Metropolitan Racial Residential Segregation and Cardiovascular Mortality: Exploring Pathways

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ABSTRACT   *Racial residential segregation has been associated with an increased risk for heart disease and stroke deaths. However, there has been little research into the role that candidate mediating pathways may play in the relationship between segregation and heart disease or stroke deaths. In this study, we examined the relationship between metropolitan statistical area (MSA)-level segregation and heart disease and stroke mortality rates, by age and race, and also estimated the effects of various educational, economic, social, and health-care indicators (which we refer to as pathways) on this relationship. We used Poisson mixed models to assess the relationship between the isolation index in 265 U.S. MSAs and county-level (heart disease, stroke) mortality rates. All models were stratified by race (non-Hispanic black, non-Hispanic white), age group (35–64 years, ≥65 years), and cause of death (heart disease, stroke). We included each potential pathway in the model separately to evaluate its effect on the segregation–mortality association. Among blacks, segregation was positively associated with heart disease mortality rates in both age groups but only with stroke mortality rates in the older age group. Among whites, segregation was marginally associated with heart disease mortality rates in the younger age group and was positively associated with heart disease mortality rates in the older age group. Three of the potential pathways we explored attenuated relationships between segregation and mortality rates among both blacks and whites: percentage of female-headed households, percentage of residents living in poverty, and median household income. Because the percentage of female-headed households can be seen as a proxy for the extent of social disorganization, our finding that it has the greatest attenuating effect on the relationship between racial segregation and heart disease and stroke mortality rates suggests that social disorganization may play a strong role in the elevated rates of heart disease and stroke found in racially segregated metropolitan areas.*

KEYWORDS   *Residential segregation, Racial segregation, Metropolitan, Heart disease, Stroke, Cardiovascular disease, Social context, Economic context*

INTRODUCTION

Heart disease and stroke are among the leading causes of death in the U.S.A,[1] and yet there are substantial race- and place-based variations in heart disease and stroke mortality rates which have been partially attributed to various social structures and processes including residential segregation.[2–4] Williams and Collins[5] proposed a

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conceptual framework for understanding how residential segregation—and associated spatial concentration of poverty—acts as a fundamental determinant of population health. Williams and Collins suggest that wide-ranging health patterns emerge as a result of the manner in which segregation spatially and socially patterns poverty, economic and educational opportunity, and social order or disorder. Metropolitan areas with high black–white residential segregation are characterized by isolation of black residents from quality schools, employment, and healthy environments when compared to white residents,[5–10] as well as greater exposure to spatially concentrated poverty, violent crime, and related manifestations of social disorganization.[11] Segregation may therefore fundamentally influence race–place variation in health outcomes such as heart disease and stroke mortality because of the associated health consequences of differential geographies of opportunity and distribution of exposures.[5,12] Specifically, metropolitan segregation could racially pattern access to preventive health care, healthful food environments, green space, and exposure to stress from discrimination, disordered residential environments, and fear of violence.

Although the results of several studies have shown an association between racial residential segregation and cardiovascular health,[9,13–15] few studies have explicitly tested the hypothesized contextual processes which may mediate this association. In one study that did do so, Collins and Williams[9] found that two socioeconomic factors (poverty status and occupational status) substantially attenuated a positive association between segregation and heart disease mortality rates among black men; this finding suggests that these factors may serve as pathways between segregation and heart disease mortality. Other study findings have shown variations in the relationship between segregation and cardiovascular diseases by age and race, as well as variations by age, race, and place in the extent to which certain variables (including poverty) may mediate this relationship. These findings suggest that further examination of suspected mediating factors is warranted.[2,3,15] Williams and Collins'[5] examination of segregation as a fundamental cause of racial differences in health highlights the complexities of this construct; segregation operates at multiple geographic levels and through multiple mechanisms that lead to living environments that are deleterious to health; these environments often limit access to quality education, job opportunities, political power, quality health care, and social order. Using this model as a basis for our study design, we attempted to determine the extent to which black–white residential segregation in metropolitan areas was associated with heart disease and stroke mortality rates, as well as the extent to which these relationships were affected by ten variables proxying the county-level economic, social, and health-care environments.

