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Neighborhood influences on the association between maternal age and birth weight: A multilevel investigation of age-related disparities in health

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Abstract

It was hypothesized that the relationship between maternal age and infant birthweight varies significantly across neighborhoods and that such variation can be predicted by neighborhood characteristics. We analyzed 229,613 singleton births of mothers aged 20–45 from Chicago, USA in 1997–2002. Random coefficient models were used to estimate the between-neighborhood variation in age-birthweight slopes, and both intercepts- and-slopes-as-outcomes models were used to evaluate area-level predictors of such variation.

The crude maternal age-birthweight slopes for neighborhoods ranged from a decrease of 17 grams to an increase of 10 grams per year of maternal age. Adjustment for individual-level covariates reduced but did not eliminate this between-neighborhood variation. Concentrated poverty was a significant neighborhood-level predictor of the age-birthweight slope, explaining 44.4 percent of the between-neighborhood variation in slopes. Neighborhoods of higher economic disadvantage showed a more negative age-birthweight slope. The findings support the hypothesis that the relationship between maternal age and birthweight varies between neighborhoods. Indicators of neighborhood disadvantage help to explain such differences.

Keywords

birth weight; maternal age; poverty; social environment; socioeconomic factors; multi-level modeling

Low birthweight presents an important public health concern. Weight at birth is a good indicator of a mother's and an infant's nutritional status, as well as the newborn's chances for survival, growth, and long term health and psychosocial development. Studies have linked low birthweight to intellectual and cognitive delays (Boardman, Powers, Padilla, & Hummer,

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2002; Roberts, Bellinger, & McCormick, 2007), neurosensory impairments and growth retardation (Hack, Flannery, Schluchter, Cartar, Borawski, & Klein, 2002) and behavior problems (McCormick, Brooks-Gunn, Workman-Daniels, Turner, & Peckham, 1992), as well as problems later in life, including adult risk for stroke and cardiovascular disease (Rich-Edwards, Stampfer, Manson, Rosner, Hankinson, Colditz et al., 1997), and diabetes (McCance, Pettitt, Hanson, Jacobsson, Knowler, & Bennett, 1994).

The risk of low birthweight is unevenly distributed along social and economic lines, such as race and socioeconomic position. Infants of African-American women, for example, are twice as likely to be low birthweight as infants of White women (CDC, 2002). Much less investigated are the social disparities found in the risk of low birthweight associated with increasing maternal age. In this paper, we bring together research on the impact of urban neighborhoods on the health and development of residents with research on racial/ethnic and social disparities in health across the life course, to explore the systematic geographic patterning of the association between maternal age and birthweight.

Neighborhoods constitute a key determinant of racial and socioeconomic disparities in health, as they shape individual opportunities and expose residents to multiple risks and resources over the lifecourse (Leventhal & Brooks-Gunn, 2000; Sampson, 2003). A growing literature has shown that the neighborhood environment is associated with reproductive health outcomes, and recent studies suggest that neighborhood poverty aggravates the increasing risk of low birthweight with maternal age (J. W. Collins, Simon, Jackson, & Drolet, 2006; Geronimus, 1992; Rauh, Andrews, & Garfinkel, 2001). However, to our knowledge, no study has attempted to quantify the extent to which the change in birthweight per year of maternal age actually differs between neighborhoods, and to test how much of that variation is attributable to neighborhood-level characteristics. Given the high level of residential segregation by socioeconomic position and race/ethnicity in the United States, research on neighborhood effects on reproductive health constitutes a key area of health disparities research (Williams & Collins, 2001; Williams & Jackson, 2005).

This study is based on prior investigations that used data from Chicago to examine two features of race/ethnic and socioeconomic disparities in infant birthweight. In one set of analyses (J. W. Rich-Edwards, Buka, Brennan, & Earls, 2003), we investigated the association between maternal age and low birthweight among black and white mothers. Maternal age is an important determinant of birth outcomes, considered to represent the mother's level of biological and psychosocial preparation for childbearing (Geronimus, 1996). Similar to the results of Geronimus (1996) and others we observed dramatically divergent patterns for black and white mothers. For white women, the risk of low birthweight did not change significantly with maternal age. In contrast, black women experienced a 5% higher risk of low birthweight births for each additional year of maternal age. These racial/ethnic differences in birth outcomes were fully accounted for by indices of social and economic disadvantage (J. W. Rich-Edwards et al., 2003). For both black and white mothers, infant birthweights decreased with increasing maternal age for women who were unmarried, smokers or who resided in poorer neighborhoods.

In a second manuscript, we shifted the focus of analysis from maternal characteristics to features of the neighborhood of residence (Buka, Brennan, Rich-Edwards, Raudenbush, & Earls, 2003). In a series of multilevel analyses we investigated the association between infant birthweights and neighborhood characteristics, including racial composition, economic disadvantage, and perceived social support. After adjustment for individual-level risk factors, infant birthweights differed significantly in relation to several features of the neighborhoods in which women resided. For black infants only, mean birthweight decreased significantly as the neighborhood level of economic disadvantage increased. For white infants only, infant

birthweight increased along with the level of perceived neighborhood social support reported by neighborhood residents.

