BLACK-WHITE RESIDENTIAL SEGREGATION AND PHYSICAL ACTIVITY

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This multilevel study explores the potential relationship between Black-White residential segregation and physical activity. It combines data on physical activity from the 2001 Behavioral Risk Factor Surveillance System (BRFSS), a national telephone survey of adults overseen by the Centers for Disease Control and Prevention (CDC), with a measure of racial segregation. Using hierarchical linear modeling, it controlled for age, sex, Black race, Hispanic ethnicity, education, income, and amount of urban sprawl. For each one-point increase in the Black-White Dissimilarity Index (on a 0–100 scale), the modeled risk of being physically inactive increased by .7% (odds ratio [OR]=1.007, 95% confidence interval [CI]=1.003, 1.011). The relationship between segregation and physical activity was similar for Blacks and Whites, though not statistically significant for the Black-only analysis. This finding may imply that the pathway between segregation and ill health includes physical inactivity. (*Ethn Dis*. 2006;16:495–502)

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INTRODUCTION

Physical inactivity contributes to poor health and has been linked to cancer, heart disease, obesity, and death.[1–4] Despite health warnings,[5] almost 26% of adult Americans reported being physically inactive in 2001. Another 29% reported some physical activity but did not meet current guidelines.[6]

Because of its relationship to health, physical inactivity has been extensively studied. The reasons for the persistence of inactivity are complex and may result from an interaction of personal, social, and environmental factors.[7–9] Individual level risk factors, including age, income, sex, Black race, Hispanic ethnicity, and education are all associated with physical activity levels.[10–12] Recently, the "built" environment, the presence or absence of sidewalks, the size and connections of streets, and urban sprawl is seen as influencing activity levels.[13–17] This study examines the role of the social environment in physical activity. While the social environment has many dimensions—income inequality, social capital, etc—one continuing feature of the contemporary US social environment is residential racial segregation, the pattern of distribution of Whites and non-Whites, particularly Blacks, that results in the concentration of people of color in certain neighborhoods. (For the purposes of this article, Black means non-Hispanic Black and White means non-Hispanic White unless otherwise indicated.)

Black-White segregation has declined from its peak shortly after World War II but remains high.[18,19] Despite fair housing laws, improved economic opportunities, and increased suburbanization, African Americans continue to be highly segregated.[20,21] Some observers, focused on Black versus non-Black (including Asian and Hispanic) segregation, have concluded that segregation has had a steeper decline.[22,23] But this finding might be as much a reflection on residential patterns of other non-White groups as on increased integration of Blacks into White neighborhoods.[24] Black-White segregation remains high relative to other groups (Hispanic-White and Asian-White), and it is higher than that historically experienced by other ethnic groups.[25,26]

Recently, the "built" environment, the presence or absence of sidewalks, the size and connections of streets, and urban sprawl is seen as influencing activity levels.[13–17]

A number of hypothesized pathways connect segregation and health outcomes. These pathways suggest segregation is associated with all-cause mortality, increased risk of death from preventable causes, and infant mortality.[27–29] One pathway suggests segregation results in increased stress and discrimination that ultimately affects both health status and mortality.[30,31] Increased stress may reduce the desire to be physically active. Discrimination may prevent people from accessing physical activity sites (gyms, parks, etc).

Another hypothesized pathway between segregation and health focuses on the environmental and neighborhood consequences of segregation. It outlines how segregation is associated with a decline in services such as fire protection

or hospitals.[32,33] Black neighborhoods have had a disproportionate burden of the closing of these services as fiscal problems prompt cutbacks in government budgets. Another environmental risk is that Blacks living in segregated neighborhoods are at increased risk of being exposed to pollution. These environmental injustices lead to poorer health status.[34,35] The result of these two pathways is that segregated Blacks face greater risks with fewer resources to meet these challenges.[36]

Another pathway of effect lies through segregation's impact on socioeconomic status.[37] Segregation affects educational opportunities, income, and wealth accumulation. People with lower educational status and lower incomes are more likely to be physically inactive.[38,39]

This study explores the role of segregation in the risk of physical inactivity. Perhaps continued high levels of segregation influence the ongoing problem of a lack of physical activity among US adults. Segregation's effect on physical activity may be part of the pathway to ill health outlined above.

