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# Structural racism, socio-economic marginalization, and infant mortality

J. Bishop-Royse [a, c, *], B. Lange-Maia [b, c], L. Murray [c], R.C. Shah [c, d], F. DeMaio [c, e, f]

[a] Faculty Scholarship Collaborative, DePaul University, Chicago, IL 60614, USA
[b] Department of Preventative Medicine, Rush University Medical Center, Chicago, IL 60612, USA
[c] Center for Community Health Equity, Chicago, IL, USA
[d] Department of Family Medicine, Rush Alzheimer's Disease Center, Rush University Medical Center, Chicago, IL 60612, USA
[e] Center for Health Equity, American Medical Association, Chicago, IL 60611, USA
[f] Department of Sociology, DePaul University, Chicago, IL 60614, USA

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ABSTRACT

*Objectives:* We examine associations between infant mortality rates (IMRs) and measures of structural racism and socio-economic marginalization in Chicago, Illinois. Our purpose was to determine whether the Index of Concentration at the Extremes (ICE) was significantly related to community-level IMRs.
*Study design:* We use a cross-sectional ecological public health design to examine community-level factors related to IMRs in Chicago neighborhoods.
*Methods:* We use data from the Chicago Department of Public Health and the American Community Survey to examine IMR inequities during the period 2012–2016. Calculations of the ICE for race and income were undertaken. In addition, we calculated racialized socio-economic status, which is the concentration of affluent Whites relative to poor Blacks in a community area. We present these ICE measures, as well as hardship, percent of births with inadequate prenatal care (PNC), and the percent of single-parent households as quintiles so that we can compare neighborhoods with the most disadvantage with neighborhoods with the least. Negative binomial regression was used to determine whether the ICE measures were independently related to community IMRs, net of hardship scores, PNC, and single-parent households.
*Results:* Spearman correlation results indicate significant associations in Chicago communities between measures of racial segregation and economic marginalization and IMRs. Community areas with the lowest $ICE_{Race}$ scores (those with the largest concentrations of Black residents, compared with White) had IMRs that were 3.63 times higher than those communities with the largest concentrations of White residents. Most associations between community IMRS and measures of structural racism and socio-economic marginalization are accounted for in fully adjusted negative binomial regression models. Only ICERace remained significantly related to IMRs.
*Conclusions:* We show that structural racism as represented by the ICE is independently related to IMRs in Chicago; community areas with the largest concentrations of Blacks residents compared with Whites are those with the highest IMRs. This relationship persists even after controlling for socio-economic marginalization, hardship, household composition/family support, and healthcare access. Interventions to improve birth outcomes must address structural determinants of health inequities.


## Introduction

Overall, infant mortality rates (IMRs) fell dramatically in the United States during the period 1950 to 2015, from 29.2 to 6.9 deaths per 1000 births.[1] However, improvements in infant survival have not been distributed equitably; during this period, Black infants remained over twice as likely as White infants to die in the

* Corresponding author.
*E-mail addresses:* jbishopr@depaul.edu (J. Bishop-Royse), Brittney_Lange-Maia@rush.edu (B. Lange-Maia), lashawntmurray@gmail.com (L. Murray), Raj_C_Shah@rush.edu (R.C. Shah), FDEMAIO@depaul.edu (F. DeMaio).

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first year of life.[2–7] Furthermore, there is evidence that racial inequities in infant death have even increased.[8]

Much of the research in this area has examined the contribution of individual-level (compositional) characteristics on racial inequities in infant mortality. Maternal characteristics such as age, marital status, race, ethnicity, socio-economic status, parity, smoking, and substance use, as well as maternal physiological and reproductive factors (e.g. shortened cervix and bacterial vaginosis), are related to infant outcomes.[9] Yet, these factors do not account for the well-documented racial and socio-economic inequities in infant mortality.[10]

Clearly, community-level research on inequalities in infant health is needed. Researchers have begun to explore the association between neighborhood characteristics and inequities in infant mortality. Promising scholarship in social epidemiology has focused on the impact of structural racism and socio-economic marginalization on excess risk of death for Black infants. An important development in this work has been a focus on structural racism as a driver of health inequities.[11] However, there is no consensus on how to observe and measure structural racism, particularly at the population level. Wallace et al.[12] used state-level measures of population incarceration, educational attainment, income, and occupational status as proxies for structural racism. Others have examined inequities in infant mortality using the Index of Concentration at the Extremes (ICE), which Krieger et al.[13] have proposed as a tool for monitoring public health inequities across communities.