METHODS

Study Sample
Our study sample consisted of non-Hispanic black and non-Hispanic white residents of the 265 (of a total of 374) U.S. metropolitan statistical areas (MSAs) with at least 5,000 non-Hispanic black residents in 2010. As defined by the U.S. Census Bureau, an MSA is an area consisting of one or more counties with a core urban area of at least 50,000 residents *or* a Census Bureau-defined "urbanized area" with a total population of at least 100,000 residents (75,000 in New England). The 265 MSAs in our study contained a total of 935 counties.

Mortality Data

County-level death records were obtained from the National Center for Health Statistics (NCHS) National Vital Statistics Surveillance System for the 2-year time period January 1, 2008–December 31, 2009. We abstracted data for non-Hispanic white and non-Hispanic black decedents aged 35 years or older whose underlying cause of death was heart disease or stroke as indicated by the following codes from the *International Classification of Diseases*, 10th edition (ICD-10): I00–I09, I11, I13, or I20–I51 (heart disease) or I60–I69 (stroke). To calculate age-adjusted death rates for heart disease and stroke, we divided county-level death counts by county-level 2-year NCHS intercensal population estimates for 2008 and 2009.

Residential Segregation

Racial residential segregation in each MSA was based on the black isolation index,[16] which reflects the population-weighted average proportion of black residents in all census tracts within each MSA. This index approximates the probability that two residents randomly selected out of a residential area are both black and can be used to indicate the extent to which black residents are isolated from white residents within an MSA and the probability that a black resident will live in a predominantly black neighborhood. The index ranges from 0 to 1 with higher values indicating greater racial residential segregation and thus a greater probability that blacks and whites are distributed in separate neighborhoods throughout the metropolitan environment. Census tracts were used as the subunit to calculate the isolation index for each MSA. We used the following equation to calculate the isolation index among blacks:

$$_xP^*_x = \sum_{i=1}^{n}[x_i/X][x_i/t_i],$$

where x_i represents the number of blacks in a census tract i, n represents the total number of census tracts within an MSA, X represents the total number of blacks in the MSA, and t_i represents the total population of the census tract. We will refer to the isolation index as "segregation index."

County-Level Pathway Variables

Pathway variables (hereafter referred to as "potential pathways") represent area-based characteristics which describe access to education, economic, social, employment, safety, and health-care resources.[5–11] We included the following variables as proxies: percentage of adults without a high school diploma represented educational context; percentage of individuals living in poverty, percentage of adults who were unemployed, and median household income represented economic context; percentage of female-headed households and violent crime clearance rate represented social context; percentage of residents without health insurance, number of primary care physicians per 1,000 population, number of hospitals per 1,000 population, and preventable hospitalization rate represented health-care context.

Percentage of adults without a high school diploma, percentage of uninsured adults, and percentage of female-headed households were from the 2006 to 2010 American Community Survey 5-year estimates. Poverty and median household income data were from the 2010 U.S. Census Bureau's Small Area Income and Poverty Estimates. Percentage of unemployed adults was from the 2010 Bureau of Labor Statistics (BLS) data. Violent crime clearance rates (which represent the percentage of violent crimes resolved) were from the 2008 Uniform Crime Reporting Program of the Federal Bureau of Investigation via the Inter-University Consortium for Political and Social Research.[17] Number of primary care physicians and number of hospitals per 1,000 population were

from the 2008 Area Resource File. Preventable hospitalization rates (the number of hospitalizations for ambulatory care-sensitive conditions per 1,000 Medicare beneficiaries) were from the 2003–2007 Dartmouth Atlas of Health Care.[18]

Statistical Analysis

We used Poisson mixed effects models to examine the relationship between segregation and county-specific heart disease or stroke death rates. Death rates and potential pathway variables were measured at the county level, and the segregation index was measured at the MSA level. To account for correlation in county-level characteristics among counties within the same MSA and unmeasured MSA-level sources of variation, we included MSA as a random effect in all models.

