Association of community-level inequities and premature mortality: Chicago, 2011–2015

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ABSTRACT

Background Substantial disparities in life expectancy exist between Chicago's 77 defined community areas, ranging from approximately 69 to 85 years. Prior work in New York City and Boston has shown that community-level racial and economic segregation as measured by the Index of Concentration at the Extremes (ICE) is strongly related to premature mortality. This novel metric allows for the joint assessment of area-based income and racial polarisation. This study aimed to assess the relationships between racial and economic segregation and economic hardship with premature mortality in Chicago.

Methods Annual age-adjusted premature mortality rates (deaths <65 years) from 2011 to 2015 were calculated for Chicago's 77 community areas. ICE measures for household income (<US\$25 000 vs ≥US\$100 000), race (black vs non-Hispanic white), combined ICE measure incorporating income and race, and hardship index were calculated from 2015 American Community Survey 5-year estimates.

Results Average annual premature mortality rates ranged from 94 (95% CI 61 to 133) deaths per 100 000 population age <65 to 699 (95% CI 394 to 1089). Compared with the highest ICE quintiles, communities in the lowest quintiles had significantly higher rates of premature mortality (ICE_{Income} rate ratio (RR)=3.06, 95% CI 2.51 to 3.73; ICE_{Race} RR=3.07, 95% CI 2.62 to 3.58; $ICE_{Income+Race}$ RR=3.27, 95% CI 2.84 to 3.77). Similarly, compared with communities in the lowest hardship index quintile, communities in the highest quintile had significantly higher premature mortality rates (RR=2.79, 95% CI 2.18 to 3.57).

Conclusions The strong relationships observed between ICE measures and premature mortality—particularly the combined ICE metric encompassing race and income—support the use of ICE in public health monitoring.

INTRODUCTION

Life expectancy at birth in Chicago is approximately 76.9 years, slightly under the national average life expectancy of roughly 78.7 years.[1 2] Disparities are evident when examining life expectancy between racial/ethnic groups in Chicago—ranging from 71.7 years for black residents, 78.8 years for non-Hispanic white residents, to 84.6 years for Hispanic and Latino residents.[2] Disparities are also pronounced between Chicago's 77 officially designated communities (which have been used to study the city's social inequalities since the 1920s[3]) with a gap of nearly 15 years existing between the communities with the highest (83 years) and lowest (68 years) life expectancy.[2] Undoubtedly, localised data are important for identifying communities and populations in greatest need for interventions.

The national trend is towards a small decline in black–white segregation in many US cities; however, the Chicago metropolitan area remains starkly segregated by race.[4 5] Prior work in Chicago has shown a strong relationship between community-level racial/ethnic make-up and health outcomes, with communities of predominantly black residents having higher rates of diabetes-related and stroke-related mortality, low birth weight and maternal smoking.[6–9] Community-level income has also been extensively related to health, with many communities of colour having lower income (and worse health outcomes) compared with higher-income, predominantly white communities.[2 6–8 10] Prior studies in this area have largely looked at only 'one end of the spectrum'—disadvantage—without considering the distribution of affluence in the city.[11] A limitation to examining community-level racial make-up or median household income is that they do not capture the unequal distribution of income and race across communities. Accounting for the distribution of affluence and poverty, rather than poverty alone, is important for understanding the spatial distribution of health outcomes.

Recently, the Index of Concentration at the Extremes (ICE)[12] has been incorporated into the public health literature to relate health outcomes with area-level spatial social polarisation, particularly with regard to race and income.[13–15] For example, in New York City and Boston, an ICE measure that incorporates both area-level income and race was more strongly associated with premature mortality and infant mortality compared with poverty.[13 14] The advantage of the combined income and racial polarisation iteration of ICE is that it jointly captures both racial and economic polarisation without collinearity, which often occurs when adding race and poverty into a single model. ICE has not yet been applied to public health data on a large scale in Chicago; however, the hardship index[16]—a relative index encompassing households below poverty, per cent of residents without a high school diploma (age ≥25 years), unemployment rate (age ≥16 years), per cent of residents age <18 or >64 years, per capita income and crowded housing (>1 person per room)—is predominantly used by the Chicago Department of Public Health's improvement strategy, which specifically calls for promoting health equity.[17] In terms of life expectancy in Chicago, residents in areas of high economic hardship have 5 years lower life expectancy than those in areas of medium or low hardship.[17] The hardship index includes multiple aspects of economic conditions; nevertheless, it does not directly account for racial or ethnic segregation, and it also focuses on disadvantage rather than quantifying extremes in advantage and disadvantage.

