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Neonatal and Child Mortality

Privilege and deprivation in Detroit: infant mortality and the Index of Concentration at the Extremes

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Abstract

Background: Enhanced understanding of spatial social polarization as a determinant of infant mortality is critical to efforts aimed at advancing health equity. Our objective was to identify associations between spatial social polarization and risk of infant death.

Methods: We conducted a cross-sectional analysis of all birth records issued to non-Hispanic (NH) Black and White women in Wayne County, MI, from 2010 to 2013 ($n = 84\ 159$), including linked death records for deaths occurring at less than 1 year of age. Spatial social polarization was measured in each Census tract of maternal residence ($n = 599$) using the Index of Concentration at the Extremes (ICE)—a joint measure of racial and economic segregation—estimated from American Community Survey 2009–2013 data. Log-Poisson regression models quantified relative risk (RR) of infant death (all-cause and cause-specific) associated with tertiles of the index, adjusting for maternal demographic characteristics and tract-level poverty.

Results: The crude infant-mortality rate was more than 2-fold higher among NH Black infants compared with NH Whites (14.0 vs 5.9 deaths per 1000 live births). Half of the 845 infant deaths (72% NH Black, 28% NH White) occurred in tracts in the lowest tertile of the ICE distribution, representing areas of relative deprivation. After adjustments, risk of death among infants in the lowest tertile was 1.46 times greater than those in the highest tertile (adjusted infant-mortality rate = 3.7 deaths per 1000 live births in highest tertile vs 5.4 deaths per 1000 live births in lowest tertile, relative risk = 1.46, 95% confidence interval = 1.02, 2.09). Patterns of associations with the index differed by cause of death.

Conclusions: These findings suggest efforts to support equitable community investments may reduce incidents of death and the disproportionate experience of loss among NH Black women.

Key words: infant mortality, health equity, social segregation

Key Messages

- In this analysis of all live births and infant deaths occurring among non-Hispanic (NH) Black and White women in Wayne County, MI, from 2010 to 2013, the risk of infant mortality was greater in areas of concentrated deprivation relative to areas of concentrated privilege.
- Joint racial and socio-economic segregation contributes to the persistent racial inequity in infant mortality.
- Efforts to reduce spatial social polarization may reduce incidents of infant death and the disproportionate experience of loss among NH Black women.

Introduction

For decades, public-health researchers have studied poor and under-resourced individuals, advancing our understanding of how impoverished conditions in the home and community engender ill health.[1] Still, vast inequities in health persist, and societal groups with fewer resources experience greater morbidity and mortality compared with those with more.[2] It is the unequal distribution of resources between groups—and the historical, political and purposeful mechanisms underlying it[3]—that has received less attention in the public-health literature and advocacy around the social determinants of health.[4] The urgency in this shift in perspective is underscored by rising income inequality characterized by marked concentrations of wealth in small segments of the population in both the US and globally.[5,6] It is further compelled by increased awareness of how systems and structures define unequal access to opportunities and resources, with implications for population health inequity.[7] In the US, this is most acutely defined on the basis of race—a social, cultural and political classification—resulting in entrenched racialized health disparities.[8–10] The purposeful oppression of Black Americans from the time of the country's founding to present-day policies and practices has resulted in inextricably linked ties between race, socio-economic conditions and population health.[11,12]

Infant mortality is a long-standing measure of population health, and one particularly salient to researchers interested in advancing health equity.[13,14] A 2-fold or greater gap between non-Hispanic (NH) Black and NH White infant-mortality rates[15] has persisted in the US through recent declines in the total infant-mortality rate[16,17] and despite efforts aimed at improving access to prenatal care and early-childhood initiatives.[18] Prematurity and related conditions are a leading cause of infant mortality in the US, and the substantially greater incidence of preterm birth (<37 weeks' gestation) among NH Black women largely drives the Black–White infant-mortality gap.[19] A large body of literature explores the multi-level factors that contribute to the racial inequity in preterm birth, centring on its conceptualization as a consequence of the chronic stress associated with being Black in America.[19–30]