As a measure, the ICE has great utility because it can be derived for varying geographies: for neighborhoods,[13,14] census tracts,[13] zip codes,[15,16] cities,[17] and at the state level.[15] Most commonly, the ICE has been used to represent racial segregation, as the proportion of Black to White residents in an area, as well as economic marginalization, the proportion of poor to affluent residents in area. The ICE has been used to quantify the intersection of racial segregation and economic polarization.[13] It has been used in relation to a wide range of health outcomes, including premature mortality,[13,14,18–20] cancer,[21–23] mental health,[24] hypertension,[25] allostatic load,[26] and exposure to pollution.[27] ICE measures can be calculated for small geographic units (neighborhoods and community areas), whereas traditional measures of income inequality such as the Gini coefficient cannot. There is growing support for the use of the ICE as a proxy indicator of the historical legacy of structural racism in US cities, particularly as it relates to disinvestment and marginalization of communities.

The racial/ethnic inequities in IMRs are well established in Chicago. In 2016, the ratio of Black to White IMRs was 3.7 to 1 (with 12.7 deaths per 1000 births and 3.4 deaths per 1000 births, respectively).[28] Yet, given the well-documented inequities within Chicago, these overall rates hide substantial differences.[29] We use ICE measures of structural racism and economic marginalization to examine racial inequities in infant mortality in Chicago's 77 community areas. Our analysis examines the nature of the relationship between structural racism and factors that have long been considered important for infant health and survival such as the hardship index, healthcare access, and family household composition.

## Methods

This is a community-level ecological study. The 77 community areas in Chicago, originally defined by the University of Chicago's Social Science Research Committee in the 1920s, are used by the City of Chicago for statistical and planning purposes.[30] Infant mortality data used here originate in the geocoded vital registration records made available by the Illinois Department of Health. These data were aggregated to community area. Average IMRs for the period 2010–2014 were calculated and shared for public use through the Chicago Health Atlas, maintained by the Chicago Department of Public Health.[31]

This study uses publicly available data from the 2016 American Community Survey. ICE measures were ($ICE_{Income}$, $ICE_{Race}$, $ICE_{Income+Race}$) calculated using 2016 5-year estimates and a formula originally developed by Massey,[32] but which has been used more recently by Krieger et al.[33]:

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

In the given formula, $P$ represents the privileged group, $D$ represents the disadvantaged group, and $T$ the total population of an area. When the relative difference between the privileged and disadvantaged group is divided by the total population, the resulting value varies between −1 and 1. With this calculation, negative ICE values correspond to greater concentrations of disadvantaged residents in a community area and positive values to greater concentrations of privileged residents.

In calculating $ICE_{Income}$, we use household incomes greater than $100,000 to represent $P$ and the number of community residents with household incomes less than $25,000 to represent $D$. Positive $ICE_{Income}$ values indicate larger concentrations of affluent people (those living in households with annual incomes greater than or equal to $100,000) and negative values represent larger concentrations of individuals who are less well-off (those living in households with incomes less than $25,000). Similarly, positive $ICE_{Race}$ values represent communities with larger concentrations of White residents, whereas negative values correspond to greater concentrations of Black residents. Sometimes called 'racialized economic segregation' the combined $ICE_{Income+Race}$ metric represents the difference between high-income Whites and low-income Blacks; positive values indicate greater concentrations of affluent Whites and negative values indicate greater concentrations of poor Blacks. It should be noted that communities with ICE values of zero may be those communities with complete integration or those with substantial presence of other groups.

The hardship index is a geographically standardized measure of socio-economic disadvantage calculated at the community area and based on methods described in detail elsewhere.[34,35] In short, the hardship index combines multiple contextual-level economic conditions for a community into a single measure. The area-level characteristics that are used in this measure include the unemployment rate of persons aged older than 16 years, per capita income, the percent of residents aged younger than 18 years or older than 64 years, the percent of residents living in crowded housing, the percent of households living below poverty, and the percent of residents over the age of 25 who had not earned a high school diploma. It is important to note that the hardship index does not incorporate any information on racial segregation. These items are combined in the following formula:

$$X_i = ((Y_i - Y_{min}) / (Y_{max} - Y_{min}))*100$$

In the given formula, X and Y represent the standardized and unstandardized components, while $Y_{min}$ and $Y_{max}$ denote the minimum and maximum values of those measures. The hardship index score is a composite average of each of the standardized components with scores between 1 and 100, where larger values represent greater hardship.