Whereas life expectancy quantifies overall mortality, premature mortality is an important metric for public health monitoring as it is used to identify areas where high rates of potentially preventable deaths occur. The purpose of this work is to determine the relationship between spatial polarisation (as assessed by ICE) and hardship index with premature mortality rates in Chicago, a city with stark racial segregation and wide variation in community-level income. These measures may show different relationships in Chicago compared with New York City and Boston, given the different social and historical contexts of these cities. Monitoring health outcomes using ICE may add value beyond what is provided by the hardship index and may be useful for public health monitoring, planning and programme evaluation.

METHODS

Chicago, Illinois is composed of 77 well-defined, officially recognised, non-overlapping community areas that were used for the unit of analysis.[18] Community area boundaries have remained stable since they were established in the mid-1920s by the University of Chicago, with no updates since 1980.[3] The median community area population was 31 028 (25th–75th percentile: 18 109–48 743) as of the 2010 census.[19] Data (both for premature mortality and for index calculations) were originally obtained by census tract and then aggregated by community area using boundaries published by the City of Chicago.[18] Data from 796 of the total 807 census tracts were aggregated to the community area level for analyses. Census tracts were excluded either for missing data for calculating indices and/or for missing death data.

Premature mortality rates

Mortality data (year 2011 to 2015) were obtained from the Chicago Department of Public Health. Average premature mortality rates (per 100 000 population age <65) were calculated using 10-year age bands (except for age 0–4) and directly standardised using the year-2000 standard million population.[20] CIs (95%) were calculated using methods originally developed by Fay and Feuer[21] with modifications for the upper confidence limit by Tiwari *et al*.[22]

Index of concentration at the extremes and hardship index

Data for calculating ICE and the hardship index were from the 2015 American Community Survey 5-year estimates and downloaded by census tract. ICE values for income, race, and combined income and race (ICE_{Income}, ICE_{Race}, $ICE_{Income+Race}$, respectively) were calculated consistent with methods described by Krieger.[14] Briefly, the ICE is calculated from the following formula developed by Massey[11]:

$$ICEi = \frac{(A_i - P_i)}{Ti}$$

In this calculation, *A* represents the number of people in the advantaged group in the community, *P* is the number of deprived (ie, poor, from the original formula) people and *T* is the total population of the area. Household incomes of ≥US$100 000 and <US$25 000 were used to distinguish affluence and deprivation, respectively, for ICE_{Income}, which approximated the 80th and 20th percentiles of household income in the USA.[23] In Chicago, approximately 29% of households have income of <US$25 000 and 22.4% have income ≥US$100 000.[24] For ICE_{Race}, non-Hispanic white and black races were used as advantaged and disadvantaged groups, respectively. ICE ranges from −1 to 1. Positive values indicate greater concentration of high-income residents and/or non-Hispanic white race, and negative values indicate greater concentration of low income and/or black race. Values of zero for ICE_{Income} can theoretically represent communities with equal number of households with extreme incomes or communities where zero households have extreme incomes. ICE_{Race} community values of zero can either represent an integrated community with equal numbers of non-Hispanic white or black residents or a community where all residents are of a different race/ethnic group from the extremes defined here. The combined $ICE_{Income+Race}$ metric contrasts low-income black residents to high-income non-Hispanic white residents.