The social and economic inequities underlying population health disparities increasingly map onto the physical geography of US cities. Growing spatial social polarization—the geographic separation of socially defined groups—results in stark differences between neighbourhoods, jointly shaped by economic and racial segregation.[31–34] The Index of Concentration at the Extremes (ICE) provides a means of simultaneously quantifying economic and racial segregation. Developed for use in population health monitoring by Krieger *et al.*,[4] the ICE measures the degree to which residents in a given neighbourhood are concentrated at the extreme ends of privilege (high-income and White) or deprivation (low-income and Black). In doing so, it not only allows the study of the so-called 'disadvantaged' group, but expands the focus to include the opposite extreme, revealing the full extent of social and economic inequalities and their joint influence on population health. Values range from –1 (100% of the neighbourhood population is concentrated in the most

economically and racially deprived group) to +1 (100% of the neighbourhood population is concentrated in the most economically and racially privileged group).

Previously, the ICE as a simultaneous measure of racial and economic segregation has been associated with black carbon exposure,[35] hypertension[36] and assault.[37] Additionally, a cross-sectional ecologic analysis by Krieger *et al.*[4] demonstrated strong associations between the ICE and infant-mortality rates across Census tracts in New York City. Compelled by their findings, we sought to explore how the ICE influences risk of infant death utilizing individual-level linked birth and death records from Wayne County, MI. These include Detroit, a city characterized by large racial inequities[38] and an infant-mortality rate that consistently exceeds the national average.[15,39] We further sought to explore the degree to which the ICE explains racial inequity in risk of infant death given the broad and entrenched inequity in the experience of infant loss between NH Black and NH White women that mirrors national trends. Finally, we delved deeper into cause-specific infant deaths in order to illuminate potential underlying causal pathways linking the ICE to mortality risk and identify those amenable to targeted prevention efforts.

Methods

The Michigan Department of Health and Human Services Vital Records Division provided birth records for all births occurring in Wayne County, MI, from 2010 to 2013, inclusive. Variables from death records for cases occurring at less than 1 year of age were linked to corresponding birth records and included an analytic dataset. Records included residential Census tract Federal Information Processing System identification numbers for linkage to tract-level exposure estimates.

For the purposes of this analysis, we included only births to NH Black ($n = 43\ 314$) and NH White women ($n = 40\ 845$), representing 89% ($n = 84\ 159$) of the total 94 616 births during the study time frame.

Outcome

Our outcome of interest was infant mortality, or death of a live-born infant prior to 1 year of age. Applying the updated Dollfus infant-death classification scheme developed by Nakamura *et al.*,[40] we grouped International Classification of Diseases, tenth revision (ICD-10) codes for underlying cause of death as described in Table 1. This classification scheme groups infant deaths by common aetiology and amenability to prevention strategies.[40,41] We further explored the three leading subgroups of cause-specific deaths: preterm-related conditions, congenital anomalies and external causes (accidents, intentional or unintentional injury).

Exposure

Our primary exposure of interest was joint racial and economic segregation as captured by the ICE. We calculated the ICE for every Census tract in Wayne County, MI, using

Table 1. International Classification of Diseases, tenth revision (ICD-10) codes for infant-death classifications of prematurity and related conditions and congenital anomalies

	ICD-10 codes for underlying cause of death
Prematurity and related conditions	
Short gestation and low birth weight	P070–P073
Birth trauma, neonatal haemorrhage and haematological disorders	P10–P15; P52–P54
Respiratory distress syndrome, interstitial emphysema, pulmonary haemorrhage and atelectasis	P22; P25; P26; P280–P281
Chronic respiratory distress syndrome and respiratory diseases	P27; P282–P289
Necrotizing enterocolitis	P77
Neonatal cardiac failure and other cardiovascular disorders originating in the perinatal period	P29
Congenital anomalies	
Congenital malformations, deformations, chromosomal anomalies and congenital disorders	Q00–Q99; D82; E25
External causes	
Accidents involving transportation	V01–V99
Accidents involving falls	W00–W19
Accidental drowning and submersion, suffocation, aspiration and asphyxiation	W65–W74
Assault and other intentional injuries	X89–Y09
Injuries with undetermined intent or unspecified cause	Y10–Y34
Other unintentional injuries	W20–W64, W75–W78, W81–W99, X00–X59

