Racial Residential Segregation and Birthweight:

The Role of Specific Dimensions of Segregation

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Abstract

Five distinct dimensions of residential segregation have been identified empirically; however, there is little evidence to guide the measurement of segregation in studies of health. We developed a conceptual model and tested associations between segregation and birthweight in a sample of 434,376 singleton births to African-American or Black women living in 225 large U.S. Metropolitan Statistical Areas. In multilevel regression models of birthweight on the five segregation dimensions, isolation and clustering were significantly associated with birthweight in opposite directions. As hypothesized, higher isolation was associated with lower birthweight and higher clustering was associated with higher birthweight. While isolation appears to be deleterious to birthweight, aspects of racial contiguity appear to be mitigating, or indeed beneficial. These findings underscore the multidimensional aspects of segregation and the need for theoretically-driven measurement decisions that include the possibility of several segregation dimensions in a single analytic model.

Word Count: 143

BACKGROUND

In the United States, differences in health status between African-American and White infants have persisted for generations despite advances in perinatal health care and declines in absolute infant mortality rates (Yankauer 1950; National Center for Health Statistics [NCHS], 2004). In 2002, African-American infants were more likely than White infants to have low birthweight (13.3% versus 7.8%), shortened gestation (17.5% versus 12.0%) and fetal growth impairment (16.0% versus 9.0%) and, consequently, were more likely to die in the first year of life (14.4% versus 5.8%; NCHS, 2004; Ananth, Balasubramanian et al. 2004). Eliminating such disparities is a central aim of the U.S. national health agenda (U.S. Department of Health and Human Services, 2000).

After decades of extensive study, the etiology of poor birth outcomes and disparities among African-American infants remains unexplained (Hogan, Richardson et al. 2001). Most studies of risk factors highlight differences in individual risk attributes (e.g. demographics, health behaviors) rather than attempting to explain the genesis of such disparities (Hemminki and Starfield 1978; Paneth, Wallenstein et al. 1982; Kramer 1987; Kempe, Wise et al. 1992; Paarlberg, Vingerhoets et al. 1995; Paneth 1995; Din-Dzietham and Hertz-Picciotto 1997; Zambrana, Dunkel-Schetter et al. 1999; Kramer, Seguin et al. 2000). An exclusive focus on risk at the individual-level overlooks attributes of the maternal residential environment which also play a role in shaping the psychosocial and physiological factors that lead to poor birth outcomes (Duncan, Jones et al. 1993; Curtis and Jones 1998; Diez Roux 2001; Mullings and Wali 2001; Macintyre, Ellaway et al. 2002). Accordingly, recent research has turned to contextual or ecological factors to provide a more complete explanation of the sources of birth outcome disparities by race/ethnicity (O'Campo, Xue et al. 1997; Johnson, Drisko et al. 1999; Pearl, Braveman et al. 2001; Rauh, Andrews et al. 2001; Buka, Brennan et al. 2003; English, Kharrazi et al. 2003; Morenoff 2003; Sastry and Hussey 2003).

One potentially important contextual influence on health is racial/ethnic residential segregation (hereafter referred to as segregation). Segregation is defined as the spatial separation of one group from another on the basis of race or ethnicity (Massey and Denton 1988; Iceland, Weinberg et al. 2002). In the United States, African Americans are the most segregated racial/ethnic minority group and this has been true over time and even with recent declines in overall levels of segregation (Iceland, Weinberg et al. 2002). Today, according to standard segregation measures, more than 60% of U.S. Blacks living in urban areas would have to change their residence to achieve an even geographic distribution, such that the proportion of Blacks neighborhood-by-neighborhood matched the proportion in the area as a whole; and in some cities including Detroit, Milwaukee and Newark this figure exceeds 80% (Iceland, Weinberg et al. 2002).

Segregation and Birth Outcomes

The effects of segregation on the life chances of African Americans are widely thought to be significant and adverse (Massey and Denton 1993). Yet surprisingly little research has considered segregation as a potential source of the well-documented birth outcome disparities sustained by this population.

Most studies of segregation and health, recently reviewed elsewhere (Williams and Collins 2001; Acevedo-Garcia and Lochner 2003; Acevedo-Garcia, Lochner et al. 2003), have examined the effects of segregation on adult mortality (Fang, Madhavan et al. 1998; Guest, Almgren et al. 1998; Hart, Kunitz et al. 1998; Collins and Williams

1999; Jackson, Anderson et al. 2000; Cooper, Kennelly et al. 2001) and infant mortality (Yankauer 1950; LaViest 1989; Polednak 1991; LaVeist 1993; Polednak 1996; Guest, Almgren et al. 1998). One study focused on low birthweight (Ellen 2000).

Of the studies focused on infant outcomes, most found deleterious effects of segregation on low birthweight and infant mortality, even when area-level socioeconomic status (SES) was controlled (LaViest 1989; Polednak 1991; LaVeist 1993; Ellen 2000). At the same time, there is evidence that some aspects of segregation may be protective for infant outcomes, or at least not harmful (LaVeist 1993; Roberts 1997; Pickett, Collins et al. 2005). In one study, African-American political power was associated with segregation and with lower rates of African-American infant mortality (LaVeist 1993). In another study, lower rates of low birthweight were reported in neighborhoods with a higher proportion of African-American residents when maternal race/ethnicity was controlled (Roberts 1997). Finally, Pickett and her colleagues (2005) found that African-American women living in predominantly African-American census tracts in Chicago with positive income congruity (defined as residence in wealthier census tracts than women with comparable education) had lower rates of preterm birth, while this association was not significant for African-American women living in more racially-mixed tracts. The authors concluded that the benefits of income congruity may be countered by racism or stigma associated with residence in racially-mixed neighborhoods (Pickett, Collins et al. 2005).