The hardship index was calculated by community area using methods developed by Nathan and Adams.[16 25] Rather than relying on poverty or income alone, the index encompasses multiple aspects of economic conditions for an area, including households below poverty, per cent of residents without a high school diploma (age ≥25 years), unemployment rate (age ≥16 years), per cent of residents age <18 or >64 years, per capita income and crowded housing (>1 person per room). Values of the hardship index are standardised within a geographical area in order to differentiate areas of relative high and low hardship. The hardship index is commonly used by the City of Chicago's Department of Public Health and has been incorporated into Healthy Chicago 2.0, the city's public health plan for 2016–2020.[17] The following formula is used for standardising the components of the index[16]:

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

Here, *X* represents the standardised component for a given variable. *Y* represents the unstandardised variable value for a given community, Y_{min} denotes the minimum value of that variable across communities and Y_{min} indicates the maximum value of that variable. Each of the six components are calculated in the same manner, with the exception of per capita income, where the Y_{min} and Y_{max} values are reversed so that low values of income translate to higher hardship. The composite index is an average of each of the standardised components. The hardship index ranges from 1 to 100, with higher values representing areas of higher hardship. Because values are standardised based on the minimum and maximum values for the city, the hardship index is relative to other communities in the city and values cannot be compared across cities unless they are standardised as such.

Statistical methods

Descriptive statistics including median, 25th and 75th percentiles of ICE measures and the hardship index were determined as values were not normally distributed. Maps of premature mortality, hardship index and ICE measures were created by community area to visually represent the spatial distribution of each across Chicago. Scatterplots were created to visually assess the variability of ICE and hardship index values and premature mortality rates among the 77 communities. We calculated quintiles of each ICE measure and hardship index, and the rate ratio between the highest and lowest quintiles was compared using negative binomial regression models (as we had evidence

Table 1 Descriptive statistics for Index of Concentration at the Extremes (ICE) and hardship index for Chicago's 77 community areas

Index	Median	25th to 75th Percentile	Range	Possible range
ICE_{Income}	−0.13	0.33 to 0.03	−0.67 to 0.40	−1 to 1
ICE_{Race}	0.11	−0.87 to 0.40	−1.0 to 0.86	−1 to 1
$ICE_{Income+Race}$	0.01	−0.35 to 0.14	−0.66 to 0.40	−1 to 1
Hardship index	45.0	34.0 to 54.8	9.0 to 85.4	1 to 100

for overdispersion in Poisson models). ICE measures and hardship were not included in the same models as they were highly correlated with each other (correlations ranging from −0.70 to −0.85, p<0.001). Sensitivity analyses excluding Fuller Park and Burnside, the two smallest community areas with populations of <3000 residents each, were also performed as their premature mortality rates had large CIs. All statistical analyses were performed using SAS V.9.3 (SAS Institute, Cary, North Carolina, USA). Maps were created using Tableau visual analytic software V.9.1 (Tableau, Seattle, Washington, USA).

RESULTS

Sizeable differences in premature mortality rates existed across community areas, ranging from 94 deaths per 100 000 population age <65 in the Loop (95% CI 61 to 133) to 699 deaths per 100 000 population age <65 in Fuller Park (95% CI 394 to 1089). A map of the distribution of premature mortality is presented in online supplementary appendix figure A1, where the communities with the highest premature mortality rates are primarily concentrated in Chicago's west and south sides.

Median (25th and 75th percentile) index values are listed in table 1. Values for ICE_{Race} were most varied and ranged nearly from −1 to 1, indicating a large degree of white and black racial segregation across the city. Less extreme values of ICE_{Race} typically represented communities with primarily Hispanic/Latino or Asian residents. Values of ICE_{Income} near zero generally indicated a lower (but balanced) percentage of extreme household income. Maps with the distribution of ICE and hardship values are presented in online supplementary file appendix figure A2, and the values of each measure by community, along with premature mortality rates, are presented in online supplementary table A1.

Scatterplots (figure 1) visually depict the variability of ICE and hardship values with corresponding premature mortality rates. Strong inverse relationships were evident between each of the ICE measures and premature mortality, though there was a wide range of premature mortality rates at very low ICE_{Race} values. Finally, although it was evident that communities with low hardship also had low rates of premature mortality, there was a large range of premature mortality rates for some of the mid-to-high hardship communities. Some high hardship communities had very high rates of premature mortality, while others had premature mortality rates on par with low hardship communities.