The current investigation seeks to combine these two lines of inquiry, and investigate how “place” may explain previously-detected social disparities in the relationship between birthweight and maternal age. Our focus again is on trends in infant birthweight in relation to maternal age: the age-birthweight slope. But unlike prior investigations, we now focus on the extent to which these slopes vary across urban neighborhoods, the stability of neighborhood differences over time, and features of neighborhoods that are associated with positive versus negative slopes. Such research can help us move “neighborhood effects” research further, by using the maternal age-birthweight slope to conduct a dynamic investigation of the ways that geography may generate different patterns of health risk by age, and to direct public health resources to high-need subgroups that may exist in different types of neighborhoods.

We focus on two aspects of neighborhoods that may play a key role in moderating the variation in birthweight by maternal age: neighborhood disadvantage and social support. A consistent relationship exists between neighborhood concentration of poverty and mean birthweight (J. W. Collins et al., 2006; Gorman, 1999; Ocampo, Xue, Wang, & Caughy, 1997; Rauh et al., 2001; Roberts et al., 2007). Disadvantaged neighborhoods present a number of risks relevant to infant birth outcomes, including inadequate health services, diminished access to nutritional food in local stores, and higher exposure to stress and to environmental toxins (Macintyre, Maciver, & Sooman, 1993; Robert, 1999). Previous studies have proposed that neighborhood disadvantage may not only impact overall health, but also accelerate the process of aging, thus increasing the risk of negative health outcomes, such as lower birthweight, earlier in life (Geronimus, 1992, 1996; Geronimus, Bound, Waidmann, Colen, & Steffick, 2001).

We move beyond the examination of socioeconomic factors, to investigate how a key social process in the residential environment, neighborhood support, may influence health. Cohesive social networks, trust and reciprocal exchanges among residents have been associated with lower rates of mortality (Kawachi, Kennedy, Lochner, & ProthrowStith, 1997) and morbidity (Seeman & McEwen, 1996). Moreover, epidemiological evidence indicates that, during pregnancy, social support from a partner, family member, and others appears to be associated with better fetal growth (N. L. Collins, Dunkelschetter, Lobel, & Scrimshaw, 1993; Hoffman & Hatch, 1996). Very few studies have looked at the impact of neighborhood social processes on infant outcomes; the selected few have found that neighborhood support and related social processes were associated with higher mean birthweight (Buka et al., 2003; Morenoff, 2003). The question remains whether it may also play a role in moderating differences in birthweight by maternal age.

The study hypotheses are:

1. The relationship between maternal age and infant birthweight varies between urban neighborhoods
2. The variation of infant birthweight by maternal age is partly explained by characteristics of the neighborhood of residence, above and beyond the individual characteristics of residents.
3. Structural (e.g., economic disadvantage) and social (e.g. social support) features of neighborhoods partly explain the systematic geographic distribution of maternal age-birthweight slopes.
4. The neighborhood distribution of maternal age-birthweight slopes is stable over time.

MATERIALS AND METHODS

Birth outcomes

Data on infant birthweight came from Chicago birth certificates for the years 1997 through 2002. We included births to women of all race/ethnicities, ages 20–45 years that bore infants of 750–4,500 grams birthweight, excluding multiple births and births with missing data for key study parameters (described below).

Neighborhood measures

Neighborhood-level data for the city of Chicago were collected in 1995 as part of the Project on Human Development in Chicago Neighborhoods (PHDCN) (Earls & Buka, 1997). PHDCN combined the 847 census tracts of Chicago to create 343 homogeneous “neighborhood clusters” (NCs) which were defined based on geographic boundaries and knowledge of traditional Chicago neighborhoods. The clusters included either single, large census tracts or combined contiguous tracts that were comparable in terms of racial/ethnic composition, household income, educational levels, and housing density. Each cluster included approximately 8,000 residents (see Buka, Brennan, Rich-Edwards et al, 2003 for additional details).

Measures of neighborhood socioeconomic disadvantage were obtained by linking birth certificates to these 343 NCs. Concentrated neighborhood poverty was derived from the US 1990 census, and was calculated for each NC as the first principal component of the proportion of residents 1) living below the poverty line, 2) on public assistance, and 3) unemployed.

Neighborhood support data were obtained from the 1995 PHDCN Community Survey. A multistage sampling strategy was used to select a sample of 8,782 respondents from the 343 NCs. The survey was designed to produce a representative sample of each NC and to reliably estimate neighborhood-level social processes. For the measure of neighborhood support, respondents were asked how strongly they agreed (on a 5-point scale) with 10 statements such as: “this is a close-knit neighborhood” and “people do favors for each other” (Buka et al., 2003; Sampson, Raudenbush, & Earls, 1997). The responses of individual residents were aggregated to develop a neighborhood-level measure.

