2017-05-15

Association of Changes in Neighborhood-Level Racial Residential Segregation With Changes in Blood Pressure Among Black Adults: The CARDIA Study

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Keywords
Racial residential segregation, neighborhoods, blood pressure, UMCCTS funding

JAMA Internal Medicine | Original Investigation

Association of Changes in Neighborhood-Level Racial Residential Segregation With Changes in Blood Pressure Among Black Adults
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IMPORTANCE Despite cross-sectional evidence linking racial residential segregation to hypertension prevalence among non-Hispanic blacks, it remains unclear how changes in exposure to neighborhood segregation may be associated with changes in blood pressure.

OBJECTIVE To examine the association of changes in neighborhood-level racial residential segregation with changes in systolic and diastolic blood pressure over a 25-year period.

DESIGN, SETTING, AND PARTICIPANTS This observational study examined longitudinal data of 2280 black participants of the Coronary Artery Risk Development in Young Adults (CARDIA) study, a prospective investigation of adults aged 18 to 30 years who underwent baseline examinations in field centers in 4 US locations from March 25, 1985, to June 7, 1986, and then were re-examined for the next 25 years. Racial residential segregation was assessed using the Getis-Ord G_i* statistic, a measure of SD between the neighborhood's racial composition (ie, percentage of black residents) and the surrounding area's racial composition. Segregation was categorized as high (G_i* >1.96), medium (G_i* 0-1.96), and low (G_i* <0). Fixed-effects linear regression modeling was used to estimate the associations of within-person change in exposure to segregation and within-person change in blood pressure while tightly controlling for time-invariant confounders. Data analyses were performed between August 4, 2016, and February 9, 2017.

MAIN OUTCOMES AND MEASURES Within-person changes in systolic and diastolic blood pressure across 6 examinations over 25 years.

RESULTS Of the 2280 participants at baseline, 974 (42.7%) were men and 1306 (57.3%) were women. Of these, 1861 (81.6%) were living in a high-segregation neighborhood; 278 (12.2%), a medium-segregation neighborhood; and 141 (6.2%), a low-segregation neighborhood. Systolic blood pressure increased by a mean of 0.16 (95% CI, 0.06-0.26) mm Hg with each 1-SD increase in segregation score after adjusting for interactions of time with age, sex, and field center. Of the 1861 participants (81.6%) who lived in high-segregation neighborhoods at baseline, reductions in exposure to segregation were associated with reductions in systolic blood pressure. Mean differences in systolic blood pressure were −1.33 (95% CI, −2.26 to −0.40) mm Hg when comparing high-segregation with medium-segregation neighborhoods and −1.19 (95% CI, −2.08 to −0.31) mm Hg when comparing high-segregation with low-segregation neighborhoods after adjustment for time and interactions of time with baseline age, sex, and field center. Changes in segregation were not associated with changes in diastolic blood pressure.

CONCLUSIONS AND RELEVANCE Decreases in exposure to racial residential segregation are associated with reductions in systolic blood pressure. This study adds to the small but growing body of evidence that policies that reduce segregation may have meaningful health benefits.

JAMA Intern Med. doi:10.1001/jamainternmed.2017.1226
Published online May 15, 2017.

Supplemental content

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Racial residential segregation is the systematic separation of groups into different neighborhoods by race. While largely thought to be caused by structural discrimination (eg, in housing and lending markets), differential residential preferences by race are believed to play a role as well.[1,2] Residential segregation has been identified as a fundamental cause of black-white health disparities because of its effect on access to a wide range of health-promoting resources and opportunities, including quality education, jobs, healthy food options, and social capital.[3-6] Some cross-sectional evidence suggests that the greater the segregation, the higher the hypertension prevalence in black communities.[7-9] To our knowledge, no study has yet investigated the association of changes in exposure to segregation with changes in blood pressure or the association of moving to less segregated neighborhoods with improvements in blood pressure. Longitudinal analyses are required to strengthen these causal inferences and to determine whether policies that reduce segregation have beneficial effects on blood pressure.

First, using more than 25 years of data, we examined the association between change in neighborhood-level racial residential segregation and change in blood pressure in the total sample of non-Hispanic black participants of the Coronary Artery Risk Development in Young Adults (CARDIA) study. Second, to better understand the effect of reducing segregation on blood pressure, we investigated the association of reduction in segregation with reduction in systolic and diastolic blood pressure among the subset of black CARDIA participants living in highly segregated neighborhoods at baseline.