Compared with the highest ICE quintiles, communities in the lowest quintiles had significantly higher rates of premature mortality (ICE_{Income} rate ratio (RR)=3.06; ICE_{Race} RR=3.07; $ICE_{Income+Race}$ RR=3.27; table 2). Similarly, compared with communities in the lowest hardship index quintile, communities in the highest quintile had significantly higher premature mortality rates (RR=2.79). When comparing model fit statistics, the $ICE_{Income+Race}$ model had the lowest AIC (Akaike Information Criteria) and Bayesian Information Criteria values (834.8 and 848.9, respectively) compared with the other models (ICE_{Income} AIC=885.9, BIC=900.0; ICE_{Race} AIC=847.9, BIC=862.0; hardship index AIC=921.4, BIC=935.5). Though a formal

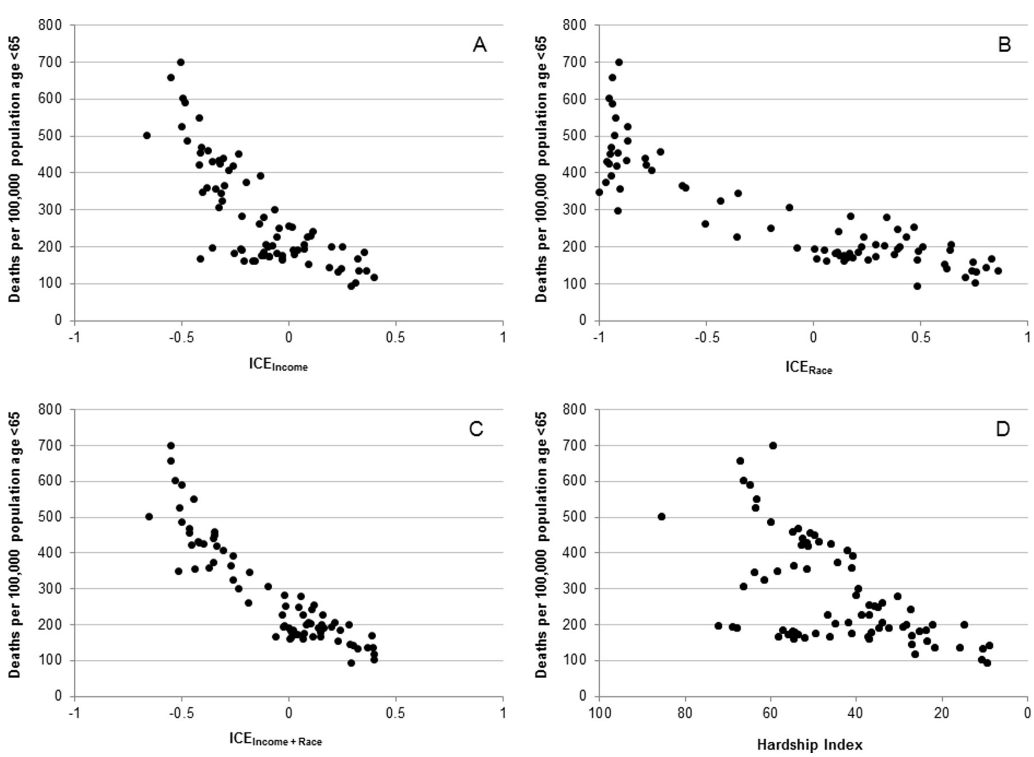

Figure 1 Scatterplots of raw data displaying relationships between (A) ICE_{Income}, (B) ICE_{Race}, (C) $ICE_{Income+Race}$ and (D) hardship index (axis reversed, larger values indicate higher hardship) and age-adjusted premature mortality rate (years 2011–2015; deaths per 100 000 population age <65 years) by Chicago community area. ICE, Index of Concentration at the Extremes.