All models that included neighborhood-level characteristics also controlled for mean maternal age. In order to properly detect and estimate heterogeneity in the maternal age-birthweight slope, it has been recommended that the individual-level covariate of interest (in this case, maternal age) be group-mean centered, and accompanied with a group level counterpart (in this case, mean neighborhood maternal age) that is grand-mean centered (S. W. Raudenbush & Bryk, 2002).

Individual-level measures

Data analyses controlled for individual-level characteristics that have been associated with maternal age and birthweight, including marital status, maternal education, maternal smoking, prenatal care, maternal race/ethnicity and parity (Buka et al., 2003; Geronimus, 1996; J. W. Rich-Edwards et al., 2003), all extracted from the birth certificates. Three possible values were considered for maternal education: less than high school education, high school education and more than high school education, and four values were considered for maternal race/ethnicity: black, white, Hispanic and other. Maternal smoking was measured as the number of cigarettes the mother smoked per day during pregnancy. Prenatal care was operationalized as receipt of any prenatal care during the first trimester. Parity was measured as primiparity / other. Marital status was considered as married vs. not married.

Analytic approach

The statistical modeling approach was based on the assumption that the change in birthweight with increasing maternal age depends on the neighborhoods where mothers reside (Jones & Duncan, 1995; Subramanian, Kim, & Kawachi, 2002). A multilevel modeling framework allowed us to model the between-neighborhood variation in birthweight as a function of maternal age (Subramanian et al., 2002). The study estimated a set of six hierarchical linear regression models with 229,613 births nested within 342 NCs. Such models were estimated using the HLM program (Raudenbush, Bryk, Cheong, & Congdon, 2004) Version 5.63.

Step 1. Test Hypotheses 1 and 2: The relationship between maternal age and infant birthweight varies between neighborhoods, and is partly explained by neighborhood characteristics—We used three approaches to test whether the variation of infant birthweight by maternal age is partly explained by the neighborhood of residence.

1) First, we needed to test hypothesis 1: to establish the baseline level of variation in birthweight between neighborhoods, and test whether a significant level of neighborhood variation existed in the maternal age-birthweight slope.

Null model: a two-level null model of individuals nested within NCs, with no predictor variables in the fixed or random parts of the model; estimates the mean birthweight in grams. Variance was estimated between individuals within NCs, and between NCs.

Model 1: adds maternal age as an individual-level predictor; the beta coefficient for age is allowed to vary between NCs. The association between maternal age and birthweight is allowed to vary between NCs, so that not only can we estimate an average maternal age-birthweight slope for the sample (β_1), but also mean slopes for each of the 342 neighborhoods (β_{1j}).

2) Once we established a significant contextual variation in the maternal age-birthweight slope, we used a descriptive approach to characterize the neighborhoods in the sample that had a negative maternal age-birthweight slope, in comparison to those that had a positive maternal age-birthweight slope. Maternal age-birthweight slopes were estimated for each NC by adding the empirical Bayes residual of the slope to the fitted value from *Model 1* described above (unadjusted for any individual or neighborhood-level characteristics). These residuals are based on the deviation of the empirical Bayes estimates of a randomly varying level-1 coefficient, that is maternal age, from its predicted or “fitted” value based on the level-2 (neighborhood-level) model (S. W. Raudenbush & Bryk, 2002). We then divided the neighborhoods into those that had a negative maternal age-birthweight slope and those that had a positive maternal age-birthweight slope. This allowed us to conduct descriptive analyses of how these two types of neighborhoods differed in terms of both resident and neighborhood characteristics that might account for some portion of the neighborhood variation in the slopes.

3) We then proceeded to build on this descriptive analysis, and tested whether the neighborhood variation in maternal age-birthweight slopes found in Model 1 could be fully accounted for by characteristics of the neighborhood residents.

Model 2 builds on *Model 1* by including all measured individual-level predictors in the fixed part of the model (maternal education, marital status, parity, receipt of prenatal care in the first trimester, smoking in pregnancy, race/ethnicity of the mother). Birth certificate year was not included in the model as it was not significantly associated with mean birthweight. The model estimated the between-NC variation in birthweight and in the birthweight-maternal age slope, after taking into account compositional differences of neighborhood residents. Age was centered at the group level to detect and properly model slope heterogeneity between

neighborhoods (S. W. Raudenbush & Bryk, 2002). All other level-1 variables were grand-mean centered.

Step 2. Test hypothesis 3: Structural and social features of neighborhoods partly explain the geographic distribution of maternal age-birthweight slopes—

Once we tested whether the variation of maternal age-birthweight slopes was partly explained by neighborhood of residence, above and beyond maternal-level characteristics, we expanded the statistical models to incorporate neighborhood-level characteristics. We used such models to test whether structural and social features of neighborhoods could account for remaining geographic variation in maternal age-birthweight slopes.