Key Points

Question Are changes in exposure to neighborhood-level racial residential segregation associated with changes in blood pressure?

Findings In this cohort study of 2280 black adults, increases in neighborhood-level racial residential segregation were associated with small but statistically significant increases in systolic blood pressure, and reductions in segregation levels were associated with more than a 1–mm Hg decrease in systolic blood pressure.

Meaning Policies that reduce racial residential segregation may have meaningful health benefits, such as reductions in blood pressure.

Methods

The CARDIA study is a prospective, multicenter investigation of changes in cardiovascular disease risk factors, onset, and progression during the transition from young adulthood to middle age. From March 25, 1985, to June 7, 1986, a total of 5115 black and white adults aged 18 to 30 years were recruited and examined in field centers in 4 locations: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California.[10,11] (The race/ethnicity of all participants were self-reported.) These participants were re-examined 2, 5, 7, 10, 15, 20, 25, and 30 years later, with a high participant retention rate of 91%, 86%, 81%, 79%, 74%, 72%, 72%, and 71%, respectively. Our current study uses data from all of the examination years in which participant addresses were geocoded: the baseline and 7-, 10-, 15-, 20-, and 25-year examinations. Given the unique historical context of residential segregation of black from white individuals in the United States and the nearly nonoverlapping levels of segregation scores in black and white CARDIA participants, we limited participation in our study to black adults. Of the 2637 baseline participants, 313 (11.9%) were excluded for not having 2 measures of blood pressure, and 44 (1.7%) were excluded for missing data on baseline covariates. The final total sample comprised 2280 participants. Data analyses were performed between August 4, 2016, and February 9, 2017. The CARDIA study was approved by the institutional review boards at each field center: the University of Alabama at Birmingham, Northwestern University, University of Minnesota, and Kaiser Permanente. All participants provided written informed consent.

Neighborhood-level racial residential segregation of black individuals from other racial/ethnic groups was measured at each available examination using the local Getis-Ord G_i^* statistic[12] based on the following geocoded addresses of CARDIA participants linked to the US census closest to the examination year: 1980 for the baseline year, 1990 for years 7 and 10, 2000 for years 15 and 20, and 2010 for year 25. The G_i^* statistic returns a *z* score for each neighborhood (census tract) that indicates the number of SDs that the racial composition (in this case, percentage of black individuals) of the focal tract and neighboring tracts is from the mean racial composition of the larger areal unit surrounding the tract (in this case, the metropolitan area or county). See eAppendix 1 in the Supplement for further details on the racial residential segregation measure.

Segregation was modeled continuously for the analyses of all black participants. Segregation was categorized as high (G_i^* >1.96), medium (G_i^* 0-1.96), and low (G_i^* <0) for the analyses in the subset of participants in the high-segregation category at baseline. The cut points for the segregation categories were chosen to be consistent with the critical *z* score values for a 95% CI (−1.96 to 1.96), which corresponds to statistical significance at the α = .05 level.[13] No participants lived in areas with G_i^* less than −1.96; thus, we used a cut point of 0 for the low category to indicate a *z* score equal to or below the mean racial composition of the surrounding metropolitan area or county.

Blood pressure was measured at each CARDIA examination by trained technicians using either a random-zero mercury sphygmomanometer (baseline to year 15) or an oscillometer (years 20-25). Oscillometer readings have been calibrated to the sphygmomanometric measures.[14] Resting systolic and diastolic blood pressure were measured 3 times at 1-minute intervals; the mean of the second and third measurements was used in the analyses. We accounted for treatment effects by adding 10 mm Hg to the observed systolic blood pressure and 5 mm Hg to the observed diastolic blood pressure in treated participants.[15] We also conducted a sensitivity analysis in which we adjusted for self-reported medication use as a covariate instead.

In our analyses, we adjusted for several covariates associated with residential segregation and blood pressure as potential confounders or mediators, including age, sex, current marital status (married or cohabiting vs not married or cohabiting), educational level (high school graduate or less, some college, or college degree or higher), neighborhood poverty (percentage of neighborhood residents living below the US Census Bureau–defined poverty threshold), and neighborhood population density. Individual income data were not collected at baseline and thus were not included in our primary analyses. For sensitivity analyses, we ran all models adjusting for time-varying income using data from the year 5 examination for baseline income.