Table 2 Premature mortality rate (2011–2015): rate ratios (RRs) in relation to ICE and the hardship index by Chicago community area

	ICE_{Income}		ICE_{Race}		$ICE_{Income+Race}$		Hardship index	
Quintile*	**Rate**	**RR (95% CI)**	**Rate**	**RR (95% CI)**	**Rate**	**RR (95% CI)**	**Rate**	**RR (95% CI)**
Q5 (high ICE values/ low hardship)	158.79	Ref	151.47	Ref	153.33	Ref	155.80	Ref
Q4	210.00	1.32 (1.09 to 1.61)	205.26	1.36 (1.16 to 1.58)	207.87	1.36 (1.18 to 1.56)	221.01	1.42 (1.11 to 1.81)
Q3	224.19	1.41 (1.16 to 1.72)	198.68	1.31 (1.12 to 1.54)	194.40	1.27 (1.10 to 1.47)	315.42	2.02 (1.58 to 2.59)
Q2	341.79	2.15 (1.77 to 2.62)	397.58	2.62 (2.25 to 3.06)	362.38	2.36 (2.05 to 2.72)	296.31	1.90 (1.49 to 2.43)
Q1 (low ICE values/ high hardship)	485.85	3.06 (2.51 to 3.73)	464.33	3.07 (2.62 to 3.58)	501.45	3.27 (2.84 to 3.77)	434.46	2.79 (2.18 to 3.57)

*Quintile cut-points:
ICE_{Income}, Q1: −0.67 to −0.38; Q2: −0.36 to −0.22; Q3: −0.22 to −0.09; Q4: −0.08 to 0.09; Q5: 0.09 to 0.40.
ICE_{Race}, Q1: −1.0 to −0.92; Q2: −0.91 to −0.20; Q3: −0.12 to 0.17; Q4: 0.18 to 0.48; Q5: 0.49 to 0.86.
$ICE_{Income+Race}$, Q1: −0.65 to −0.42; Q2: −0.40 to −0.06; Q3: −0.03 to 0.04; Q4: 0.05 to 0.16; Q5: 0.17 to 0.40.
Hardship index, Q1: 85.4 to 58.4; Q2: 58.2 to 51.4; Q3: 50.9 to 40.1; Q4: 39.6 to 28.4; Q5: 27.4 to 9.0.
ICE, Index of Concentration at the Extremes; RR, rate ratio.

statistical test does not exist to compare them, the AIC and BIC values indicate that the $ICE_{Income+Race}$ model is the best fit.

Results remained consistent in sensitivity analyses excluding Burnside and Fuller Park (results not shown).

DISCUSSION

In Chicago, community area-level ICE and hardship index scores were significantly related to premature mortality rates. The strongest rate ratios (comparing highest quintiles to lowest) were between the ICE measure incorporating income and race, followed by ICE_{Race}, while the 'weakest' (although still strong) relationship was with the hardship index. The City of Chicago Department of Public Health often uses the hardship index in monitoring and in identifying communities to target for interventions and for improvement. Though the hardship index was significantly related to premature mortality rates, relationships were stronger with ICE measures. This suggests that the distribution of income and racial segregation could be more strongly related to premature mortality than economic conditions themselves.

This study extends work in New York City[14] and Boston[13] to Chicago. In New York and Chicago, the gradient between $ICE_{Income+Race}$ and premature mortality was steeper compared with the other indices; it was steepest for ICE_{Income} (at the neighbourhood level) in Boston. Chicago and New York City metropolitan areas are two of the most segregated in the nation, while Boston is relatively less so.[5] Also, these cities vary on household income distribution, with Chicago having an overall lower median household income.[23] Since the ICE_{Income} cutpoint was based on national income distributions, the definition of 'extremes' have different meanings for these cities. For example, household income of US$100 000 or more represents a greater degree of affluence in Chicago versus New York City and Boston given Chicago's lower median income and lower cost of living. This may have also contributed to the differing results, in addition to the different social, historical and cultural aspects of these cities.

ICE_{race} values of zero can potentially have two different interpretations. They either represent a balance of the extremes—that is, an integrated community with equal number of black and white residents—or no residents from the extreme groups. In Chicago, ICE_{Race} values close to zero typically represented communities of primarily Hispanic/Latino or Asian residents, highlighting the limitation of only being able to contrast two groups as extremes. For example, Armour Square's population is 73% Asian, 11% non-Hispanic White and 10% black,[26] and has an ICE_{Race} value of 0.01. Similarly, Gage Park has an ICE_{Race} value of 0.00, while 92% of the population is Hispanic/Latino, 3% black and 4% non-Hispanic White.[27] While ICE_{Race} values ranged nearly from −1 to 1, ICE_{Income} values were far less extreme. More communities had negative ICE_{Income} values than positive, indicating a propensity for communities to have larger concentrations of low-income households. Several communities had ICE_{Income} values near 0, and these communities generally had low, but balanced, proportions of household incomes at the extremes. As an example, Irving Park has an ICE_{Income} value of 0.01, with 21.7% and 20.6% having household incomes of ≥US$100 000 and <US$25 000, respectively (data not shown).