Model 3 (a and b) extended model 2 and estimated the average association of each of the neighborhood-level predictors *separately* with birthweight and with the maternal age-birthweight slope. *Model 4:* Incorporated parameters for both proportion of neighborhood support *and* concentrated neighborhood poverty into a single model. These models also adjusted for the individual-level covariates included in Model 2.

We used GIS software to construct maps of the maternal age-birthweight slopes in 1994–96, in 1997–2002, and the level of concentrated poverty in 1990. The NC-level slopes presented in these maps were estimated from Model 2, and portray the predicted mean birthweight-maternal age slope, net of individual-level risk factors included in this model.

Step 3. Test hypothesis 4: The neighborhood distribution of maternal age-birthweight slopes is stable over time—Finally, we evaluated the stability over time of the maternal age-birthweight association at the neighborhood level. We estimated maternal age-birthweight slopes for each NC, from *Model 1*, as described above in section 1. This yielded a distribution of predicted neighborhood maternal age-birthweight slopes for the current study period, 1997–2002. *Model 1* was recalculated using birth data from 1994–1996. We weighted both sets of slopes by the posterior standard error of the empirical Bayes estimate for the slope, in order to incorporate the uncertainty associated with comparing two sets of estimated, rather than observed, values. The Pearson's correlation coefficient between the weighted slopes for the two periods was calculated to estimate the stability of these slopes over time.

RESULTS

Sample

Of the 292,294 singleton births recorded to mothers in Chicago between 1997 and 2002, 4,467 could not be mapped to one of the 343 study neighborhoods and 37 were missing data on maternal age. 937 births occurred in one neighborhood with missing data on neighborhood support, 5,152 had birthweight lower than 750 or larger than 4,500 grams, and 47,837 were born to mothers younger than 20 or older than 45. For the 233,864 remaining births, 136 had missing information on race, 47 did not report marital status, 434 did not include information on cigarette smoking during pregnancy, and 3,634 were missing information on maternal education. The remaining study sample included 229,613 births nested within 342 NCs.

Step 1. Test hypotheses 1 and 2—Table 1 presents the results of the multilevel models to test the magnitude of baseline variation that occurs between neighborhoods. The *Null* model (with no predictors, Table 1) shows that 5 percent of the total variation in birthweight occurred between neighborhoods (calculated as item $M/(L+M)$). *Model 1* indicates that there is also a significant between-neighborhood variation in the association between maternal age and birthweight ($\delta^2_{u1}=40.7$; $p<0.0005$). The range in the magnitude of the maternal age-birthweight slope across neighborhoods is illustrated in Figure 1A: predicted neighborhood slopes ranged

from a decrease of 17 grams per additional year of maternal age to an increase of 10 grams per year of maternal age.

Table 2 presents a characterization of the study neighborhoods according to their estimated maternal age-birthweight slopes, unadjusted for any individual or neighborhood-level characteristics. Approximately half (43.3 percent) of the study neighborhoods had a negative maternal age-birthweight slope, that is, where babies born to older mothers were smaller than babies born to younger mothers. The remaining 56.7 percent had a positive maternal age-birthweight slope, where in contrast babies born to older mothers were larger than babies born to younger mothers (Table 2). Mothers who resided in NCs with negative slopes had smaller infants (3,137.8 grams) than those who resided in NCs with positive slopes (3,347.8 grams) ($t=-84.7$; $p<0.0001$). Mothers from NCs with negative slopes were significantly ($p<0.05$) younger, of lower educational attainment, less likely to be married, of higher parity, were more likely to have smoked during pregnancy, and were more likely to be black. NCs with negative maternal age-birthweight slopes had higher levels of concentrated poverty and lower levels of neighborhood support.

The findings in Table 3 indicate that part of the difference between neighborhoods likely results from differences in the composition or characteristics of women residing in the neighborhoods. Adjusting for such maternal characteristics reduced the between-neighborhood variation by 51.8 percent (Model 2). As estimated in this model, mothers who were one year older had infants who were 2.9 grams lighter in birthweight (item B). Figure 1B illustrates the distribution of these slopes across NCs, now adjusted for neighborhood composition. A comparison with Figure 1A shows reduced variability following the inclusion of these individual-level covariates. However, the estimated between-neighborhood variation remained significant ($\sigma^2_{u1}=19.6$; $p<0.0005$).

Step 2. Test hypothesis 3—We next considered the association between specific neighborhood characteristics and the relation between maternal age and birthweight. Model 3a (Table 4) presents a slopes-as-outcomes model that includes concentrated neighborhood poverty as the predictor of mean birthweight and the maternal age-birthweight slope. Concentrated poverty was a significant predictor of mean birthweight and of the maternal age-birthweight slope within a neighborhood. As concentrated neighborhood poverty in the neighborhood increases, the lower level of birthweight found in older mothers became more pronounced.

Model 3b indicates that neighborhood support was a significant predictor only of mean birthweight, and not of the maternal age-birthweight slope. In Model 4, neighborhood support is used only as a predictor of mean birthweight. Mothers who resided in neighborhoods with a one standard deviation higher level of concentrated poverty had infants with a 13.5-gram lower birthweight and presented babies with 2.6 grams lower birthweight for every additional year of maternal age.