Taken together, the findings from the small body of work on segregation and birth outcomes must be considered in light of two general limitations. First, most studies of segregation and health focus almost exclusively on a single measure of segregation

(LaVeist 1989; Polednak 1991; Polednak 1996; Guest, Almgren et al. 1998; Hart, Kunitz et al. 1998; Cooper, Kennelly et al. 2001; Fabio, Li et al. 2004), often without theoretical justification for the dimension chosen for examination (Acevedo-Garcia and Lochner 2003). This narrow focus contrasts sharply with studies within sociology that have identified five distinct dimensions of segregation (Massey and Denton 1988; Massey, White et al. 1996). Greater understanding of how distinct aspects of segregation operate to affect health outcomes could identify causal pathways and mechanisms for segregation-health relationships.

Second, most studies of segregation and infant health have used ecological designs that do not allow inferences about the health of individuals. Strong positive associations observed in areas may be negative at the individual level of analysis and vice versa (Robinson 1950; Macintyre and Ellaway 2000). We found only two empirical studies that explicitly measured at least one dimension of segregation and employed multilevel methods. Both found small, independent harmful effects—on health status (Subramanian, Acevedo-Garcia et al. 2005) and on low birthweight (Ellen 2000). A third study did not observe segregation directly, but found that neighborhood-level fixed effects—which include but are not limited to segregation—accounted for approximately 30% of the difference in birthweight between Black and White infants in Chicago (Sastry and Hussey 2003). Two additional studies, summarized above, used multilevel analytic methods but conceptualized segregation as the proportion of Black residents in a neighborhood rather than using direct measures of any of specific dimensions (Roberts 1997; Pickett, Collins et al. 2005).

Segregation and Birth Outcomes

Individual Factors: At the individual level, poor birthweight outcomes are believed to arise through three inter-related, potentially modifiable mechanisms: prolonged and heightened stress, maternal health status and health-related behaviors (Kramer, Seguin et al. 2000; Hogue, Hoffman et al. 2001; Kramer, Goulet et al. 2001; Gennaro 2005; Patrick and Bryan 2005; Rich-Edwards and Grizzard 2005).

Psychosocial stress is believed to lead to physiological changes that increase the risk of poor birth outcomes, including increased cortisol, altered blood-pressure response and immune system compromise (Wadhwa, Sandman et al. 1993; Paarlberg, Vingerhoets et al. 1995; Paarlberg, Vingerhoets et al. 1999; Culhane, Rauh et al. 2001; Wadhwa, Culhane et al. 2001; Culhane, Rauh et al. 2002; Rich-Edwards and Grizzard 2005). Studies show small but consistent harmful effects on birth outcomes of chronic, day-to-day exposure to stress (Hoffman and Hatch 1996; Sandman, Wadhwa et al. 1997; Hogue, Hoffman et al. 2001); job-related physical and emotional demands (Berkowitz 1995); perceived discrimination (Collins, David et al. 2004; Mustillo, Krieger et al. 2004); and mothers' unfavorable perceptions of their residential environments (Collins, David et al. 1998).

Psychosocial stress may influence maternal health status by sensitizing women to increased cardiovascular reactivity, which triggers higher pulse and blood pressure when similar stressors are encountered in the future (Ananth and Wilcox 2001; Hogue, Hoffman et al. 2001; Krieger 2001). This association with higher blood pressure is important because maternal hypertension, which is a known correlate of preterm birth and fetal growth restriction, disproportionately affects African-American women (Samadi, Mayberry et al. 1996; Zhang, Meikle et al. 2003).

Maternal stress and health status also affect health behaviors (McCormick, Brooks-Gunn et al. 1990; Floyd, Rimer et al. 1993; Emmons 2000). As influences on birth outcomes, maternal health behaviors may be harmful, as in the case of smoking, alcohol or drug use; while others may be protective including adopting a nutritious diet, taking prenatal vitamins and using early and regular prenatal care (Kramer 1987; Kramer, Seguin et al. 2000).

The Role of Segregation: Maternal stress, health status and behaviors are influenced by structural aspects of the social, economic and political contexts in which women live and work (Curtis and Jones 1998; Mullings and Wali 2001; Williams and Collins 2001; Macintyre, Ellaway et al. 2002; Acevedo-Garcia, Lochner et al. 2003). Urban environmental stressors (e.g. crime, noise, pollution) may be more prevalent in areas of concentrated poverty and segregation (Williams and Collins 2001; Lopez 2002). Harmful behaviors may be adopted in response to stressful living conditions or behaviors of other neighborhood residents (Curtis and Jones 1998; Williams and Collins 2001; Macintyre, Ellaway et al. 2002; Acevedo-Garcia and Lochner 2003). Accordingly, we propose that segregation operates through specific community attributes which, in turn, influence the individual factors associated with birth outcomes.

Concentrated Poverty and Neighborhood Quality: Segregation is associated with concentrated poverty and neighborhood quality (Massey and Fischer 2000; Williams and Collins 2001; Acevedo-Garcia and Lochner 2003). We characterize neighborhood quality by structural factors—that is, the opportunities, resources and constraints presented to residents (Ross 2000). Because segregation leads to concentrated poverty (Massey and Fischer 2000), segregated areas are vulnerable to the withdrawal of resources and amenities distributed through the marketplace (Massey and Denton 1993). With residents having less to invest in their properties, neighborhoods deteriorate. Attributes associated with poor neighborhood quality—such as crime, unemployment or inadequate housing—are plausible influences on birth outcomes through increased maternal stress and related effects on maternal health (O'Campo, Xue et al. 1997; Roberts 1997; Morenoff 2003). The availability and quality of resources and amenities, including health and social services, affects access to obstetric care and possibly birth outcomes (O'Campo, Xue et al. 1997; Williams 2002). In one Chicago study, infant mortality increased over time in poor neighborhoods where hospitals closed and declined in neighborhoods where hospitals remained open (Almgren and Ferguson 1999).

