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Using Index of Concentration at the Extremes as Indicators of Structural Racism to Evaluate the Association with Preterm Birth and Infant Mortality—California, 2011–2012

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Abstract Disparities in adverse birth outcomes for Black women continue. Research suggests that societal factors such as structural racism explain more variation in adverse birth outcomes than individual-level factors and societal poverty alone. The Index of Concentration at the Extremes (ICE) measures spatial social polarization by quantifying extremes of deprived and privileged social groups using a single metric and has been shown to partially explain racial disparities in black carbon exposures, mortality, fatal and non-fatal assaults, and adverse birth outcomes such as preterm birth and infant mortality. The objective of this analysis was to assess if local measures of racial and economic segregation as proxies for structural racism are associated and preterm birth and infant mortality experienced by Black women residing in California. California birth cohort files were merged with the American Community Survey by zip code (2011–2012). The ICE was used to quantify privileged and deprived groups (i.e., Black vs. White; high income vs. low income; Black low income vs. White high income) by zip code. ICE scores range from − 1 (deprived) to 1 (privileged). ICE scores were categorized into five quintiles based on sample distributions of these measures: quintile 1 (least privileged)–quintile 5 (most privileged). Generalized linear mixed models were used to test the likelihood that ICE measures were associated with preterm birth or with infant mortality experienced by Black women residing in California. Black women were most likely to reside in zip codes with greater extreme income concentrations, and moderate extreme race and race + income concentrations. Bivariate analysis revealed that greater extreme income, race, and race + income concentrations increased the odds of preterm birth and infant mortality. For example, women residing in least privileged zip codes (quintile 1) were significantly more likely to experience preterm birth (race + income ICE OR = 1.31, 95% CI = 1.72–1.46) and infant mortality (race + income ICE OR = 1.70, 95% CI = 1.17–2.47) compared to women living in the most privileged zip codes (quintile 5). Adjusting for maternal characteristics, income, race, and race + income concentrations remained negatively associated with preterm birth. However, only race and race + income concentrations remained associated with infant mortality. Findings support that ICE is a promising measure of structural racism that can be used to address racial disparities in preterm birth and infant mortality experienced by Black women in California.

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Background

Black women continue to be at increased risk of preterm birth (PTB) (infants born before 37 weeks gestation) and infant mortality (IM) (infant deaths from birth to under 1 year of age) compared to White women in the United States (US) and in California [1, 2]. In 2016, approximately 12% of Black women giving birth in California had a PTB compared to 8% of White women [1]. Similar disparities were seen in the infant mortality rate for Black (9.3 deaths per 1000 live births) and White (3.9 deaths per 1000 live births) infants in California [2]. To date the majority of studies examining Black-White disparity in PTB and IM have focused on individual level factors including behavior risks, genetic and biological markers, and pregnancy characteristics [3–10]. More recently, there has been a paradigm shift focused on monitoring and investigating the social determinants of health outcomes, including PTB and IM [11–14]. The role of structural racism in explaining variation seen in racial disparities in PTB and IM has been examined but is often challenged by inadequate measures that do not account for the co-occurring processes of structural racism such as spatial racial *and* income distributions [15–21].

Structural racism involves systematic laws and processes used to differentiate access to services, goods, and opportunities in society by racial groups [22–28]. Historically, structural racism has been used to advantage Whites over Blacks in the American society through the implementation of laws such as redlining (e.g., discriminatory practices used to limit mortgage loans to Black families in specific neighborhoods) which has resulted in disparities in access to quality education, housing, employment, wealth, and excessive incarceration rates [22–28]. Therefore, structural racism perpetuates both racial and socioeconomic disadvantage, which has been historically centered in oppressing Black bodies within the US context [22–28]. Residential segregation indices (e.g., dissimilarity, isolation, concentration indices) are the most commonly used proxy for structural racism as they represent spatial and compositional distribution of racial and ethnic groups across neighborhoods [25–29]. Research suggests that higher levels of segregation are associated with adverse birth outcomes among Black women, after adjusting for individual characteristics and neighborhood poverty [26–28, 30]. Studies consistently show that racial segregation is a stronger predictor of health inequities than income segregation, with the interaction between racial and income segregation exhibiting strong effects on spatial isolation among people living in poverty [31–33]. However, there are relatively few measures of structural racism that capture both racial and income disparities [11–14, 34, 35].