2009–2013 American Community Survey (ACS) 5-year estimates of household income by race/ethnicity. Following the formula described by Krieger *et al.*,[4] we calculated the ICE in each Census tract by taking the difference between of the number of NH White persons whose annual household income was greater than or equal to the eightieth percentile (>$100 000) minus the number of NH Black persons whose household income was less than the twentieth income percentile (<$25 000), divided by the total population with known income in the tract. Birth records in each Census tract were assigned their corresponding value of the ICE. To avoid assumptions about linearity, we categorized the ICE into tertiles, with the lowest tertile representing tendency towards the extreme of concentrated deprivation and the highest tertile likewise representing concentrated privilege.

Covariates

Potential individual-level confounders available on the birth record included maternal race (NH Black, NH White), maternal age (<20, 20–29, 30–34, 35+), marital status (not married, currently married), plurality (singleton, multiple birth) and prenatal-care-insurance type (private, Medicaid, self-pay/other). We additionally included the percentage of individuals living below the federal poverty level in each Census tract (ACS 2009–2013 5-year estimate) to isolate the independent effect of extreme concentrations of deprivation and privilege above the impact of poverty (or the absence of poverty) alone.

Statistical analysis

We conducted descriptive analyses to identify the distribution of socio-demographic characteristics across births and characteristics of the Census tracts in which they occurred. In order to explore the degree of clustering of deaths within tracts and the relevance of the ICE as a tract-level feature, we compared intra-class correlation coefficients (ICCs) derived from an empty or unconditional means multi-level model to one including the ICE only. The ICC quantifies the degree to which variance in the outcome may be explained by differences between tracts vs differences between individuals within tracts, calculated as follows: $V_{neighborhood}/[V_{neighborhood} + V_{individual}]$, where $V_{neighborhood}$ = variance between neighbourhood and $V_{individual}$ = variance within neighbourhoods or between individuals. Since the outcome variable is binary, the ICC was calculated using Snijders formula where $V_{student} = \prod^2/3$.[42,43]

In order to estimate the population-average effect of the ICE on risk of infant death, we utilized the modified Poisson regression approach[44,45] with generalized estimating equations (GEEs) to estimate the relative risks (RRs) and 95% confidence intervals (CIs), accounting for clustering of multiple births within tracts. In order to identify association between the ICE and risk of death as well as the degree to which the ICE explained racial differences in risk of death, we fit a series of models as follows: (i) ICE tertiles alone, (ii) maternal race alone, (iii) mutually adjusted ICE and maternal race, and (iv) fully adjusted ICE, race, individual-level covariates and tract-level poverty. We included a test for linear trend based on the *p*-value for the ICE tertile regression coefficient. We first explored infant death due to any cause as our primary outcome of interest. Subsequently, we repeated the modelling for cause-specific deaths, in each instance excluding deaths from all other causes from the reference group (which included only living infants). All analyses were conducted in SAS v 9.4 (SAS Institute Inc., Cary, NC).

Results

Births occurring during the study time frame ($n = 84\,159$) were fairly evenly distributed between NH Black and NH White women (51.5 and 48.5%, respectively; Table 2). However, nearly 72% of the 845 infant deaths were among NH Black women. NH Black women experienced 14.0 infant deaths per 1000 live births—more than double the infant-mortality rate among NH White women (5.9 deaths per 1000 live births). Women experiencing infant loss were more likely to be adolescent women, women not married at the time of birth, women with Medicaid insurance and those with a multiple-gestation pregnancy (Table 2).

Figure 1 depicts the visually pronounced clustering of privilege and deprivation across Census tracts in Wayne County (map created using ArcGIS software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license. Copyright © Esri. All rights reserved). Tracts where births to NH Black or NH White women occurred ranged in ICE values from –0.82 to 0.67 with a mean of –0.1 suggesting that, on average, the proportion of the tract population in the most deprived group exceeded the proportion in the most privileged group. Half of all infant deaths (50.1%) occurred in Census tracts with the lowest values of the ICE, representing areas of concentrated deprivation.

