2 (100.8, 105.6)	141.7 (139.2, 144.2)	150.0 (147.5, 152.6)	9.0 (8.3, 9.6)	6.7 (6.0, 7.3)	0.4 (0.2, 0.5)	7.5 (6.8, 8.2)	252.9 (249.6, 256.2)	293.4 (289.8, 297.0)
CT: % below poverty										
Q1 (most impoverished)	138.2 (126.5, 150.7)	263.3 (258.6, 268.0)	178.5 (174.6, 182.4)	208.5 (204.4, 212.6)	21.4 (20.1, 22.7)	8.4 (7.6, 9.2)	4.3 (3.7, 4.9)	23.6 (22.2, 25.0)	358.0 (352.6, 363.4)	401.2 (395.5, 406.8)
Q2	102.4 (92.2, 113.5)	196.8 (193.3, 200.4)	170.3 (167.3, 173.3)	187.8 (184.7, 190.8)	15.8 (14.9, 16.7)	8.8 (8.1, 9.6)	1.8 (1.5, 2.2)	16.8 (15.7, 17.8)	328.5 (324.5, 332.6)	365.2 (360.8, 369.5)
Q3	86.2 (76.3, 97.0)	166.3 (163.2, 169.4)	161.8 (159.1, 164.6)	185.3 (182.5, 188.1)	14.2 (13.4, 15.0)	8.9 (8.2, 9.6)	0.7 (0.5, 0.9)	14.0 (13.1, 14.9)	315.7 (312.0, 319.3)	346.0 (342.1, 350.0)
Q4	81.0 (71.7, 91.3)	139.1 (136.3, 141.8)	155.1 (152.6, 157.7)	178.4 (175.7, 181.0)	11.9 (11.1, 12.6)	8.0 (7.3, 8.7)	0.4 (0.3, 0.5)	11.6 (10.7, 12.4)	301.6 (298.1, 305.1)	328.7 (325.0, 332.5)
Q5 (least impoverished)	67.1 (58.9, 76.0)	119.5 (117.0, 122.1)	148.7 (146.2, 151.2)	159.5 (156.9, 162.0)	10.2 (9.5, 10.8)	8.1 (7.4, 8.8)	0.3 (0.2, 0.5)	10.6 (9.8, 11.5)	272.4 (269.0, 275.7)	307.1 (303.4, 310.7)

[a]Cases with missing values on a given variable were excluded when calculating incidence rates by that variable.

[b]ICD-10 codes used for underlying cause of death.

[c]All rates age-standardized to the year 2000 standard million except for the age-specific rates and child mortality rates.

[d]We included decedents classified as Cape Verdean in the non-Hispanic Black category.

[e]Using 2013 National Center for Health Statistics, 'large metro' was defined as counties in metropolitan statistical areas of 1 million or more population; 'small and medium metro' was defined as counties in metropolitan statistical areas of population of less than 1 million; 'non-metro' was defined as counties in micropolitan statistical areas and those that did not qualify as micropolitan.

[f]Using 2010 Census boundaries, 59 of 351 Massachusetts towns were nested within census tracts containing two or more towns. To ensure that these towns conformed to the multilevel structure of the rest of the data (i.e. at least one census tract nested within a town), we aggregated these 59 towns into 21 super-towns.

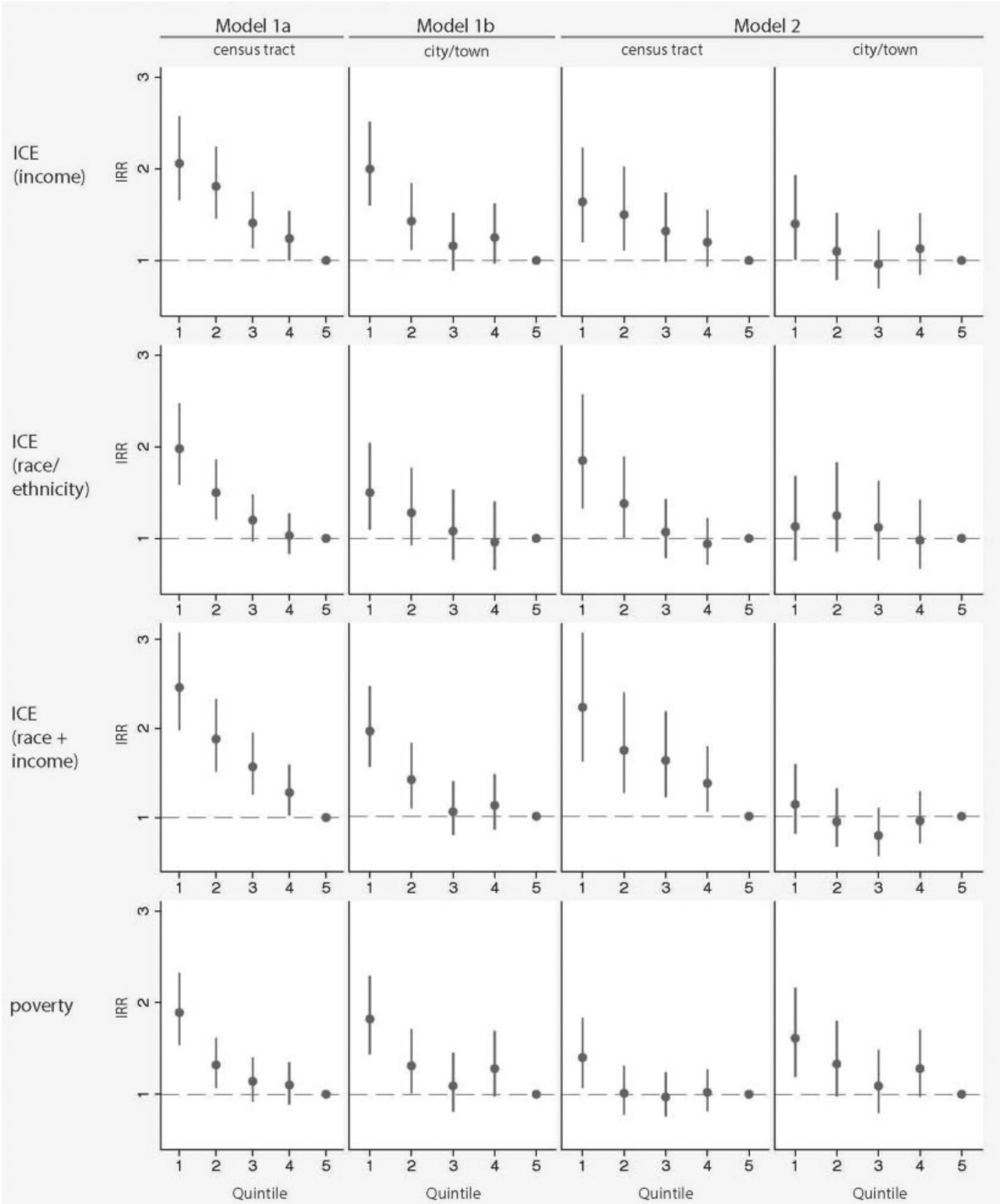

Figure 1. Child mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 20107–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

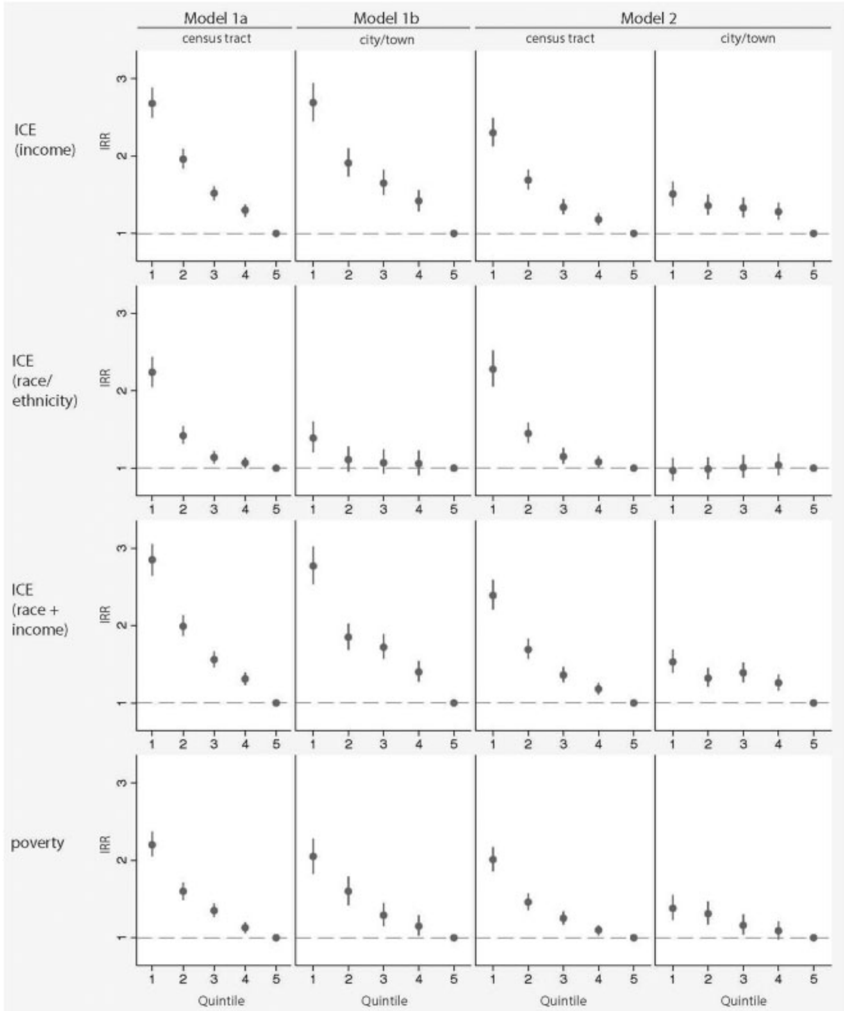

Figure 2. Premature mortality (< 65 years) incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

for racialized economic segregation at the city/town level in Model 2 remained associated with cancer and cardiovascular mortality, as did the poverty rate for cardiovascular mortality, and among the Hispanic population this ICE remained associated with diabetes mortality (Figure 13–15).