METHODS

The data source for this study is the Behavioral Risk Factor Surveillance System (BRFSS), a national telephone survey of adults administered by states and overseen by the Centers for Disease Control and Prevention (CDC). While states may add their own questions, they all use a standardized questionnaire that periodically includes a section on physical activity. The full 2001 survey consisted of >200,000 interviews from all 50 states, Puerto Rico, Guam, the Virgin Islands, and the District of Columbia. Only those respondents living in metropolitan areas (and excluding Puerto Rico, Guam, and Virgin Island metropolitan areas) were included in this study.[40] The Federal Office of Management and Budget defines metropolitan areas in consultation with state and local authorities. Both the US Census Bureau and the CDC use these definitions when collecting and analyzing data. The survey is generally available in both English and Spanish.

Since the BRFSS originated in 1984 (several years passed before it was extended to include every state), it has been extensively used to study health outcomes and risk behaviors. Relevant to this study, the BRFSS has been a data source used to analyze the prevalence of cardiovascular risk factors and physical activity problems.[41–44] It has been used to study health issues on a national, interstate, and intrastate basis.[45–47] This study does not attempt to analyze differences in physical activity rates between metropolitan areas, for example, comparing inactivity risk in Atlanta to the risk in San Francisco. While the full sample is large, the numbers of respondents in any individual metropolitan area may be too small to give stable results. This limitation precludes using the sample in a multilevel analysis of the correlates of physical activity across metropolitan areas.

The BRFSS includes questions on the frequency, duration, and intensity of leisure time exercise. Based on these questions, the CDC calculates whether a respondent meets physical activity guidelines. Respondents who report moderate activity ≥30 minutes per day at least five days per week or vigorous activity ≥20 minutes per day at least three days a week are considered to meet current physical activity guidelines. If reported physical activity was <30 minutes per day or less than five days per week or vigorous activity was <20 minutes per day or less than three days per week, the respondent was considered to have some activity, but not meet current guidelines. Those respondents who report less than 10 minutes per week of moderate or vigorous physical activity or report no moderate or vigorous physical activity are classified as physically inactive.[48] This study compared the risk of being physically inactive to not being physically inactive.

A number of demographic characteristics are associated with changed risk of physical inactivity. Increased education and higher income were associated with a decreased risk of physical inactivity. Conversely, female sex, Black race, Hispanic ethnicity, and increased age are all associated with an increased risk of physical inactivity. The BRFSS database contains questions that allow for the creation of dummy variables for female sex, Black race, and Hispanic ethnicity. Race is classified in the BRFSS based on self-report. Respondents were allowed to report more than one race. Separately, respondents were asked if they were of Hispanic ethnicity. The BRFSS reports responses in several different ways. In this analysis, White refers to people who reported they were White only and were not Hispanic. Similarly, Black refers to people who reported they were Black only and were not Hispanic. All persons who said they were Hispanic were coded as Hispanic, regardless of their self-reported race(s). Non-Hispanic, multiracial people and non-Hispanic, other-race people were coded as belonging to their respective categories, but categorical variables were not included in this analysis because of their small numbers. Again because of their numbers in this sample, the analysis does not distinguish between Black and White Hispanics. Race is a social construct and is not meant to have any biological meaning.

Education levels and ages are also in the data. The BRFSS asks respondents to report household income data by using categories. The mean point of a respondent's income category was assigned to each respondent, and the ratio of that income to the official poverty threshold for the respondent's household size was calculated. This income ratio was then used in this study to control for household income while simultaneously adjusting for household size. For example, if a respondent's total household income was $25,000–$35,000 and his or her house-

hold size was three, the respondent was assigned an income ratio of 2.123 (30,000/14,128).