Exposure to Discrimination: Discrimination, or differential treatment based solely on race or ethnicity (Williams, Lavizzo-Mourey et al. 1994), is both a major cause and consequence of residential segregation and the concentrated poverty experienced by African Americans (Massey and Denton 1993; Polednak 1997; Williams and Collins 2001). Within segregated areas there is evidence of discrimination in housing policies, bank loans, labor market and real estate transactions (Massey and Denton 1993; Polednak 1997). Such discrimination leads to unequal opportunities for home ownership and employment thereby further contributing to psychosocial stress, economic disadvantage, harmful behaviors and, plausibly, to poor birth outcomes.

At the same time, when SES is controlled, segregation may actually protect residents from discrimination. Within racially homogeneous communities there may be less chronic stress in response to experiences of discrimination or perceptions of being judged by others. When stigma is attached to racial or ethnic minority status, higher segregation may provide " . . . shelter from a hostile majority population" (Pickett et al., 2005, p. 2236).

Diffusion of Social Norms and Health Information: Modal neighborhood characteristics or norms are influenced by socioeconomic conditions and other structural factors. At the same time, such norms may affect maternal stress, health status and behaviors. There is evidence, for example, that individuals are more likely to smoke if they live in neighborhoods where a greater proportion of the population smokes (Diehr, Koepsell et al. 1993), possibly because there is less social stigma attached to the behavior. Norms regarding pregnancy spacing, appropriate childbearing age and maternal health-related behaviors are relevant to birth outcomes (Kogan, Martin et al. 1998; Alexander, Kogan et al. 1999).

Segregation plausibly informs the diffusion of social norms and information within and between racial/ethnic groups. In predominantly African-American neighborhoods, *within-group* norms for health behaviors would be strengthened; whereas, in more racially heterogeneous environments, within-group norms could be weakened by exposure to the norms of other racial/ethnic groups. Within-group social norms may be salutary—for example, African-American women have very low rates of smoking during pregnancy (National Center for Health Statistics, 2004). Within-group norms may also include risk factors for poor birth outcomes. In one study using data collected for the Panel Survey of Income Dynamics, African-American women living in racially segregated neighborhoods had a 50% higher rate of premarital first births than their counterparts living in racially-mixed integrated environments, controlling for SES (Sucoff and Upchurch 1998).

Political Power: Residents of segregated neighborhoods in areas with regional political representation may be more likely to elect African-American politicians and acquire political power that translates to better birth outcomes. For instance, African-American politicians may be inclined to distribute health and social service resources in ways that benefit African-American communities (LaViest 1992). To this point, LaViest (1989) found higher African-American political power had protective effects on infant mortality and was also associated with segregation.

Social Support and Social Cohesion: At the neighborhood level, higher segregation could foster within-group social support, a sense of belonging and greater community cohesion. Residents in racially homogeneous communities may have more opportunities to develop and maintain community identity. The associated social support may buffer the negative effects of stress by stimulating beneficial neuro-endocrine responses (Hoffman and Hatch 1996).

Specific Dimensions of Segregation and Birthweight: Five distinct dimensions of residential segregation have been identified empirically (Massey and Denton 1988; Massey, White et al. 1996). We propose two of these dimensions—isolation and clustering—could operate through different mechanisms to have contrasting effects on birthweight.

Isolation reflects the probability that African Americans will encounter other African Americans (as opposed to Whites) in random daily encounters in their neighborhoods of residence (Massey and Denton 1988; Massey, White et al. 1996).

Clustering measures the extent to which African Americans live in contiguous neighborhoods (Massey and Denton 1988; Massey, White et al. 1996). Rather than focusing on individual neighborhoods, clustering addresses distributions, specifically the degree to which the neighborhoods in which African-American residents reside adjoin one another or cluster together.

Higher isolation and higher clustering both reflect higher segregation. The two dimensions are correlated; however, they do not overlap completely and each represents a distinct geographic residential pattern (Massey and Denton 1988; Massey, White et al. 1996). Figure 1 presents these patterns graphically and illustrates the conceptual difference between the two dimensions.

As measures of segregation, both dimensions are associated with the spatial concentration of deleterious and protective factors that influence birthweight as we outlined above. In light of the results of prior studies (Guest, Almgren et al. 1998; Collins and Williams 1999; Subramanian, Acevedo-Garcia et al. 2005), we expect the effect of isolation on birthweight outcomes will be deleterious.

In contrast, when isolation is controlled, we propose that unique pattern of neighborhood geographic contiguity associated with clustering may be associated with more optimal birth outcomes. In other words, holding isolation constant (i.e. comparing across columns within rows of Figure 2) it is possible that African-American residents who live in areas with segregated clusters are at lower risk for poor birthweight outcomes. Clustering could reflect geographic opportunities for African-American-owned businesses and churches; health and social services that address the needs of community members; and the development of horizontal ties. Additionally, geographically contiguous African- American communities may have greater opportunities to develop community cohesion and to organize politically and consequently may have greater power to elect African-American politicians to represent their region. As previously stated, African-American political power may be associated with more optimal health outcomes (LaVeist 1992; LaVeist 1993).

Finally, we propose the three remaining dimensions of segregation (evenness, concentration and centralization) will not significantly influence birthweight. ***Evenness*** reflects the distribution of minority group across neighborhoods but not the spatial patterns of the distribution. Evenness is positively correlated with measures of exposure and clustering (Massey and Denton 1988; Massey, White et al. 1996; Cutler, Glaeser et al. 1999), which do capture relevant spatial patterns of minority group residence. The spatial features of the exposure and clustering dimensions are expected to lead to better performance as predictors of birth outcomes. In the two health studies that examined evenness simultaneously with another segregation dimension, evenness had little or no independent effects (Collins and Williams 1999; Ellen 2000).