Using the Poisson mixed model, we first calculated interquartile rate ratios and 95 % confidence intervals of heart disease and stroke mortality rates for each of the potential pathway variables. Because preliminary regression models showed that age and race modified the relationship between the segregation index and mortality rates, we stratified subsequent analyses by age group (35–64 vs. ≥65 years) and race (blacks vs. whites). All rates were age-adjusted. We used model 1 to assess the relationship between segregation and mortality rates while controlling for sex. In subsequent models, we added each potential pathway variable to determine its effect on this relationship. We estimated mortality rate ratios for MSAs at the 75th percentile of segregation compared to those at the 25th percentile of segregation.

Counties were excluded from the model if information was not available for a potential pathway variable. This occurred in the case of models that included violent crime clearance rates and preventable hospitalization rates, where 24 and 12 counties, respectively, were excluded.

RESULTS

The distribution of the segregation index and potential pathway variables are shown in (Table 1). Our results showed that all potential pathway variables were statistically significantly associated with both heart disease and stroke mortality rates except for number of primary care physicians per 1,000 population (which was associated with neither) (Table 2) and the violent crime clearance rate (which was associated only with the stroke mortality rate) (Table 2). Positive associations were observed for percent female-headed households, percent less than high school education, percent poverty, percent unemployed, percent uninsured, hospitals per 1,000, and preventable hospitalizations rate. Inverse associations were observed for median household income and crime clearance rate.

Figures 1 through 4 summarize results from the Poisson models, stratified by race, age, and cause of death. Each figure shows rate ratios of heart disease or stroke death rates for residents of MSAs with segregation at the 75th percentile as compared to the 25th percentile, controlling for gender alone (model 1) and for each potential pathway variable in the model separately (models 2–11).

Among blacks aged 35–64, segregation was positively associated with both heart disease mortality rates (rate ratio (RR)=1.19; 95 % confidence interval (CI)=1.11, 1.27) and stroke mortality rates (RR=1.11; 95 % CI=1.02, 1.22) (Fig. 1a, b). However, when we controlled for percentage of female-headed households, the association between segregation and both heart disease and stroke death rates was attenuated (12 and 10 %, respectively) such that both segregation–mortality associations were no longer statistically significant. Controlling for percentage of adults in poverty and median household income also attenuated the association between segregation and stroke mortality rates among blacks aged 35–64 years, though by a smaller amount (6.3 and 5.4 %, respectively). Among blacks

TABLE 1 Distribution and interquartile ranges of counties and metropolitan statistical areas

	Number	25th percentile	Median	75th percentile
Segregation[a]	265	0.2	0.4	0.5
% Female-headed household[a]	935	9.6	11.6	13.8
% Less than high school[a]	935	10.6	13.9	18.8
% Poverty[b]	935	10.6	14.3	18.2
Median Household Income[b]	935	41,462	47,566	56,628
% Unemployment[c]	935	7.8	9.2	10.7
% Uninsured[a]	935	12.7	16.1	19.8
Violent crime clearance rate (% crimes resolved)[d]	911	39.7	55.3	69.3
Primary care physicians per 1,000 population[e]	935	0.5	0.9	1.4
Hospitals per 1,000 population[e]	935	0.008	0.02	0.03
Preventable hospitalization rate[f]	923	57.5	68.9	82.9

Note: Segregation is defined by the isolation index and is calculated at the MSA level; the remaining variables represent county-level percentages and rates

[a]American Community Survey, 2006–2010; [b]Small Area Income Poverty Estimates, 2010; [c]Bureau of Labor Statistics, 2010; [d]Uniform Crime Reporting, 2008; [e]Area Resource File, 2008; [f]Dartmouth Atlas of Health Care, 2003–2007

aged ≥65 years, segregation was also positively associated with heart disease death rates (RR=1.13; 95 % CI=1.08, 1.19); however, it was not associated with stroke death rates (Figs. 2a, b). The relationship between segregation and heart disease death rates remained significant even after we adjusted for percentage of female-headed households.