The most commonly used measure of segregation is the Dissimilarity Index, which can be described as the percentage of Blacks who would have to move in order to achieve a uniform distribution across a metropolitan area.[49–51] This study uses the Dissimilarity Indices calculated by the Mumford Institute of State University of New York at Albany from 2000 Census data based on tract-level data.[52] The formula is:

$$D_{bw} = \frac{1}{2}\sum |(b_i/B) - (w_i/W)|$$

Where w is the total number of White persons living in tract i, b is the total number of Black persons living in tract i, W is the total number of White persons in the metropolitan area, and B is the total number of Black persons in the metropolitan area. The Black-White segregation rate for each respondent's metropolitan area was assigned according to the BRFSS metropolitan area variable code. Representative Black-White Dissimilarity Index values include Atlanta (65.61) and St. Louis (74.35). Many alternative measures of segregation exist, including measures of isolation, clustering, unevenness, concentration, and centralization.[53–55] To explore the possibility that the results in this study were affected by the choice of segregation measure, the final regression analysis was repeated using P^* (Isolation Index). P^* is the average percentage of Whites in the census tract of each Black in a given metropolitan area.[56]

Urban sprawl, a pattern of overall metropolitan development that is low density, decentralized, and associated with an increased risk of physical inactivity, was included as a variable in this analysis.[57] The ubiquity of racial residential segregation and urban sprawl has led many observers to link the two.[58] Conceptually, White flight to the suburbs traps Blacks in inner cities, simultaneously increasing both sprawl and segregation. Furthermore, sprawl may increase inequality, further increasing segregation.[59,60] Among its other health effects, sprawl is associated with an increased risk of physical inactivity.[61] In order to control for the possibility that sprawl was confounding the effects of segregation, this study incorporated into its analysis a measure first described in the journal Urban Affairs Review.[62] It is based on the difference between the proportion of a metropolitan area's high-density population (>3500 persons per square mile) and low-density population (200–3500 persons per square mile). This measure excludes the rural portions of metropolitan areas (<200 persons per square mile). The measure is transformed by constants to a 100-point scale, with 0 indicating the lowest levels of sprawl and 100 the highest. The formula is $SI_i=([S\%_i - D\%_I]/100 + 1) \times 50$.

Where,

- SI_i=Sprawl Index for Metropolitan Area$_i$
- $S\%_i$=percentage of total population in low-density census tracts$_i$
- $D\%_i$=percentage of the total population in high-density census tracts$_i$

Sample values include San Francisco (17.36) and Charlotte (78.21).

Descriptive statistics were calculated, and correlation coefficients were determined. Next, the percentage of people physically inactive for each quartile of Black-White segregation was calculated. Stata was used for the preliminary analysis.[63] This study used hierarchical linear modeling in the regression analysis to control for the possibility that respondents living in a given metropolitan area might share common outcomes because they live in that same metropolitan area. This method adjusts standard errors for clustering in a metropolitan area by using respondent's metropolitan area identifier. Given that segregation operates on a metropolitan-wide level but individual factors may also influence physical activity, multilevel analysis allows for the simultaneous consideration of both.[64–67] First, univariate regression was performed. Then a full multivariate logistic model comparing the risk of being physically inactive with physically active reference group was assessed. A random effects model using partial maximum likelihood methods was used for all regression analysis. Software for regression analysis was HLM6.[68] Data were weighted to account for differing probabilities that a respondent might be selected for participating in the survey. Individual-level variables included in the full regression model were Black race, Hispanic ethnicity, education, sex, income (using the ratio of household income to poverty threshold), and age. Metropolitan level variables were segregation (Dissimilarity Index), sprawl, percentage of people living in poverty, total population (in millions), and per capita income (in thousands). These additional variables were selected because they might exert an effect on physical inactivity risk. Finally, an additional series of models was assessed to further explore any potential association between segregation and physical inactivity risk. These include:

- the P^* segregation index as an replacement for the dissimilarity index to determine if the choice of segregation measure was influencing results
- an additional model with an interaction term between Black race and segregation (using the dissimilarity index)
- a regression model using quartiles of the dissimilarity index
- separate models for Blacks and Whites to determine if segregation had differential effects between the two groups

RESULTS

The final metropolitan dwelling adult population in the BRFSS 2001

Table 1. Descriptive statistics

	Number of Observations	Weighted Percent	Weighted Percent Meeting Physical Activity Guidelines	Weighted Percent Physically Active But Not Meeting Guidelines	Weighted Percent Physically Inactive	Weighted Percent Did Not Know/ Declined to Answer
Total BRFSS	212,510		42.34%	36.13%	14.94%	6.60%
Metropolitan sample	121,894		42.70%	37.12%	14.34%	5.84%
Sex						
Male	49,870	48.40%	45.37%	36.14%	13.28%	5.21%
Female	72,024	51.60%	40.19%	38.04%	15.34%	6.45%
Race/ethnicity						
White Non-Hispanic	92,081	68.69%	45.77%	37.13%	11.99%	5.60%
Black Non-Hispanic	12,258	10.28%	34.08%	37.24%	21.41%	7.27%
Hispanic	9129	13.22%	37.87%	36.61%	20.25%	5.27%
Education						
Never attended school or only kindergarten	183	.18%	22.12%	26.75%	40.37%	10.76%
Grades 1–8	3708	4.31%	24.17%	32.29%	34.61%	8.92%
Grades 9–11	8077	7.56%	34.51%	32.13%	25.04%	8.31%
Grade 12 or GED	34,940	28.56%	39.41%	36.20%	16.89%	7.50%
College 1–3 years	33,559	27.50%	44.98%	37.75%	12.12%	5.15%
College 4 years or more	41,133	31.68%	48.42%	39.34%	8.42%	3.82%
Refused	294	.22%	20.25%	30.56%	28.59%	20.61%
Segregation quartiles (Black-White Dissimilarity Index)						
First (<43.6)	30,955	14.02%	46.14%	37.10%	12.43%	4.33%
Second (43.61–54.78)	30,502	23.54%	44.36%	37.06%	12.80%	5.78%
Third (54.79–65.60)	30,463	25.20%	42.50%	36.90%	14.39%	6.22%
Fourth (65.61–84.72)	29,974	37.23%	40.48%	37.31%	16.01%	6.20%

dataset consisted of 121,894 participants in 311 metropolitan areas. The dissimilarity index segregation variable varied from 20.24 to 84.72, with a mean of 54.64 and a standard deviation of 14.57. It had a close to normal distribution, so it may be used in regression analysis (skew of .0004, kurtosis of 2.278). See Table 1 for other descriptive statistics. The sample size varies substantially between metropolitan areas (20 to 4600). Similarly, the number of Black respondents also had a large range (0 to 1600) (Table 1).

The quartile distribution of Black-White Dissimilarity Index scores highlights the potential association between segregation and physical activity. Those respondents living in metropolitan areas with the highest levels of segregation were almost three times as likely to be inactive as those living in metropolitan areas with the lowest levels of segregation. The two intermediate segregation-level quartiles both had increased inactivity over lower levels. This association was significant at the .01 level. Among the correlation statistics, education and income were the most highly related (Pearson correlation coefficient .37, $P<.000$), but this correlation was not high enough to affect the regression results (Table 2).