High levels of ***concentration*** indicate dense populations of minority group members rather than a diffuse population spread over greater physical space (Massey and Denton 1988). Such population patterns are relevant for the spread of infectious disease (Acevedo-Garcia 2000; Acevedo-Garcia 2001; Acevedo-Garcia and Lochner 2003). Although sexually transmitted diseases may play a role in increasing rates of preterm birth, this is not a leading hypothesis for the poor birth outcomes or disparities experienced by African-American mothers and infants (Kramer 1998; Kramer, Goulet et al. 2001).

High ***centralization*** indicates African-American residents are likely to have reduced access to suburban areas and to occupy crowded, substandard housing in central business areas (Massey and Denton 1988). There is evidence that the central city-suburb distinction by race/ethnicity has become less apparent over the last four decades (Fischer, Stockmayer et al. 2004). Moreover, the correlates of centralization and are poorly understood (Massey and Denton 1989; Fischer, Stockmayer et al. 2004; Wilkes and Iceland 2004). Socioeconomic status and nativity, two important correlates of birthweight (Kramer 1998; Kramer, Goulet et al. 2001) are not associated with centralization (Wilkes and Iceland 2004). In one study, higher centralization was associated with low birthweight in models adjusted for evenness (Ellen 2000); however, it is not clear whether these findings would be robust if other segregation dimensions had been taken into account.

PURPOSE

This study examines whether specific dimensions of segregation are associated with birthweight of African-American infants in the expected directions. We hypothesize isolation will be associated with lower birthweight, while clustering will be associated with higher birthweight, when both dimensions are controlled along with other important individual and ecologic risk factors. The associations with isolation and clustering are expected to remain robust controlling for the remaining three dimensions (evenness, concentration and centralization), while the remaining dimensions are expected to have no independent effects on birthweight outcomes.

METHODS

Design and Data Sources: A cross-sectional cohort design and data from three publicly available sources were used to describe relationships between segregation and birthweight. Maternal and infant data were obtained from the 2002 U.S. Natality Detail Files issued by the National Centers for Health Statistics and linked to selected attributes of MSAs from the 2000 U.S. Census Summary File 3 and measures of Black-white segregation obtained from the U.S. Census Bureau, Housing and Household Economic Statistics Division (Iceland, Weinberg et al. 2002). The datasets were linked using the unique geographic identification codes representing maternal MSA of residence or the New England County Metropolitan Area identification code for New England residents.

MSAs were chosen as the geographic unit of analysis for three reasons. First, they are defined by standard methods and on a national basis which enhances the generalizability of results. Second, MSAs are coherent economic and social units that reasonably reflect residential housing markets and thus the social and economic structures responsible for segregation (Wilkes and Iceland 2004). Finally, MSA-level intervention is feasible as each area has a local government responsible for implementing health-related policies.

Sample: The study sample included all singleton births to U.S.-born African-American women living in U.S. MSAs with a population of at least 100,000 residents. Twins and higher order multiple births were excluded (approximately 3%) because they are known to have lower birthweight and shorter lengths of gestation than singletons (Martin and Park 1999). We excluded foreign-born African-American women from the study (approximately 13%) because among recent immigrants with strong ethnic ties, place effects such as segregation may be less important than cultural values, practices and supports. Furthermore, maternal nativity may serve as a proxy measure for the length of time a mother has lived in her neighborhood. Unlike foreign-born mothers, some U.S. born mothers would have lived all their lives in the same geographic area.

To protect confidentiality, geographic identifiers for MSAs with fewer than 100,000 residents are not specified in public-use birth files. In geographic regions with a small African-American population, segregation indices are less reliable, being more susceptible to random changes and geocoding errors (Massey, White et al. 1996; Iceland, Weinberg et al. 2002); therefore, we follow other researchers (Ellen 2000; Subramanian, Acevedo-Garcia et al. 2005) and restrict our analyses to MSAs with at least 5,000 African Americans. Observations with missing or implausible birthweight (<500 grams or >6,000 grams) or gestational age (<20 weeks and >43 weeks) were excluded from the analysis as these observation were likely to be misclassified stillbirths or represent errors in recording of birthweight or length of gestation. The final study sample included 434,376 singleton births to African-American women living in 225 MSAs.

Dependent Variables: Birthweight was measured as a continuous variable in grams to permit detection of subtle associations that might not be apparent using arbitrary low birthweight dichotomies. Two additional outcomes were examined: preterm birth, defined as birth occurring prior to 37 weeks gestation based on the best estimate of gestational age as reported on the birth certificates; and fetal growth restriction, defined as birthweight less then 10th percentile for gestational age according to a sex-specific growth standard (Alexander, Himes et al. 1996). These component outcomes were examined because infants with low birthweight may be born too early or too light for gestational age; moreover, the factors leading to preterm birth and fetal growth restriction are believed to be etiologically distinct (Wen, Goldenberg et al. 1990; Savitz, Blackmore et al. 1991).

Dimensions of Segregation: To measure the dimensions of segregation, we used the indices recommended by Massey and Denton following their empirical analysis of approximately 20 measures of segregation (Massey and Denton 1988; Massey, White et al. 1996): Lieberson's xP*x Index (isolation), White's Spatial Proximity Index (clustering), the Dissimilarity Index (evenness), the Absolute Centralization Index (centralization) and the Relative Concentration Index. Both indices considered two population groups and were computed for non-Hispanic Blacks, with non-Hispanic Whites as the reference group (Iceland, Weinberg et al. 2002). Because the functional form of segregation-health relationships has not been verified; we defined the segregation measures in four categories to account for potential non-linear relationships across the distribution. Indicators for each category were included our regression models, with the lowest category excluded as the reference. The categories were determined *a priori* using cut-points defined in the sociology literature (Massey and Denton 1988; Massey and Denton 1989): very low (≤ 0.3), low (>0.3 and ≤0.4), moderate (>0.4 and ≤0.6) and high segregation (above 0.6).