Among whites aged 35–64 years, segregation had a marginally significant relationship with heart disease death rates (RR=1.06; 95 % CI=1.00, 1.12) but was not associated with stroke death rates (Fig. 3a, b). Percentage of female-headed households and the preventable hospitalization rate most strongly attenuated the relationship between segregation and heart disease death rates in this group. Among whites aged ≥65 years, segregation was positively associated with heart disease death rates (RR=1.06; 95 % CI=1.02, 1.10) but not with stroke death rates (Fig. 4a, b). The association between segregation and heart disease death rates was attenuated to null when percentage female-headed households and preventable hospitalizations rate were added independently to the model.

DISCUSSION

We found that segregation at the MSA level was positively associated with heart disease mortality rates among blacks aged 35 or older and with stroke mortality rates among blacks aged 35–64. Among whites, we found a marginally significant relationship between segregation and heart disease mortality rates among those aged 35–64 and a positive association between segregation and heart disease mortality rates among those aged ≥65 years. These statistically significant associations were most strongly attenuated by adjustment for percentage of female-headed households.

Our findings concerning the relationship between MSA racial residential segregation and heart disease death rates were mostly consistent with results from a previous study by Collins and Williams,[9] which showed that segregation in 107 MSAs during 1990 was

TABLE 2   Interquartile rate ratios of heart disease and stroke death rates by county-level contextual variables, 265 metropolitan statistical areas, 2007–2008

	Heart disease rate ratios		Stroke rate ratios	
	Rate ratio (75th to 25th percentile)	(95 % CI)	Rate ratio (75th to 25th percentile)	(95 % CI)
% Female-headed household[a]	1.18	(1.13, 1.22)	1.11	(1.06, 1.16)
% Less than high school[a]	1.27	(1.21, 1.34)	1.17	(1.11, 1.24)
% Poverty[b]	1.25	(1.19, 1.31)	1.20	(1.14, 1.27)
Median household income[b]	0.81	(0.77,0.85)	0.82	(0.78, 0.87)
% Unemployment[c]	1.14	(1.10, 1.19)	1.09	(1.04, 1.15)
% Uninsured[a]	1.13	(1.07, 1.18)	1.11	(1.06, 1.16)
Violent crime clearance rate (% crimes resolved)[d]	0.92	(0.87, 0.97)	1.00	(0.94, 1.05)
Primary care physicians per 1,000 population[e]	0.97	(0.93, 1.01)	0.96	(0.92, 1.01)
Hospitals per 1,000 population[e]	1.11	(1.06, 1.17)	1.13	(1.08, 1.19)
Preventable hospitalization rate[f]	1.22	(1.15, 1.29)	1.10	(1.04, 1.17)

[a]American Community Survey, 2006–2010
[b]Small Area Income Poverty Estimates, 2010
[c]Bureau of Labor Statistics, 2010;
[d]Uniform Crime Reporting, 2008
[e]Area Resource File, 2008
[f]Dartmouth Atlas of Health Care, 2003–2007

positively associated with heart disease mortality rates among black men and women aged 15–64 who resided in those MSAs.[9] Adjustment for socioeconomic deprivation reduced
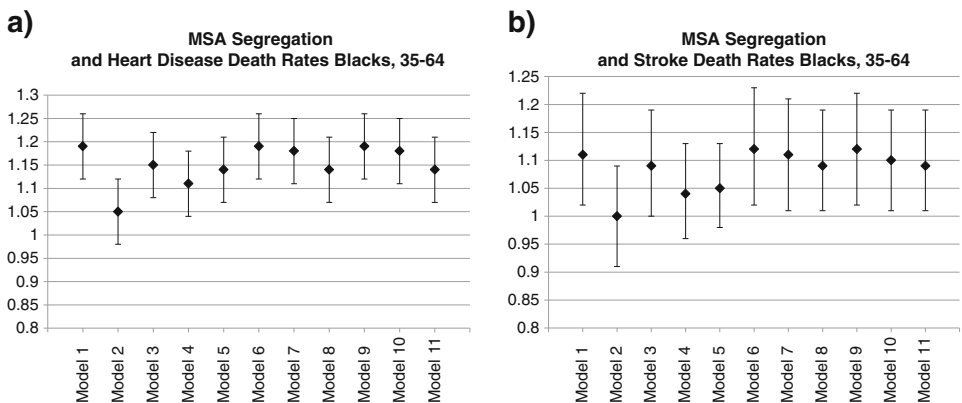