Concentrated neighborhood poverty explained the largest amount of variation in the association between maternal age and birthweight. Adjustment for concentrated neighborhood poverty reduced the between-neighborhood variability in the slope by 44.4 percent (Model 2 compared to Model 3a and Model 4), beyond the individual-level characteristics.

The maps presented in Figures 2 and 3 illustrate the strength of association between concentrated neighborhood poverty and neighborhood differences in the maternal age-birthweight association over time. The same neighborhoods that showed higher levels of concentrated poverty in 1990 (Figure 2), tended to have a negative maternal age-birthweight slope (net of all the individual-level characteristics of mothers in the neighborhood) in both

1994–1996 (Figure 3a) and in 1997–2002 (Figure 3b). Visual inspection of Figures 3a and 3b gives an indication of the stability over time of the maternal age-birthweight slopes.

Step 3. Test hypothesis 4—The significant variation across neighborhoods in the association between maternal age and offspring birthweight is stable over time. Neighborhood maternal age-birthweight slopes for a prior time period, 1994–1996, correlated 0.85 ($p < 0.001$) with the neighborhood mean slopes from 1997–2002 (Figure 4).

DISCUSSION

Infant birthweight has long been considered an indicator of maternal and child health status and of the general level of population health ((MSH), 1997; Caiazzo, Cardano, Cois, Costa, Marinacci, Spadea et al., 2004; Zahniser, Halpin, Hollinshead, Kessel, & Koontz, 1987). Research has documented regional variation in mean birthweight and in rates of low birthweight (Buka et al., 2003; Gorman, 1999; Hogue & Vasquez, 2002; Juul, Olsen, & Knudsen, 1989; Luginaah, Lee, Abernathy, Sheehan, & Webster, 1999), and such data have been used to identify areas that may warrant further investment in service provision.

Previous research has also demonstrated that the association between maternal age and the birthweight of her infant is not constant across persons and places, but varies according to individual characteristics such as social and economic position and place of residence (J. W. Collins et al., 2006; Geronimus, 1996; Rauh et al., 2001; J. W. Rich-Edwards et al., 2003; Wildsmith, 2002). By estimating neighborhood maternal age-birthweight slopes over the full range of neighborhoods in a major US city, our research suggests that maternal age-birthweight *slopes* also serve as meaningful indicators of how a region or group fares over time—such slopes may serve as an index of age-related differences in health status, a novel and important public health metric.

For the first time, we demonstrate significant regional variation in the range of maternal age-birthweight slopes through a thorough multilevel analysis. We find that the maternal age-birthweight slope varied considerably (from -17 g to $+10$ grams per year of maternal age) between Chicago's neighborhoods. The crude variation in the slopes is in itself noteworthy, since it supports the view that disparities in health status by age might be associated with characteristics of the places where different groups reside. However, such crude differences across neighborhoods could simply be the consequence of compositional differences. Indeed, roughly half of the observed variation between neighborhoods in maternal age-birthweight slope was attributable to individual characteristics of mothers residing in different neighborhoods. However, after accounting for these, there remained statistically significant variation across neighborhoods in the maternal age-birthweight slope: ranging from NCs where women who are one year older have babies that are smaller by 11.6 grams, to NCs where women older by one year have babies who are larger by 5.6 grams. Although this difference might seem small at the individual level, at the aggregate level a small individual difference experienced by a large number of mothers over a sustained period of time can translate into a substantial population-level difference (Rose, 1992). We also found that the geographical distribution of the slopes was stable over time, with a neighborhood-level correlation of 0.85 between 1994–1996 and 1997–2002.

The study findings make three important contributions to the literature on “neighborhood effects” on health. First, it indicates that neighborhoods may not only partially account for observed disparities in health, but may also be associated with the *timing* at which populations experience negative health outcomes. The steep decrease in birthweight with advancing maternal age evident among mothers who reside in more disadvantaged neighborhoods may reflect a process whereby more disadvantaged populations are at risk of experiencing health

problems earlier than less disadvantaged groups (Braveman, Egerter, Cubbin, & Marchi, 2004). In neighborhoods of higher economic disadvantage, younger individuals may exhibit the morbidity that is evident among significantly older individuals in more affluent areas: in this case, they may run the risk of having low birthweight infants earlier than their more economically advantaged counterparts. This phenomenon is confirmed by a previous study by Collins et al., which found that in extremely impoverished neighborhoods, older women were at significantly higher risk of having low birthweight babies than their same-age counterparts in nonimpoverished neighborhoods (J. W. Collins et al., 2006). A similar phenomenon has also been described in the accelerated age-associated rise in blood pressure (Braveman et al., 2004) or in the overall faster rate of decline in health over time experienced by Blacks (Ferraro & Farmer, 1996). Geronimus (Geronimus et al., 2001) for example, found that the probability of experiencing a functional limitation at age 35 in some African-American populations corresponded to the probability of experiencing limitations in White populations at age 55; comparable patterns were found between poor and non-poor populations (Geronimus et al., 2001).