Data on the percentages of community area residents living in single-parent households and pregnancies with late or inadequate prenatal care (PNC) originated in the U.S. Census Bureau's American Community Survey[36] and were provided in the Chicago Health

Atlas.[31] We included these additional measures to represent family and household characteristics, as well as healthcare access that has been previously shown to impact pregnancy outcomes. Family household composition/social support is represented in our analyses by the percentage of households in a community with children aged younger than 18 years who live with their own unmarried parents. These families may include cohabiting couples but not children living with married stepparents.

Finally, the percentage of births with PNC that was determined to be late or inadequate is included as a measure of healthcare access for the residential population. This item is availability at the community level in the Chicago Health Atlas.[31] It is based on the Adequacy of Prenatal Care Utilization Index (APNCU), which combines two birth certificate elements: when PNC was initiated and the number of prenatal visits from care initiation to delivery.[37] The APNCU measure combines these two components into a single summary score, where scores of 80% or greater are considered adequate. To get the percentage of births in a community area that received late/inadequate care, we subtracted the percentage that received early and adequate care based on the APNCU from 100%.

In addition to descriptive statistics and interquartile range, Spearman correlations were calculated. Quintiles for each of the ICE measures, hardship, as well as late/inadequate PNC, and single-parent households were calculated. Over dispersion in these data provided support for using negative binomial regression analysis. Results from these models were used to calculate incidence risk ratios (IRRs), allowing us to compare the highest and lowest quintiles, which represent the least and most disadvantaged communities, respectively. Finally, we present a series of regression models illustrating the impact of ICE measures, hardship scores, as well as household composition and healthcare access on community-level IMRs in Chicago.

## Results

Community-level IMRs ranged from 0.9 to 20.6 deaths per 1000 live births during the period 2012–2016. Fig. 1 shows scatter plots of community IMRs, ICE measures, hardship, PNC and parental psychosocial support in Chicago. We document strong linear relationships between disadvantage and IMRs; communities with greater levels of disadvantage tend to have higher infant death rates.

Descriptive statistics are shown in Table 1. The median $ICE_{Income}$ score was −0.12, indicating that the 50th percentile community was slightly economically disadvantaged. The median $ICE_{Race}$ score was 0.11, which represents a community that had a greater concentration of White residents than Black. For hardship, where higher scores represent greater disadvantage, the middle 50% of scores ranged from 25.88 to 48.83. The median community area had about 9.8 residents living in single-parent households. In terms of PNC, the median community area had about 29.4% of births with late or inadequate PNC. Spearman correlation analysis show strong, significant correlations between these measures and the IMR ($P \leq 0.001$).

In general, more advantaged communities had significantly lower rates of infant mortality than less advantaged communities. Communities in the highest quintiles (i.e. those with the most advantage) in terms of $ICE_{Income}$, $ICE_{Race}$, and $ICE_{Income+Race}$ had IMRs of 4.39, 3.82, and 4.10 deaths per 1000 births, respectively (not shown). Least advantaged communities (those in the lowest