Given that structural racism is a multidimensional construct, there is an imperative need to utilize a multidimensional measure that takes into consideration racial and income disparities [11, 13, 14, 34–39]. Massey developed the index of concentration at the extremes (ICE) to measure spatial social polarizations of both deprived and privileged socioeconomic groups simultaneously in one measure [29]. Krieger and colleagues expanded ICE to include race and race + income disparities allowing scientific researchers and local officials the ability to distinguish between extreme low and high concentrations of racial and income disparities in one measure [40]. ICE race, income, and race + income have been used to explain the Black-White disparity gap in hypertension, black carbon exposures, birth outcomes, mortality, and fatal and non-fatal assaults [14, 35, 40, 41]. Krieger and colleagues found that ICE measures perform best using census tract as the neighborhood unit compared to city/town or community districts [35]. There are currently no studies that have assessed the utility of ICE measures in understanding poor health outcomes at the zip code level. Despite critiques about zip code level data [42, 43], zip codes are a commonly used geographic unit to examine the relationship between neighborhood exposures and poor health outcomes [44–48], In comparison to census tracts, zip codes are slightly larger geographic units and can provide more stable estimates of neighborhood measures of racial and economic disparities [49, 50]. Additionally, patterns of inequality may differ across geographic units warranting investigation to assess if social determinants should also be monitored at the zip code level [34–36].

There is a dearth of literature examining the association between ICE (i.e., race, income, and race + income) and adverse birth outcomes. To our knowledge, three studies have assessed the association between ICE measures and adverse birth outcomes, with no California-based studies [11–13]. The first two studies found that most deprived ICE race, income, and race + income

neighborhoods reported higher rates of IM and PTB [12, 13]. Only one study has assessed the association between neighborhood-level ICE measures and women's individual adverse birth outcomes [11]. Huynh and colleagues found that all ICE measures were associated with PTB, and only ICE race and race + income were associated with IM in adjusted models [11]. However, it remains unknown how ICE measures are associated with Black women's birth outcomes, and if ICE measures, quantified at the zip code level, are related to adverse birth outcomes. To address current gaps in the literature, this study examined the associated between ICE race, income, and race + income as proxies for structural racism measured at the zip code level on PTB and IM among Black women and their offspring residing in California.

Methods

Study Population

In this retrospective study, our sample was drawn from California live births between January 1, 2011, and December 31, 2012 ($n = 1{,}005{,}811$), contained in a birth cohort database maintained by the California Office of State Health Planning and Development. The sample was merged with zip code data available from the U.S. Census American Community Survey (2011–2012). The California live birth cohort file contains information related to infant birth and death, maternal and infant characteristics, and recorded hospital discharge diagnoses and procedures pre(inter)conception, during pregnancy, and up to 12 months postpartum. The sample was restricted to singletons of non-Hispanic Black race/ethnicity ($n = 52{,}773$) with gestations between 22 and 43 weeks at birth ($n = 52{,}559$), linked birth certificate and mother's and baby's hospital discharge records ($n = 50{,}368$), with birthweight not missing and within three standard deviations from the mean for sex and gestational age ($n = 50{,}004$) [51], with a valid zip code of residence ($n = 49{,}629$), and zip codes with at least 10 non-Hispanic Black women ($n = 47{,}771$) (see Fig. 1).