The empty multi-level model (a function of the tract-level random intercept) revealed that, whereas variance in risk of infant death was predominantly due to individual-level differences, nearly 8% of the variance in infant death occurred at the tract level. Addition of the ICE to the model reduced the ICC to 4.0%, suggesting that differing concentrations of privilege and deprivation explain a

Table 2. Selected characteristics of the study population: live births and infant deaths occurring among non-Hispanic Black and non-Hispanic White women in Wayne County, MI, from 2010 to 2013 ($n = 84\ 159$)

	Total live births		Infant death			
			No ($n = 83\ 314$)		Yes ($n = 845$)	
	N	%	*N*	%	*N*	%
Index of Concentration at the Extremes (ICE) tertile						
1 (concentrated deprivation)	27 753	33.0	27 329	32.8	424	50.1
2	27 779	33.0	27 505	33.1	274	32.4
3 (concentrated privilege)	28 627	34.0	28 480	34.2	147	17.4
Race						
Non-Hispanic Black	43 314	51.5	42 708	51.3	606	71.7
Non-Hispanic White	40 845	48.5	40 606	48.7	239	28.3
Maternal age						
<20	9672	11.5	9528	11.4	144	17.0
20–29	46 271	55.0	45 828	55.0	443	52.4
30–34	17 789	21.1	17 632	21.2	157	18.6
35+	10 424	12.4	10 323	12.4	101	12.0
Marital status						
Married	34 738	41.3	34 532	41.5	206	24.5
Not married	49 378	58.7	48 744	58.5	634	75.5
Plurality						
Singleton	938	96.2	80 234	96.3	704	83.3
Multiple birth	3221	3.8	3080	3.7	141	16.7
Insurance type						
Private	44 344	52.8	43 980	52.9	364	43.8
Medicaid	37 913	45.2	37 483	45.1	430	51.7
Self-pay/other	1673	2.0	1636	2.0	37	4.5
	Mean	SD	Mean	SD	Mean	SD
ICE (continuous)	–0.1	0.3	–0.1	0.3	–0.3	0.3
Census tract poverty level	28.1	18.1	28.0	18.1	34.3	17.2

substantial portion of tract-level variance in risk of infant death across Wayne County.

Table 3 contains results from the series of GEE models estimating risk of infant death (all causes). In all models, the ICE tertile measure test for trend indicated $p < 0.05$. The crude model (Model 1) indicates an almost 3-fold increase in risk of death comparing the bottom to top tertiles of the ICE and a smaller but still 2-fold increased risk between the middle and top tertiles. Adjusting for tract-level poverty, maternal race and other individual-level covariates reduced the ICE effect size as shown in Model 4, but a 46% increase in risk comparing the bottom and top tertiles remained (RR = 1.46, 95% CI = 1.02, 2.09).

Before adjustments, risk of infant death was more than 2-fold greater among NH Black women compared with NH White women (Model 2; RR = 2.39, 95% CI = 2.01, 2.83). However, adjusting for the ICE substantially decreased the magnitude of the racial inequity in mortality risk down to RR = 1.63 95% CI = 1.30, 2.05. Adjusting for additional individual-level covariates contributed minimal additional reduction (Model 4: RR = 1.48, 95% CI = 1.17, 1.86).

There were 236 (27.9%) deaths attributed to prematurity and related conditions—125 resulting from congenital anomalies (14.8%) and 121 (14.3%) due to external causes. Figure 2 provides a visual representation of the RRs associated with tertiles of the ICE from a crude model, a race-only adjusted model and a fully adjusted model for all causes and for cause-specific categories (data for both panels of Figure 2 can be found in Supplementary Tables 1–3, available as Supplementary data at *IJE* online). The ICE was strongly associated with increased risk of deaths from prematurity and related conditions and external causes both crudely and independently of maternal race. However, sparse data yielded imprecise estimates in the fully adjusted models: although point estimates suggested increased risk, CIs included the null. The ICE was not associated with congenital anomalies in any model.