FIGURE 1.   Interquartile rate ratios of segregation and heart disease (**a**) and stroke death rates (**b**) controlling for potential pathways, blacks, aged 35–64 years. Model 1 = MSA Isolation, Gender. Model 2=Model 1 + %Female-headed households. Model 3=Model 1+ % Less than high school. Model 4=Model 1+%Poverty. Model 5=Model 1+Median Household Income. Model 6=Model 1+%Unemployment. Model 7=Model 1+%Uninsured. Model 8=Model 1+Violent Crime Clearance rate. Model 9=Model 1+#Primary care physicians per 1,000 population. Model 10=Model 1+# Hospitals per 1,000 population. Model 11=Model 1+Preventable hospitalization rate.
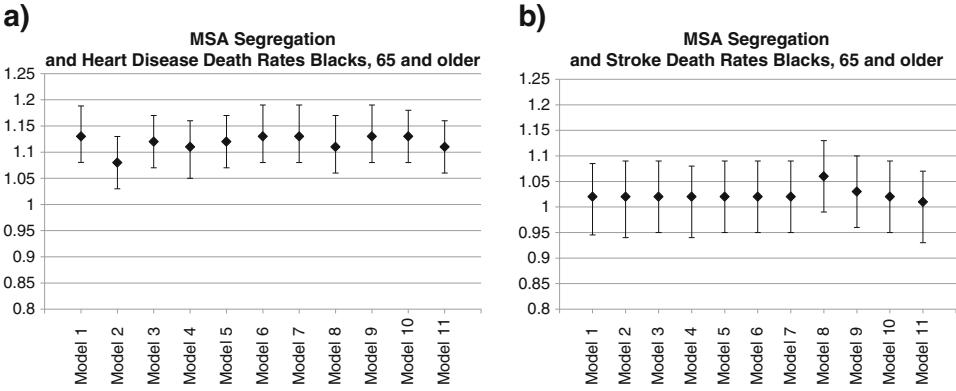
FIGURE 2. Interquartile rate ratios of segregation and heart disease (**a**) and stroke death rates (**b**) controlling for potential pathways, blacks, aged 65 years and older. Model 1 = MSA Isolation, Gender. Model 2=Model 1 + %Female-headed households. Model 3=Model 1+ % Less than high school. Model 4=Model 1+%Poverty. Model 5=Model 1+Median Household Income. Model 6=Model 1+%Unemployment. Model 7=Model 1+%Uninsured. Model 8=Model 1+Violent Crime Clearance rate. Model 9=Model 1+#Primary care physicians per 1,000 population. Model 10=Model 1+# Hospitals per 1,000 population. Model 11=Model 1+Preventable hospitalization rate.

this association among black men but not among black women. However, in contrast to our results, their findings showed no significant relationship between segregation and heart disease mortality rates among white men or women. The difference in these findings could be a result of the different time periods involved, the difference in the age range of the two study populations, or the greater number of MSAs in our study.[9] We are not aware of any studies that have examined the association between MSA-level racial residential segregation and stroke mortality rates. Despite the differences in results, this study confirms the association between residential segregation and heart disease mortality
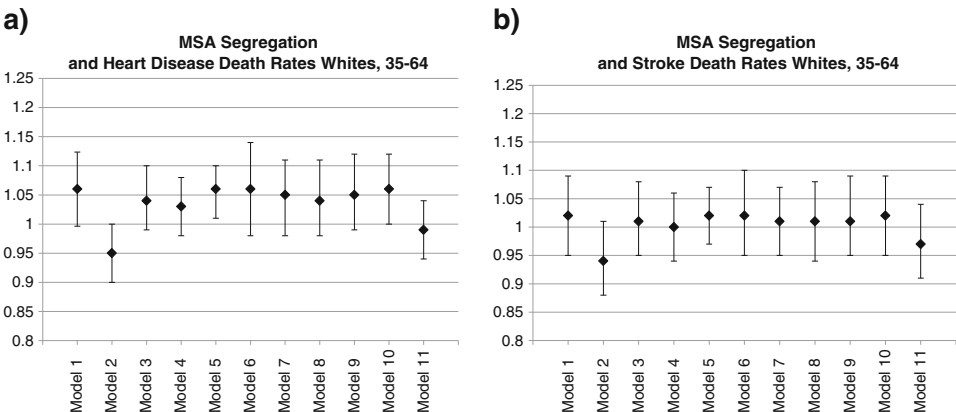