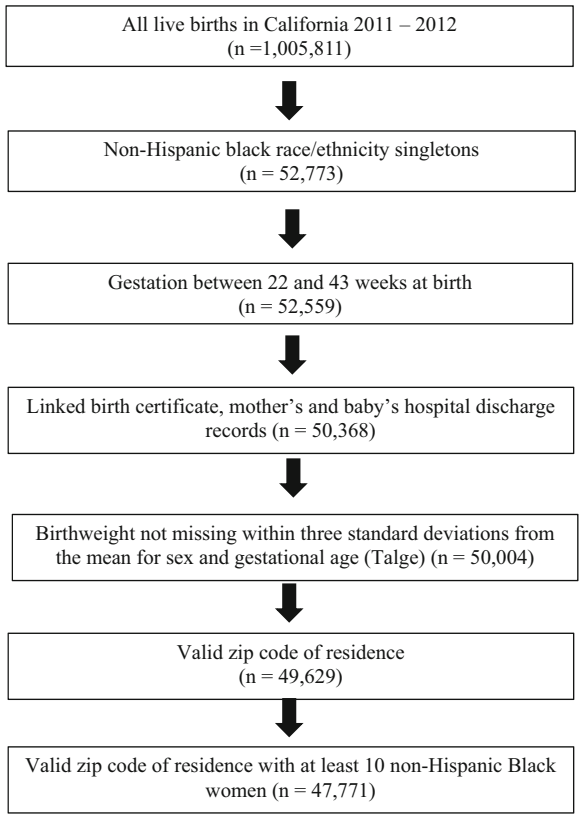

Fig. 1 Sample selection

Measures

Maternal characteristics were obtained from birth certificate data and included maternal age more than 34 years versus maternal age 14 to 34 years; maternal education less than 12 years or more than 12 years versus 12 years; Medi-Cal coverage (California's Medicaid, public insurance for low-income persons) for delivery versus not Medi-Cal coverage; participation in the Women, Infants, and Children (WIC, federally funded health and nutrition program) versus no participation; nulliparous versus multiparous pregnancies; maternal birthplace outside of the US versus in the US; report of smoking during pregnancy versus no report of smoking; and maternal body mass index (BMI) (calculated from prepregnancy weight and height) categorized as underweight (less than 18.5 kg/m^2), overweight (25.0 to 29.9 kg/m^2), or obese (30.0 kg/m^2 or more) compared to normal BMI (18.5 to 24.9 kg/m^2). Also included were three or fewer prenatal care visits versus four or more visits, and previous PTB versus no previous PTB. Hospital discharge ICD-9 diagnoses complicating pregnancy included the following: no hypertension versus any hypertension, no diabetes versus any diabetes, no infection versus any infection, no alcohol or drug use versus any alcohol or drug use, and no mental disorder versus any mental disorder.

The US Census American Community Survey (2011–2012) was used to generate ICE scores using zip code data. ICE measures spatial social polarization by quantifying extremes of deprived and privileged social groups in a single metric. ICE measures were computed using the following formula:

$$ICE_i = \frac{(A_i - P_i)}{T_i}$$

A_i represents the number of persons belonging to the privileged extreme, while P_i is the number of persons who belong to the deprived extreme in the ith zip code [14, 29, 35, 41, 52]. T_i is the total population in the ith zip code. This study used three distinct ICE measures proposed by Krieger and colleagues: ICE race, ICE income, and ICE race + income. The ICE race privilege group were non-Hispanic White people and the deprived group non-Hispanic Black people. The ICE income-deprived group were people who made < $25,000 annually, while privileged were people who made ≥ $100,000, representing the US 20th verse 80th percentile of household income. Lastly, the ICE race + income-deprived group were non-Hispanic Black people who made < $25,000 annually, while privileged were non-Hispanic White people who made ≥ $100,000 [14, 35, 41, 52]. ICE is a continuous variable that ranges from − 1 to 1, where − 1 corresponds with complete deprivation and 1 with completed privilege. ICE scores were categorized into five quintiles based on sample ($n = 623$) distributions of these measures: quintile 1 (least privileged) to quintile 5 (most privileged).

Statistical Analysis

Descriptive and comparative analyses were used to describe maternal characteristics comparing women who lived in the quintile 1 (least privileged) compared to all other quintiles. Generalized linear mixed models were used to account for nesting of individuals in zip codes, and to test the association between ICE zip code measures and adverse birth outcomes in women. All models were adjusted for age, education, nativity, Medi-Cal, WIC, prenatal care visits, pregnancy BMI, cigarette use, alcohol and drug use, infection, diabetes, hypertension, depression, and previous PTB. A separate analysis was performed for each ICE measure. All data analyses were conducted in IBM® SPSS® Statistics version 24.0 (Armonk, NY) and SAS version 9.4 (Cary, NC). Methods and protocols for the study were approved by the Committee for the Protection of Human Subjects within the Health and Human Services Agency of the State of California. Data used for the study were received by the California Preterm Birth Initiative at the University of California San Francisco by June 2016. The study was supported by the California Preterm Birth Initiative within the University of California, San Francisco.