Whereas adjusting for the ICE reduced the magnitude of racial inequity in risk of death from prematurity and

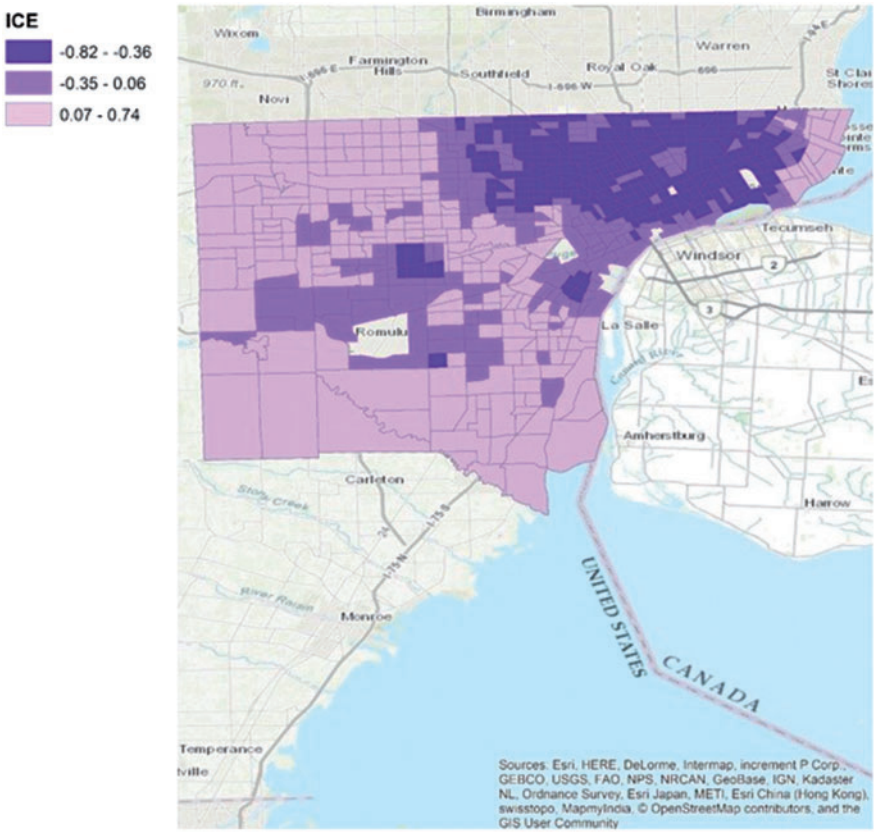


Figure 1. Map of the ICE by Census tract in Wayne County, MI.

related conditions, a 2-fold increased risk among NH Black infants persisted in the final fully adjusted model (Figure 2). Conversely, in models exploring risk of death from external causes, adjusting for the ICE greatly reduced the more than 3-fold crude elevated risk among NH Black women, effectively eliminating the racial inequity. There was no racial difference in risk of death due to external causes in the fully adjusted model (RR = 1.01, 95% CI = 0.51, 2.01). Race was not associated with congenital anomalies in any model.

Discussion

Utilizing data on all live births occurring in Wayne County, MI, from 2010 to 2013, we explored how the unequal communities in which women live—their relative tendency towards concentrations of deprivation or privilege—influence the likelihood that their infant will experience a first birthday. Central to our findings is the significant proportion of variance in infant death experienced by women in Wayne County explained by racial and economic segregation at the tract level. Women residing in areas of relative deprivation were nearly 1.5 times more likely to experience loss of an infant compared with women in other areas. This relationship held independently of socio-demographic characteristics and regardless of the absolute poverty level of the Census tract.

Previous research on the health effects of racial residential segregation posit that the lack of investments in highly segregated areas[46] results in limited access to quality education, employment, healthy foods and health-care services. The absence of these health-promoting features in turn underlies the increased incidence of adverse health outcomes in these communities.[47] The same pathways are likely true for associations found between infant mortality and the ICE. However, the added nuance of the ICE over other typical measures of segregation is that it captures relative distributions of resources within a neighbourhood (or tract) and therefore the conditions that engender social and ultimately health inequity.[4] Indeed, taking this area-level characteristic into account reduced the vast inequity in infant-mortality risk between Black and White women on an individual level. For two of the three leading causes of death, racial inequity was eliminated entirely such that there was no race-based difference in risk of infant death from congenital anomalies or external causes between Black and White women above and beyond the risk associated with the relative degree of deprivation that characterized their neighbourhood.

