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A Comparison of MSA/Rural Residence and Rural Racial Segregation in the Risk of Preterm Birth in Georgia

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Abstract

A Comparison of MSA/Rural Residence and Rural Racial Segregation in the Risk of Preterm Birth in Georgia

By Cara M. Batenhorst

Preterm birth (PTB) is currently on the rise in the United States and is estimated to occur in twice as many black births as white births. Individual maternal characteristics and neighborhood level characteristics have been shown to alter the effect of race on preterm birth. Comparisons of urban and rural residence with preterm birth are not prominent in the literature, and no existing literature analyzes the patterns of racial segregation in the association of preterm birth and race. The purpose of this study was to evaluate the risk of preterm birth for rural mothers compared to mothers in Metropolitan and Micropolitan Statistical Areas (MSA). A secondary goal was to evaluate the association of preterm birth with two measures of segregation, dissimilarity and isolation, among rural residents. Individual-level birth records for births to non-Hispanic white women and non-Hispanic black women in Georgia from 1998 to 2002 were merged with MSA and county level segregation measures that were derived from census data. A logistic regression model of preterm birth with MSA/Rural Residence that included the maternal characteristics, neighborhood level characteristics, as well as interaction terms of the covariates with MSA/Rural Residence was analyzed to address the primary study question. For the secondary purpose, a logistic model of preterm birth with isolation, dissimilarity, the maternal characteristics, neighborhood level characteristics, and interaction terms for isolation and dissimilarity with race was analyzed using a restricted cohort of rural mothers. For aim 1, black women in the rural counties were at a higher risk of preterm birth than their white neighbors and black women in MSAs. The opposite effect was true for white women with the risk of preterm birth higher among women in MSAs. For aim 2, as isolation increases and dissimilarity is held constant, there is an increase in the risk of preterm birth for black women in the rural cohort. For white women, the risk of preterm birth actually decreases when controlling for dissimilarity and increasing isolation. Birth outcomes are not well studied among rural women and further studies are needed to better understand the effects of rural residence on birth outcomes.

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Introduction

Live birth prior to 37 weeks gestation, *preterm birth (PTB)*, is currently on the rise in the United States and is estimated to contribute to nearly one third of all infant deaths and predict lifelong ill-health effects. In the United States, black infants are twice as likely to be born preterm compared to white infants (1, 2, 3). In 2006, the annual percentage of births at less than 37 weeks gestation in Georgia were 18.5% for non-Hispanic black women and 12.5% for non-Hispanic white women (3). Individual maternal risk factors such as smoking, marital status, prenatal care, and mother's age contribute to the explanation of the disparity in preterm birth rates between non-Hispanic black and non-Hispanic white mothers, but do not adequately explain the variation in the risk between these two groups. Neighborhood level risk factors should be considered in models for preterm birth in an attempt to better understand the gap in preterm birth rates between non-Hispanic black and non-Hispanic white women.

The purpose of this research paper will be to continue the evaluation of the difference in preterm birth rates between black and white mothers by evaluating the risk between women living in urban and rural areas. A secondary objective of this study is to determine if the risk of preterm birth changes when measures for racial segregation are added to the model.

Background

The Urban and Rural Divide in Health Outcomes

The difference between urban and rural rates of preterm birth is an important public health question that has not recently been evaluated in epidemiological literature. Urban and rural comparisons are important because these comparisons seek to determine if there is a need for increased public health action to reduce a potential disparity between rural and urban women.

Sociological differences between rural and urban areas are frequently identified in the literature. Cordes found that rural students spend an average of one year less in the educational system than urban students (4). The poverty rate was shown to be higher in rural areas than it is in urban areas in a study by Miller (5). In addition to higher poverty rates, rural women are expected to utilize prenatal care at a lower rate than urban women (6, 7). Alexy et al found that urban women were more likely to have had a previous abortion, use cigarettes, have neonatal complications, have maternal complications, have a history of drug use, or a history of emotional physical abuse but less likely to have poor pregnancy weight gain and a poor diet history compared to rural women (8). The socioeconomic and sociological differences between rural and urban areas are expected to influence the rates of poor birth outcomes, such as preterm birth and low birth weight.

Some older studies have found an association of birth outcomes with urban or rural residence, while others have not found associations. Nesbitt et al found urban women were more likely to have complicated labor and delivery but linked the association to the limited availability of obstetric emergency services in rural areas (9). Hulme and Blegen evaluated the differences between women living in urban, adjacent to urban, and rural regions and found that women who lived in areas that were adjacent to urban areas were less likely to have a poor birth outcome, while women in the rural areas had the highest risk of both low gestational age and birthweight (10). Each of these studies were limited by small sample sizes and are believed to be less relevant for understanding differences between urban and rural birth outcomes now that they are more than 10 years old and the population composition in both rural and urban areas have changed in that time.

More recently, Hillemeier et al reviewed births in central Pennsylvania to identify the risk of low birth weight and preterm birth for four residential density categories: urban focused, large rural city focused/town-focused, small rural town-focused, and isolated rural town-focused. In their models for low birth weight, the risk of low birth weight was lower for the large-city focused compared to urban-focused but approximately the same for both rural designations compared to urban-focused. A similar result was found for preterm births, but the difference between large city-focused and urban-focused was less impressive with a reported p-value of 0.07. The risk comparing urban to both rural designations remained insignificant in their model. The study had a few limitations, the most important of which was that the study sample did not contain the largest urban distinction for comparison (11).