Results

Table 1 displays zip code level ICE scores for California and the study sample. Across 3341 Californian zip codes, ICE scores ranged from − 1 to 1. The mean value for ICE measures for California zip codes ranged from 0.031 (SD = 0.284) for ICE income, 0.507 (SD = 0.315) for ICE race, and 0.228 (SD = 0.189) for ICE race + income. Among the study sample of non-Hispanic Black women ($n = 623$ zip codes), ICE scores ranged from − 0.831 to 0.627. Black women were most likely to reside in zip codes with greater extreme income concentrations ($\overline{M} = -0.070, SD = 0.284$), and moderate extreme race ($\overline{M} = 0.078, SD = 0.296$) and race + income ($\overline{M} = 0.047, SD = 0.193$) concentrations. The majority of Black women included in this study were less than 34 years old, had more than 12 years of education, used Medi-Cal as a primary source of insurance during prenatal care, and participated in the WIC program (see Table 2). Relatively few women reported being foreign born or attending three or fewer prenatal care appointments (see Table 2).

Preterm Birth

Approximately 10% of women had a PTB (see Table 1). Higher percentages of women who resided in the least privileged income ($n = 1060$, 11.0%), race ($n = 954$, 10.2%), and race + income ($n = 1018$, 10.6%) quintiles delivered prematurely compared to women who resided in the most privileged income ($n = 802$, 8.4%), race ($n = 843$, 8.8%), and race + income ($n = 795$, 8.3%) quintiles (see Fig. 2). There was an increased likelihood for PTB among women residing in quintile 1 compared to quintile 5 across all ICE measures (see Table 3). Odd ratios

across ICE measures showed an increased risk of PTB of over 18 to 32% for Black women residing in quintile 1. Additionally, women residing in quintiles 2 (ICE income, race, and race + income), 3 (ICE race and race + income), and 4 (ICE race + income) were also at an elevated risk for PTB compared to women who resided in quintile 5 (see Table 2).

Adjusting for maternal characteristics, ICE measures remained significantly associated with PTB (see Table 2). Across all ICE measures, living in quintile 1 significantly increased a woman's odds of having a PTB compared to women who resided in quintile 5 (see Table 2). For example, women who lived in the least privileged race + income quintile (quintile 1) had over a 25% increased chance of having a PTB compared women who lived in the most privileged race + income quintile (quintile 5). For ICE race + income, residing in quintiles 1 through 4 compared to the most privileged quintile (quintile 5) increased a women's likelihood of having a PTB. In addition to residing in quintile 1, women who resided in ICE income quintiles 2 and 4 were respectively 1.14 and 1.12 times as likely to have a PTB compared to women residing in quintile 5 (see Table 3).

Infant Mortality

Less than 1% ($n = 259$, 0.50%) of women were impacted by IM, with an IM rate of 5.4 deaths per 1000 live births for the study sample (see Table 1). Women who lived in the least privileged income ($n = 66$, 0.70%), race ($n = 64$, 0.70%), and race + income ($n = 71$, 0.70%) quintiles carried a higher burden of IM compared to women living in the most privilege quintiles (ICE