Cigarette smoking was dichotomized as current vs not current. Leisure time physical activity was assessed with the CARDIA physical activity questionnaire, which included questions on the frequency of participation in 13 categories of sports and exercise during the previous 12 months.[16] A score was summed across all activities and expressed continuously in exercise units. The reliability and validity of the instrument are comparable to other activity questionnaires.[17,18] Body mass index was calculated as weight in kilograms divided by height in meters squared. Body weight in light clothing was measured to the nearest 0.5 lb using a balance beam scale. (To convert pounds to kilograms, multiply by 0.45.) Height without shoes was measured to the nearest 0.5 cm using a vertically mounted centimeter ruler and a metal carpenter's square.

We calculated descriptive statistics for study variables by examination year and segregation category (high and medium/low). Segregation scores can change over time if participants move to neighborhoods with different levels of segregation or if participants stay in the same place and the level of segregation changes in their neighborhood. To get a better sense of what drove changes in segregation score, we used a paired *t* test to calculate the mean within-person change in segregation score between each successive examination separately for "movers" (those who changed census tracts between examinations) and "stayers" (those who did not). Fixed-effects regression models were used to estimate the association of within-person changes in segregation with within-person changes in blood pressure.[19] Fixed-effects models focus only on within-person variation rather than between-person variation. This approach has the advantage over mixed-effects models in that it tightly controls for all measured and unmeasured time-invariant characteristics. In fixed-effects models, characteristics that do not change over time are conditioned out of the estimation process. For this reason, fixed-effects models cannot be used to examine the main effects of time-invariant characteristics. However, interactions involving these variables can be examined. Baseline time-invariant covariates, including age, sex, and field center, were tested for interactions with time to allow for different trends in blood pressure over time that were associated with these characteristics. All statistically significant interactions (α = .05) were retained in the models.

Our first set of multivariable regression models was designed to assess the overall relationship between within-person changes in neighborhood-level racial residential segregation and within-person changes in blood pressure over the follow-up period. For these analyses, we modeled segregation continuously using the total sample of participants (n = 2280). We also assessed whether this relationship varied by participant age, neighborhood poverty, educational level, and income by testing interaction terms between these covariates and segregation. To investigate whether reductions in segregation were associated with reductions in blood pressure among residents who lived in highly segregated neighborhoods at baseline, we examined this relationship among the 1861 participants (81.6% of the total sample) living in highly segregated neighborhoods at baseline. For these analyses, we modeled segregation categorically to estimate changes associated with more meaningful changes in levels of segregation. As a sensitivity analysis, this same model was run excluding the participants who changed to lower-segregation neighborhoods but changed back to high-segregation neighborhoods at any subsequent examination. All statistical analyses were conducted using SAS, version 9.4 (SAS Institute Inc).

Results

Of the 2280 participants at baseline, 974 (42.7%) were men and 1306 (57.3%) were women. Of these, 1861 (81.6%) were living in a high-segregation neighborhood; 278 (12.2%), a medium-segregation neighborhood; and 141 (6.2%), a low-segregation neighborhood. The median (interquartile range) follow-up time for participants was 24.8 (4.8) years. Overall, the mean (SD) segregation score was 4.8 (3.1) at baseline, 3.9 (3.1) at year 7, 3.0 (3.1 and 2.8) at years 10 and 15, and 2.5 (2.9 and 2.6) at years 20 and 25. **Table 1** presents baseline and subsequent examination year characteristics separately for those who lived in highly segregated census tracts at baseline (1861 [81.6%]) and those who did not (419 [18.4%]). Both the mean segregation scores and the mean percentage of neighborhood poverty decreased over time for participants who started out in high-segregation neighborhoods (Table 1). Segregation scores increased and neighborhood poverty remained steady among those who started in medium- or low-segregation neighborhoods, whereas the segregation scores and poverty rates both decreased for those who lived in a high-segregation census tract at baseline.

Almost all participants (2144 [94%]) moved at least once, and more than half (1179 [51.7%]) moved 3 or more times over the follow-up examinations. Participants lived in 10 different metropolitan areas or counties at baseline, and by year 7 they lived in more than 100 (**Figure**). By year 25, participants lived in more than 170 metropolitan areas or counties. Participants who stayed in the same neighborhood for more than 2 successive examinations did not experience large changes in segregation scores between those 2 examinations (**Table 2**). In contrast, those who moved tended to move to less-segregated neighborhoods, particularly in earlier examinations.