United States Census Bureau data is often used to define urban and rural designations. Metropolitan statistical areas and micropolitan statistical areas are defined by the US Census Bureau and represent counties that enclose centralized urban areas and the surrounding counties that have a high degree of social and economic interaction. If a neighboring county has at least 25% employment interchange between the county and the central city, it will be included in the MSA. Metropolitan statistical areas have an urban core with 50,000 or more residents and micropolitan statistical areas are slightly smaller with population sizes of at least 10,000 but less than 50,000 residents. For the purposes of this study, Metropolitan Statistical Areas and Micropolitan Statistical Areas are combined to represent urban areas.

Racial Residential Segregation

Unlike rural density, the evaluation of segregation as a predictor of poor birth outcomes has increased in the literature in the last 15 years. Racial segregation is one process by which different races are sorted into residential environments in which they may be isolated from other racial or ethnic groups (12). Sociological literature indicates that racial segregation predicts access to social and material resources, which may influence health and disease therefore causing health disparities (12, 13, 14, 15).

The sociological literature shows that the association between disease and racial segregation exists through fundamental, intermediate, and proximate pathways that are inter-related and influence health outcomes. Fundamental factors include historical conditions, political order, legal codes, social and cultural institutions, racism, and poor distribution of economic and educational opportunities. Intermediate health consequences of racial segregation are the physical environment (pollution, land use, etc) and community infrastructure and social environment (public resources, police services, retail resources, housing quality, and education quality). The proximate factors associated with racial segregation include violent crime, financial insecurity, neighborhood conditions, environmental stressors, unfair treatment, differential dietary practices, physical activity, participation in neighborhood organizations, and structures for social support (16).

Patterns of racial segregation are found when racial segregation is analyzed. Inconsistent usage of the measurement methods that identify the various racial segregation patterns to predict health outcomes is prominent in the literature. Four measures of segregation are used in birth outcomes literature and are derived from sociological and geographical methods with values ranging from 0 to 1, where 1 is considered complete segregation and 0 represents no segregation (17). It is generally accepted that values greater than 0.6 for these segregation measures are evidence of highly segregated areas (17). *Exposure* or *isolation* segregation refers to the probability that a specified race will have contact with members of the same race within their neighborhood. *Unevenness* or *dissimilarity* is the degree to which each neighborhood has the same racial composition as the overall population. *Centralization* is the degree with which a specified race's neighborhoods are in the center of a metropolitan area. Finally, *clustering* is the tendency of racial neighborhoods to cluster together (17). A related measure, the *proportion of a racial or ethnic minority,* is often used as a crude measure of racial distribution but is not a true measure for segregation and therefore should be used with an understanding that it is not a descriptive of a measure of racial segregation (18).

Racial Residential Segregation and Birth Outcomes

A number of studies have used the various segregation measures to evaluate poor birth outcomes in metropolitan areas. With the variation in measurement of segregation, some measures, such as unevenness and clustering have been found to have a protective effect, while exposure/isolation and racial proportion have been shown to increase risk of poor birth outcome (19, 20, 21, 18).

Mason et al found that an increase in the percentage of a census tract that was black was associated with a moderate increase in the individual risk of preterm birth (19). Shaw et al also found a significant association between percentage of census tract that was black and low birth weight or preterm birth when using a dataset from 2000 that contained births to non-Hispanic black and Hispanic mothers (20).

Bell et al evaluated birth weight and preterm birth for black women in 225 metropolitan statistical areas in 2002 and found that low, moderate, and high isolation were all associated with lower birth weight. For preterm birth, the moderate and high isolation groups were more likely to have a preterm birth. Bell et al also evaluated clustering for the same cohort and identified a protective effect of high clustering for both birth weight and preterm birth (21). Kramer and Hogue measured unevenness and isolation to evaluate very-preterm birth and low birth weight in birth cohort of 311 Metropolitan Statistical Areas from 2002 to 2004. The authors found a strong effect of increased isolation on risk of very preterm birth among black women but found a protective effect of unevenness, conditional on isolation (18).

Strait et al used a segregation index that included other neighborhood level characteristics. Using vital statistics and census data from 92 metropolitan statistical areas in 1980, 1990, and 2000, the authors found that black mothers in highly segregated and extremely poor areas had an increased risk of infant mortality, but this effect over time was influenced more by neighborhood poverty than segregation (22).

Osypuk and Acevedo-Garcia evaluated preterm birth by creating a hyper-segregation measure for the metropolitan level. The authors categorized segregation as a measure greater than 0.6 for each of the measures of segregation. Regions with four or more segregation variables valued greater than 0.6 were classified as hyper-segregated. The authors found that blacks in hyper-segregated areas were at greater risk of preterm birth than blacks in non-hyper-segregated areas (23).

The previous use of racial residential segregation and birth measures has been noted with limitations. The evaluation of racial segregation and birth measures has been limited to large metropolitan areas. No studies of racial segregation with any health outcome have been performed in rural areas. Lichter et al determined that rural locations, particularly those located within the southern United States, have levels of segregation that are similar or higher than metropolitan areas (24). For this reason, an evaluation of racial segregation and a birth outcome using a cohort of mothers from a rural area is important for continuing the understanding of racial segregation and the effect it has on birth outcomes.

Methods

Hypothesis

Rural residence is hypothesized to result in a differential risk of preterm birth for rural mothers compared with mothers in MSAs controlling for race. Secondly, racial segregation measures are hypothesized to adjust the risk of preterm birth for rural residents.