Table 1 ICE distributions for California and study sample, 2011–2012

	California population ($N = 3341$)				Sample population ($N = 623$)			
	Range				Range			
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
ICE income	0.031	0.284	− 1.000	1.000	− 0.070	0.206	− 0.738	0.621
Quintile 1	− 0.364	0.166	− 1.000	− 0.204	− 0.332	0.067	− 0.738	− 0.247
Quintile 2	− 0.119	0.049	− 0.205	− 0.035	− 0.185	0.031	− 0.246	− 0.146
Quintile 3	0.031	0.039	− 0.036	0.102	− 0.099	0.032	− 0.145	− 0.036
Quintile 4	0.187	0.050	0.103	0.275	0.023	0.037	− 0.035	0.112
Quintile 5	0.423	0.122	0.276	1.000	0.249	0.096	0.113	0.621
ICE race	0.507	0.315	− 0.831	1.000	0.078	0.296	− 0.831	0.837
Quintile 1	0.038	0.149	− 0.831	0.195	− 0.370	0.162	− 0.831	− 0.137
Quintile 2	0.320	0.072	0.196	0.439	− 0.046	0.050	− 0.136	0.037
Quintile 3	0.546	0.057	0.440	0.639	0.090	0.029	0.038	0.144
Quintile 4	0.730	0.049	0.640	0.807	0.236	0.051	0.145	0.332
Quintile 5	0.900	0.064	0.808	1.000	0.475	0.108	0.333	0.837
ICE race + income	0.228	0.189	− 1.000	1.000	0.047	0.193	− 0.375	0.627
Quintile 1	− 0.015	0.096	− 1.000	0.073	− 0.234	0.075	− 0.375	− 0.117
Quintile 2	0.121	0.026	0.073	0.165	− 0.046	0.034	− 0.116	− 0.005
Quintile 3	0.210	0.027	0.165	0.260	0.048	0.031	− 0.004	0.101
Quintile 4	0.319	0.036	0.261	0.385	0.154	0.032	0.102	0.210
Quintile 5	0.505	0.103	0.386	1.000	0.315	0.084	0.211	0.627

Across the study sample, the number of Black women per ICE measure and quintiles are the following: ICE income (Quintile 1 = 9653; Quintile 2 = 9740; Quintile 3 = 9252; Quintile 4 = 9577, Quintile 5–9549); ICE race (Quintile 1 = 9363; Quintile 2 = 9816; Quintile 3 = 9602; Quintile 4 = 9449; Quintile 5 = 9542); and ICE race + income (Quintile 1 = 9580; Quintile 2 = 9592; Quintile 3 = 9601; Quintile 4 = 9469; Quintile 5 = 9529)

SD standard deviation

Table 2 Maternal characteristics for Black women in California, 2011–2012 ($N = 47{,}771$)

Maternal characteristics	*n*	Percent
Age		
< 34 years	41,454	86.8
> 34	6317	13.2
Education		
< 12	7467	15.6
12	1116	2.3
> 12	23,464	49.1
Nativity		
Born in the USA	43,004	90
Foreign born	4767	10
Medi-Cal		
No	21,153	44.3
Yes	26,618	55.7
WIC		
No	13,552	28.4
Yes	34,219	71.6
Prenatal care visits		
> 3 visits	46,320	97
≤ 3 visits	1451	3
Pregnancy BMI(e.g., < 18.5 m/kg^2)		
Normal weight	17,803	37.3
Underweight	2030	4.2
Overweight	11,801	24.7
Obese	13,131	27.5
Cigarettes		
No	43,214	90.5
Yes	4557	9.5
Alcohol and drugs		
No	44,723	93.6
Yes	3048	6.4
Infection		
No	38,827	81.3
Yes	8944	18.7
Diabetes		
No	43,820	91.7
Yes	3951	8.3
Hypertension		
No	41,523	86.9
Yes	6248	13.1
Depression		
No	46,144	96.6
Yes	1627	3.4
Preterm birth (any)		
No	43,168	90.4
Yes	4603	9.6
Infant mortality (any)		
No	47,512	99.5
Yes	259	0.5
Previous preterm birth		
No	47,057	98.5
Yes	714	1.5

BMI body mass index, *WIC* Women, Infants and Children's Program

income ($n = 43$, 0.05%), ICE race ($n = 43$, 0.50%), and ICE race + income ($n = 39$, 0.40%)) (see Fig. 2). Bivariate analyses revealed that across all ICE measures, residing in the least privileged income, race, and race + income quintiles (quintile 1) significantly increased the odds of women experiencing an infant death compared to women who lived in the most privileged respective quintiles (quintile 5) (see Table 2). Across ICE measures, women residing in quintile 1 had over a 41 to 70% elevated risk for IM.