Non-chronic disease mortality

Among the total population (Figure 6–8) and the White non-Hispanic population (Figure 16–18), results for suicide and accidental poisoning—both acute types of mortality—resembled those for premature mortality, also with no effect modification by gender. Thus, in Model 2, the respective CT and city/town Q1 vs Q5 rate ratios for accidental poisoning for the total population were, for the ICE for racialized economic segregation, 3.47 (95% CI 2.89, 4.17) and 1.95 (95% CI 1.55, 2.44); and for poverty they were 2.50 (95% CI 2.11, 2.96) and 1.68 (95% CI 1.34, 2.12). For the non-Hispanic Black and Hispanic population, however, the 95% CI for the ICE and poverty measures at both levels typically included 1. For HIV/AIDS, the different measures, by contrast, tended to perform similarly for the total population and the White non-Hispanic population at each level, with no effect modification by gender; for the non-Hispanic Black and Hispanic populations, all of the rate ratios had very wide 95% confidence intervals and were not distinguishable from 1.

Deaths attributable to smoking

Results for this outcome (and also deaths not attributable to smoking) were similar to those observed for the total population and the White non-Hispanic population for premature mortality and cardiovascular mortality (Figures 9–10 and 19–20). For the non-Hispanic Black and Hispanic Black populations, however, associations generally were

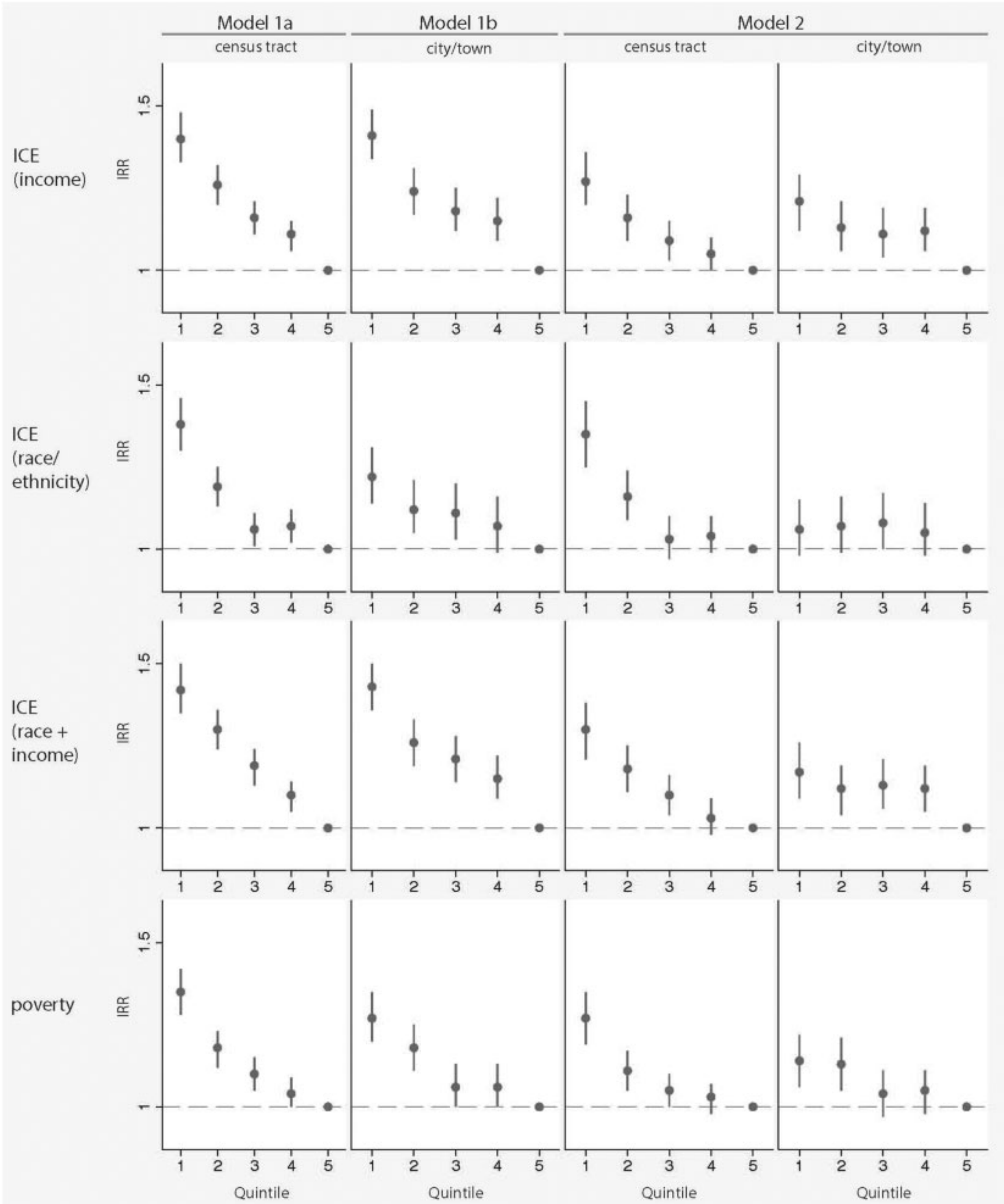

Figure 3. Cancer (all-site) mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