Covariates: The multivariate models included variables that might confound associations between segregation and birthweight outcomes. Maternal age was categorized as below age 20; age 20-34; and age 35 years and above (the reference category is age 20-34). Measures of parity included indicators of the number of prior live births greater than 20 weeks gestation, categorized as none; one to three; and more than three (the reference category is one to three).

Maternal education was included to control for confounding by SES. Income is not collected on vital records; moreover, education may provide a more stable measure of SES than income as it is not subject to fluctuation when women select out of the work force for reasons related to pregnancy. Maternal education was defined by indicators of less than <12 years, 12 years only and > 12 years (the reference category is 12 years only).

Prenatal care use was categorized according to the Adequacy of Prenatal Care Utilization Index (APNCU), a summary index based on the number of prenatal visits, the month prenatal care began, and the length of gestation (Kotelchuck 1994; Kotelchuck 1994; Alexander and Kotelchuck 1996). Indicator variables were created for each category: none, inadequate, intermediate, adequate, intensive, or missing (the reference category is adequate). The inadequate and intermediate categories were combined to create an indicator of receiving inadequate care.

Other perinatal characteristics included dummy variables for maternal smoking during pregnancy; medical complications (defined as report of chronic or pregnancy-related hypertension, diabetes or cardiac problems); married; and history of a prior preterm infant.

To control for confounding by MSA-level SES, variables collected for the 2000 U.S. Census were included to represent the proportion of residents above age 25 with more than 12 years of education and the proportion with 12 years only; the proportion with less than 12 years was excluded as the reference group. Education was chosen as the area-level measure of SES because it corresponds directly with the measures of SES available in the birth records used at the individual-level of analysis.

To account for potential geographic variation, we included indicators of the mother's census region of residence: northeast, midwest, south or west (the reference category is west). Since segregation increases with both population and the proportion of Black residents in a region (Wilkes and Iceland 2004), all models included control variables representing MSA population (log-transformed to correct skewness) and the MSA proportion of Black residents.

Of the control variables listed above, some could be in the causal pathway between segregation and birth outcomes. For example, segregation could influence the uptake or availability of prenatal care, maternal age at birth, education or the presence of complications. Any of these variables could, in turn, influence birth outcomes. By including these variables in our models, we estimate the influence of segregation, net the influence of these factors. Our estimates for segregation are therefore conservative.

None of the covariates had more than 10% missing data; therefore those with missing values (smoking, medical complications, education, parity, prenatal care) in the birth records were imputed with the race-specific mean (for continuous variables) or mode for categorical variables. For each covariate, an indicator variable was created (1=missing and imputed; 0=not missing) and included in all regression models. Of note, data on maternal smoking is not collected on birth records in California and was missing for approximately 10% of the study sample. Sensitivity analyses were conducted by repeating multivariate models with and without the maternal smoking covariate, with no substantial changes in reported findings.

Statistical Analysis: Bivariate analyses (t-tests and chi-square tests) were used to compare the distribution of the study variables and a matrix of the correlations of the study variables was examined to assess for potential multicollinearity problems in the multivariate models. To examine relationships between segregation and birth outcomes, we used multivariate regression models with standard errors corrected for aggregation bias (i.e. clustering of observations by MSA) using the Huber-White estimate of variance (Deaton 1997). Results of these models provide estimates of the average influence of segregation across the study MSAs. The analytic models were estimated first with measures of isolation and clustering and, second, with the addition of measures of centralization, concentration and evenness.

RESULTS

In the 225 MSAs, the mean population was 2.5 million residents (Standard Deviation=570,275; Median=194,378; Range: 102,008 to 9,519,338). The mean proportion of Black residents was 0.16 (Standard Deviation=0.09; Median=0.14; Range=0.02 to 0.51). A summary of the distribution of the study variables is presented in Table 2.

Although measures of segregation are known to be correlated (Massey and Denton 1988; Massey, White et al. 1996; Cutler, Glaeser et al. 1999), the correlation coefficients for the segregation categories and study variables were all well below |0.80|, the value at which estimation problems due to multicollinearity might arise in multivariate models (Goldberger 1991; Kennedy 1998; Greene 2000).

Isolation and Birth Outcomes

In regression models including only the isolation and clustering categories (Table 3), moderate and high isolation were associated with lower birthweight (Model 1) and higher rates of preterm birth (Model 2). In these models, the relationships were approximately linear, with estimates of greater magnitude as isolation increased. Low compared to very low isolation was associated with very slightly elevated odds of fetal growth restriction (Model 3).

When the individual and ecological covariates were added to the models (Table 4), all isolation categories were significantly associated with lower birthweight (Model 4) and fetal growth restriction (Model 6); the two highest isolation categories were associated with higher odds of preterm birth (Model 5). Again, there was a fairly monotonic increase associated with higher segregation in the birthweight and preterm birth models; whereas, the odds of fetal growth restriction were slightly elevated by approximately the same magnitude in the low, moderate and high isolation categories, compared to the very low category.

Clustering and Birth Outcomes

In the models including only the segregation categories (Table 3), all clustering categories were associated with higher birthweight and lower odds of preterm birth (Models 1 and 2). Clustering was not associated with fetal growth restriction (Model 3).

Controlling for the remaining individual and ecological covariates in the birthweight model (Table 4, Model 4), low and high clustering compared to very low clustering was associated with higher birthweight by about 25 grams; the estimate was similar in the moderate category, but only marginally significant. In the fully adjusted preterm birth model (Table 4, Model 5), only high clustering was associated with lower rates of preterm birth (OR=0.86; 95% CI: 0.75, 0.99). Again, none of the clustering estimates were significantly associated with fetal growth restriction (Table 4, Model 6).