In adjusted models, only ICE race and race + income measures remained significantly associated with IM (see Table 2). Women who lived in the least privileged race (aOR = 1.54, 95% CI = 1.03–2.30) and race + income (aOR = 1.68, 95% CI = 1.14–2.47) quintiles were at an increased odds of experiencing an infant death compared to women who resided in the most privileged quintiles (quintile 5).

Discussion

Findings from our study confirm the utility of using ICE to measure race, income, and race + income inequalities and for investigating the social determinants of PTB and IM in California at the zip code level. Among Black women included in our study, 10% had a PTB with less than 1% experiencing an infant death (IM rate 5.42 deaths per 1000 live births). Across all ICE measures, there was an increased likelihood for PTB and IM among Black women residing in quintile 1 compared to quintile 5. In adjusted models, all ICE measures remained significantly associated with PTB, while only ICE race and race + income continued to be related to IM. ICE measures were more strongly related to IM,

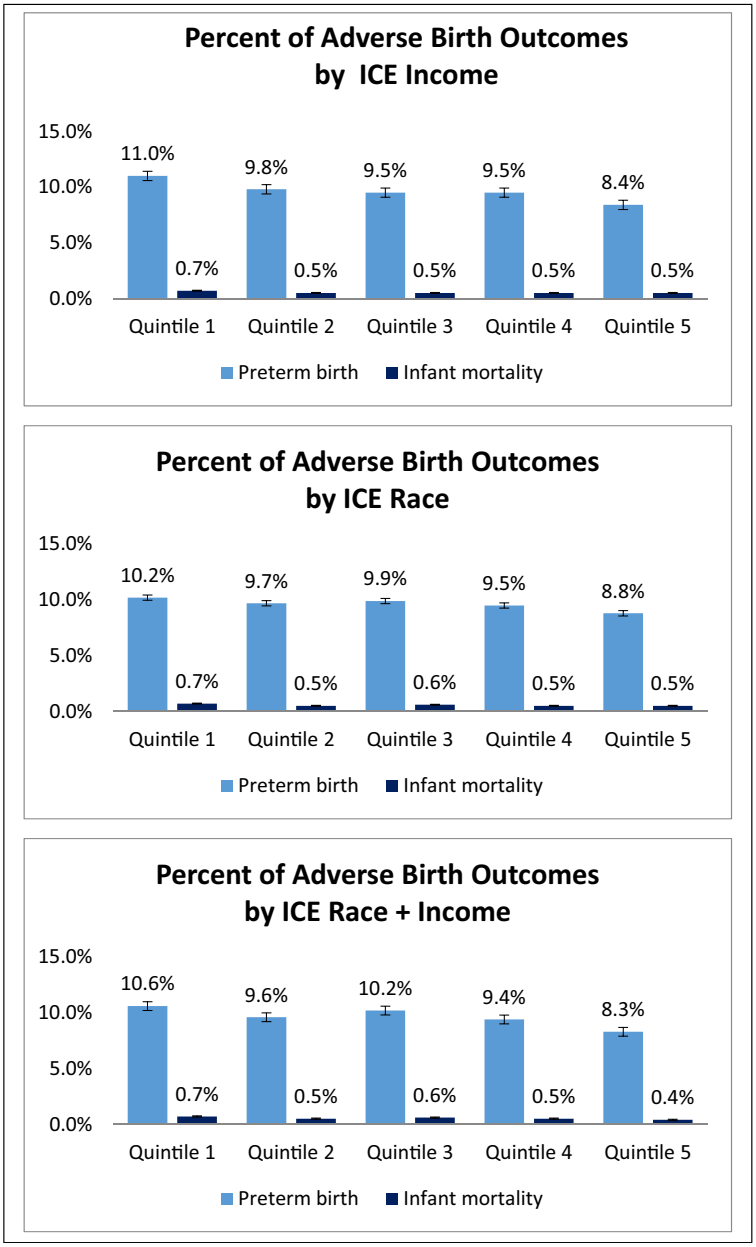

Fig. 2 Distribution of preterm birth and infant mortality across ICE measures and quintiles

increasing the risk among women residing in quintile 1 by 54 and 68%.