FIGURE 3. Interquartile rate ratios of segregation and heart disease (**a**) and stroke death rates (**b**) controlling for potential pathways, whites, aged 35–64 years. Model 1 = MSA Isolation, Gender. Model 2=Model 1 + %Female-headed households. Model 3=Model 1+ % Less than high school. Model 4=Model 1+%Poverty. Model 5=Model 1+Median Household Income. Model 6=Model 1+%Unemployment. Model 7=Model 1+%Uninsured. Model 8=Model 1+Violent Crime Clearance rate. Model 9=Model 1+#Primary care physicians per 1,000 population. Model 10=Model 1+# Hospitals per 1,000 population. Model 11=Model 1+Preventable hospitalization rate.
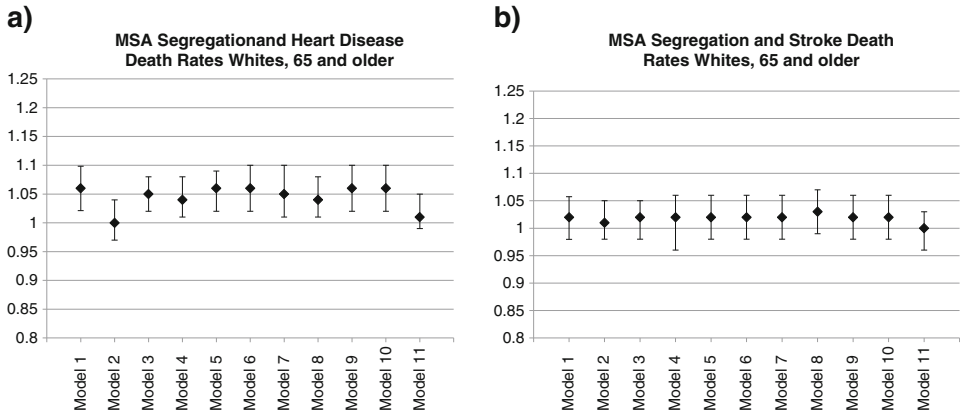
FIGURE 4. Interquartile rate ratios of segregation and heart disease (**a**) and stroke death rates (**b**) controlling for potential pathways, whites, aged 65 years and older. Model 1 = MSA Isolation, Gender. Model 2=Model 1 + %Female-headed households. Model 3=Model 1+ % Less than high school. Model 4=Model 1+%Poverty. Model 5=Model 1+Median Household Income. Model 6=Model 1+%Unemployment. Model 7=Model 1+%Uninsured. Model 8=Model 1+Violent Crime Clearance rate. Model 9=Model 1+#Primary care physicians per 1,000 population. Model 10= Model 1+# Hospitals per 1,000 population. Model 11=Model 1+Preventable hospitalization rate.

rates and introduces the possibility that segregation has an impact on both blacks and whites living in segregated environments.