Data Source

For this study, individual-level birth records that include standard birth certificate data and data on maternal residence from 1998 to 2002 were obtained from the Office of Health Indicators for Planning (OHIP) of the Georgia Department of Community Health. Emory University IRB approval was obtained as an amendment to IRB Protocol IRB00038882.

Eligibility Criteria

Observations that were part of a multiple birth, had a gestational period of less than 20 weeks, and weighed less than 500g or more than 6000g were excluded from our study. For the purpose of the research question, only observations from non-Hispanic black and non-Hispanic white mothers were included in the study. Missing values were assumed to be at random for the covariates; observations that had missing values for the covariates of interest were excluded from the study.

Definition of Key Variables

Preterm birth was the outcome of interest in this study and is indicated if the reported gestational age on the birth certificate was less than 37 weeks. The primary predictor variable, MSA/Rural Residence, was determined by the mother's residence in either a Metropolitan or Micropolitan Statistical Area or a rural county. Residence in a rural county was treated as the referent group for analysis.

Three secondary predictor variables were available for the analysis of racial segregation. Dissimilarity (D), isolation (I) and Theil's Entropy Index (H), were calculated using a macro designed by Graham and O'Sullivan for ArcGIS v 9.2 (Esri, Redlands, California) that calculated a unique segregation value for each Georgia Metropolitan or Micropolitan Statistical Area as well as for each rural county which is not part of an MSA for 1990, 2000 and 2007 (25). Dissimilarity and Theil's Entropy Index are two calculated measures of unevenness, which measures how equally a minority group is distribute throughout the region of interest. For these measures, a value of 0 is equivalent to equal racial distribution throughout the region and a value of 1 indicates that the minority is completely separated from the majority group. Dissimilarity is used more frequently than Theil's Entropy Index and is calculated by using a weighted average of absolute deviation for each individual neighborhood and comparing this average to the theoretical maximum for the full area. Theil's Entropy Index is a measurement of each neighborhood and how it defers from the extent of racial diversity, or entropy, of a city. Dissimilarity and Theil's Entropy Index are often interpreted as the proportion of the minority that would have to move to reach perfect racial distribution. As a measure of exposure, isolation is a segregation measure that evaluates the probability of interaction between members of the same minority and is calculated using a minority-weighted average for each neighborhood (17). These values were used to linearly interpolate the individual measures of segregation for each year between census estimates from 1990 and 2000 and similarly each year between census measures from 2000 and a commercial demographic projection from 2007.. Towns

County did not have a valid measure for each variable for 1990; therefore, the values of each segregation measure from 2000 were substituted for the missing interpolated data. The input data was census block group counts, but the segregation measures were then calculated using three geographic neighborhood scales of analysis: 500 meters, 2000 meters or 4000 meters. The scales of analysis are used as inputs in the calculation of these measures of segregation and are estimates of the circular area surrounding an individual's home in which individuals interact with their neighborhood. Little attention has been paid to the appropriateness of neighborhood size in calculating segregation measures in rural areas, so it is unknown what the appropriate choice of neighborhood scale should be for a rural segregation study.

Definition of Covariates

The covariates included in the analysis were maternal characteristics of race, age, adequacy of prenatal care, marital status, tobacco use during pregnancy, and alcohol use during pregnancy, and neighborhood level characteristics of the percentage of the mother's census tract that is black and a neighborhood deprivation index (NDI) for the mother's census tract.

Maternal race was determined by race and ethnicity data from the birth certificate data and defined as either as non-Hispanic white or non-Hispanic black with non-Hispanic white as the referent group. Maternal age was defined by grouping women ages 10-19, 20-34, 35-53 and setting the middle group as the reference category. The adequacy of prenatal care was determined using the Kotelchuk index, which defines adequacy of prenatal care into four categories: inadequate, intermediate, adequate, or adequate plus. The variable was recoded to use three dummy variables with the adequate group coded as the referent group. Mother's marital status was a binary variable that treated married mothers as the referent group and all other classifications (unmarried, widowed, divorced, or never married) as the non-referent group. For alcohol use, mothers who did not use alcohol during pregnancy were the referent group and all others were the non-referent group. Likewise for tobacco use, mothers who did not use tobacco during pregnancy were the referent group and all others were the non-referent group. Percentage black in the mother's census tract is a continuous variable and was not altered for this analysis. The neighborhood deprivation index (NDI) is a census-based measure that scores a neighborhood based off of eight inputs for deprivation that describe levels of Education, Employment, Housing, Occupation, and Poverty within a neighborhood. The NDI was operationalized for use with census data in Georgia and was left as a continuous variable for analysis.

Analysis

For each segregation measure, a correlation analysis was performed to compare geographic scale. The correlation matrix showed that the individual segregation measures for the three neighborhood scales were highly correlated. As previously mentioned, no study has evaluated the appropriate scale for rural areas; therefore, the 500-meter scale was chosen due to its smaller size and the potential for better resolution in rural areas. Using the 500-meter scale, each of the segregation measures was compared for collinearity using the Collinearity Macro developed by Zack, Singleton, and Satterwhite for SAS 9.2. As expected, the two measures of unevenness (dissimilarity and entropy) were highly collinear while the isolation measure was not equivalent to either segregation measure. With the research goal in mind and a desire to compare to previous studies using segregation measures, the measures of dissimilarity and isolation were chosen as the exposure variables.