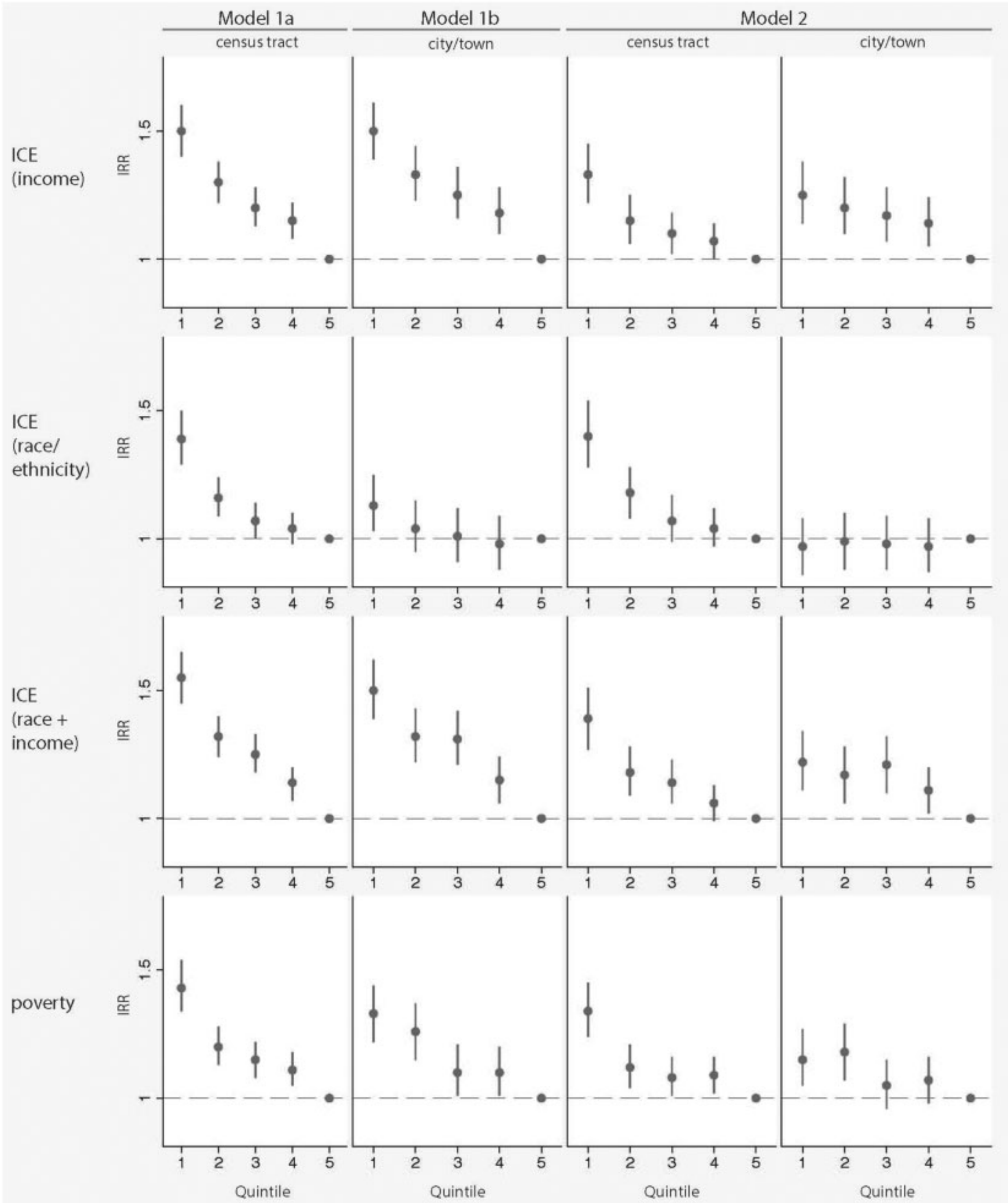

Figure 4. Cardiovascular mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

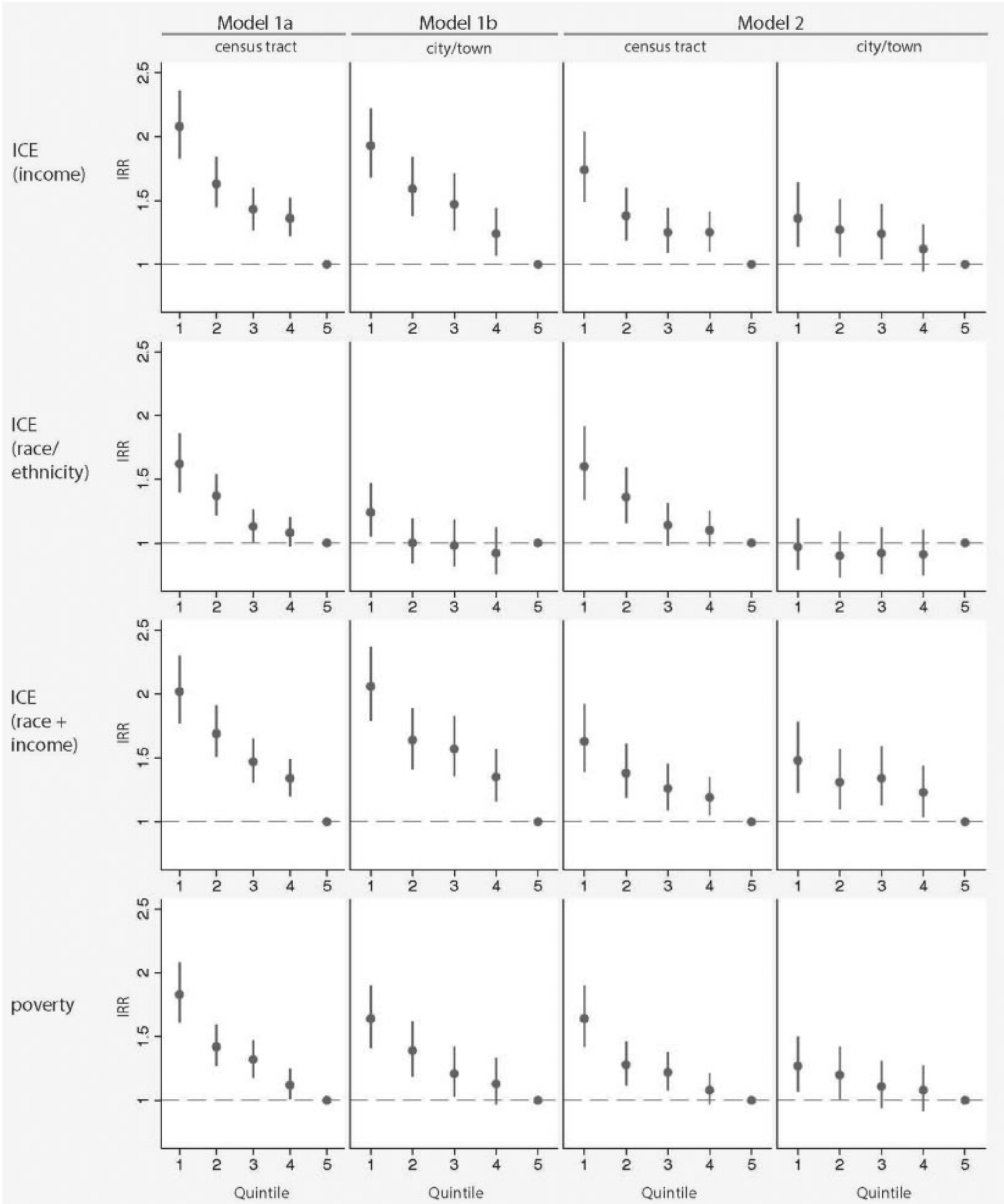

Figure 5. Diabetes mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

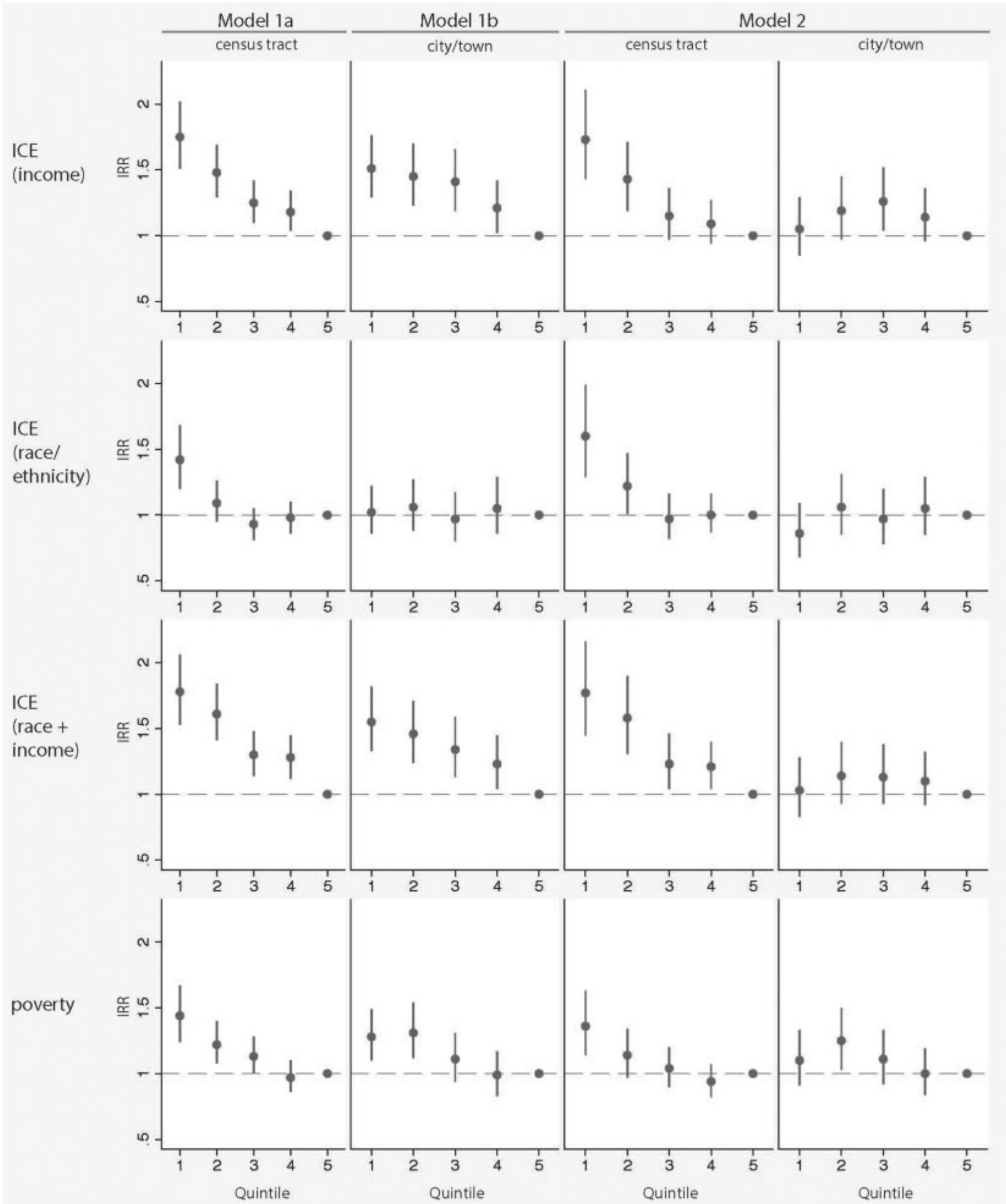

Figure 6. Suicide incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

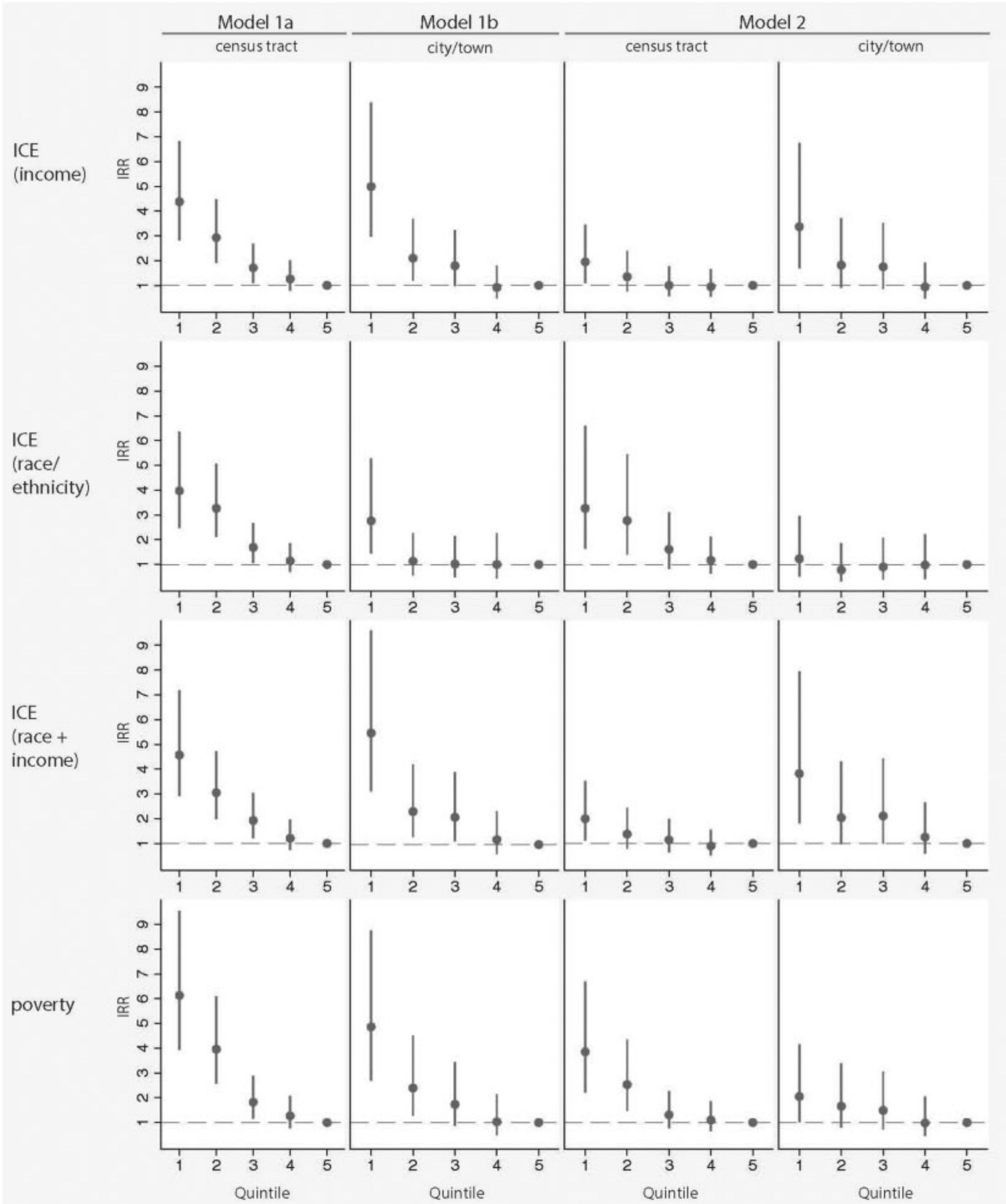

Figure 7. HIV/AIDS mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

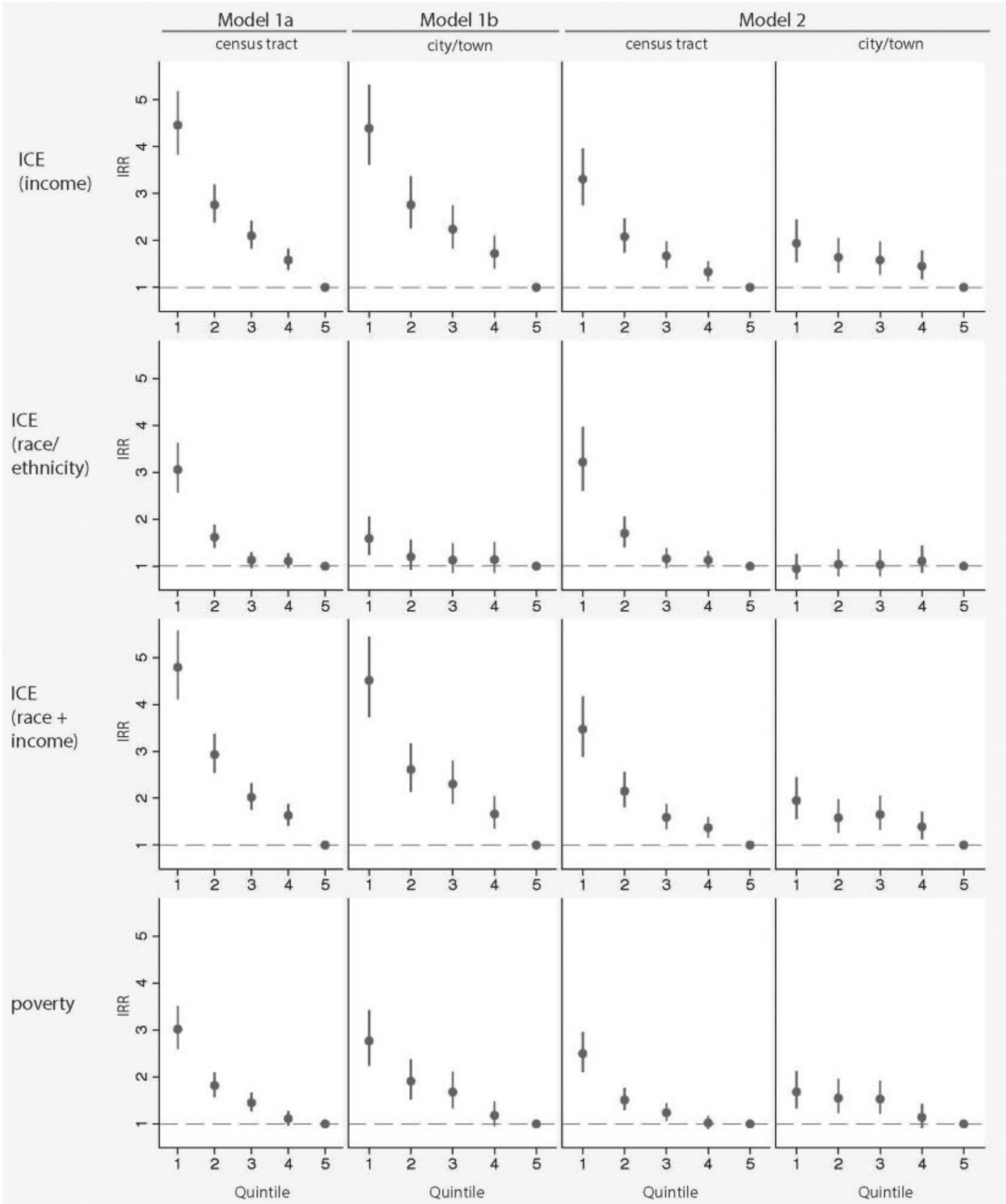