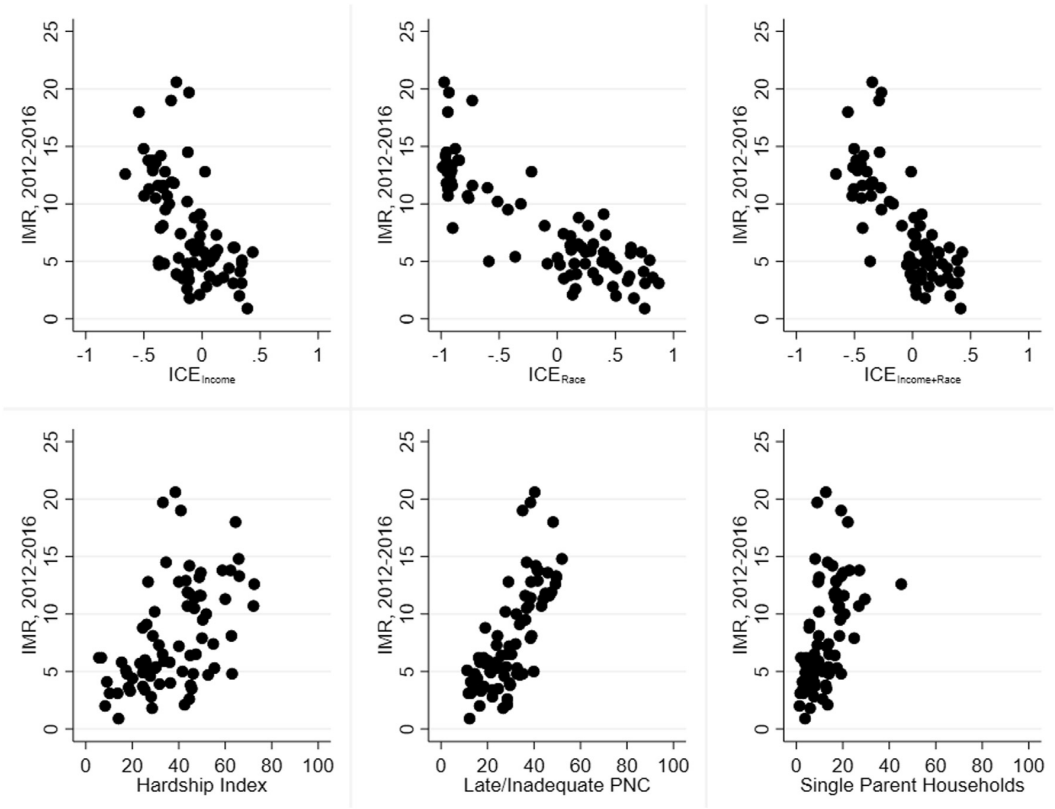


**Fig. 1.** Scatter plots of infant mortality rates and contextual–level measures in Chicago community areas, 2012–2016.

**Table 1**
Descriptive statistics and correlation of predictors with infant mortality (2010–2014) for Chicago's 77 community areas.

| Variable | Median | IQR | Possible range | Spearman correlation analysis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IMR | $ICE_{Income}$ | $ICE_{Race}$ | $ICE_{Income + Race}$ | Hardship index | Late/inadequate PNC, % | Single-parent household, % |
| IMR (per 1000 births) | 6.4 | 4.70 to 11.60 | 0.9 to 20.6 | 1.00 | | | | | | |
| $ICE_{Income}$ | −0.12 | −0.33 to 0.06 | −1 to 1 | −0.63* | 1.00 | | | | | |
| $ICE_{Race}$ | 0.11 | −0.84 to 0.39 | −1 to 1 | −0.80* | 0.84* | 1.00 | | | | |
| $ICE_{Income + Race}$ | 0.01 | −0.35 to 0.13 | −1 to 1 | −0.75* | 0.95* | 0.95* | 1.00 | | | |
| Hardship index | 38.5 | 25.88 to 48.83 | 1 to 100 | 0.53* | −0.90* | −0.76* | −0.84* | 1.00 | | |
| % late/inadequate PNC | 29.4 | 21.00 to 38.60 | 0 to 100 | 0.74* | −0.93* | −0.90* | −0.94* | 0.85* | 1.00 | |
| % single-parent households | 9.8 | 6.06 to 17.16 | 0 to 100 | 0.63* | −0.82* | −0.80* | −0.84* | 0.88* | 0.81* | 1.00 |

*Spearman rank-order correlation coefficient $P \leq 0.01$. IMR, infant mortality rate; PNC, prenatal care; ICE, Index of Concentration at the Extremes; IQR, Inter-Quartile Range.

quintile of these measures) fared much worse, with $ICE_{Income}$, $ICE_{Race}$, and $ICE_{Income+Race}$ IMRs of 11.70, 13.87, and 12.68 deaths per 1000 births, respectively (not shown). Fig. 2 shows plots of rate ratios by quintile for study measures. In this analysis, the least advantaged communities (with the largest concentrations of disadvantage) had the highest risk ratios, compared with the communities with the smallest concentration of disadvantage ($ICE_{Income}$ IRR = 2.68; $ICE_{Race}$ RR = 3.63; $ICE_{Income+Race}$ IRR = 3.10). In addition, communities with the most hardship, the greatest proportions of births with late or inadequate PNC, and those with the greatest percentages of single-parent households had much greater IMR risk ratios than those communities with the least (hardship RR = 2.39; percent of births with late/inadequate PNC IRR = 3.29, percent of single-parent households IRR = 2.53).