To compare MSA/Rural Residence, a crude logistic model and a fully adjusted logistic model were analyzed. Crude Model 1 included Preterm Birth, MSA/Rural Residence and Race. For the fully adjusted Model 1, the maternal characteristics of race, age, adequacy of prenatal care, marital status, tobacco use during pregnancy, and alcohol use during pregnancy, and neighborhood level characteristics of the percentage of the mother's census tract that is black and a neighborhood deprivation index were added to Crude Model 1. A modeling technique that evaluated the potential interactions of all of the covariates and the MSA/Rural Residence variable was used. Using backwards elimination based on log-likelihood ratio chi-square tests with significance cut point of 0.05, the final model was found.

To evaluate racial segregation in rural counties (Model 2), a similar modeling technique was used. Again, a basic crude logistic model that included preterm birth, race, isolation, and dissimilarity was run for comparison (Crude Model 2). With the desire to compare with previous studies of racial segregation in the MSAs, the full model included each of the variables from crude model 2 and the maternal and neighborhood covariates to the model. A test for the interactions of race with isolation and race with dissimilarity was performed as well as tests for interaction of isolation and dissimilarity with the maternal covariates. A backwards elimination approach was used to test for the appropriateness of the interaction of the segregation measures with the covariates.

Confounding analysis was performed on the final adjusted models to determine if any of the covariates that were not part of any of the interaction terms should be dropped from the model using a 10% comparison standard to the full model. While other models had odds ratio estimates within 10% of the fully adjusted model, only small changes in precision occurred by dropping variables from the model. For this reason, every covariate was left in the model for overall comparability of the three individual models. Each adjusted model was checked for collinearity using the Collinearity Macro for SAS. No issues with collinearity were identified. All analysis was performed in SAS v 9.2 (SAS Institute, Cary, North Carolina).

Results

After restricting the dataset to non-Hispanic black and non-Hispanic white mothers, there were 530,364 total births in the Georgia birth cohort from 1998-2002. After excluding observations with missing values, the final analysis contained 503,641 total births to women in 62 rural counties and 37 MSAs from Georgia. There were a total of 53,201 preterm births identified in our cohort; 5,685 preterm births were in the rural counties and 47,516 preterm births were in the MSAs. Among white mothers, 27,361 births were preterm with 3,286 in the rural counties and 24,075 in the MSAs. Among black mothers, 25,840 births were preterm with 2,399 in the rural counties and 23,441 in the MSAs. A total of 354,705 births were to women in highly dissimilar areas of which 36,872 were preterm. A total of 386,841 births were to women in highly isolated areas of which 41,078 were preterm. See Tables 1-3 for descriptive statistics for the categorical variables and Tables 4-7 for descriptive statistics of the continuous variables.

A direct comparison of descriptive statistics for MSAs and rural counties is shown in Table 1. The majority of the preterm births (89.3%) were from mothers from MSAs and only 10.7% of preterm births occurred in rural counties. However, the overall percentage of preterm birth within each group was 10.5% in MSAs and 11.6% in rural counties.

Women in MSAs were older, less likely to use tobacco, be married, have inadequate or intermediate prenatal care, and were more likely to use alcohol, live in a highly segregated area, or have a higher percentage of black neighbors compared to women in rural counties (See Tables 1 and 4). 81.5% of births were to women in highly isolated MSAs while only 33.2% of births were to women in highly isolated rural counties. Similarly, 73.6% of births were to women in highly dissimilar MSAs while only 40.8% of births were in highly dissimilar rural counties.

As is often cited in the literature, the rate of preterm birth was higher for black women compared to white women. In the full cohort, 13.6% of black women had preterm births and only

8.7% of white women had preterm births. Comparison of preterm birth rates by race for the MSA and the rural counties yields slightly different results but shows the trend for increased rates of preterm birth for black women (See Tables 2 and 3). In the MSA group, 8.6% of white women and 13.4% of black women had preterm births. In the rural counties, 9.9% of white women and 15.3% of black women had preterm births.

Model 1: *How does MSA/Rural Residence affect the risk of Preterm Birth for Black and White Women in Georgia?*

For comparison, an analysis containing only preterm birth, race and MSA status was performed. The results Crude Model 1 are shown in Table 8. The crude odds ratio (OR) comparing women in rural counties to women in MSAs while holding race constant was 1.16 (95% CI: 1.13, 1.20).

Model 1 is a fully adjusted model that evaluates the effect of MSA/Rural Residence on preterm birth and adjusts for race, marital status, tobacco use, alcohol use, mother's age, adequacy of prenatal care, neighborhood deprivation index, and neighborhood percent black. This model also includes two significant interaction terms: MSA/Rural Residence with race and MSA/Rural Residence with marital status. The potential interaction terms of race with age, race with marital status, MSA/Rural Residence with neighborhood deprivation index, and MSA/Rural Residence with neighborhood percent black were determined to be insignificant and removed from the model. The logistic model results for Model 1 are shown in Table 8. After confounding analysis, all potential covariates were left in the model for comparison to other models. Among women who are married, the odds ratio for those living in a rural county compared to women living in a MSA is 1.07 (95% CI: 1.02, 1.13) for black women and 0.93 (95% CI: 0.87, 0.99) for white women. Comparison of the differences between black and white mothers in the model yields highly significant odds ratios regardless of MSA/Rural Residence, but changing the MSA status of the comparison group does result in small changes to the risk of preterm birth. The odds ratio comparing a black Woman to a white woman is 1.51 (95% CI: 1.47, 1.55) for women in MSAs and 1.74 (95% CI: 1.62, 1.86) for women in rural counties. The odds ratio results for Model 1 are displayed in Table 9.