There are only three other studies that have examined the association between ICE measures and adverse birth outcomes at the census tract and community district levels [11–13]. Across ICE measures, Black women who resided in quintile 1 (most deprived) reported higher rates of PTB and similar rates of IM compared to women who lived in similar neighborhoods in New York City and Boston, MA. Our results suggest that Black women who resided in the most deprived neighborhoods in California had similar odds of PTB compared to women in Boston, MA, who lived in similar neighborhoods of ICE scores. The disparity gap in PTB and IM between quintile 1 (most deprived) and quintile 5 (most privileged) was wider among New York City women and residents in comparison to Black women in our study sample. Differences in the gradient of risk associated with ICE measures in the present study compared to previous studies are likely due to measuring

Table 3 Unadjusted and adjusted random effect models: ICE measure quintiles, preterm birth, and infant mortality, 2011–2012

	ICE income		ICE race		ICE race + income	
	Unadjusted OR (CI)	Adjusted aOR (CI)	Unadjusted OR (CI)	Adjusted aOR (CI)	Unadjusted OR (CI)	Adjusted aOR (CI)
Preterm birth						
Quintile 1 (most deprived)	1.32 (1.19–1.46)*	1.29 (1.16–1.44)*	1.18 (1.05–1.32)*	1.15 (1.02–1.30)*	1.31 (1.72–1.46)*	1.25 (1.12–1.40)*
Quintile 2	1.17 (1.06–1.29)*	1.14 (1.03–1.27)*	1.14 (1.02–1.27)*	1.11 (0.99–1.24)	1.17 (1.05–1.30)*	1.13 (1.01–1.26)*
Quintile 3	1.11 (1.00–1.23)	1.10 (0.99–1.23)	1.13 (1.01–1.25)*	1.09 (0.97–1.21)	1.22 (1.10–1.35)*	1.18 (1.05–1.31)*
Quintile 4	1.23 (1.01–1.25)*	1.12 (1.01–1.25)*	1.09 (0.98–1.21)	1.11 (0.99–1.23)	1.13 (1.01–1.25)*	1.12 (1.01–1.25)*
Quintile 5 (most privileged)	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Infant mortality						
Quintile 1 (most deprived)	1.46 (1.01–2.12)*	1.41 (0.91–2.48)	1.52 (1.02–2.26)*	1.54(1.03-2.30)*	1.70 (1.17–2.47)*	1.68 (1.14–2.47)*
Quintile 2	1.13 (0.77–1.65)	1.10 (0.83–2.33)	1.16 (0.76–1.75)	1.13 (0.74–1.71)	1.05 (0.70–1.57)	1.01 (0.67–1.52)
Quintile 3	1.12 (0.75–1.66)	1.09 (0.68–2.10)	1.23 (0.82–1.85)	1.19 (0.79–1.80)	1.37 (0.93–2.02)	1.29 (0.87–1.93)
Quintile 4	1.10 (0.73–1.64)	1.08 (0.75–2.40)	1.13 (0.75–1.71)	1.13 (0.75–1.72)	1.09 (0.72–1.65)	1.07 (0.70–1.63)
Quintile 5 (most privileged)	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.

Adjusted models controlled for age, education, nativity, Medi-Cal, WIC, prenatal care visits, pregnancy BMI, cigarette use, alcohol and drug use, infection, diabetes, hypertension, depression, and previous preterm births

OR odds ratio, *aOR* adjusted odds ratio, *CI* confidence interval

*p value < 0.05

ICE at the zip code level. Research indicates that exposures to structural racism may operate differently by geographic scale, where social context and health policies represent distinct patterns [34, 38, 53]. We focused on zip codes as they represent larger local geographic units providing more robust estimates of racial and economic disparity [43, 49, 50]. Findings from the Public Health Disparities Geocoding Project suggest that zip codes provide instable socioeconomic estimates, in comparison to census tracts and blocks, and recommend using census tract as the unit of analysis for monitoring public data [42]. Nonetheless, findings from this study revealed similar relationships between ICE measures and adverse birth outcomes as previous studies focused on census tract and community district levels, furthermore illuminating the effect that structural racism, measured at the zip code level, has on PTB and IM in Black women and their offspring.