Figure 8. Accidental poisoning mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

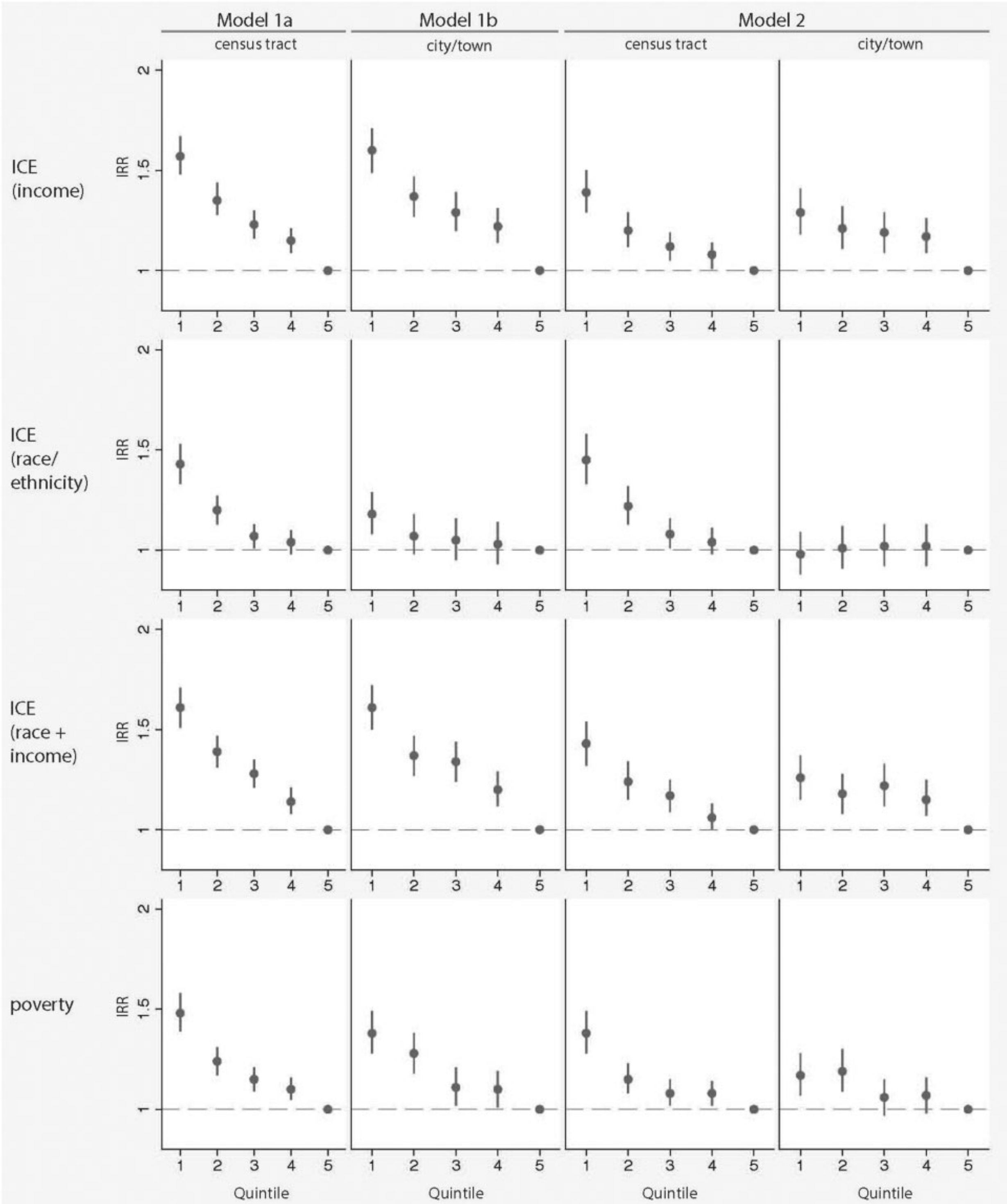

Figure 9. Mortality due to smoking incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

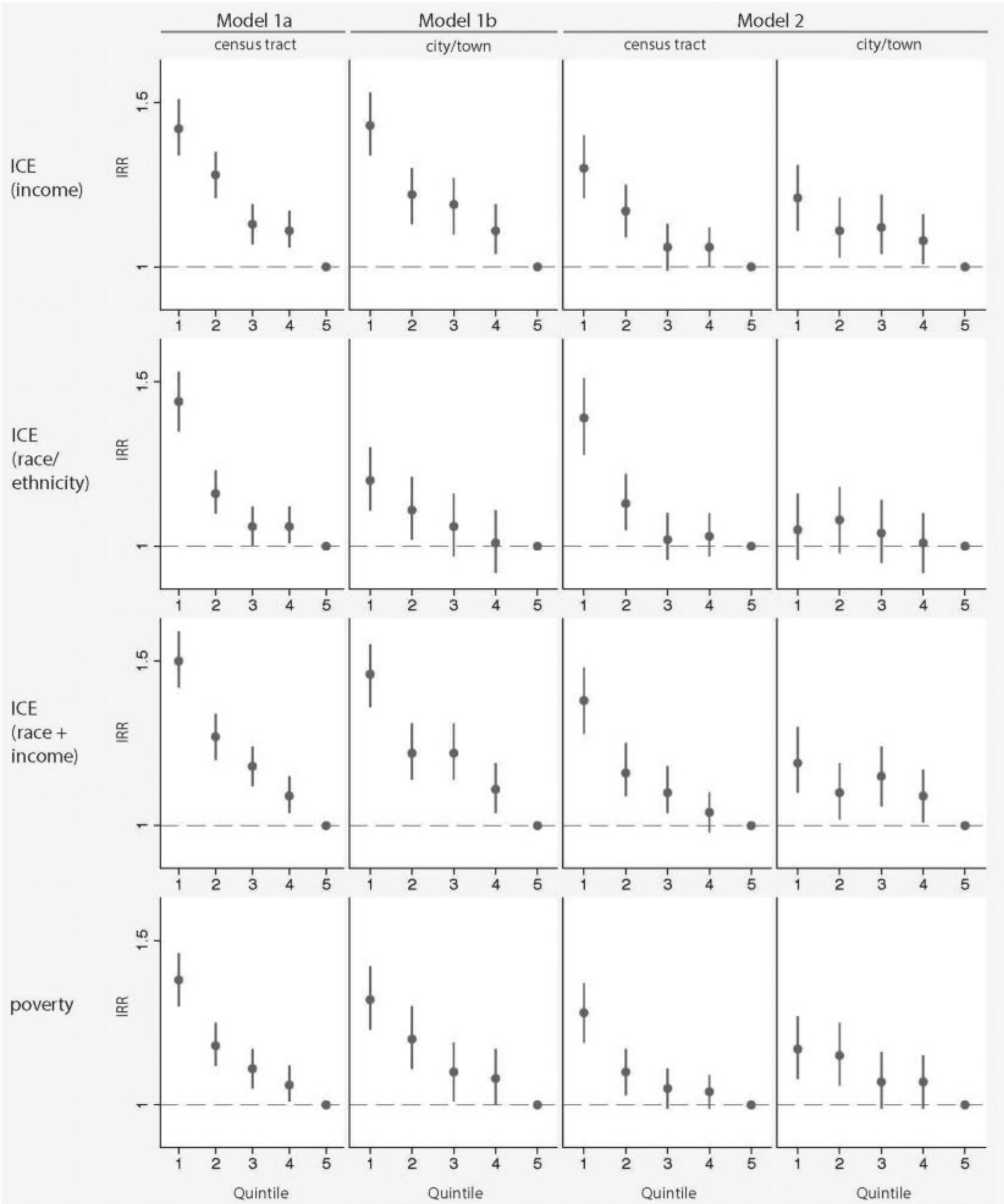

Figure 10. Mortality not due to smoking incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) for the total population, Massachusetts, 2010–2014. *Results from multilevel Poisson models for age-standardized mortality rates that adjusted for gender, race/ethnicity, and urbanicity.