As an important interaction term with MSA/Rural Residence, marital status and its effect on the risk of preterm birth depends on the mother's residence. Controlling for race, the odds ratio comparing unmarried women to married women is 1.23 (95% CI: 1.20, 1.27) for women in MSAs and 1.13 (1.06, 1.21) for women in rural counties.

Model 2: *How does the addition of the Segregation Measures change risk of Preterm Birth for Black and White Women living in Rural Counties in Georgia?*

A basic crude logistic model containing only preterm birth, race, dissimilarity, and isolation was run. The logistic modeling results are shown in Table 10. For this model, holding race and dissimilarity constant, the odds ratio for women in counties with an isolation value that is 1 standard deviation more than the value for women in another county is 1.02 (95% CI: 0.99, 1.04). Similarly, holding race and isolation constant, the odds ratio for women in counties with a dissimilarity value that is 1 standard deviation more than the value for women in another county is 0.99 (95% CI: 0.97, 1.02). Holding race constant, the odds ratio for women in counties with dissimilarity and isolation values that are 1 standard deviation more than the values for these measures for women in another county is 1.01 (95% CI: 0.99, 1.03).

The fully adjusted model for Model 2 added marital status, tobacco use, alcohol use, maternal age, adequacy of prenatal care, neighborhood deprivation index, and percentage black to Crude Model 2. This model has interaction terms for isolation with race and dissimilarity with race. None of the interactions terms for isolation and dissimilarity with the other covariates were found to be significant. After confounding analysis, none of the covariates were dropped due to small changes in precision for the compared models. The results for Model 2 are shown in Table 10.

The odds ratio estimates for Model 2 are in Table 11. The odds ratio for preterm birth comparing white women in a county that has a value for isolation that is 1 standard deviation more than the value for white women in the comparison county is 0.95 (95% CI: 0.92, 0.99). The odds ratio for preterm birth for white women in a county that has a value for dissimilarity that is 1 standard deviation more than the value for white women in the comparison county is 1.03 (95% CI: 1.00, 1.07). The odds ratio for preterm birth for white women in a county that has values for dissimilarity and isolation that are 1 standard deviation more than the values for white women in the comparison county is 0.98 (95% CI: 0.95, 1.01).

The comparison of black women in a county that has a value for isolation that is 1 standard deviation more than the value for isolation for black women in a comparison county results in an odds ratio of 1.06 (95% CI: 1.01, 1.11). The odds ratio for preterm birth for black women in a county that has a value for dissimilarity that is 1 standard deviation more than the value of dissimilarity for black women in the comparison county is 0.97 (95% CI: 0.93, 1.02). The odds ratio for preterm birth for black women in a county that has values for dissimilarity and isolation that are 1 standard deviation more than the values for dissimilarity and isolation for black women in the comparison county is 1.03 (95% CI: 0.99, 1.07).

In this model, the largest disparity is apparent when comparing across racial groups within the rural cohort. When comparing black women to white women and setting dissimilarity equal to 0.6 and isolation equal to 0.6, the odds ratio is 1.76 (95% CI: 1.61, 1.92). When comparing black women to white women and setting dissimilarity equal to 0.6 and isolation equal to 0.3, the odds ratio is 1.35 (95% CI: 1.14, 1.59). When comparing black women to white women and setting dissimilarity equal to 0.3 and isolation equal to 0.6, the odds ratio is 2.15 (95% CI: 1.77, 2.61). When comparing black women to white women and setting dissimilarity equal to 0.3 and isolation equal to 0.3, the odds ratio is 1.64 (95% CI: 1.44, 1.88). Odds ratios are shown in Table 12.

Discussion

The effect of MSA/Rural residence on preterm birth is apparent in Georgia. Model 1 indicates that black women with otherwise equivalent risk profiles that live in the rural counties are at an increased risk compared to both their white neighbors in rural counties and black women in the MSAs. The interaction of race with MSA status results in a different risk for white women in Georgia; white women in the MSAs appear to be at a slightly higher risk of preterm birth compared to white women in the rural counties. The interaction of MSA/Rural Residence with race is an interesting effect of residence and has not previously been analyzed in the literature. In their study of the differences in preterm birth rates in isolated rural towns, small rural towns, large rural cities, and urban cities, Hillemeier et al found no difference between the risk in preterm birth in the isolated towns and the urban cities (11). The results that show no difference between isolated towns and urban cities might have a different effect if these authors included interaction of race with their urban/rural designations.

We also found a significant interaction of MSA/Rural Residence with marital status. This interaction indicates that the beneficial effect of marriage on the risk of preterm birth is different between urban and rural areas. In urban areas, the difference in risk of preterm birth between married and unmarried women is larger than a similar comparison of married and unmarried mothers in rural areas. As a protective effect, marriage can bring stability, financial security, and support to a woman during her pregnancy. Perhaps a greater community bond and system of support exists in rural areas, and this bond may help to curb the effect of marital status on preterm birth. As a new finding, this is an effect that should be explored further.

For Model 2, we cannot definitively make any statistical predictions about the effect of dissimilarity among rural women, but the effect of dissimilarity while holding isolation constant is nearly significant for white women and may show an increased risk of preterm birth. Dissimilarity is a measure of unevenness and compares the racial composition of neighborhood level composition (in this case, the 500-meter radius) to the overall MSA or rural county composition to approximate the proportion of blacks that would have to move to a different block group to produce a more even racial distribution across all block groups.

For isolation, however, as isolation increases and dissimilarity is held constant, we see an increase in the risk of preterm birth for black women in the rural cohort. For white women, the risk of preterm birth actually decreases when we control for dissimilarity and increase isolation. Isolation is a measure that indicates the probability that any two randomly drawn individuals in a given neighborhood are both black.