As has been previously reported, ICE has several advantages over other measures of racial segregation (for example, the Index of Dissimilarity) as it works well in small areas and contextualises values by both advantaged and disadvantaged groups.[14] Still, a limitation of ICE, particularly for ICE values encompassing race/ethnicity, is that only two groups are included in the calculation. Chicago has a large Hispanic and Latino population, and the primarily Hispanic/Latino communities were generally represented by less extreme ICE_{Race} values.

A limitation of the hardship index is that despite including multiple aspects of economic conditions, different communities can end up having similar hardship index scores through very different means. For example, Brighton Park and West Garfield Park each have high hardship index values at 68 and 65, respectively. However, Brighton Park's high score was primarily driven by the large percentage of residents without a high school diploma, crowded housing and per capita income, while West Garfield Park's high poverty rate, low per capita income and high dependent population primarily drove its high hardship score (data not shown). Though the overall hardship index values are similar for these communities, the premature mortality rates are very different: 191 deaths per 100 000 population age <65 (95% CI 150 to 238) for Brighton Park and 589 deaths per 100 000 population age <65 (95% CI 471 to 720) for West Garfield Park. Conversely, these communities have vastly different ICE values, reflective of their differences in racial and ethnic groups as well as differences in income concentrations, which is masked in their hardship scores.

A limitation to this work is that while community areas are well defined in Chicago and many are bounded by rivers and parks, communities are not independent of one another. Communities that are close in proximity may be more similar to each other than to communities further away, but are treated as independent observations in this analysis.

In Chicago, the hardship index is already used to identify priority populations for some health targets in the city's current public health improvement strategy.[17] The strong relationships observed between ICE measures and premature mortality rates support the use of these measures in public health monitoring as it can factor in both race and income, as well as quantifying both ends of the spectrum. This work further confirms that ICE—particularly the ICE metric combining income and race—may be better suited for monitoring health disparities compared with metrics only considering economic conditions. Though this study does not imply causation, it is evident that work to reduce health inequities is warranted, particularly in areas with high economic and racial segregation.

What is already known on this subject

- The Index of Concentration at the Extremes (ICE) has recently been used in public health studies to measure income and racial/ethnic polarisation, and can be used to jointly assess the two. Monitoring health outcomes using ICE may add value beyond traditional measures of area-level income and racial composition, and may be a valuable tool for public health monitoring, planning and programme evaluation.

What this study adds

- We assessed the relationships between ICE and hardship index scores with premature mortality rates in Chicago at the community level. The ICE measure incorporating income and race had the strongest relationship with premature mortality rates, though the ICE measures incorporating race and income separately, as well as economic hardship were all significantly associated with premature mortality.
- This work further confirms that the combined income and race ICE measure may be better suited for monitoring health disparities compared with metrics only considering economic conditions.