Centralization, Concentration and Dissimilarity

For all three birth outcomes, the estimates for isolation and clustering remained robust, changing little in magnitude or significance, when the three remaining dimensions were added to the models. Because the changes in the estimated coefficients and odds ratios were minimal, these results are not shown in tables. Concentration, centralization and evenness had no significant independent effects on any of the birth outcomes we examined.

DISCUSSION

This study adds to the growing evidence of associations between segregation and health by examining birth outcomes of African-American infants. Our analysis indicates that some of the risk of poor birth outcomes among Black women is indeed associated with residential segregation but that the effects differ dramatically according to the dimension of segregation considered. We defined segregation in terms of isolation and clustering, finding that both dimensions had meaningful, opposite associations with infant birth status, chiefly through influences on length of gestation rather than fetal growth impairment.

Among U.S.-born African-American women, residence in MSAs with a higher probability that African Americans would encounter other African Americans in their own neighborhood of residence (i.e. higher MSA-level isolation) was associated with giving birth to infants with lower birthweight, higher rates of prematurity and higher rates of fetal growth restriction in models controlled for individual- and area-level SES and other important covariates. These results suggest isolation may serve as a proxy for more immediate harmful influences on maternal and infant health (e.g. the diffusion of harmful social norms, discrimination or poor neighborhood quality) when clustering is controlled.

In contrast, residence in MSAs in which African-American neighborhoods were more likely to be contiguous (i.e. higher MSA-level clustering) was associated with more optimal birth outcomes although at some levels of clustering, and in the fetal growth models, this effect was not significant when individual and ecological covariates were taken into account. Residential clustering may be a correlate of community attributes that are health-promoting (e.g. protection from discrimination, greater African-American political power, improved neighborhood services or social cohesion). Another explanation for these protective effects may be that high clustering estimates reflect higher SES *within* the cluster of neighborhoods where Blacks reside. Because segregation persists at all levels of SES (Massey and Fong 1990), affluent and low-income Blacks would reside in geographically contiguous neighborhoods in MSAs with the highest possible levels of clustering. Thus, high clustering possibly reflects the influence of somewhat higher SES than does isolation. We found no empirical evidence to support this proposition, nor could we test it directly with our data. The geographic identifiers for our sample pinpoint MSA of residence, but not neighborhood of residence; therefore, we cannot determine whether the women in our sample lived in *neighborhoods* with high clustering or higher SES.

Future research will be required to empirically support or refute the causal mechanisms we propose in our conceptual model. Our findings of both deleterious and protective effects of segregation underscore the complexity and heterogeneity of health-related influences within racially homogeneous communities. These findings are consistent with those of other multilevel quantitative studies (O'Campo, Xue et al. 1997; Johnson, Drisko et al. 1999; Pearl, Braveman et al. 2001; Rauh, Andrews et al. 2001; Buka, Brennan et al. 2003; English, Kharrazi et al. 2003; Morenoff 2003; Sastry and Hussey 2003) as well as with recent qualitative research (Mullings and Wali 2001).

Our data and statistical modeling approach provide average estimates for women living within MSAs with particular levels of segregation. Because the birth record data were geo-coded for MSA of residence, but not census tract, we cannot determine how our findings would differ for women living within more or less segregated *neighborhoods*. Future research conducted with data collected for neighborhood of residence is required for a better understanding of these relationships. We found we could not use random effects models for the analysis because significant Hausman tests indicated violation of the random effects model assumption that the random effects and regressors were uncorrelated (Greene 2000). By employing multivariate models with standard errors corrected for aggregation bias, we did not have the advantage of allowing the estimates of the intercepts to vary by MSA and our findings may reflect confounding by unobserved MSA-level variables.

Results of our analysis are subject to limitations associated with use of data derived from vital records (Dobie, Baldwin et al. 1998; DiGiuseppe, Aron et al. 2002). For example, we may have underestimated the influence of SES. Our data were limited to maternal- and MSA-level education as measures of SES. Additional measures of occupation, income and assets would provide more complete information. Thus, the segregation estimates in this analysis could represent inadequate control for socioeconomic segregation (Polednak 1996). The segregation indices we used assume only two population groups (African American and White) and therefore do not capture the influence of residents' interactions with members of other racial/ethnic groups. By using census tracts as proxies for social ties that arise within neighborhoods, segregation indices may not reflect the social spaces in which individuals interact on a daily basis, the true social distance between racial/ethnic groups, or residents' perceptions of their neighborhoods' boundaries (Coulton, Korbin et al. 2001). Finally, our results may also be subject to selection bias insofar as women with particular attributes that influence birth outcomes self-select into particular neighborhoods.

These limitations notwithstanding, the reported estimates are meaningful. Although the magnitude of the segregation estimates is quite small (i.e. Birthweight = 14 – 70 grams and Odds Ratios = 0.86 -1.3) they are comparable to findings from other multilevel studies of place effects on birth outcomes (O'Campo, Xue et al. 1997; Buka, Brennan et al. 2003; Pickett, Collins et al. 2005). More importantly these estimates apply to large population groups (e.g. all births to U.S.-born African-American women in the study MSAs). Further, by accounting for individual race/ethnicity, the proportion of Black residents in the MSA, maternal education and MSA-level education, our findings indicate independent effects of segregation, over and above the influence of the educational and racial/ethnic composition of the population.

CONCLUSIONS

The conceptual framework established for this study is a basis for future research on segregation and health. This framework and the results of our analysis suggest that residential segregation may be both deleterious and protective, depending on the dimension of segregation under investigation. Our findings underscore the multidimensional aspects of segregation and the need for theoretically-driven measurement decisions, including the possibility of more than one segregation dimension in a single analytic model.