Previous studies of racial segregation have restricted analysis to urban areas. For urban areas, the effects of both isolation and dissimilarity on preterm birth rates are demonstrated in the literature. Kramer et al found a similar effect of dissimilarity and isolation in their study of very preterm birth in MSAs. For isolation, the authors found an increased risk among black women of very preterm birth in the MSAs with higher isolation. For dissimilarity, the authors did find a lower risk of very preterm birth in MSAs with higher dissimilarity, conditional on the degree of isolation in the MSA (18). Bell et al also found similar results for increasing isolation. In their study of black mothers, these authors found that higher isolation was associated with higher rates of prematurity (21). The findings in this study indicate that racial segregation, specifically isolation, may have the same effect on preterm birth in rural counties as it does in MSAs. The effect of dissimilarity while holding isolation constant is not replicated in the rural areas.

While residential location and segregation significantly adjust the risk of preterm birth for mothers in Georgia, it is clear from this data that maternal characteristics such as race, marital status, and age and neighborhood characteristics play a large role in a woman's individual risk for preterm birth. While there is still unexplained variance in the model, each of these variables are important for understanding disparities in preterm birth.

Strengths and Weaknesses

This study attempts to address the issue of preterm birth risk in several stratified groups. The comparison of risk of preterm birth for urban and rural mothers is a relatively novel approach and is not well addressed in the literature. Of the studies that do address this issue, the cohorts are restricted to small regions or a single comparison of urban or rural. Using a large cohort of births from 1998 to 2002, we are able to address the issue of small sample size and include large metropolitan areas, smaller but still urbanized micropolitan areas, and rural counties.

While this study is beneficial for furthering the understanding of rural and urban differences as well as the effect of two segregation measures on the risk of preterm birth, there are a number of weaknesses. Preterm birth is a measure that relies on the accuracy of coding for gestational age and as a result is a measure that is inherently subject to misclassification bias. The reliability of methods used to determine true gestational length is questionable, so infants near the 37-week divide could be inappropriately sorted into the wrong category for preterm birth. Another form of bias could occur in the assumption that missing values are occurring at random in our dataset. If there is a trend to some of the missing values, bias is likely in this study. For example, if most of the deleted observations are preterm births from rural counties, the observed odds ratios comparing women in rural counties to women in MSAs will be biased towards the null and the models will underestimate the effect. An opposite effect, however, could occur if the observations were non-preterm births from rural counties. A few known predictors of preterm birth were not included in analysis, such as mother's educational attainment, mother's insurance payor, and birth parity. The inclusion of this individual level information could contribute further to an improved understanding of the risk of preterm birth for various groups in Georgia.

Future Directions

To further address the study question, it would be beneficial to run a correlated logistic model with the individual counties as potential random effects in the models. With the methods used, we are already taking into account a likeness between women within the same MSA or rural county. Adding the random effect of MSA/Rural Residence to the model could provide some additional information that will further illustrate the differences between MSA and rural counties. This analysis could also provide more specific information for individual counties or metropolitan areas. In addition to a longitudinal analysis, an analysis that evaluates the risk of other poor birth outcomes could further illustrate the effects of urban or rural residence as well as segregation on these similar health outcomes in rural areas. As a new method for analysis of rural health outcomes, the application of segregation measures is not well understood in the literature. A thorough analysis of neighborhood scale is needed to determine the most appropriate input for calculating each of the measures of segregation. Lastly, this study illustrates the effects of urban and rural residence on preterm birth within the state of Georgia. These results may be generalizeable to other southern states that have similar racial and industrial histories but a comparison of these effects is needed in other US regions in order to understand if they are unique to Georgia.

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Table 1. Descriptive statistics for categorical variables stratified by residence in a MSA or rural county

Categorical Variables	MSA Residents N= 454,571 Total	(Percent)	MSA Residents N=47,516 Total PTB	(Percent)	Rural County Residents N= 49,070 Total	(Percent)	Rural County Residents N=5,685 Total PTB	(Percent)
Preterm								
Preterm	47,516	(10.5)	47,516	(100.0)	5,685	(11.6)	5,685	(100.0)
Not Preterm	407,055	(89.6)			43,385	(88.4)		
Used Tobacco?								
Yes	41,922	(9.2)	5,357	(11.3)	7,036	(14.3)	961	(16.9)
No	412,649	(90.8)	42,159	(88.7)	42,034	(85.7)	4,724	(83.1)
Used Alcohol?								
Yes	3,665	(0.8)	462	(1.0)	259	(0.5)	51	(0.9)
No	450,906	(99.2)	47,054	(99.0)	48,811	(99.5)	5,634	(99.1)
Married?								
Yes	169,116	(37.2)	22,079	(46.5)	20,793	(42.4)	2,838	(49.9)
No	285,455	(62.8)	25,437	(53.5)	28,277	(57.6)	2,847	(50.1)
Prenatal Care								
Inadequate	39,301	(8.7)	5,328	(11.2)	5,380	(11.0)	758	(13.3)
Intermediate	54,284	(11.9)	2,107	(4.4)	6,404	(13.1)	282	(5.0)
Adequate	203,642	(44.8)	6,518	(13.7)	18,794	(38.3)	762	(13.4)
Adequate Plus	157,344	(34.6)	33,563	(70.6)	18,492	(37.7)	3,883	(68.3)
Age								
<20 Years	61,576	(13.6)	7,758	(16.3)	9,762	(19.9)	1,254	(22.1)
20-34 Years	338,564	(74.5)	33,600	(70.7)	36,006	(73.4)	3,949	(69.5)
> 34 Years	54,431	(12.0)	6,158	(13.0)	3,302	(6.7)	482	(8.5)