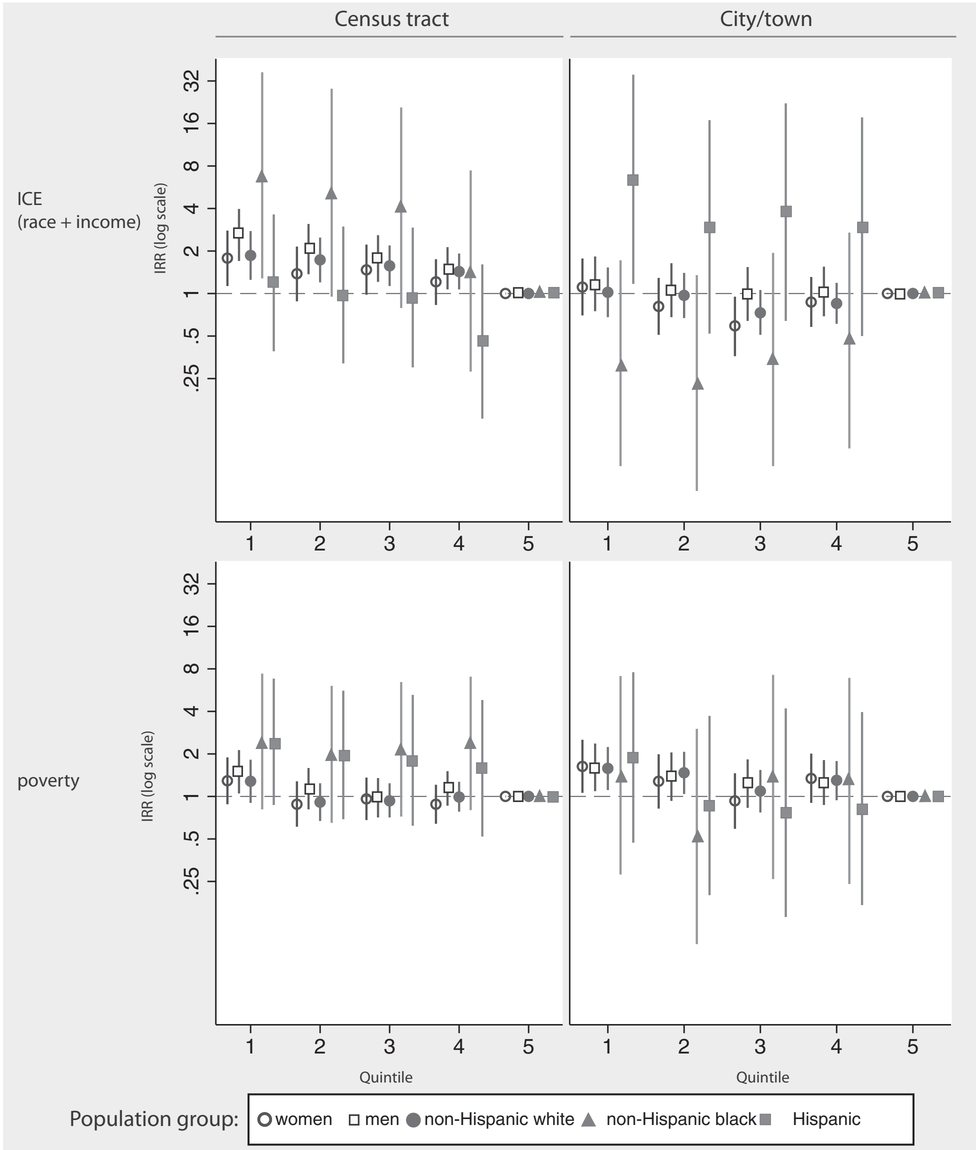

Figure 11. Child mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

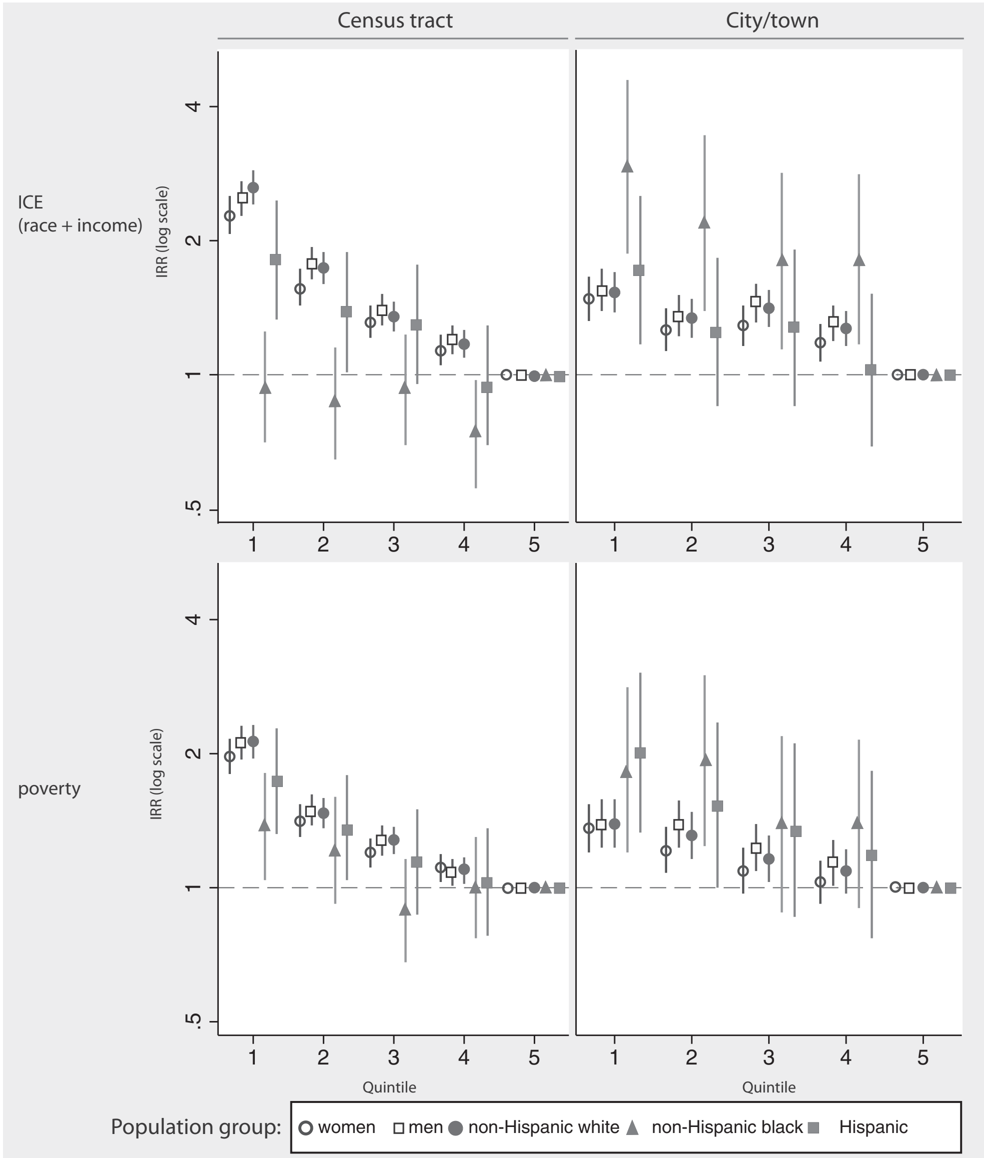

Figure 12. Premature mortalty (age <65) incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

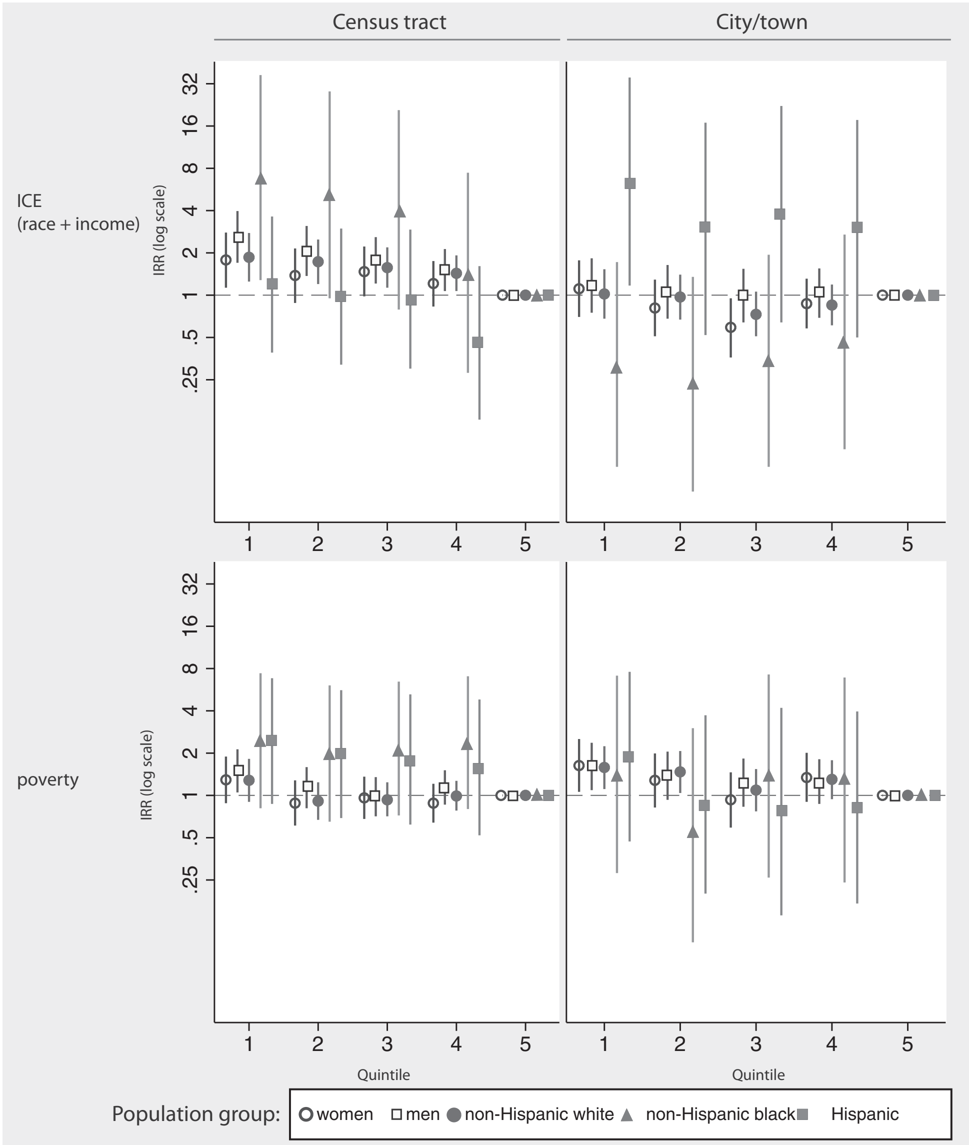

Figure 13. Cancer (all-site) mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