Future declines in isolation could represent positive steps toward improving birth outcomes among African-American infants while aspects of racial contiguity appear to be mitigating or indeed beneficial. These results indicate that residential segregation is a complex, multidimensional phenomenon and have important implications for the re-interpretation of results from prior studies as well as for future research designed to explore and explicate racial and economic disparities in health outcomes.

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Table 1: Measures of Segregation (Iceland, Weinberg et al. 2002)

Dimension	Index	Interpretation	Formula
Dissimilarity	Index of Dissimilarity or D-Index	the proportion of minority group residents that would have to move to create an even distribution of the groups across the geographic area	$D = (0.5)\sum_{i=1}^{n} \left\lvert \frac{x_i}{X} - \frac{y_i}{Y} \right\rvert$
Concentration	Relative Concentration Index	the equality of the share of the urban environment occupied by a minority group measured relative to a majority group	$RCO = \dfrac{\left(\dfrac{\sum_{i=1}^{n} \frac{x_i a_i}{X}}{\sum_{i=1}^{n} \frac{y_i a_i}{Y}} \right) - 1}{\left(\dfrac{\sum_{i=1}^{n1} \frac{t_i a_i}{T_1}}{\sum_{i=n2}^{n} \frac{t_i a_i}{T_2}} \right) - 1}$
Exposure	P* Index of Interaction	probability a minority resident will share a geographic sub-area with majority group residents	${}_xP_y^* = \sum_{n=1}^{n} \left[\left(\frac{x_i}{X} \right) \left(\frac{y_i}{t_i} \right) \right]$
	P* Index of Isolation	probability minority group residents will share a geographic sub-area with other minority group residents	${}_xP_x^* = \sum_{n=1}^{n} \left[\left(\frac{x_i}{X} \right) \left(\frac{x_i}{t_i} \right) \right]$
Centralization	Absolute Centralization Index	extent to which minority group members reside in central urban areas	$AC = \sum_{n=1}^{m} (X_{i-1} A_i) - \sum_{n=1}^{m} (X_i A_{i-1})$
Clustering	Spatial Proximity Index	extent to which minority group members reside in contiguous areas as opposed to areas scattered the region	$SP = \frac{XP_{xx} + YP_{yy}}{TP_{tt}}$

Notation:

i	indexes sub-areas	$i \in \{1,2...n\}$
x_i	Population of group x in smaller geographic area i (e.g. census tract)	
X	Population of group x in a larger geographic area (e.g. metropolitan statistical area)	
y_i	Population of majority group y in sub-area i	
Y	Population of group y in a larger geographic area	
T_i	Total population in sub-area i	$(T_i = x_i + y_i)$
$n1$	Point of sub-areas (small to large) where the cumulative total population equals minority population	
$n2$	Point in rank of sub-areas (large to small) where the cumulative total population equals minority population	
T_1	Total population of tracts from 1 to $n1$	
T_2	Total population of tracts from $n2$ to n	
a_i	Land area of sub-area i	
A_i	Sum of a a_i ' i equal to the total land area in the larger geographic area	

$$P_{xx} = \sum_{i=1}^{n} \sum_{i=j}^{n} \frac{x_i x_j c_{ij}}{X^2}$$

$$P_{xy} = \sum_{i=1}^{n} \sum_{i=j}^{n} \frac{x_i y_j c_{ij}}{XY}$$

$c_{ij} = \exp(-d_{ij})$ Refers to a contiguity matrix that equals 1 when units i and j are contiguous and otherwise 0.

d_{ij} is the distance between area i and area j centroids, where $d_{ii} = (0.6a_i)^{0.5}$

Table 2: Characteristics of the Study Sample [a, b]

225 U.S. Metropolitan Statistical Areas, 2002

Variable	%
Education	
Less than 12 years	23.2
12 years	38.2
More than 12 years	38.6
Mother's Age (years)	
Less than 20	16.9
20-34 years	72.4
35 or more	10.7
Parity	
No prior live births	37.4
1-3 prior live births	55.4
4 or more prior live births	7.2
Married	32.5
Medical Complications	8.4
Prior Preterm Birth	1.5
Adequacy of Prenatal Care Use	
None	2.0
Inadequate	33.7
Adequate	38.2
Adequate-plus	26.1
Female Infant	49.2
Smoking	8.1
Region of Residence	
Northeast	18.8
South	50.9
Midwest	21.5
West	8.8
% Black Residents in MSA above the Median	72.1
MSA Population Size above the Median	53.5
MSA Isolation (xP*x)	
Mean (SD) range	.59 (.16) .04-.83
Very Low (≤0.3)	4.8
Low (>0.3 and ≤0.4)	8.6
Moderate (>0.4 and ≤0.6)	34.5
High (>0.6)	52.1
MSA Clustering (SP Index)	
Mean (SD) range	.37 (.20) .01-.82
Very Low (≤0.3)	43.4
Low (>0.3 and ≤0.4)	12.3
Moderate (>0.4 and ≤0.6)	29.1
High (>0.6)	15.2
Birthweight in grams Mean (SD)	3111 (639)
Preterm Birth	17.0
Fetal Growth Restriction	15.2

[a] n=434,376 births to African American, Non-Hispanic women

[b] SD=standard deviation; SP=Spatial Proximity

Table 3: Unadjusted Regression Models of Isolation and Clustering on Birth Weight Outcomes[a, b]

n=434,376 births to African-American women in 225 U.S. Metropolitan Statistical Areas, 2002