Table 2. Descriptive statistics for MSA residents stratified by race

Categorical Variables	White Mothers N= 279,965 Total	(Percent)	N=24,075 Total PTB	(Percent)	Black Mothers N=174,606 Total	(Percent)	N=23,441 Total PTB	(Percent)
Preterm								
Preterm	24,075	(8.6)	24,075	(100.0)	23,441	(13.4)	23,441	(100.0)
Not Preterm	255,890	(91.4)			151,165	(86.6)		
Used Tobacco?								
Yes	34,159	(12.2)	3,905	(16.2)	7,763	(4.4)	1,452	(6.2)
No	245,806	(87.8)	20,170	(83.8)	166,843	(95.6)	21,989	(93.8)
Used Alcohol?								
Yes	2,443	(0.9)	194	(0.8)	1,222	(0.7)	268	(1.1)
No	277,522	(99.1)	23,881	(99.2)	173,384	(99.3)	23,173	(98.9)
Married?								
Yes	54,758	(19.6)	5,759	(23.9)	114,358	(65.5)	16,320	(69.6)
No	225,207	(80.4)	18,316	(76.1)	60,248	(34.5)	7,121	(30.4)
Prenatal Care								
Inadequate	15,298	(5.5)	1,526	(6.3)	24,003	(13.7)	3,802	(16.2)
Intermediate	32,424	(11.6)	860	(3.6)	21,860	(12.5)	1,247	(5.3)
Adequate	133,455	(47.7)	3,199	(13.3)	70,187	(40.2)	3,319	(14.2)
Adequate Plus	98,788	(35.3)	18,490	(76.8)	58,556	(33.5)	15,073	(64.3)
Age								
<20 Years	28,583	(10.2)	2,949	(12.2)	32,993	(18.9)	4,809	(20.5)
20-34 Years	213,200	(76.2)	17,518	(72.8)	125,364	(71.8)	16,082	(68.6)
> 34 Years	38,182	(13.6)	3,608	(15.0)	16,249	(9.3)	2,550	(10.9)

Table 3. Descriptive statistics for rural county residents stratified by race

Categorical Variables	White Mothers				Black Mothers			
	N= 33,352 Total (Percent)		N=3,286 Total PTB (Percent)		N= 15,718 Total (Percent)		N= 2,399 Total PTB (Percent)	
Preterm								
Preterm	3,286	(9.9)	3,286	(100.0)	2,399	(15.3)	2,399	(100.0)
Not Preterm	30,066	(90.1)			13,319	(84.7)		
Used Tobacco?								
Yes	6,236	(18.7)	795	(24.2)	800	(5.1)	166	(6.9)
No	27,116	(81.3)	2,491	(75.8)	14,918	(94.9)	2,233	(93.1)
Used Alcohol?								
Yes	135	(0.4)	15	(0.5)	124	(0.8)	36	(1.5)
No	33,217	(99.6)	3,271	(99.5)	15,594	(99.2)	2,363	(98.5)
Married?								
Yes	8,498	(25.5)	930	(28.3)	12,295	(78.2)	1,908	(79.5)
No	24,854	(74.5)	2,356	(71.7)	3,423	(21.8)	491	(20.5)
Prenatal Care								
Inadequate	2,445	(7.3)	285	(8.7)	2,935	(18.7)	473	(19.7)
Intermediate	4,067	(12.2)	139	(4.2)	2,337	(14.9)	143	(6.0)
Adequate	13,472	(40.4)	416	(12.7)	5,322	(33.9)	346	(14.4)
Adequate Plus	13,368	(40.1)	2,446	(74.4)	5,124	(32.6)	1,437	(59.9)
Age								
<20 Years	5,501	(16.5)	592	(18.0)	4,261	(27.1)	662	(27.6)
20-34 Years	25,481	(76.4)	2,396	(72.9)	10,525	(67.0)	1,553	(64.7)
> 34 Years	2,370	(7.1)	298	(9.1)	932	(5.9)	184	(7.7)

Table 4. Descriptive statistics for continuous variables stratified by residence in a MSA or rural county

	MSA Residents N=454,571		Rural County Residents N=49,070	
Continuous Variables	Mean	Std Dev	Mean	Std Dev
Dissimilarity	0.62	0.09	0.56	0.13
Isolation	0.64	0.11	0.54	0.17
Percent Black	0.33	0.31	0.28	0.22
NDI	-0.25	0.94	0.24	0.52

Table 5. Descriptive statistics for continuous variables restricted to preterm births and stratified by residence in a MSA or rural county

	MSA Residents N=47,516		Rural County Residents N=5,685	
Continuous Variables	Mean	Std Dev	Mean	Std Dev
Dissimilarity	0.62	0.08	0.55	0.14
Isolation	0.64	0.10	0.53	0.17
Percent Black	0.38	0.33	0.31	0.22
NDI	-0.10	1.00	0.29	0.52

Table 6. Descriptive statistics for continuous variables stratified by residence in a MSA or rural county and race