A 1-SD increase in segregation score was associated with a mean systolic blood pressure increase of 0.16 (95% CI, 0.06-0.26) mm Hg after adjusting for time and interactions of time with baseline age, sex, and field center (**Table 3**; eAppendix 2 in the Supplement provides a more detailed description of the interactions of age, sex, and field center with time).

Table 1. Selected Baseline and Follow-up Examination Characteristics of Study Participants by Baseline Segregation Category

Characteristic	Baseline	Year 7	Year 10	Year 15	Year 20	Year 25	*P* for Trend
Living in High-Segregation Neighborhood at Baseline[a]							
No. examined	1861	1508	1490	1359	1284	1273	
Systolic BP, mean (SD), mm Hg	111.5 (11.0)	111.7 (13.4)	113.3 (14.2)	117.3 (16.3)	120.8 (16.7)	124.7 (17.1)	<.001
Diastolic BP, mean (SD), mm Hg	68.9 (10.0)	71.3 (11.3)	75.1 (11.4)	77.7 (13.3)	77.9 (12.2)	80.3 (11.9)	<.001
Current BP-lowering medication use, No. (%)	19 (1.0)	46 (3.1)	87 (5.8)	177 (13.0)	320 (24.9)	478 (37.6)	<.001
Census tracts, No.	204	517	725	704	775	771	
G_i* statistic, mean (SD)	5.7 (2.5)	4.4 (3.0)	3.3 (3.2)	3.2 (2.8)	2.7 (2.9)	2.6 (2.6)	<.001
Neighborhood poverty, mean (SD), %	25.8 (12.7)	25.0 (15.8)	20.6 (15.1)	19.6 (13.5)	17.4 (13.0)	20.3 (13.3)	<.001
Neighborhood population density, median (IQR), No./km^2	4049.9 (2599.6-6164.1)	3678.8 (1681.4-6143.1)	2649.9 (1208.8-5084.3)	2519.2 (1210.8-4937.0)	2085.2 (889.5-4341.3)	1792.9 (813.0-3783.7)	
Educational level ≤ high school, No. (%)	253 (13.6)	130 (8.6)	143 (9.6)	109 (8.0)	90 (7.0)	1 (8.0)	<.001
Currently married or cohabiting, No. (%)	529 (28.4)	724 (48.0)	756 (50.7)	671 (49.4)	626 (48.8)	605 (47.5)	<.001
Physical activity, mean (SD), exercise units	375.2 (308.4)	312.8 (285.9)	299.7 (274.7)	311.3 (279.5)	293.0 (276.7)	277.1 (261.2)	<.001
Current smoking, No. (%)	640 (34.4)	517 (34.3)	490 (32.9)	389 (28.6)	334 (26.0)	301 (23.6)	<.001
BMI, mean (SD)	25.4 (5.7)	28.2 (6.9)	29.2 (7.2)	30.6 (7.4)	31.3 (7.6)	32.1 (7.8)	<.001
Living in Medium- or Low-Segregation Neighborhood at Baseline[a]							
No. examined	419	345	331	311	295	277	
Systolic BP, mean (SD), mm Hg	111.1 (10.7)	110.2 (11.6)	112.1 (12.2)	116.2 (15.3)	119.8 (14.7)	122.7 (14.3)	<.001
Diastolic BP, mean (SD), mm Hg	68.6 (10.1)	70.4 (10.1)	74.3 (9.6)	76.5 (11.5)	75.4 (11.4)	77.7 (10.1)	<.001
Current BP-lowering medication use, No. (%)	1 (0.2)	7 (2.0)	9 (2.7)	27 (8.7)	52 (17.6)	98 (35.4)	<.001
Census tracts, No.	187	248	288	280	263	257	
G_i* statistic, mean (SD)	0.51 (0.96)	1.56 (2.37)	1.61 (2.68)	1.80 (2.46)	1.83 (2.70)	1.89 (2.57)	<.001
Neighborhood poverty, mean (SD), %	15.5 (10.5)	15.1 (10.7)	14.2 (12.5)	13.9 (11.4)	13.5 (11.3)	16.4 (12.3)	.78
Neighborhood population density, median (IQR), No./km^2	3846.4 (1850.4-7121.0)	3359.7 (1197.1-6163.6)	2172.2 (826.0-4564.8)	2239.3 (847.8-4592.7)	1784.3 (727.8-4186.6)	1740.5 (726.8-3932.1)	
Educational level ≤ high school, No. (%)	34 (8.1)	16 (4.6)	22 (6.7)	20 (6.4)	12 (4.1)	11 (4.0)	<.001
Currently married or cohabiting, No. (%)	131 (31.3)	169 (49.0)	183 (55.3)	158 (50.8)	157 (53.2)	142 (51.3)	<.001
Physical activity, mean (SD), exercise units	418.3 (296.9)	356.7 (328.9)	336.6 (336.9)	366.3 (353.2)	320.3 (307.9)	323.1 (276.4)	<.001
Current smoking, No. (%)	108 (25.8)	89 (25.8)	85 (25.7)	81 (26.1)	59 (20.0)	47 (17.0)	.004
BMI, mean (SD)	25.0 (5.5)	27.6 (6.3)	28.4 (6.4)	30.0 (6.7)	30.5 (6.8)	32.2 (7.3)	<.001