Second, this paper implies that not only may women residing in more disadvantaged environments experience poor health earlier, but the health disparities between people living in neighborhoods of more vs. less concentrated poverty become wider with age through middle adulthood (Geronimus, Hicken, Keene, & Bound, 2006). This is evident in the finding that in women of older ages, the mean birthweight becomes increasingly lower in more disadvantaged neighborhoods, while in more affluent neighborhoods it remains stable or increases.

Potential mechanisms through which neighborhood structural characteristics may impact birth outcomes have been described by Morenoff in Chicago: residence in high-poverty neighborhoods may be associated with chronic exposure to stressful social conditions as well as reduced access to opportunities for social engagement which might mitigate such environmental stress (Morenoff, 2003). Repeated exposure to stress and reduced access to social coping mechanisms could build mothers' allostatic load, which can lead to premature aging of the body (McEwen & Seeman, 1999). Epel et al for example, found that stress was associated with increased telomere shortening and higher oxidative stress, which are both known determinants of cell aging and longevity (Epel, Blackburn, Lin, Dhabhar, Adler, Morrow et al., 2004). A lower density of social networks could also limit access to types of information and tangible aid that can improve use of and compliance with medical care, as well as positive health-care behaviors (Buka et al., 2003; Cohen, 1988; Paarlberg, Vingerhoets, Passchier, Dekker, & Vangeijn, 1995). More disadvantaged neighborhoods may also suffer from reduced availability of health care services (S. W. Raudenbush & Bryk, 2002).

The most important contribution of this approach is that it identifies a novel method of monitoring area-level health. Neighborhood maternal age-birthweight slopes can serve as a geographic barometer of health that reflects not only overall infant health status (e.g., mean birthweight), but also disparities in health by age. Public health practitioners and policymakers can collaborate with researchers to estimate and interpret both the mean birthweight (i.e., intercept) and maternal age-birthweight slope for small geographic areas, and apply these for descriptive and planning purposes. For example, they may detect certain neighborhoods where, on average, infants have a high birthweight (i.e. a high intercept), but where older women have infants with markedly lower birthweight than younger women (i.e. a steep negative slope). Other neighborhoods may have little change in birthweight by maternal age (i.e. a relatively flat slope), but offspring may, on average, have low birthweight. Using only mean birthweight as the barometer of birth outcomes could have led practitioners to identify the first type of neighborhood as highly successful, and to ignore the risk of low birthweight that older women experience. Instead, investigating the geographic variation in patterns of mean birthweight and variation in birthweight by age can help us understand the specific types of risks present in

different types of neighborhoods, and can allow public health practitioners to target resources to the priority groups and service needs that arise in different residential environments. In the first type of neighborhood, practitioners might focus on reducing the risk for low birthweight among the older age groups, while in the second type of neighborhood a population-wide strategy to increase the mean birthweight is required. Once they've implemented a strategy to improve birth outcomes in different neighborhoods, practitioners can also use the intercept and slope as monitoring tools, to determine whether they have indeed increased mean birthweight and reduced age disparities in the risk for low birthweight in selected neighborhoods. The stability of the mean neighborhood maternal age-birthweight slopes over time indicates that it may show considerable reliability as an indicator and reflection of population health.

This study had several limitations. The largest is the limited data available on birth certificates. In particular, a more sensitive measure of individual level socioeconomic position might have further reduced the estimated amount of between-neighborhood variance. Moreover, a set of maternal characteristics, including nutritional factors and maternal BMI could be systematically distributed across neighborhoods and could account for the neighborhood variability. The amount of time elapsed between measurement of neighborhood concentrated poverty and birth outcomes might also pose a constraint in the classification of the contextual exposure, as neighborhoods may have changed in the almost 10 years between the two measures. Given the relative stability of neighborhoods however, and the comparability of findings obtained when the same models were estimated with 1994–1996 birth outcome data, this does not seem to present a significant concern. The lack of information on the number of years of residence in the recorded neighborhood may also pose a constraint, as we do not know if exposure to the current neighborhood environment was of sufficient duration or at the times in the lifecourse where it would have played the most important role in determining birth outcomes.

It is also possible that we may have underestimated the amount of variation in the maternal age-birthweight slope that could be attributed to neighborhood factors, by adjusting for certain individual-level maternal risk factors. Maternal smoking and lack of prenatal care, for example, may be consequences of neighborhood disadvantage and norms. For instance, neighborhoods with higher levels of cohesion and interpersonal interaction may encourage mothers to seek prenatal care or to stop smoking during pregnancy. If this proved to be true, the current results would present an underestimate of the true impact that neighborhood factors may have on the relationship between maternal age and birthweight.