	MSA Residents				Rural County Residents			
	White Mothers		Black Mothers		White Mothers		Black Mothers	
	N=279,965		N=174,606		N=33,352		N=15,718	
Continuous Variables	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Dissimilarity	0.62	0.09	0.62	0.08	0.58	0.13	0.52	0.13
Isolation	0.62	0.13	0.66	0.07	0.56	0.18	0.49	0.16
Percent Black	0.17	0.17	0.58	0.32	0.20	0.20	0.46	0.17
NDI	-0.60	0.66	0.30	1.05	0.08	0.48	0.58	0.44

Table 7. Descriptive statistics for continuous variables restricted to preterm births stratified by residence in a MSA or rural county and race

	MSA Residents				Rural County Residents			
	White Mothers		Black Mothers		White Mothers		Black Mothers	
	N=24,075		N=23,441		N=3,286		N=2,399	
Continuous Variables	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Dissimilarity	0.62	0.09	0.62	0.08	0.58	0.13	0.52	0.13
Isolation	0.63	0.12	0.66	0.07	0.56	0.18	0.50	0.16
Percent Black	0.17	0.17	0.59	0.31	0.20	0.19	0.46	0.17
NDI	-0.55	0.68	0.37	1.06	0.09	0.48	0.58	0.44

Table 8. Logistic regression results for Crude Model 1 and Model 1

	Crude Model 1		Model 1	
	Beta (SE)		Beta (SE)	
Intercept	-2.21	(0.01)**	3.66	(0.02)**
Exposure Variables				
MSA/Rural Residence				
MSA	Ref		Ref	
Rural County	-0.15	(0.02)**	0.01	(-0.02)
Maternal Characteristics				
Race				
White	Ref		Ref	
Black	0.50	(0.01)**	0.55	(0.04)**
Married?				
No			0.13	(0.03)*
Yes			Ref	
Used Tobacco?				
No			Ref	
Yes			0.37	(0.02)**
Used Alcohol?				
No			Ref	
Yes			0.13	(0.05)*
Mother's Age				
<20 Years			0.11	(0.01)**
20-34 Years			Ref	
> 34 Years			0.19	(0.02)**
Prenatal Care				
Inadequate			1.31	(0.02)**
Intermediate			0.12	(0.02)**
Adequate			Ref	
Adequate Plus			2.08	(0.01)**
Neighborhood Characteristics				
NDI			0.05	(0.01)**
Percent Black			0.06	(0.03)*
Interaction Terms				
MSA*Race			0.14	(0.04)**
MSA*Marital Status			0.09	(0.04)*

* $p < 0.05$
** $p < 0.0001$

Table 9. Odds ratio estimates for Model 1

Odds Ratio Description	Married OR (95% CI)		Not Married OR (95% CI)	
Black Mothers V. White Mothers, in MSAs	1.51	(1.47, 1.55)	1.51	(1.47, 1.55)
Black Mothers V. White Mothers, in rural counties	1.74	(1.62, 1.86)	1.74	(1.62, 1.86)
Rural county V. MSA, Black Mothers	1.07	(1.02, 1.13)	1.17	(1.08, 1.26)
Rural county V. MSA, White Mothers	0.93	(0.87, 0.99)	1.01	(0.97, 1.06)

Table 10. Logistic regression results for Crude Model 2 and Model 2

	Crude Model 2		Model 2	
	Beta (SE)		Beta (SE)	
Intercept	-2.20	(0.03)**	-3.52	(0.11)**
Exposure Variables				
Continuous Dissimilarity	-0.31	(0.07)**	0.43	(0.13)*
Continuous Isolation	0.30	(0.05)**	0.11	(0.04)*
Maternal Characteristics				
Race				
White	Ref		Ref	
Black	0.49	(0.01)**	1.15	(0.06)**
Married?				
No			0.02	(0.07)
Yes			Ref	
Used Tobacco?				
No			Ref	
Yes			1.89	(0.04)**
Used Alcohol?				
No			Ref	
Yes			0.47	(0.04)**
Mother's Age				
<20 Years			0.45	(0.17)*
20-34 Years			Ref	
> 34 Years			0.13	(0.04)*
Prenatal Care				
Inadequate			0.30	(0.06)**
Intermediate			0.35	(0.2)
Adequate			Ref	
Adequate Plus			-0.41	(0.15)*
Neighborhood Characteristics				
NDI			0.10	(0.05)
Percent Black			-0.01	(0.13)
Interaction Terms				
Dissimilarity*Race			-0.67	(0.33)*
Isolation*Race			0.89	(0.25)*

* $p < 0.05$
** $p < 0.0001$

Table 11. Odds ratio estimates comparing changes in isolation and dissimilarity for black and white women in rural Georgia counties (Model 2).

	White Residents		Black Residents	
Odds Ratio Description	OR	(95% CI)	OR	(95% CI)
Comparison of women with a standard deviation difference in Isolation	0.95	(0.92, 0.99)	1.06	(1.01, 1.11)
Comparison of women with a standard deviation difference in Dissimilarity	1.03	(1.00, 1.07)	0.97	(0.93, 1.02)
Comparison of women with a standard deviation difference in Dissimilarity and a standard deviation difference in Isolation	0.98	(0.95, 1.01)	1.03	(0.99, 1.07)

Table 12. Odds ratio estimates for comparing black and white mothers in rural Georgia counties (Model 2).

	Rural Residents	
Odds Ratio Description	OR	(95% CI)
Black V. White, D=0.6 and I=0.6	1.76	(1.61, 1.92)
Black V. White, D=0.6 and I=0.3	1.35	(1.14, 1.59)
Black V. White, D=0.3 and I=0.6	2.15	(1.77, 2.61)
Black V. White, D=0.3 and I=0.3	1.64	(1.44, 1.88)