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REFERENCES

1 Arias E. United States life tables, 2010. *Natl Vital Stat Rep* 2014;63:1–63.
2 Hunt BR, Tran G, Whitman S. Life expectancy varies in local communities in Chicago: racial and spatial disparities and correlates. *J Racial Ethn Health Disparities* 2015;2:425–33.
3 Keating AD, ed. *Chicago neighborhoods and suburbs: a historical guide*. Chicago, IL: University of Chicago Press, 2008.
4 Frey WH. Census shows modest declines in black–white segregation. https://www.brookings.edu/blog/the-avenue/2015/12/08/census-shows-modest-declines-in-black-white-segregation/ (accessed 23 Mar 2018).
5 University of Michigan Population Studies Center Institute for Social Research. New racial segregation measures for large metropolitan areas: analysis of the 1990–2010 decennial census. https://www.psc.isr.umich.edu/dis/census/segregation2010.html (28 accessed Mar 2018).
6 Hunt BR, Whitman S, Henry CA. Age-adjusted diabetes mortality rates vary in local communities in a metropolitan area: racial and spatial disparities and correlates. *Diabetes Care* 2014;37:1279–86.
7 Hunt BR, Deot D, Whitman S. Stroke mortality rates vary in local communities in a metropolitan area. *Stroke* 2014;45:2059–65.
8 Hunt BR, Whitman S. Maternal smoking in Chicago: a community-level analysis. *J Health Care Poor Underserved* 2011;22:194–210.
9 De Maio F, Shah RC, Schipper K, *et al*. Racial/ethnic minority segregation and low birth weight: a comparative study of Chicago and Toronto community-level indicators. *Crit Public Health* 2017;27:541–53.
10 Whitman S, Silva A, Shah A, *et al*. Diversity and disparity: GIS and small-area analysis in six Chicago neighborhoods. *J Med Syst* 2004;28:397–411.
11 Krieger N, Waterman PD, Spasojevic J, *et al*. Public health monitoring of privilege and deprivation with the index of concentration at the extremes. *Am J Public Health* 2016;106:256–63.
12 Massey DS. The prodigal paradigm returns: ecology comes back to sociology. In: Booth A, Crouter A, eds. *Does it take a village? Community effects on children, adolescents, and families*. Mahwah, NJ: Lawrence Erlbaum Associates, 2001:41–8.
13 Krieger N, Waterman PD, Gryparis A, *et al*. Black carbon exposure, socioeconomic and racial/ethnic spatial polarization, and the Index of Concentration at the Extremes (ICE). *Health Place* 2015;34:215–28.
14 Krieger N, Waterman PD, Batra N, *et al*. Measures of local segregation for monitoring health inequities by local health departments. *Am J Public Health* 2017;107:903–6.
15 Feldman JM, Waterman PD, Coull BA, *et al*. Spatial social polarisation: using the Index of Concentration at the Extremes jointly for income and race/ethnicity to analyse risk of hypertension. *J Epidemiol Community Health* 2015;69:1199–207.
16 Montiel LM, Nathan RP, Wright DJ. Nelson A, ed. *An update on urban hardship*. New York: Rockefeller Institute of Government, State University of New York, 2004.
17 Dircksen JC, Prachand NG. *Healthy Chicago 2.0: partnering to improve health equity*. Chicago: City of Chicago, 2016.
18 City of Chicago. Community maps. https://www.cityofchicago.org/city/en/depts/doit/supp_info/community_maps.html (accessed 3 Apr 2017).
19 City of Chicago. Community area 2000 and 2010 census population comparisons. https://www.cityofchicago.org/city/en/depts/dcd/supp_info/community_area_2000and2010censuspopulationcomparisons.html (accessed 3 Apr 2017).
20 Anderson RN, Rosenberg HM. Age standardization of death rates: implementation of the year 2000 standard. *Natl Vital Stat Rep* 1998;47:1–16.
21 Fay MP, Feuer EJ. Confidence intervals for directly standardized rates: a method based on the gamma distribution. *Stat Med* 1997;16:791–801.
22 Tiwari RC, Clegg LX, Zou Z. Efficient interval estimation for age-adjusted cancer rates. *Stat Methods Med Res* 2006;15:547–69.
23 United States Census Bureau. Historical income tables: Households. Table H-1. Income limits for each fifth and top 5 percent. https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-income-households.html (accessed 8 Dec 2017).
24 United States Census Bureau. Income in the past 12 months (in 2015 inflation-adjusted dollars) 2011–2015 American Community Survey 5-year estimates, Table S1901. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF (accessed 29 Jan 2018).
25 Nathan RP, Adams CF. Four perspectives on urban hardship. *Polit Sci Q* 1989;104:483–508.
26 Chicago Metropolitan Agency for Planning. Community data snapshot: Armour Square. http://www.cmap.illinois.gov/documents/10180/126764/Armour+Square.pdf (accessed 3 Jan 2018).
27 Chicago Metropolitan Agency for Planning. Community data snapshot: Gage Park. http://www.cmap.illinois.gov/documents/10180/126764/Gage+Park.pdf (accessed 3 Jan 2018).