It remains important to demonstrate with longitudinal data whether women exposed to disadvantage over time actually experience faster age-associated deterioration of reproductive health, compared to other women. This would help to validate the interpretation of the maternal age-birthweight slope as a marker of cumulative health status. Moreover, we recognize that the worse birth outcomes observed in older mothers in more disadvantaged neighborhoods could reflect a cohort effect—that younger cohorts are healthier and subject to fewer racial disparities than older cohorts. Recent research has begun to refute this claim however: Geronimus et al. for example, found in a cohort analysis, that over a 10-to 14-year period, mean allostatic load scores for Blacks aged 15–59 increased from 2.59 to 3.15, while for whites of the same age range they increased 2.11 to 2.71 (Geronimus et al., 2006).

The salient role that neighborhood economic conditions played in modifying age-related disparities in health in our study, highlight the need for public health practitioners to shift away from solely focusing on health care as a strategy to reduce age disparities in health, and to consider interventions aimed at improving neighborhood characteristics (Geronimus et al., 2006). We can test such a hypothesis by building on social experiments such as Moving to Opportunity (Kling, Liebman, & Katz, 2007). A promising approach to delay the age at which

individuals in disadvantaged environments experience low birthweight for example, might involve a collaboration between public health and housing in order to conduct community-level social experiments that de-concentrate poverty (for example, by creating areas of mixed-income housing and promoting opportunities for home ownership) (Sampson, 2002, 2003). An indicator such as the neighborhood maternal age-birthweight slope can serve to monitor the impact of social interventions on age-related disparities in health. Intervention at the contextual level may have a large population impact, given that a neighborhood-level exposure will affect many of its residents, across multiple generations.

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Figure 1.

Figure 1A. Distribution of neighborhoods according to estimated maternal age-birth weight slopes: Unadjusted model, Chicago, 1997–2002

Figure 1B. Distribution of neighborhoods according to estimated maternal age-birth weight slopes: Model adjusted for individual-level characteristics, Chicago, 1997–2002

Disadvantage by NC 1990

Figure 2.
Level of neighborhood concentrated disadvantage in 1990, Chicago

Maternal age-birth weight slope by NC
1994-1996

Maternal age-birth weight slope by NC
1997-2002

Figure 3.
Mean neighborhood maternal age-birth weight slopes in 1994–1996 and 1997–2002, Chicago

Figure 4.
Comparison of neighborhood maternal age-birth weight slopes in 1994-96 and 1997-2002,
Chicago

Table 1

Random coefficient models: Association between birth weight and maternal age, among women aged 20–45 in Chicago, 1997–2002^a

Coefficient in grams (SD) ^b	Null model	Model 1
Fixed effect: average association between maternal age and mean birth weight across neighborhoods		
A. Intercept	3,258.9 (6.6) ^c	3,258.7 (6.6) ^c
B. Maternal age		−0.4 (0.4)
Random effect: variation around the average value across neighborhoods		
<i>Level 1: variation between individuals in:</i>		
L. Mean birth weight, σ^2_{ϵ}	293,711.50	292,706.40
<i>Level 2: variation between neighborhoods in:</i>		
M. Mean birth weight, $\sigma^2_{\mu 0}$	14,457.3 ^c	14,416.9 ^c
N. Maternal age-birth weight slope, $\sigma^2_{\mu 1}$		40.7 ^c
<i>Level 2: covariation between:</i>		
O. Mean birth weight and maternal age-birth weight slope, $\sigma_{\mu 0 \mu 1}$		653.3

^a All models are based on 229,613 births nested in 342 neighborhoods

^b SD, standard deviation

^c $p < 0.0005$

Table 2

Selected sample characteristics by type of neighborhood, for births to women aged 20–45 in Chicago, 1997–2002^a

	Total sample	NCs with negative maternal age-birth weight slopes ^b	NCs with positive maternal age-birth weight slopes
	(n=342)	(n=148)	(n=194)
Total births (no.)	229,613	79,104	150,509
Birth weight (g) (mean (SD) ^c)	3,275.5 (553.6)	3,137.8 (586.4)	3,347.8 (521.3)
Maternal age (mean (SD))	27.9 (5.5)	26.7 (5.4)	28.5 (5.4)
Mother: more than high school degree (%)	41.0	34.8	44.3
Mother unmarried (%)	45.3	73.9	30.2
Mother primiparous (%)	25.7	16.4	30.6
No prenatal care in the first trimester (%)	23.5	28.4	20.9
Smoking in pregnancy (%)	8.4	16.1	4.4
Hispanic mothers (%)	36.7	10.0	50.7
Black mothers (%)	35.1	85.0	8.9
White mothers (%)	23.4	3.1	34.0
Other race (%)	4.9	1.9	6.5
Neighborhood mean maternal age (SD)	26.4 (2.4)	24.3 (1.1)	27.4 (2.3)
Concentrated disadvantage (mean (SD))	−0.09 (0.9)	0.7 (1.0)	−0.5 (0.5)
Neighborhood support (mean(SD))	−0.1 (0.9)	−0.4 (0.8)	0.1 (1.0)
Proportion of mothers married(%/ range)	46.2 (4.3–96.6)	18.9 (4.3–76.8)	60.5 (12.5–96.6)

^a All characteristics are significantly different in the two types of neighborhoods at the 0.05 level ($p < 0.05$)

^b An unadjusted model was used to estimate the maternal age-birth weight slope for each neighborhood cluster. The clusters were then divided into those that had a negative maternal age-birth weight slope, and those that had a positive maternal age-birth weight slope. T-tests and chi-square tests were used to test the significance of the difference in individual and neighborhood-level characteristics between the two groups. Tests that involved individual-level characteristics were based on the total number of individuals (229,613), while tests that involved neighborhood measures were based on the total number of neighborhood clusters (342).