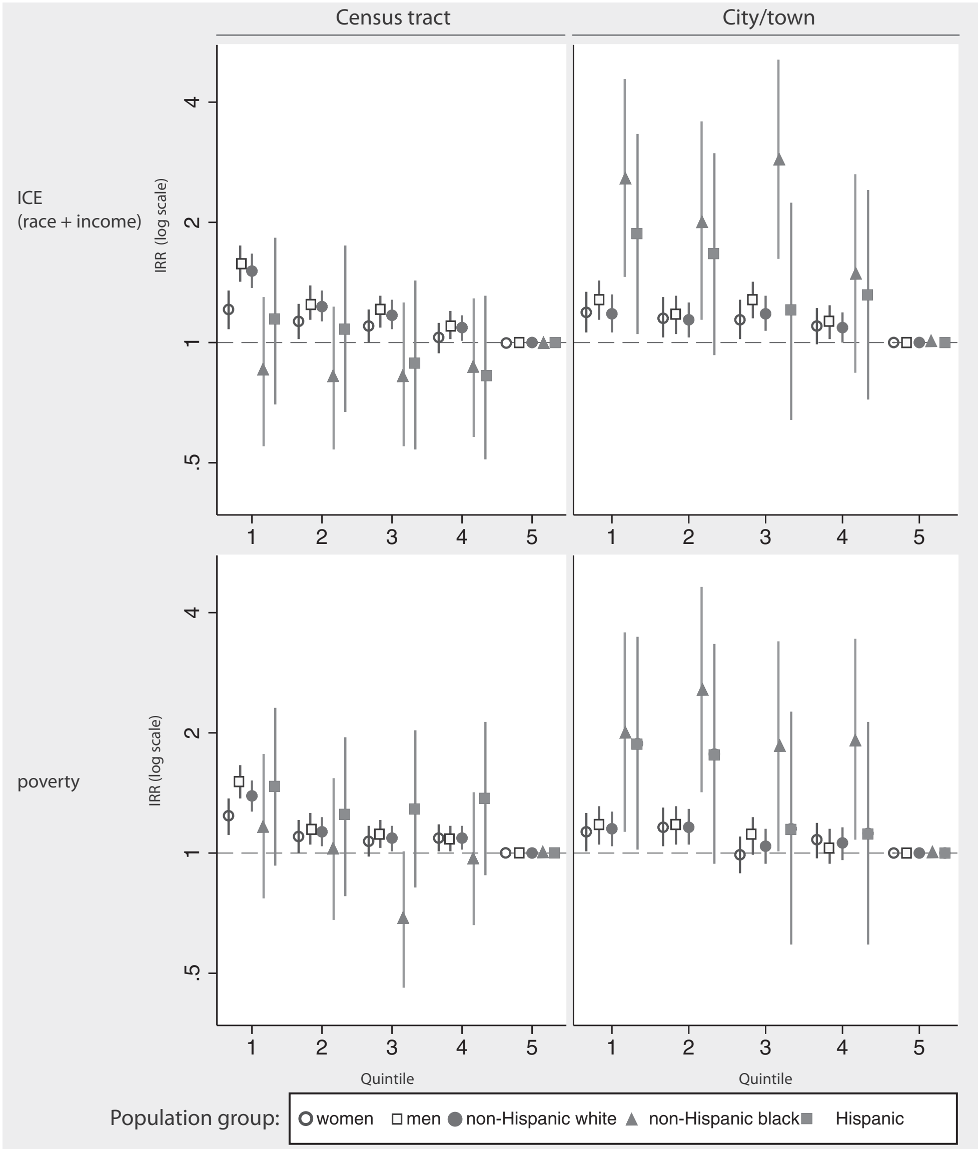

Figure 14. Cardiovascular mortalty incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