Multivariable negative binomial regression models are shown below in Table 2. All measures were related to IMRs in unadjusted bivariate models at the $P \leq 0.001$ level (model 1). Communities with the largest proportions of affluent residents have IMRs that are 77% lower than those of communities with the greatest proportions of residents whose incomes are $25,000 per year or less ($ICE_{Income}$ IRR = 0.233). Communities with the largest proportions of White residents had IMRs that were 54% lower than those with the greatest proportions of Black residents ($ICE_{Race}$ IRR = 0.456). Communities that had the largest share of affluent White residents had IMRs that were 79% lower than those of communities with the greatest proportions of poor Blacks ($ICE_{Income+Race}$ IRR = 0.215). A one unit increase in hardship increases the IMR by 1.8% (hardship IRR = 1.018). A one percentage increase in single-parent households and births receiving late/inadequate PNC increases the infant death rate in Chicago by 4.0% and 3.9%, respectively (% single parent household IRR = 1.04, % late/inadequate PNC IRR = 1.039). Each of the unadjusted models had chi-squared statistics (which estimate

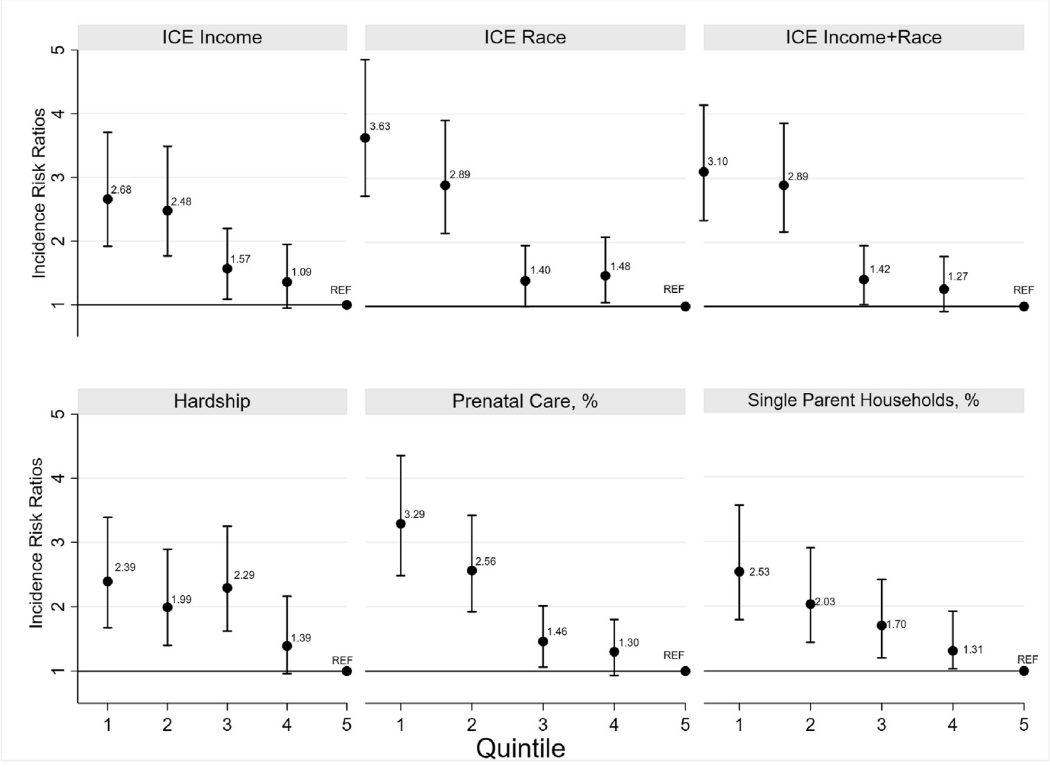


**Fig. 2.** Infant mortality rate incidence risk ratios by quintile, 2012–2016.

**Table 2**
Binomial regression results.

| Variable | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| | Unadjusted | Hardship, %late/inadequate PNC, % single-parent household | $ICE_{Income}$, hardship, %late/inadequate PNC, % single-parent household | $ICE_{Race}$, hardship, %late/inadequate PNC, % single-parent household | $ICE_{Income+Race}$ hardship, late/inadequate PNC, % single-parent household |
| $ICE_{Income}$ | 0.233*** | – | 0.922 | – | – |
| | (0.048) | – | (0.492) | – | – |
| $ICE_{Race}$ | 0.456*** | – | – | 0.456*** | – |
| | (0.031) | – | – | (0.075) | – |
| $ICE_{Race+Income}$ | 0.215*** | – | – | – | 0.217*** |
| | (0.031) | – | – | – | (0.095) |
| Hardship | 1.018*** | 0.982*** | 0.981** | 0.993 | 0.985** |
| | (0.003) | (0.006) | (0.006) | (0.006) | (0.006) |
| % single-parent households | 1.040*** | 1.016 | 1.015 | 0.999 | 1.000 |
| | (0.007) | (0.008) | (0.008) | (0.009) | (0.009) |
| % late/inadequate PNC | 1.039*** | 1.054*** | 1.054*** | 1.008 | 1.018 |
| | (0.004) | (0.007) | (0.009) | (0.012) | (0.012) |
| Constant | – | 2.421*** | 2.522** | 6.87*** | 6.455*** |
| | – | (0.347) | (0.902) | (1.739) | (2.010) |
| Model $\chi^2$ | – | 73.33*** | 73.36*** | 96.09*** | 85.07*** |
| AIC | – | 374.51 | 376.48 | 353.75 | 364.37 |
| BIC | – | 386.23 | 390.55 | 367.82 | 378.43 |