^c SD, standard deviation

Table 3

Random coefficient models: Association between birth weight and maternal age, controlling for selected maternal characteristics, among women aged 20–45 in Chicago, 1997–2002^a

Coefficient in grams (SD) ^b	Model 2
<i>Fixed effect: average association between predictors and mean birth weight across neighborhoods</i>	
A. Intercept	3,273.4 (1.9) ^c
B. Maternal age	−2.9 (0.3) ^c
C. Mother married	67.6 (3.1) ^c
Maternal race (White is the reference group)	
D. Black	−212.5 (5.1) ^c
E. Hispanic	−43.3 (4.7) ^c
F. Other	−198.2 (6.4) ^c
Maternal education (More than 12 years is the reference group)	
G. Elementary education	−49.6 (4.2) ^c
H. High school	−32.2 (3.3) ^c
I. Prenatal care (access to care in first trimester)	43.7 (3.2) ^c
J. Parity (first birth)	−77.6 (2.8) ^c
K. Cigarettes smoked per day	−20.9 (0.5) ^c
<i>Random effect: variation around the average value across neighborhoods</i>	
<i>Level 1: variation between individuals in:</i>	
L. Mean birth weight, σ^2_{ϵ}	283,520.40
<i>Level 2: variation between neighborhoods in:</i>	
M. Mean birth weight, $\sigma^2_{\mu 0}$	803.6 ^c
N. Maternal age-birth weight slope, $\sigma^2_{\mu 1}$	19.6 ^c

^a All models are based on 229,613 births nested in 342 neighborhoods

^b SD, standard deviation

^c $p < 0.0005$

Table 4

Fully-adjusted models: predicting the between-neighborhood variation in the association between maternal age and birth weight by concentrated neighborhood poverty and support, among women aged 20–45 in Chicago, 1997–2002 ^{a, b}

Coefficient in grams (SD) ^c	Model 3a	Model 3b	Model 4
Fixed effect: average association across neighborhoods, controlling for marital status, parity, cigarette use, maternal education, prenatal care in first trimester, and maternal race/ethnicity			
<i>Model for mean birth weight: average association between neighborhood predictors and mean birth weight across neighborhood clusters</i>			
A. Intercept (mean birth weight)	3,272.7 (1.8) ^d	3,273.4 (1.8) ^d	3,273.1 (1.8) ^d
B. Mean maternal age in the neighborhood cluster	1.5 (1.2)	4.3 (1.1) ^d	0.5 (1.2)
C. Concentrated neighborhood poverty	-15.4 (2.9) ^d		-13.5 (3.0) ^d
D. Neighborhood support		7.5 (2.1) ^d	6.9 (2.1) ^d
<i>Model for maternal age-birth weight slope: average cross-level interactions between maternal age-birth weight slope and neighborhood predictors across neighborhood clusters</i>			
F. Intercept (average individual maternal age-birth weight slope)	-2.8 (0.3) ^d	-2.8 (0.3) ^d	-2.8 (0.3) ^d
G. Mean maternal age in the neighborhood cluster	0.2 (0.2)	1.1 (0.1) ^d	0.2 (0.2)
H. Concentrated neighborhood poverty	-2.6 (0.4) ^d		-2.6 (0.4) ^d
I. Neighborhood support		-0.5 (0.3)	
Random effect: variation around the average value across neighborhoods			
<i>Level 1: variation between individuals in:</i>			
N. Mean birth weight, $\sigma^2_{\epsilon 0}$	283,501.20	283,502.70	283,503.50
<i>Level 2: variation between neighborhoods in:</i>			
K. Mean birth weight, $\sigma^2_{\mu 0}$	635.7 ^d	679.6 ^d	615.1 ^d
L. Maternal age-birth weight slope, $\sigma^2_{\mu 1}$	10.9 ^d	13.8 ^d	10.9 ^d
Percentage of variation in slope reduced by model (in comparison to variation in slope in Model 2, 19.6)	44.40%	29.60%	44.40%

^a All models control for the same individual-level characteristics included in Model 2: maternal race/ethnicity, marital status, education, access to prenatal care, parity, and cigarettes smoked per day.

^b All models are based on 229,613 births nested in 342 neighborhoods

^c SD, standard deviation

^d p<0.0005

$p < 0.05$