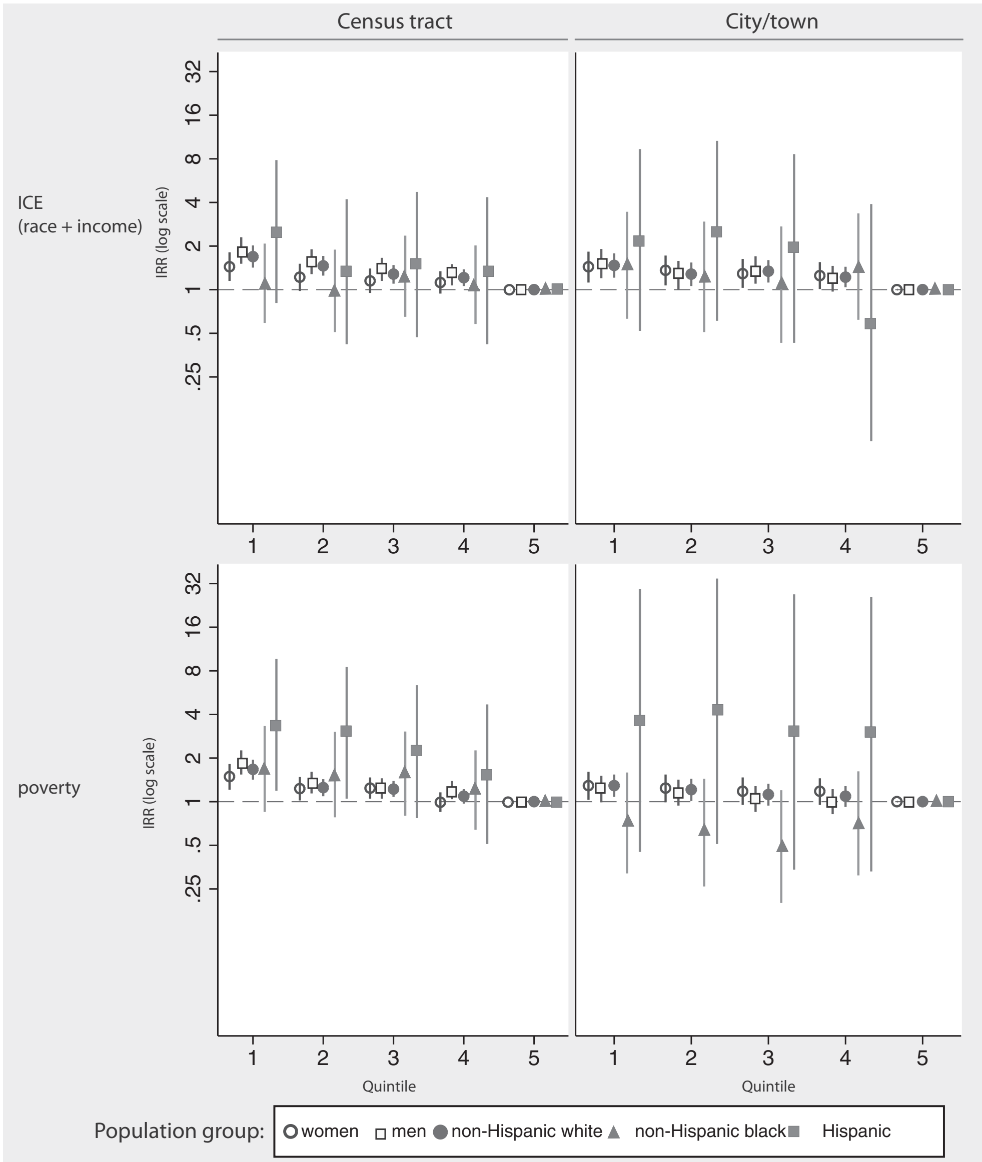

Figure 15. Diabetes mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

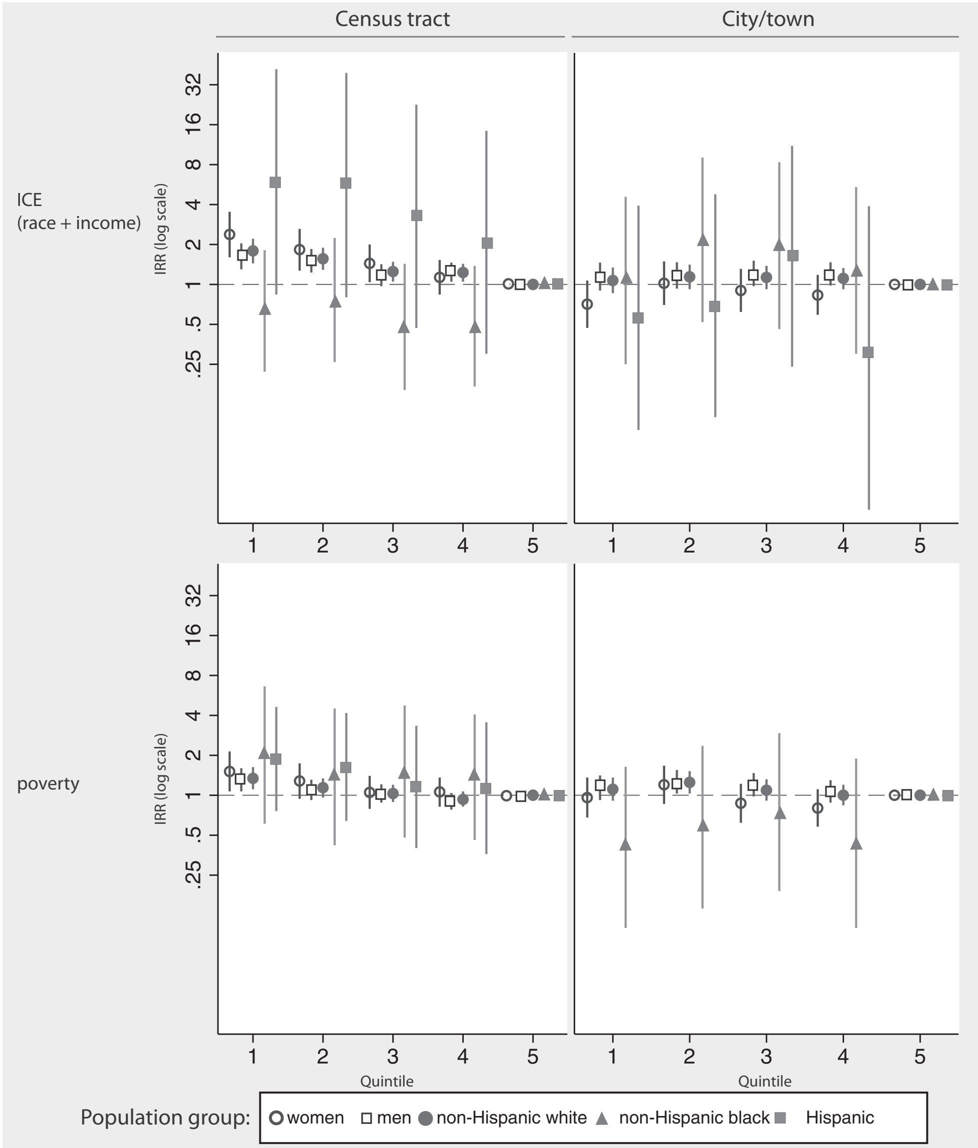

Figure 16. Suicide incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

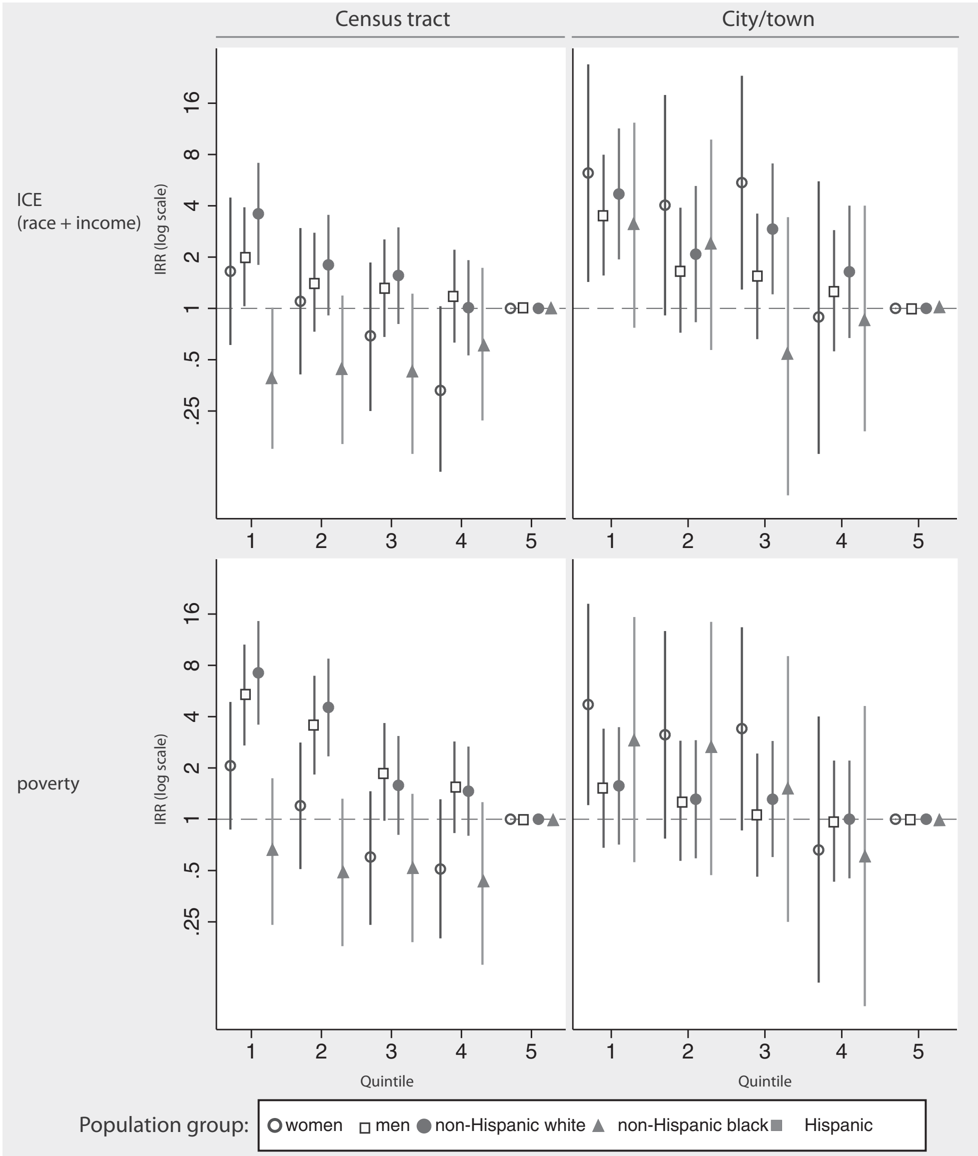

Figure 17. HIV mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

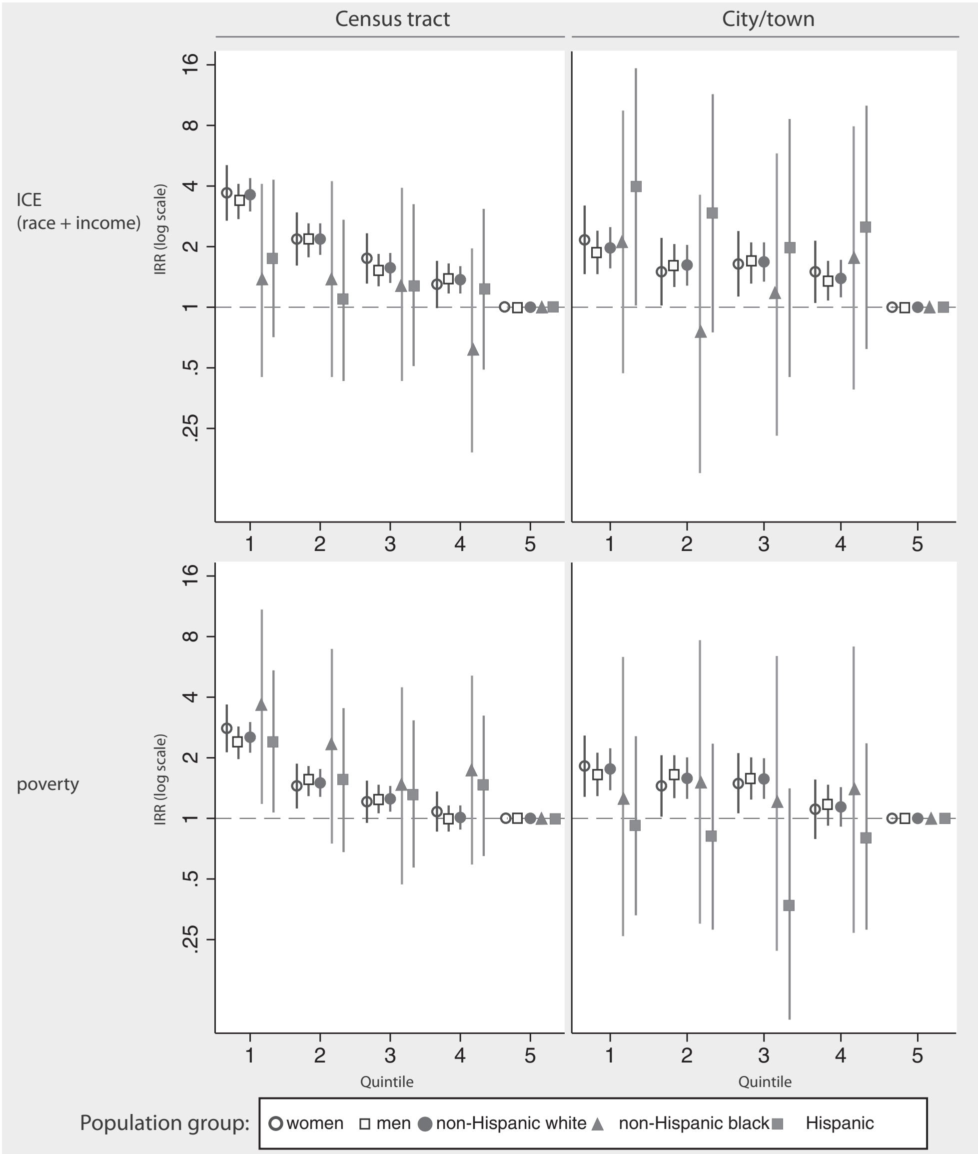

Figure 18. Accidental poisoning mortality incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