| Observations | 77 | 77 | 77 | 77 | 77 |

***$P < 0.001$, **$P < 0.01$, *$P < 0.05$. Standard errors in parenthesis. PNC, prenatal care; ICE, Index of Concentration at the Extremes

the probability of the coefficients being equal to zero) at *P*-values less than or equal to 0.001.

When hardship, percent of births with late-inadequate PNC, and percent of residents living in single-parent households were included together in model 2, we show that hardship and PNC were independently associated with community IMRs but single-parent households was not ($\chi^2 = 73.36$, $P \leq 0.001$). Interestingly, increasing hardship scores were associated with trivial declines in IMRs in Chicago community areas, while increasing the proportion of births receiving late/inadequate PNC was related to higher IMRs.

The independent associations between $ICE_{Income}$ and IMRs were attenuated to non-significance in model 3 with the inclusion of hardship, percent late or inadequate PNC, and percent of residents living in single-parent households, ($\chi^2 = 96.09$, $P \leq 0.001$). $ICE_{Race}$ remained significantly related to IMRs in model 4 (IRR = 0.456), where the effects of covariates for hardship, PNC, and living in single-parent households were ameliorated. The association between IMRs and $ICE_{Income+Race}$ remained significant in model 5 (IRR = 0.217), but hardship was also significant (IRR = 0.985) compared with the unadjusted IRR in model 1 ($\chi^2 = 85.07$, $P \leq 0.001$). AIC and BIC values are lowest for model 4 (which includes $ICE_{Race}$, hardship, percent of births with late/inadequate PNC, and percent of residents living in single-parent households), indicating it is the best fitting of all the models.

## Discussion

In Chicago, community-level measures of racial segregation, economic marginalization, hardship, the percent of single-parent households, and the percent of births with late/inadequate PNC were significantly related to community-level IMRs in 2012–2016. The strongest of these effects was $ICE_{Race}$, where communities with the highest concentrations of Black residents had IMRs that were 3.5 times higher than those of communities with the highest concentrations of White residents. We interpret these community-level findings as evidence of inequities produced by a long history of economic disinvestment and marginalization of communities, which has been suggested elsewhere.[38,39] While previous research positioned 'Black race' as a risk factor for adverse birth outcomes,[40,41] studies similar to ours contribute to shifting the narrative toward structural drivers of health inequities.[42–44]