Table 2. Continuous variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Age	46.04	17.44	18	99
Sprawl	58.61	21.06	3.94	100
Income ratio	3.29	2.67	0	11.06
Segregation (Dissimilarity Index)	54.64	14.57	20.24	84.72
Segregation (P* Isolation Index)	55.53	20.55	6.60	95.40
Per capital income	26,473	5,126	13,339	49,695
Percent poverty	12%	4%	6%	36%
Total population	720,000	1,210,000	60,000	9,520,000

In the univariate analyses, all the models performed as predicted. However, three variables, sprawl, total population, and female sex, were not statistically significant (Table 3). In the full model that controlled for other potential explanatory variables, each one-point increase in segregation resulted in a modeled .0072% increased risk of being physically inactive (odds ratio [OR] 1.007, 95% confidence interval [CI] 1.003–1.011) (Table 4). In this full model that used the Dissimilarity Index, 16.3% of the variation in the sample was on the metropolitan level and 83.7% was on the individual level. The individual-level

Table 3. Univariate regression: risk of reporting no physical activity

Variable	Odds Ratio (95% Confidence Interval)
Black–White segregation (dissimilarity index)	1.0064 (1.002, 1.011)**
Income (ratio of total household income to poverty threshold)	.825 (.812, .839)**
Sprawl	1.0027 (1.000, 1.006)
Black Race	1.5770 (1.448, 1.717)**
Hispanic ethnicity	1.711 (1.530, 1.925)**
Age	1.022 (1.02, 1.029)**
Education	.666 (.647, .685)**
Female	1.0697 (.043, 1.097)
Percent metro area in poverty	6.319 (2.048, 19.5)**
Total population metro area (millions)	1.010 (.979, 1.048)
Per capita income (thousands)	.990 (.981, 1.000)*

Multinomial logistic regression using pseudo-likelihood estimation.
Standard errors controlled for clustering on the metropolitan level.
* Significant at the .05 level.
** Significant on the .01 level.

variables, with the exception of the sex variable, performed as predicted and were statistically significant at the .01 level. The *P** variable was also statistically significant (note that it is of reverse polarity than the dissimilarity index and therefore performs in the opposite direction). The interaction variable (Black race and dissimilarity index) was not statistically significant, while the model that used quartiles of segregation (dissimilarity index) was significant. The separate analyses for Blacks and Whites had similar outcomes. In contrast to the White-only model, the odds ratio for Blacks was not statistically significant (Table 5).

Table 4. Full multivariate regression model: risk of reporting no physical activity

Variable	Odds Ratio (95% Confidence Interval)
Black–White segregation (dissimilarity index)	1.007 (1.003, 1.011)**
Sprawl	1.004 (1.001, 1.008)**
Percent in poverty	3.165 (.874, 11.468)
Total population (millions)	1.006 (.964, 1.049)
Per capita income (thousands)	1.011 (.999, 1.022)
Income (ratio of total household income to poverty threshold)	.884 (.872, .898)**
Black race	1.567 (1.425, 1.723)**
Hispanic ethnicity	1.499 (1.299, 1.729)**
Age	1.021 (1.020, 1.024)**
Education	.779 (.758 .801)**
Female	.1.019 (.953, 1.09)

Multinomial logistic regression using pseudo-likelihood estimation.
Standard errors controlled for clustering on the metropolitan level.
** Significant on the .01 level

Table 5. Summary of multiple logistic models: risk of reporting no physical activity

Model/variable	Odds Ratio (95% Confidence Interval)
Full model/Dissimilarity Index	1.007 (1.003, 1.011)**
Full model/Isolation Index	.992 (.990, .996)**
Full model/quantiles of segregation	1.089 (1.038, 1.1144)**
Full model/Black–segregation interaction	.998 (.991, 1.005)
White only model/Dissimilarity Index	1.007 (1.023, 1.027)**
Black only model/Dissimilarity Index	1.004 (.993, 1.016)

Multinomial logistic regression using pseudo-likelihood estimation.
Standard errors controlled for clustering on the metropolitan level.
** Significant on the .01 level.