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared.); BP, blood pressure; IQR, interquartile range.

[a] Getis-Ord G_i* statistic scores: greater than 1.96, high segregation; 0 to 1.96, medium segregation; and less than 0, low segregation.

This association persisted with further adjustment for time-varying neighborhood poverty, educational level, marital status, body mass index, current smoking, and physical activity. Changes in segregation score were not associated with changes in diastolic blood pressure.

Findings were similar in magnitude and statistical significance when the models were adjusted for income. Point estimates were smaller but of the same statistical significance when blood pressure medication use was adjusted for as a covariate. (See eTable 1 in the Supplement for associations of changes in all covariates with changes in blood pressure.) Interactions of neighborhood poverty, educational level, and income with segregation were not statistically significant.

Among participants living in highly segregated neighborhoods at baseline, 278 (14.9%) remained in high-segregation neighborhoods throughout the follow-up examinations, and 243 (13.1%) spent the rest of the follow-up examinations in low- or medium-segregation neighborhoods. The remainder of the sample (1340 [72.0%]) spent time in high-segregation and low- or medium-segregation neighborhoods over the follow-up periods. For those who lived in high-segregation neighborhoods at baseline, reductions in exposure to segregation were associated with reductions in systolic blood pressure (**Table 4**). Mean differences in systolic blood pressure were −1.33 (95% CI, −2.26 to −0.40) mm Hg when comparing high-segregation with medium-segregation neighborhoods and −1.19 (95% CI, −2.08 to −0.31) mm Hg when comparing high-segregation with low-segregation neighborhoods after adjustment for time and interactions of time with baseline age, sex, and field center. These associations remained essentially unchanged in fully adjusted models. (See eTable 2 in the Supplement for associations of changes in all covariates with changes in blood pressure.) Associations were even stronger in sensitivity analyses excluding participants who moved back to high-segregation neighborhoods at some point (n = 521). Changes to low-segregation neighborhoods were associated with 5.71-mm Hg (95% CI, −7.97 to −3.45-mm Hg) decreases, and changes to medium-segregation neighborhoods were associated with 3.94-mm Hg (95% CI, −6.47 to −1.41-mm Hg) decreases.

Changes in segregation category were not associated with changes in diastolic blood pressure.

Findings were similar in magnitude and statistical significance when the models were adjusted for family income. As in the models shown in Table 3, point estimates were smaller but of the same statistical significance when blood pressure medication use was adjusted for as a covariate. Associations between changes in segregation and changes in blood pressure did not vary significantly by age, educational level, income, or neighborhood poverty.

Discussion

Previous studies of the association of racial residential segregation with blood pressure have been cross-sectional, but no study has examined changes in blood pressure.[7-9,20] In a geographically diverse sample of black adults followed up for more than 25 years, we found that increases in neighborhood-level racial residential segregation were associated with small but statistically significant increases in systolic but not diastolic blood pressure. In addition, among those living in high-segregation neighborhoods at baseline, reductions in exposure to neighborhood segregation were associated with decreases in systolic blood pressure of more than 1 mm Hg.