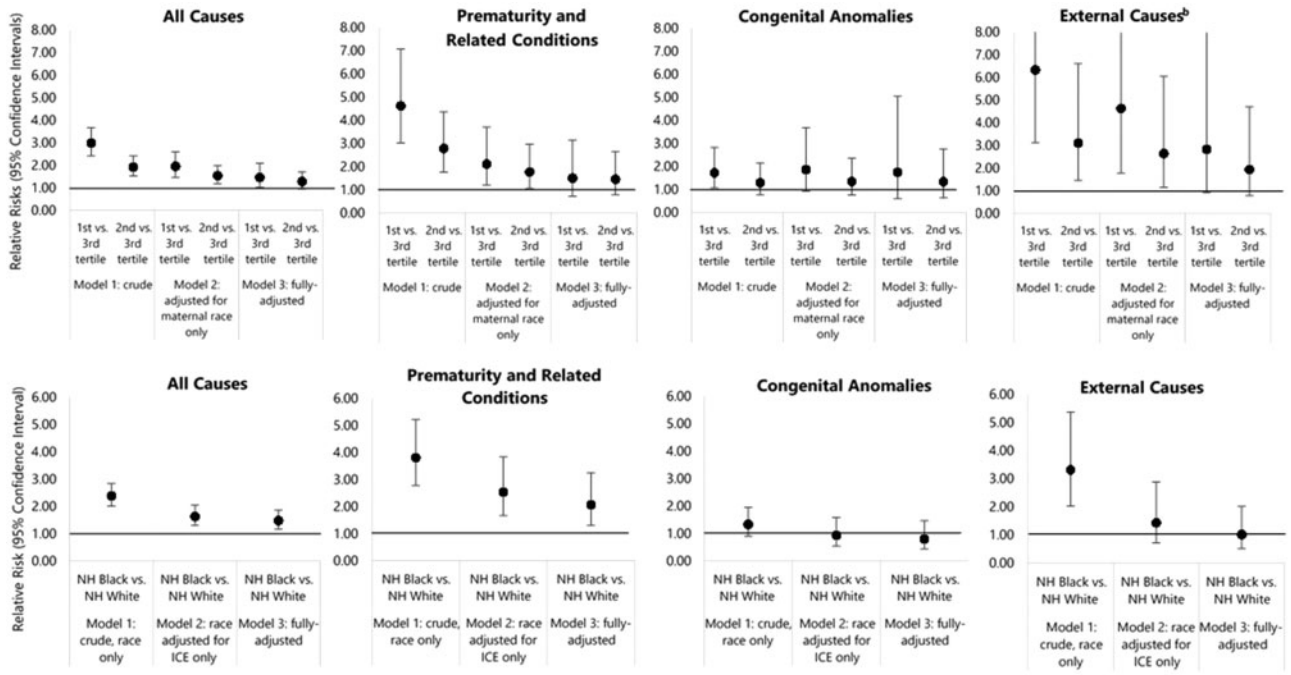
Table 3. Relative risks (RRs) and 95% confidence intervals (CIs) for associations with infant death (<1 year) from a series of models[a] including individual- and tract-level covariates, live births and infant deaths occurring among non-Hispanic Black and non-Hispanic White women in Wayne County, MI, 2010–13

	Model 1		Model 2		Model 3		Model 4	
	Crude—ICE only		Crude—Race only		Mutually adjusted model		Fully adjusted model	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Index of Concentration at the Extremes (ICE) tertile								
1 (concentrated deprivation)	2.98	(2.41, 3.67)			1.95	(1.46, 2.59)	1.46	(1.02, 2.09)
2	1.92	(1.52, 2.41)			1.54	(1.17, 1.99)	1.28	(0.95, 1.71)
3 (concentrated privilege)	Ref.				Ref.		Ref.	
Race								
Non-Hispanic Black			2.39	(2.01, 2.83)	1.63	(1.30, 2.05)	1.48	(1.17, 1.86)
Non-Hispanic White			Ref.		Ref.		Ref.	
Maternal age								
<20							Ref.	
20–29							0.75	(0.62, 0.90)
30–34							0.92	(0.72, 1.17)
35+							0.99	(0.76, 1.30)
Marital status								
Married							Ref.	
Not married							1.39	(1.12, 1.73)
Plurality								
Singleton							Ref.	
Multiple birth							5.22	(4.21, 6.46)
Insurance type								
Private							Ref.	
Medicaid							1.28	(1.10, 1.50)
Self-pay/other							2.43	(1.65, 3.57)
Poverty (per interquartile range increase)							1.18	(0.97, 1.42)

[a]Modified Poisson regression models.