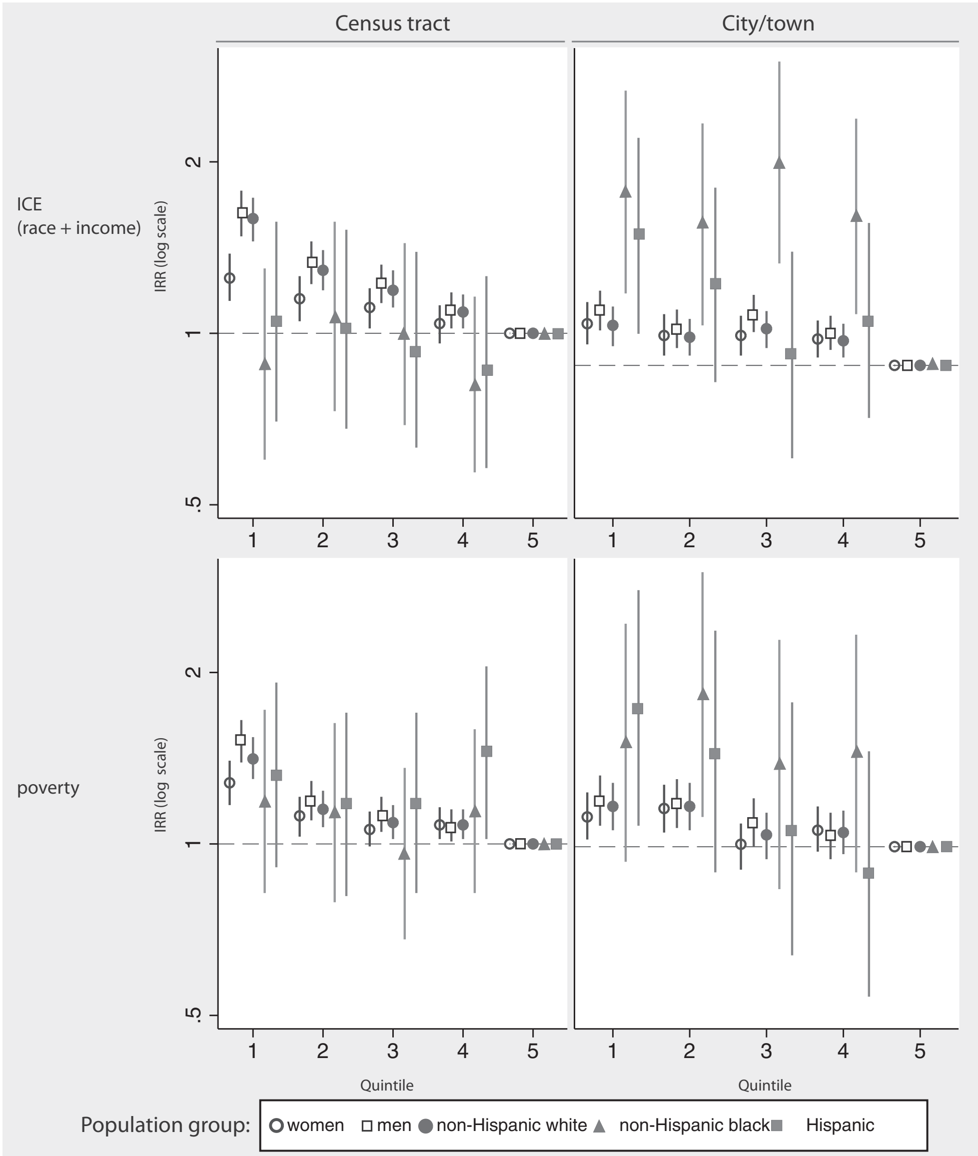

Figure 19. Mortality due to smoking incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

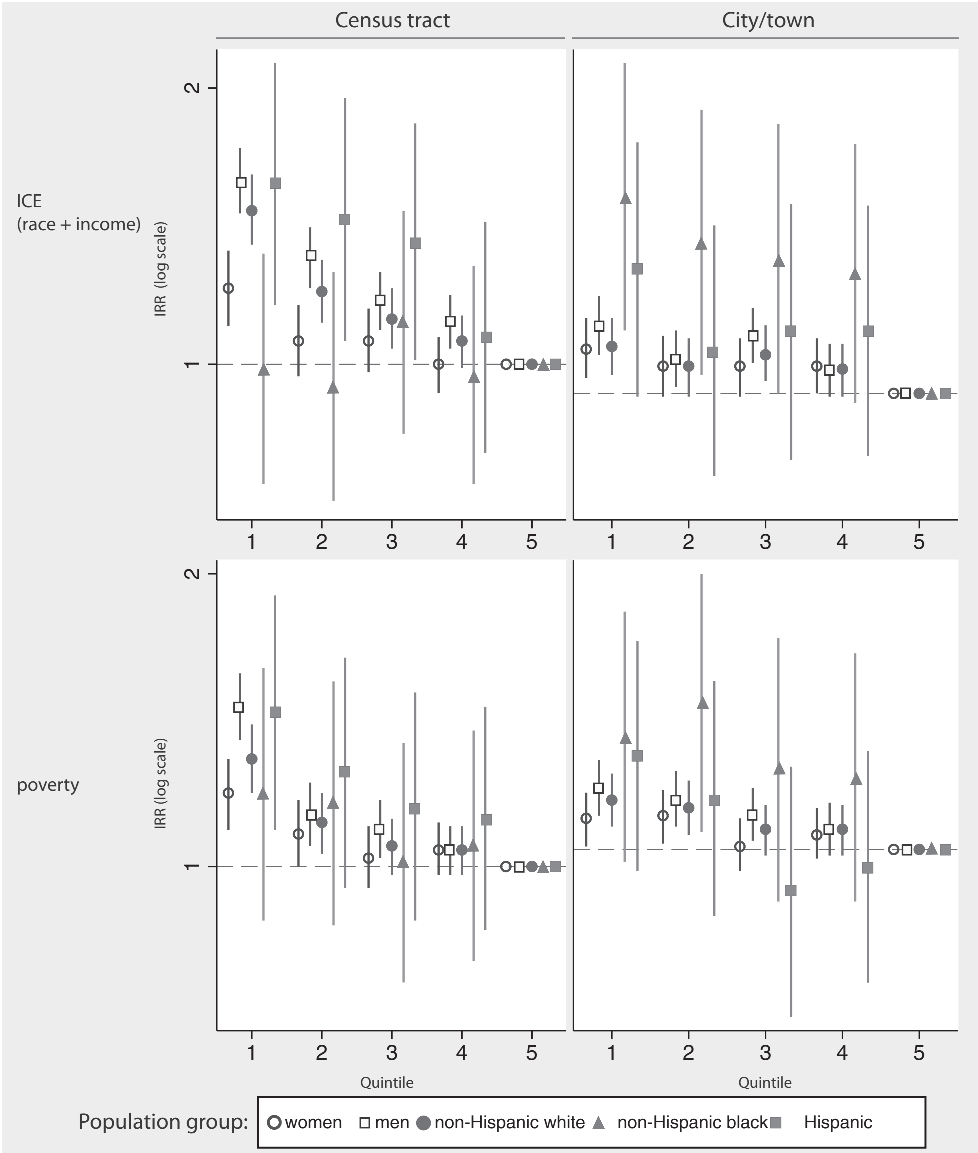

Figure 20. Mortality not due to smoking incidence rate ratios* by ICE or poverty quintile (Q5: most privileged; referent) by gender and race/ethnicity, Massachusetts, 2010–2014. *Results from gender- and race/ethnicity-stratified multilevel Poisson models for age-standardized mortality rates. All models adjusted for urbanicity. Gender-specific models adjusted for race/ethnicity and race/ethnicity-specific models adjusted for gender. Models simultaneously incorporate ICE or poverty measures at both the census tract and city/town levels.

higher at the city/town level, although most estimates were not distinguishable from 1 except for the increased risk observed for the ICE for racialized economic segregation at the city/town level (Figure 19–20).

Discussion

Our population-based observational study, using Massachusetts data for 2010–14, provides novel evidence supporting use of measures of social spatial polarization at multiple levels for multiple types of social inequality, with attention to effect modification by relevant social categories. In a US context, we detected stronger associations between mortality and the ICE compared with the poverty measure, especially for the ICE for racialized economic segregation, with associations typically greater at the census tract compared with city/town level in analyses including both levels, albeit with the city/town level showing stronger associations for populations of colour compared with the non-Hispanic White population. To our knowledge, these types of multilevel patterns and effect modification by race/ethnicity have not been previously reported.[10–13]

Our recommendations for using the ICE for public health monitoring are informed by considerations of our study's limitations and strengths. First, we relied on statewide mortality data for one state (Massachusetts) and results might not be generalizable to other US states; growing social and spatial inequality, however, is occurring throughout the USA.[6,7,10] Second, US vital statistics data can be affected by misclassification of race/ethnicity[35] and specific cause of death.[36] However, we conducted the racial/ethnic-stratified analyses for the three US racial groups who have the least misclassification,[35] and neither child nor premature mortality involve data on cause of death. Differences in associations by metric and geographical level also cannot be attributed to misclassification of cause of death, since the classification for any given outcome is the same, regardless of metric and level employed.

Deaths and population counts were obtained from different sources: MA vital statistics, which are a complete count,[21] and the ACS, which generates estimated population counts based on probability samples.[22] To mitigate against instability in the ACS estimates[37,38] and decedent counts, we used data for 5-year intervals and also categorized the ICE and poverty measures by quintile;[8,9,18] to minimize problems induced by potential numerator-denominator mismatch, we employed models using expected counts.[32] We also lacked data on individuals' lifetime residential histories; it may be that the stronger associations observed for the causes of death with temporally acute mechanisms of death, i.e. child mortality, suicide and accidental poisoning, reflect a tighter temporal match between exposure and outcome. CTs may not match individuals' subjective views of 'neighbourhoods', but they nevertheless comprise widely used administrative units employed to guide policy decisions and allocation of resources, whether or not individuals are aware of this use of CT data.[12,26] It is thus unlikely that serious bias compromises our results, and our design is strengthened by using data sources routinely employed by US states and cities for their vital statistics. Future work may want to explore issues of spatial correlation[32] and uncertainty in the ACS data.[37,38]

Bolstering our findings are: (i) results of our previous studies, summarized above;[9,13,15–18] and (ii) a study of birth outcomes in the Atlanta metro region, which observed variation by race/ethnicity in associations with an ICE for income at both the CT and the county levels, albeit with these two levels not included simultaneously.[12] Other recent health and social science investigations using the ICE, also at single levels of geography, have reported the ICE to be independently associated with health and social outcomes above and beyond individual- and household-level sociodemographic and economic characteristics.[39,40] The similar patterns of health inequities for causes of death both due and not due to smoking underscore that more than smoking contributes to US health inequities.[28] The finding of effect modification by race/ethnicity, but not gender, of associations between the ICE and mortality rates likely reflects how US neighbourhoods are segregated by income and race/ethnicity but not by gender,[11,14,30] with racial residential segregation at the city/town level remaining a profound structural determinant of racial/ethnic inequities in health, wealth and myriad other outcomes, above and beyond conditions in one's immediate residential area.[6,11,14,30]

In summary, to improve monitoring of health inequities, health agencies should routinely use measures of spatial social polarization that can be employed at multiple levels, using social categories appropriate for their countries and regions. These data should be presented both for the total population and stratified by the relevant social groups. Taking such steps will help clarify how the larger societal context, including growing extremes of privilege and deprivation, are differentially affecting people's well-being and become embodied in health inequities.

Supplementary Data

Supplementary data are available at *IJE* online.

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Conflict of interest: None declared.

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