Our finding that adjustment for area-based percentage of female-headed households most strongly attenuated the association between segregation and both heart disease and stroke mortality rates reflects the complexity of the mechanism by which segregation is associated with heart disease and stroke mortality rates. There are many theories by which this finding can be interpreted. In this study, we based our original hypotheses on the conceptual framework proposed by Williams and Collins[5] in which segregation is a multilevel construct that results in circumstances that perpetuate neighborhoods with high rates of female-headed households and high rates of poverty. Sampson also proposed a consistent theory by showing that the percentage of single-parent, female-headed households in specified areas was positively associated with poverty rates, male incarceration rates, and the ratio of female residents to male residents in those areas.[19] This cluster of community characteristics may be indicative of social disorganization, which has been defined as the inability of communities to effectively enforce social norms, achieve common goals, and advocate for needed services.[20,21] Concentrated social disadvantage and social disorganization have also been positively correlated with rates of property and violent crime.[22] The stress of living in environments void of social support and with high levels of disorder has also been found to have a negative effect on biological processes associated with the cardiovascular health of all residents, not just those with female-headed households.[23,24] In addition, the propensity for local social disorganization has been found to increase in racially segregated metropolitan areas in which black residents reside relatively far from educational or economic opportunities.[25] These findings, in conjunction with our results showing that adjustment for female-headed household substantially attenuated the relationship between segregation and heart disease and stroke mortality rates, suggest that the psychosocial and material environments produced by segregation are important contributors to geographic differences in these rates. However, these findings do not imply that female-headed households alone are

the single pathway by which segregation operates. Poverty, education, employment, and other neighborhood metrics are correlated with female-headed household rates and likely contribute to the concentration of high rates of female-headed households in certain neighborhoods.[5,25]

Our finding that most of the potential pathway variables in our study had minimal or no effect on the relationship between segregation and heart disease or stroke death rates was unexpected because racial residential segregation is hypothesized to operate through the spatial distribution of economic, educational, and health-care-related resources.[5–10]Although this finding does not indicate that the remaining potential pathway variables are not important contributors to the relationship between segregation and cardiovascular mortality rates, it may reflect that the mechanisms of these potential pathways are slightly different than female-headed households or these mechanisms are inadequately measured using census variables alone. For example, within school districts, there can be heterogeneity in quality of education.[26] Because we used percentage of adults without a high school diploma as a proxy for educational context, we were unable to assess school quality. In addition, this measure at the county scale may have masked variation in residents' educational profiles at the neighborhood or other subcounty level, thus limiting our ability to detect the possible effect of educational opportunity on the relationship between segregation and cardiovascular mortality rates. The remaining variables representing potential pathways may similarly vary greatly within a county and differ substantially by race.[27]

Results from previous studies have shown that the relationship between segregation and poor health outcomes is stronger among blacks than among whites. Our finding of an association between segregation and cardiovascular mortality rates among whites as well as among blacks suggests that the process of segregation could be associated with poorer health outcomes for both blacks and whites; the differences in the strength of the association among whites, by age, warrants further investigation.

Study Limitations

Our study had two notable limitations. First, as noted previously, because the study was cross sectional, its results do not necessarily indicate causality. Second, our results may have been affected by individual-and neighborhood-level factors not accounted for in our models, including access to healthy foods, health-care quality, and opportunities for physical activity. Previous study results have shown substantial variation in residents' access to food and alcohol stores, physical activity opportunities, and quality health-care services at the neighborhood or other subcounty level,[28–30] and these variations could be associated with both segregation and health outcomes. Also referred to as the modified area unit problem, the use of data of different spatial scales can lead to different statistical inferences.[31]

Conclusion

This study makes several important contributions to our understanding of the impact of racial residential segregation on health outcomes. It is the first study to systematically compare the associations by race and age group for both heart disease and stroke. Furthermore, it is the first to examine a wide range of potential pathways and to identify social disorganization as a potentially strong pathway of the segregation–heart disease and stroke mortality association. By analyzing counties within MSAs, we measure segregation at the scale of housing and labor

markets,[11,32] while allowing for some degree of within-MSA variation in potential pathway variables and mortality.

This study highlights the importance of testing conceptual frameworks to understand the association between racial residential segregation and heart disease and stroke mortality. Our results suggest that racial residential segregation at the MSA level may operate primarily through disruption of the social structure and social order. However, the results of this study also emphasize the importance of identifying which variables are most relevant as proxies for important processes through which racial residential segregation is associated with heart disease or stroke mortality. Future research should examine these intermediate pathways using both individual and aggregate data at multiple geographic scales to fully understand these place-based variations in cardiovascular outcomes.

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