Reductions in systolic blood pressure of this magnitude could have important implications for reducing cardiovascular events, particularly in black individuals. Systolic blood pressure is more closely associated with incident cardiovascular events than diastolic blood pressure among middle-aged and older adults, and recent work in CARDIA showed that systolic blood pressure was associated with incident cardiovascular events in younger black adults as well.[21] A study estimating cardiovascular disease incidence rates under a hypothetical population-wide intervention that reduced systolic blood pressure by 1 mm Hg found that this small change results in roughly

Figure. Study Participant Movement Across Metropolitan Areas or Counties Throughout the Follow-up Examination Periods

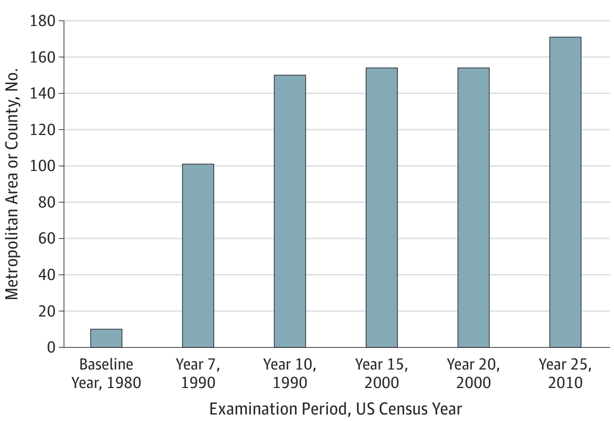

Table 2. Mean Unadjusted Within-Person Change in Gi* Statistic Between Successive Examinations Among "Movers" and "Stayers"[a]

Successive Examination Years	Stayers No.	Stayers Within-Person Change in G_i* Statistic, Mean (SD)[b]	Movers No.	Movers Within-Person Change in G_i* Statistic, Mean (SD)[b]
Year 0 to year 7	862	0.28 (0.84)	991	−1.98 (3.98)
Year 7 to year 10	493	0	1067	−1.27 (3.79)
Year 10 to year 15	848	0.18 (1.09)	622	−0.34 (3.52)
Year 15 to year 20	640	0	703	−0.74 (3.26)
Year 20 to year 25	791	0.06 (0.85)	509	−0.20 (2.96)

[a] *Movers* were those who changed census tracts between examinations; *stayers*, those who did not.

[b] Mean within-person change estimated using paired *t* tests comparing G_i* at successive examinations.

Table 3. Mean Within-Person Change in Systolic and Diastolic Blood Pressure (95% CI) Associated With a 1-SD Increase in the G_i* Statistic

Characteristic	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
Systolic BP, mean (SD), mm Hg	0.16 (0.06 to 0.26)	0.16 (0.05 to 0.28)	0.14 (0.03 to 0.26)	0.16 (0.04 to 0.27)
Diastolic BP, mean (SD), mm Hg	0.01 (−0.07 to 0.09)	0.03 (−0.06 to 0.12)	0.03 (−0.07 to 0.12)	0.05 (−0.04 to 0.14)

Abbreviation: BP, blood pressure.

[a] Model 1 adjusted for time since baseline, baseline age × time, sex × time, and field center × time.

[b] Model 2 adjusted for Model 1, neighborhood poverty, and neighborhood population density.

[c] Model 3 adjusted for Model 2, education, and marital status.

[d] Model 4 adjusted for Model 3, body mass index, current smoking, and physical activity.

Table 4. Mean Within-Person Change in Systolic and Diastolic Blood Pressure (95% CI) Associated With a Change in Segregation Category Among Study Participants in the High-Segregation Category at Baseline

Characteristic	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
Systolic BP, mean (SD), mm Hg				
High segregation	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Medium segregation	−1.19 (−2.08 to −0.31)	−1.29 (−2.21 to −0.37)	−1.22 (−2.14 to −0.30)	−1.31 (−2.23 to −0.39)
Low segregation	−1.33 (−2.26 to −0.40)	−1.49 (−2.51 to −0.47)	−1.38 (−2.40 to −0.37)	−1.48 (−2.50 to −0.47)
Diastolic BP, mean (SD), mm Hg				
High segregation	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Medium segregation	0.42 (−0.27 to 1.12)	0.33 (−0.39 to 1.06)	0.33 (−0.39 to 1.06)	0.20 (−0.51 to 0.92)
Low segregation	0.67 (−0.06 to 1.41)	0.53 (−0.28 to 1.33)	0.54 (−0.27 to 1.34)	0.42 (−0.38 to 1.21)

Abbreviation: BP, blood pressure.

[a] Model 1 adjusted for time since baseline, baseline age × time, sex × time, and field center × time.

[b] Model 2 adjusted for Model 1, neighborhood poverty, and neighborhood population density.