	Model 1		Model 2		Model 3	
	Birthweight		Preterm Birth		Fetal Growth Restriction	
	B	[95% CI]	OR	[95% CI]	OR	[95% CI]
MSA Isolation (xP*x)						
Very Low (≤0.3)	-----	-----	-----	-----	-----	-----
Low (>0.3 and ≤0.4)	-14.19	[-45.09, 16.72]	1.03	[0.92, 1.13]	1.09 **	[1.01, 1.17]
Moderate (>0.4 and ≤0.6)	-41.37 ***	[-67.64, -15.09]	1.12 ***	[1.03, 1.22]	1.05	[0.99, 1.12]
High (>0.6)	-73.19 ***	[-104.31, -42.06]	1.33 ***	[1.19, 1.50]	1.04	[0.97, 1.12]
MSA Clustering (SP Index)						
Very Low (≤0.3)	-----	-----	-----	-----	-----	-----
Low (>0.3 and ≤0.4)	31.42 ***	[9.42, 53.42]	0.90 **	[0.83, 0.98]	0.98	[0.94, 1.02]
Moderate (>0.4 and ≤0.6)	56.71 ***	[35.29, 78.12]	0.83 ***	[0.74, 0.93]	0.92	[0.90, 1.01]
High (>0.6)	42.31 ***	[18.93, 65.69]	0.83 ***	[0.76, 0.91]	0.99	[0.93, 1.07]

[a] *B*=Coefficient; OR=Odds Ratio; SP=Spatial Proximity

[b] **p<0.05 ***p<0.01

Table 4: Adjusted Regression Models of Isolation and Clustering on Birth Weight Outcomes[a, b, c]

n=434,376 births to African-American women in 225 U.S. Metropolitan Statistical Areas, 2002

	Model 4		**Model 5**		**Model 6**	
	Birthweight		**Preterm Birth**		**Fetal Growth Restriction**	
	B	**[95% CI]**	**OR**	**[95% CI]**	**OR**	**[95% CI]**
MSA Isolation (xP*x)						
Very Low (≤0.3)	-----	-----	-----	-----	-----	-----
Low (>0.3 and ≤0.4)	-30.83 ***	[-52.78, -8.87]	1.00	[0.92, 1.11]	1.14 ***	[1.04, 1.26]
Moderate (>0.4 and ≤0.6)	-56.54 ***	[-78.60, -33.36]	1.15 ***	[1.04, 1.27]	1.15 ***	[1.05, 1.25]
High (>0.6)	-68.81 ***	[-92.60, -32.20]	1.27 ***	[1.10, 1.46]	1.12 **	[1.01, 1.25]
MSA Clustering (SP Index)						
Very Low (≤0.3)	-----	-----	-----	-----	-----	-----
Low (>0.3 and ≤0.4)	22.24 **	[2.97, 41.51]	0.93	[0.84, 1.04]	0.97	[0.93, 1.02]
Moderate (>0.4 and ≤0.6)	20.51 *	[-0.51, 41.52]	0.94	[0.83, 1.07]	0.99	[0.93, 1.05]
High (>0.6)	25.57 **	[2.10, 49.05]	0.86 **	[0.75, 0.99]	1.00	[0.92, 1.08]
Age						
Less than 20 years	-11.54 ***	[-18.07, -5.01]	1.01	[0.98, 1.04]	1.02	[0.99, 1.04]
20-34 years (reference)	-----	-----	-----	-----	-----	-----
35 or more years	-42.61 ***	[-51.51, -33.71]	1.25 ***	[1.21, 1.30]	1.17 ***	[1.13, 1.20]
Medical Complications	-139.05 ***	[-151.02, -127.08]	1.87 ***	[1.81, 1.94]	1.46 ***	[1.41, 1.51]
Prior Preterm Birth	-401.02 ***	[-451.20, -350.85]	2.77 ***	[2.51, 3.07]	1.65 ***	[1.58, 1.68]
Smoking (yes/no)	-143.26 ***	[-153.20, -133.32]	1.05 **	[1.01, 1.10]	1.63 ***	[1.58, 1.68]
Married	45.91 ***	[40.19, 51.62]	0.93 ***	[0.91, 0.96]	0.87 ***	[0.85, 0.89]
Education						
< 12 years	-49.80 ***	[-57.21, -42.38]	1.03 **	[1.01, 1.07]	1.28 ***	[1.24, 1.33]
12 years	-32.28 ***	[-37.80, -26.76]	1.01	[0.98, 1.03]	1.19 ***	[1.16, 1.22]
> 12 years (reference)	-----	-----	-----	-----	-----	-----
Prenatal Care Use						
None	-422.73 ***	[-444.65, -399.80]	14.08 ***	[12.32, 16.09]	1.50 ***	[1.40, 1.61]
Inadequate	-187.03 ***	[205.89, -168.17]	8.89 ***	[7.65, 10.32]	1.13 ***	[1.09, 1.17]
Adequate (reference)	-----	-----	-----	-----	-----	-----
Intensive	-200.99 ***	[-210.96, -191.02]	7.18 ***	[6.64, 7.76]	0.95 ***	[0.93, 0.98]
MSA Population Size (log)	2.53	[-5.16, 10.22]	0.99	[0.96, 1.03]	0.99	[0.97, 1.01]
MSA Proportion Black Residents	0.13	[-0.59, 0.85]	0.98	[0.99, 1.00]	1.00	[0.99, 1.00]
MSA Socioeconomic Status						
Less than High School (%)	-----	-----	-----	-----	-----	-----
Completed High School (%)	2.19 *	[0.36, 4.74]	0.99	[0.98, 1.00]	0.99 ***	[0.98, 0.99]
College Graduates (%)	2.29 ***	[0.88, 3.71]	0.99 ***	[0.98, 0.99]	0.99 ***	[0.98, 0.99]

[a] MSA=Metropolitan Statistical Area; *B* =Coefficient; OR=Odds Ratio; SP=Spatial Proximity

[b] Models controlled for sex of the infant, parity; region of residence; and dummy variables for missing covariates [smoking, parity, prenatal care, complications, marital status, education, prior preterm birth; missing=1; non-missing=0]

[c] *p<0.10 **p<0.05 ***p<0.01