While our data are cross-sectional, there are deep historical dimensions to the relationship between structural racism and health that are worthy of further consideration. Structural racism affected both where Blacks could live and the condition of those places in the 19th and 20th centuries. Blacks arriving in Chicago found many of the same barriers that forced them out of the Jim Crow South. On arrival to Chicago, newly emigrated Blacks were pushed into segregated neighborhoods on the city's south and west sides. This was accomplished through redlining and other racist and discriminatory housing policies that systematically disinvested and marginalized whole communities, to the advantage of others As defined by Camara Jones, "racism is a system of structuring opportunity and assigning value based on phenotype ("race"), that unfairly disadvantages some individuals and communities, unfairly advantages other individuals and communities, undermines realization of the full potential of the whole society through the waste of human resources".[45] Not one single variable in a regression model can capture all of that complexity, but the ICE is a promising step toward incorporating structural racism in statistical models of health inequities.[46]

This study contributes to the growing body of evidence of the usefulness and utility of the ICE as an indicator of structural racism. Our results diverge somewhat from other research using the ICE. Using data from New York City in 2010, Krieger et al.[13] documented larger rate ratios for $ICE_{Income+Race}$ and IMRs than for $ICE_{Race}$ and IMRs (RR = 2.93 and RR = 2.77, respectively). We find the opposite, that in Chicago, the $ICE_{Race}$ rate ratios were higher than $ICE_{Income+Race}$ (RR = 3.63 and RR = 3.10, respectively). The Chicago $ICE_{Income}$ measure we calculated was based on national income distributions; a household income of $100,000 has more purchasing power in Chicago than it does in New York City, where median incomes and costs of living are higher. Lower costs of living mean that individuals have more resources to devote to preventing adverse health outcomes.[47] This may have contributed the divergent results we find. Our results are more similar to those documented by Huynh et al.,[48] who documented greater risk of death for infants born in lowest quintile $ICE_{Race}$ census tracts than for those born in lowest quintile $ICE_{Income+Race}$ census tracts (OR = 4.23 and 3.79, respectively). Similarly, they found that even after adjusting for other measures of interest, inequities for $ICE_{Race}$ were larger than for $ICE_{Income+Race}$ (OR = 1.80 and 1.54, respectively).

One limitation of using ICE measures is its non-linear nature, where extreme values on these represent either privilege (1.0) or disadvantage (−1.0) and values in the middle (0.0) represent either perfect balance between privileged and disadvantaged or the presence of large groups with 'other' statuses. For example, in Chicago, there are communities with large proportions of residents who are neither White nor Black. Four of the six community areas with $ICE_{Race}$ scores near zero are those where the Black population is much smaller than the White population, but both are outnumbered by Latinx residents, who make up 90–92% of the population in those communities. Furthermore, little is known about affluent Black communities and poor White communities in Chicago because there are so few of each.

Previous attempts to address infant health inequities have focused on individual-level interventions. While Black infant survival has increased after interventions such as the Back to Sleep campaign, there is some evidence that such interventions may actually increase some racial health disparities.[49] This occurs because such efforts do not address structural drivers of infant health that produce racial inequities in infant survival. For example, racism in health care often means unequal access, but even when Blacks have healthcare access that is comparable with Whites, they receive worse care.[50] Policies that fail to address past and ongoing structural racism will likely have limited impact on infant health inequities. Moreover, ICE measures have been suggested as useful tools for public health monitoring,[19] which would allow for the identification of communities in need of intervention. Obviously, these interventions would need to be carefully considered in the context of community and structural impacts on health. We have shown that structural racism as represented by the ICE is independently related to IMRs in Chicago; community areas with the largest concentrations of Blacks to Whites are those with the highest IMRs. This relationship persists even after controlling for socio-economic marginalization, hardship, household composition/family support, and healthcare access. Future research should examine the impact of community-level factors and individual infant and maternal factors simultaneously infant health.

## Author statements

### *Disclaimer*

The thoughts in this article are those of the authors and do not necessarily represent AMA policy.

### *Ethical approval*

The data used in the analyses described here come from publicly available files aggregated at the community level and across multiple years. Ethical approval was not sought because this research did not constitute human subject research.

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### *Competing interests*

None declared.

### *Author contributions*

F.D., R.C.S., and B.L.-M. conceptualized the study. J.B.-R., B.L.-M, and L.M. contributed to data collection and study design. J.B.-R. took primary responsibility for drafting the manuscript and conducting the statistical analyses. B.L.-M., R.C.S., and F.D.M. provided substantial guidance and revision to the final manuscript.

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