[c] Model 3 adjusted for Model 2, education, and marital status.

[d] Model 4 adjusted for Model 3, body mass index, current smoking, and physical activity.

10 fewer coronary heart disease and stroke events and approximately 20 fewer heart failure events per 100 000 person-years in black individuals.[22] Given the higher burden of elevated blood pressure and cardiovascular disease seen among black persons, even a 1-mm Hg reduction in blood pressure, such as that seen in this study, has the potential to meaningfully combat persistent health disparities.

The association between reductions in segregation and reductions in systolic blood pressure was even stronger (3- to 5-mm Hg reductions) when participants whose segregation exposure levels fluctuated over time were excluded. These decreases in segregation (from one category to another) could be caused by moves to more integrated neighborhoods or changes over time in the racial composition of neighborhoods where people reside (eg, because of gentrification). Our comparison of within-person changes in segregation scores across examinations among those who move or stay (Table 2) suggests that our findings are largely driven by moving, many of which were intercounty or intermetropolitan moves. Consistent with this finding is the suggestion from recent research using US Census data that intermetropolitan movers are more likely than intrametropolitan movers to take advantage of the opening of housing markets brought on by increased enforcement of the Fair Housing Act of 1968, which prohibited race, religion, national origin, and sex-based discrimination in the sale, rental, and financing of housing.[23]

The persistence of these findings after adjustment for neighborhood poverty, physical activity, body mass index, and smoking suggests that other factors may operate to link segregation and systolic blood pressure. For example, some salubrious dietary changes (eg, use of less sodium) may be associated with systolic blood pressure in the short term but perhaps not at all or only in the long term with body mass index. Stress may also account for the association of changes in segregation with changes in systolic blood pressure. Segregation affects the quality of schools, the value of housing, and the physical access to health-promoting resources (eg, pharmacies, full-service grocers, and gyms).[3,24,25] Improved access to these resources and opportunities for participants and their children could reduce stress and in turn systolic blood pressure. Differences in access to health care could also promote better blood pressure management.[26]

Limitations

This study is not without limitations. The use of fixed-effects models offers the advantage of accounting for measured and unmeasured time-invariant confounders, but there may still be residual confounding by unmeasured time-varying factors (eg, residential priorities and preferences). In addition, although retention rates in CARDIA are high, loss to follow-up could bias our findings if loss is patterned by residential segregation and blood pressure.

Conclusions

Among participants in our study, temporal changes in exposure to racial residential segregation were associated with changes in systolic blood pressure. Recent evidence suggests that differences of this magnitude at the population level can meaningfully reduce cardiovascular events, particularly in black individuals.[22] Several strategies need to be employed at the policy level to reduce the persistent racial health disparities we see in the United States, including policies that not only improve access to resources for those who live in segregated neighborhoods but also provide residents in segregated neighborhoods with the opportunity to move to neighborhoods with better access to resources. Findings from our observational study suggest that social policies that minimize segregation, such as the opening of housing markets, may have meaningful health benefits, including the reduction of blood pressure.

ARTICLE INFORMATION

Accepted for Publication: February 26, 2017.

Published Online: May 15, 2017. doi:10.1001/jamainternmed.2017.1226

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Author Contributions: Dr Kershaw had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
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Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Kershaw.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Kershaw.
Obtained funding: Kershaw, Gordon-Larsen, Goff, Sidney, Diez Roux, Kiefe.
Administrative, technical, or material support: Gordon-Larsen, Diez Roux.

Conflict of Interest Disclosures: None reported.

Funding/Support: This study was supported in part by grant P60 MD002249 from the Michigan Center for Integrative Approaches to Health Disparities, which is funded by the National Institute on Minority Health and Health Disparities. The Coronary Artery Risk Development in Young Adults (CARDIA) study is supported by contracts HHSN268201300025C, HHSN268201300026C, HHSN268201300027C, HHSN268201300028C, HHSN268201300029C, and HHSN268200900041C from the National Heart, Lung, and Blood Institute (NHLBI); the Intramural Research Program of the National Institute on Aging (NIA); and intra-agency agreement AG0005 between the NIA and NHLBI. The neighborhood measures used in this research were developed with grants R01HL104580 and R01HL114091 from the NHLBI. Dr Robinson is supported by grant K01CA172717 from the National Cancer Institute.

Role of the Funder/Sponsor: The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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