Structural racism has been identified as a fundamental cause of health disparities [24–26, 53]. This studied focused solely on Black women unique social stratification among Black and White people historically rooted in US society. Historical and contemporary institutionalized laws, legislation, and oppressive processes geographically separated Blacks from Whites and allocated resources, amenities, and opportunities accordingly [24, 25, 36]. This process has had long-lasting economic and health implications for Blacks [22–25]. For example, racial and ethnic segregation is reported at higher rates between Black and Whites, followed by between Whites, Latinos, and Asians [30, 54–58]. Despite shifts in segregation, Blacks across all socioeconomic groups still live in more highly segregated areas compared to Whites and other racial/ethnic groups [30, 56–58]. There are strong links between racial and income segregation and adverse birth outcomes among Black women, with relatively few articles examining the asso

ciation between the intersection of racial and income segregation [11–13, 34, 59]. ICE measures appear to be successful in capturing race and income segregation and the extent to which it is related to adverse birth outcomes experienced by Black women and their offspring in California.

ICE measures the extent to which structural racism persists by examining how concentrated deprived versus privilege groups are in neighborhoods [12, 29, 36, 39]. Findings from our study support that living in highly deprived neighborhoods is associated with PTB and IM among Black women and their offspring. To the best of our knowledge, this is the first study to examine the exposure of ICE measures at the zip code level and among Black women. Our research highlights that Black women residing in neighborhoods with ICE race + income quintiles lower than most privileged quintiles are at higher risk for PTB and that women and their infants who live in the mostly deprived quintiles are at higher risk for IM.

Strengths and Limitations

There are several strengths of this study. We used a statewide birth cohort study which allowed us to center our analysis on a large Black women and maintain robust estimates. We were also able to control for key maternal characteristics and pregnancy complications associated with PTB and IM. Similar to New York City, many neighborhoods in California have variety in race and income distributions that increase the variance of ICE measures. To our knowledge, this was the first study to examine the utility of ICE measures at the zip code level and within the state of California. Findings from our study that support exposure to ICE measures at the zip code level have similar effects on adverse birth outcomes among Black women in California compared to ICE measures at the census tract and community district levels among diverse samples of women in New York City and Boston, MA.

The primary limitation of this study was our inability to control for the duration women resided in their respective neighborhoods. Previous research supports 12 to 41% of women moved during pregnancy [60–66]; however, Black families, particularly those of low income, are more likely to move to similar neighborhoods compared to White families [66–68]. Additionally, the differing gradient of risk associated with ICE measures can be due to the modifiable areal unit problem (MAUP) [69–71]. MAUP acknowledges that geographic units such as zip codes and census tracts are arbitrary and can be modified to form different units in spatial arrangements and size [69–71]. Variation in zip code and census tract ICE exposures and adverse birth outcomes can be the result of the scaling effect. For example, it is likely that the gradient of risk associated with ICE measures and adverse birth outcomes reduces as census tracts are combined to comprise zip codes. To test for MAUP, this study should be replicated measuring the associated ICE among Black women and their offspring at different geographic scales including census tract, county, and state levels. Lastly, our data was limited to maternal characteristics and hospital discharge data, so we were unable to account for the effects of structural racism such as self-reported exposures to racial discrimination. Future research should explore how self-reported exposures to racial discrimination moderate the relationship between ICE measures and Black women's adverse birth outcomes, as well as additional socioeconomic extremes such as educational level and employment status.

Conclusions

Findings support that ICE measures, particularly at the zip code level, are independently associated with PTB and IM experienced by Black women and their offspring in California. All three ICE measures were associated with PTB, while only two were associated with IM after adjusting for maternal characteristics. However, the gradient of risk associated with ICE measures at the zip code level was lower than expected among a sample of Black women who are have an elevated risk for adverse birth outcomes and exposures to structural racism. Therefore, findings from this study support the need for additional data analyses focused on assessing ICE measures at different geographic units and health outcomes among Black women and their offspring in California.

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