Another salient finding was the pattern of associations with the ICE suggesting that the ICE impacts on infant mortality primarily through preterm delivery and related causes, as well as external causes, but not congenital anomalies. This finding is in line with the conceptualization of prematurity as a biosocial process in which social inequality manifests physically in the form of adverse maternal health.[29] Chronic stress or physiologic 'wear and tear' arising from the lived experience in neighbourhoods of relative deprivation may lead to earlier declines in health among Black women,[48,49] increasing their risk for preterm delivery[50] and infant loss. Consistently with our findings, a previous exploration of cause-specific infant death in Michigan found that individual social factors (maternal socio-economic position and behavioural risks) explained a substantial portion of the Black–White disparity in infant mortality due to preterm birth but not congenital anomalies.[51] The aetiology of congenital anomalies may involve broad environmental exposures or spontaneous gene mutations that are less sensitive to social patterning.[51,52] By far the most common underlying cause of death in the external-causes category was accidental suffocation and strangulation in bed ($n = 93$, 77%), which, like prematurity, has established social influences including maternal-health behaviours, quality of the home environment and infant-sleeping conditions.[53–55] These risk factors in turn are likely be mediators along a pathway from the ICE to infant mortality, resulting from the concentration of access to resources and opportunities to create healthy home environments in some communities while limiting them in others.

Whereas our study benefits from use of individual-level data, there are limitations to consider. First, most tracts contained fewer than five deaths in the 4 years of data available, prohibiting estimation of stable tract-level infant-mortality rates for spatial analyses and consideration of spatial autocorrelation. Such analyses would provide enhanced understanding of spatial clustering of both infant deaths and privilege/deprivation, and the influence of features within neighbouring tracts as opposed to treating each as a singular, isolated environment. A greater number of data years and cases would simultaneously improve the precision of the CIs around point estimates for



[a]Fully-adjusted models include ICE, maternal race, maternal age, plurality, insurance type, and tract-level poverty.
[b]Each graph in the panel is shown on the same y-axis scale in order to preserve comparability across graphs. Upper confidence limits that exceed the axis scale on the external causes graph are as follows: Model 1, 1st vs. 3rd tertile RR=6.33, 95% CI=3.12, 12.84; Model 2, 1st vs. 3rd tertile RR=4.63, 95% CI=1.78, 11.94; Model 3, 1st vs. 3rd tertile RR=2.82, 95% CI=0.91, 8.72.

Figure 2. Relative risks and 95% confidence intervals for all-cause and cause-specific infant death associated with ICE tertiles (top panel) and associated with maternal race (bottom panel).[a]

cause-specific types of infant death. Finally, we were limited to information reliably collected on the birth record and unable to explore factors such as prenatal-care utilization or maternal education. As such, we acknowledge the possibility of residual confounding.

Black infant mortality remains unacceptably high despite decades of well-intentioned medical and public-health efforts to improve access to prenatal care and advance maternal and neonatal medicine. It a symptom of a society that does not value all women and children equally.[18] The benefit of the ICE metric is that it quantifies the social inequality that unfairly increases risk of infant loss in some neighbourhoods while protecting against it in others. It highlights the importance of addressing racial and economic segregation in order to improve population health and reduce inequities.[56] Promoting opportunities for socioeconomic mobility and equitable community investments may begin to neutralize the spatial social polarization measured by the ICE. Moreover, its bearing on infant mortality and racial inequity in mortality risk is testament to the need for public-health efforts to move beyond a focus on individuals to explore more broadly the context in which all women—both poor and privileged—live.

Supplementary Data

Supplementary data are available at *IJE* online.

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Conflict of interest: None declared. All references have been checked for completion and accuracy. M Wallace will act as guarantor for the paper. This material has not been published previously.

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