This study found that levels of Black-White segregation were associated with an increased risk of physical inactivity after controlling for other potential explanatory variables among US adults.

DISCUSSION

This study found that levels of Black-White segregation were associated with an increased risk of physical inactivity after controlling for other potential explanatory variables among US adults. These results should be interpreted with caution. The association found here may not necessarily reflect any underlying causality. Though the BRFSS survey is available in English and Spanish, it may not reach those who speak other languages. Hierarchical linear modeling was used to control for potential problems caused by clustering on the metropolitan level, but these issues may still have affected results. The BRFSS's exclusion of the poorest adults: those living in households without telephones, adults living in group quarters, and homeless adults, might have influenced these results. These issues may reduce the study's generalizability beyond its sample of metropolitan-dwelling, English- and Spanish-speaking adults living in households with telephones. However, the results here potentially represent >150 million US residents.

Another limitation of the study is that it does not include neighborhood-level effects. Segregation affects neighborhood quality through infrastructure, maintenance, social capital, and many other pathways, and the degree to which a given neighborhood might be affected by segregation might influence an individual's inactivity risk. Unfortunately, the BRFSS does not have neighborhood identifiers.

The results of this study are consistent with those of other studies linking metropolitan level risk factors with physical activity such as urban sprawl.[69,70] This finding suggests that segregation might similarly cause potential destinations to be further apart, increase travel times, and reduce the suitability of non-automobile transportation to reach these destinations.[71] Both of these factors might eventually result in decreased physical activity.[72–75] Segregation may disperse facilities such as parks and gyms, placing them further away from homes and jobs. Presumably, greater distance to recreation facilities discourages physical activity. Perhaps the neighborhood effects of segregation, including degraded infrastructure and increased pollution, also decrease physical activity.

Another potential pathway may be related to psychological issues. Segregation may cause greater stress, reducing physical activity.[76,77] Perhaps segregation makes people afraid to leave their neighborhoods, fostering isolation and reducing physical activity.[78,79] Or segregation might result in more crime in all or some neighborhoods, which in turn would discourage physical activity.

While the association for the Black-only sample was not statistically significant, this finding may be due to the relatively small number of Blacks in the sample and the small magnitude of effect. The Black–segregation interaction term was not significant, perhaps indicating that race and segregation exert separate effects. That the association between segregation and physical activity holds for both Blacks and Whites may imply that everyone suffers from the effects of segregation. Certainly some of the results of segregation—increased distances to work and parks, greater travel times and congestion, increased isolation, and a decrease in social capital—might affect all metropolitan residents, regardless of race.[80,81] Given the similarity of effect for both Blacks and Whites, segregation may not contribute to racial disparities in health outcomes or risk factors, but that does not diminish its effects on the overall health of Americans. Segregation may affect the health of all people, not just the segregated. Others have found an association between Black-White segregation and the health outcomes of Whites.[82,83]

Segregation is probably just one factor affecting physical activity. The full model found that individual-level factors accounted for most of the variation of risk, but ≈16% of the total variation was accountable to metropolitan-level factors. Given that most of the US population lives in metropolitan areas, the population-attributable risk of these metropolitan-level factors may be important. Similarly, the magnitude of the segregation odds ratio was not large, but the size of the potential population affected by segregation may imply that the overall contribution of segregation to physical inactivity merits attention. This finding may also have health implications because shifting the entire population distribution toward greater inactivity may have a potentially greater increase in the percentages of persons who are at risk for ill health.

Segregation was and continues to be a major US social problem. Its broad effects have been outlined for some time. If the association found here is real, the implications may mean that segregation contributes to physical inactivity and may also be responsible for other contemporary health problems. Ultimately, addressing the problem of physical inactivity might also necessitate addressing the underlying social environment of the United States.

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AUTHOR CONTRIBUTIONS

Design concept of study: Lopez
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Manuscript draft: Lopez
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